CAIE AS Level Chemistry

Paper 3

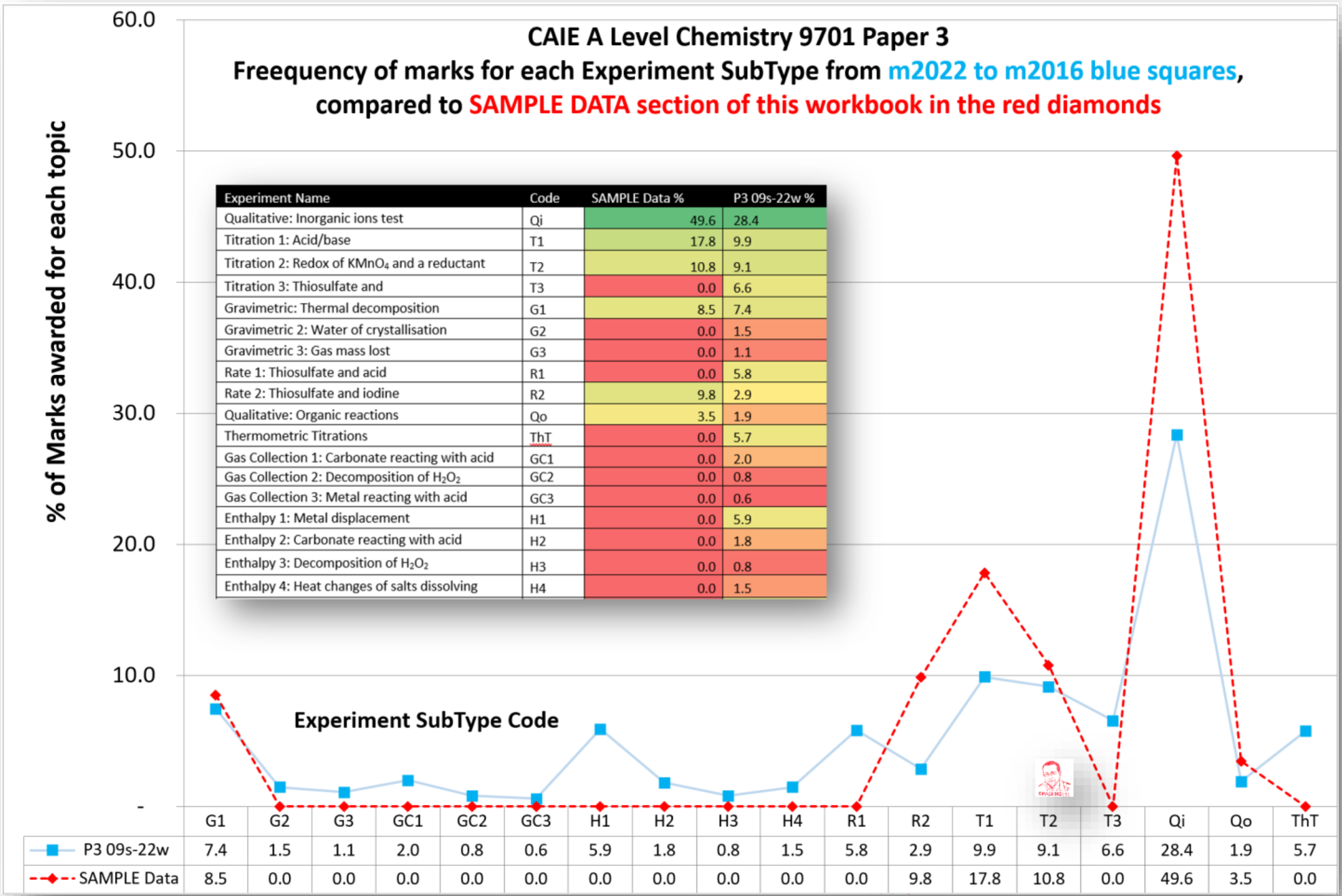
Past Exam Questions

Organised by Experiment SubType

Summer 2009 to Winter 2022 (35 Papers)

Name: ____________________________

Class: ____________



Experiment Name	Code	SAMPLE Data %	P3 09s-22w %
Qualitative: Inorganic ions test	Qi	49.6	28.4
Titration 1: Acid/base	T1	17.8	9.9
Titration 2: Redox of $KMnO_4$ and a reductant	T2	10.8	9.1
Titration 3: Thiosulfate and	T3	0.0	6.6
Gravimetric: Thermal decomposition	G1	8.5	7.4
Gravimetric 2: Water of crystallisation	G2	0.0	1.5
Gravimetric 3: Gas mass lost	G3	0.0	1.1
Rate 1: Thiosulfate and acid	R1	0.0	5.8
Rate 2: Thiosulfate and iodine	R2	9.8	2.9
Qualitative: Organic reactions	Qo	3.5	1.9
Thermometric Titrations	ThT	0.0	5.7
Gas Collection 1: Carbonate reacting with acid	GC1	0.0	2.0
Gas Collection 2: Decomposition of H_2O_2	GC2	0.0	0.8
Gas Collection 3: Metal reacting with acid	GC3	0.0	0.6
Enthalpy 1: Metal displacement	H1	0.0	5.9
Enthalpy 2: Carbonate reacting with acid	H2	0.0	1.8
Enthalpy 3: Decomposition of H_2O_2	H3	0.0	0.8
Enthalpy 4: Heat changes of salts dissolving	H4	0.0	1.5

	G1	G2	G3	GC1	GC2	GC3	H1	H2	H3	H4	R1	R2	T1	T2	T3	Qi	Qo	ThT
P3 09s-22w	7.4	1.5	1.1	2.0	0.8	0.6	5.9	1.8	0.8	1.5	5.8	2.9	9.9	9.1	6.6	28.4	1.9	5.7
SAMPLE Data	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	17.8	10.8	0.0	49.6	3.5	0.0

For and electronic version of this Paper 3 Workbook (scan code):

Contents

Introduction, Exercises and Analysis

A General Note on All These Sample Data

This is still a draft of the more complete version that might be finished in the second half of 2024.

This book cannot replace practical experience gained in a lab over years of secondary science education, but it can help to shed light on some of the patterns in how marks are assigned and how skills are assessed, especially for common experiments like the quantitative titration and the qualitative ions tests.

Section 1 contains sample data usually provided at the start of the question, or within it.

Section 2 only contains the questions in experiment subtype order ranked according to mark frequency (experiment type rank first, then within that group ranked by subtype frequency).

The sample data normally is the value that would be measured if all aspects of the experiment were performed perfectly (without any error) given the mounts of reagents used. In the real experiment you cannot get these exact figures because, for instance, of small variations and impurities in the chemicals prepared, which would affect all results using them equally (systematic error). This is why accuracy marks are compared against values that have been experimentally determined within the same centre using the same equipment, but also, importantly the same batches of solutions.

Results tables

You should create a suitable results table for every sample value for each question. The most successful students will be able to create these kinds of tables quickly and error free because they have practiced drawing up suitable tables a lot before. Good exam preparation delivers an ability to perform at a certain level, and a phrase that is sometimes used in another competitive activity, sport, is "practice it until you get it right". Outstanding exam preparation is going further to "then practice until you cannot get it wrong". The highest levels of success are all about a passionate, ranked, fascination with all aspects of the details that impact that success. It can be helpful to know that it is thought by scientists that there are different kinds of memory, with different properties; your memory from thoughtful habits and repeated practicing (a kind of long-term memory) is longer lasting.

For a neat article about the current science of memory: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5491610/

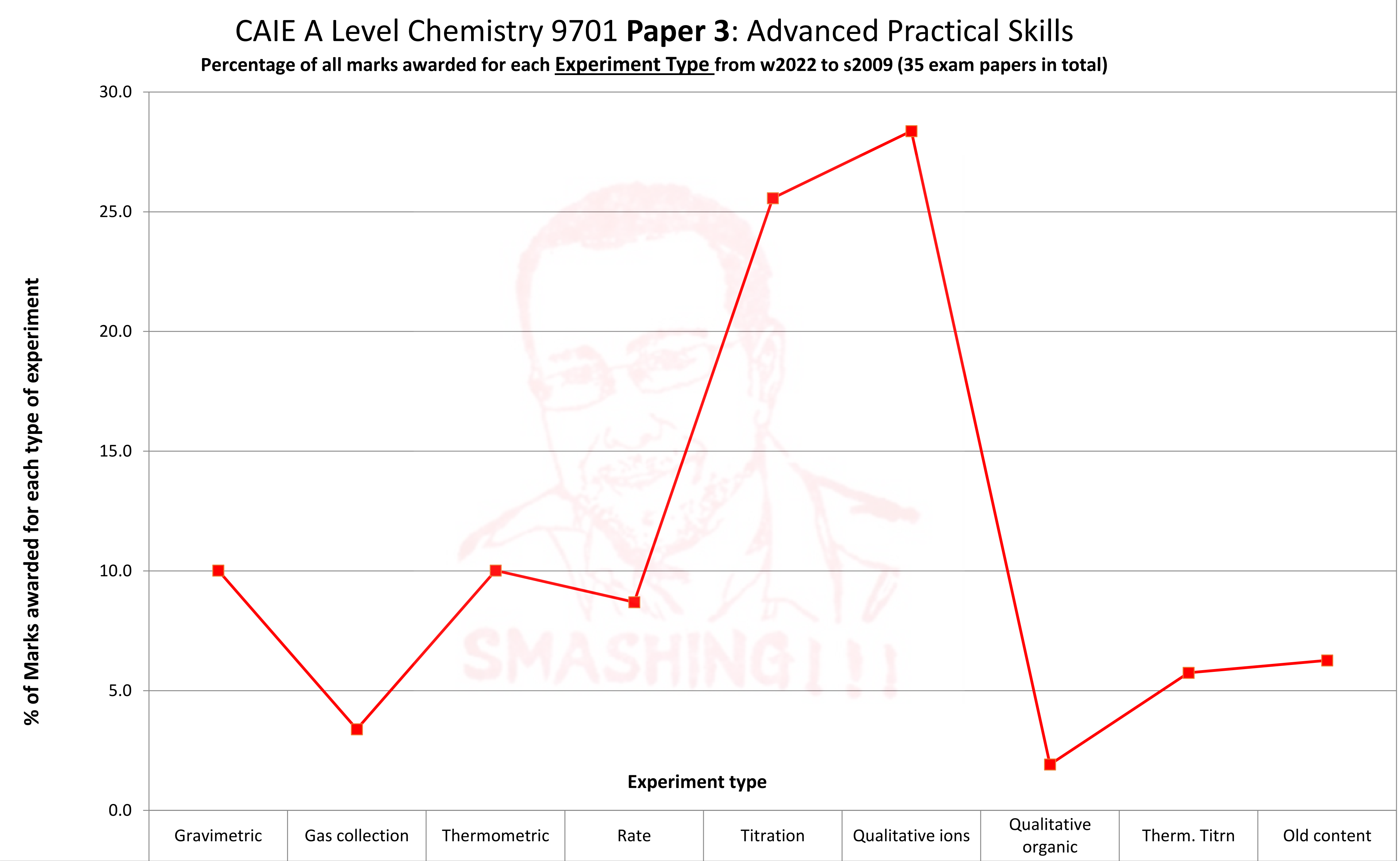
For titrations, this results table should always be the same format, like the one below. You will therefore need to think about suitable initial and final burette readings that could produce those Sample Data titres given in this book.

	Titration trial					
	ROUGH	1	2	3	4	5
FINAL burette reading (cm^3)						
Initial burette reading (cm^3)						
Titre (cm^3)						
Concordant results (tick)						

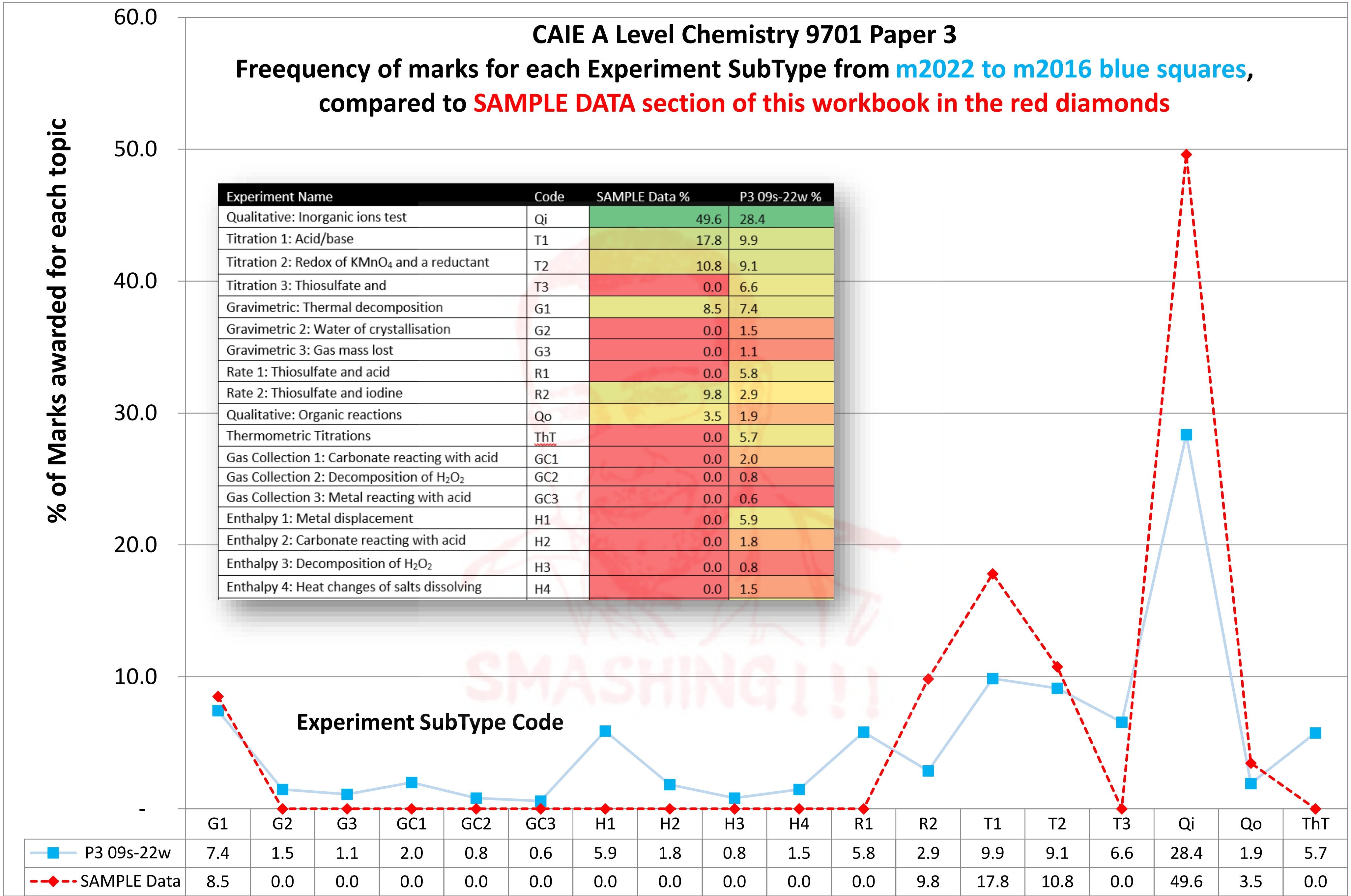
Always include units in the headings. When reading through the mark schemes, take time to think about what marks are awarded for. There are systematic reasons why marks are awarded for a complete and correct results table, learning how to use those marking rules is good; learning them consistently well, is better.

Always include the same number of decimal places for every measurement, so 0 cm^3 needs to instead be written as 0.00 cm^3 (it is a reading on an instrument, rather than an mathematical idea).

Normally, the most successful students will always have their last two titrations as within 0.05cm^3 for the titres. Often there is a mark awarded for this feature in the table. They will also only have 1 rough value and a maximum of 3 recorded titres; if you are note getting agreement to 0.1 cm^3 within 2 or 3 titrations, then the problem preventing you from getting reliable results (random error) is not going to get fixed by doing more, the time saved can used in other parts of the exam, especially making sure the calculations are done properly.

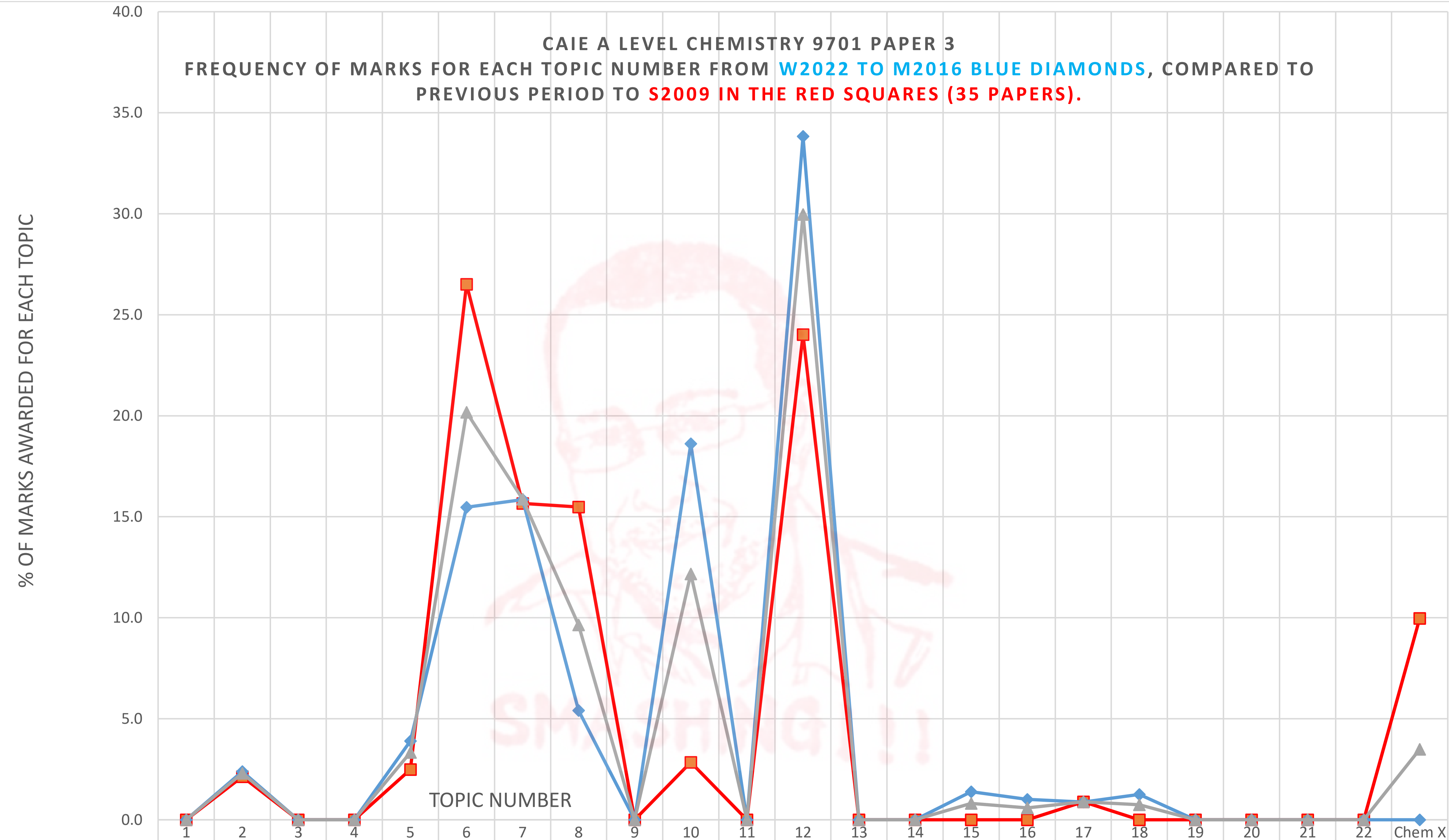


	Gravimetric	Gas collection	Thermometric	Rate	Titration	Qualitative ions	Qualitative organic	Therm. Titrn	Old content
P3 02s to 23s	10.0	3.4	10.0	8.7	25.6	28.4	1.9	5.7	6.3



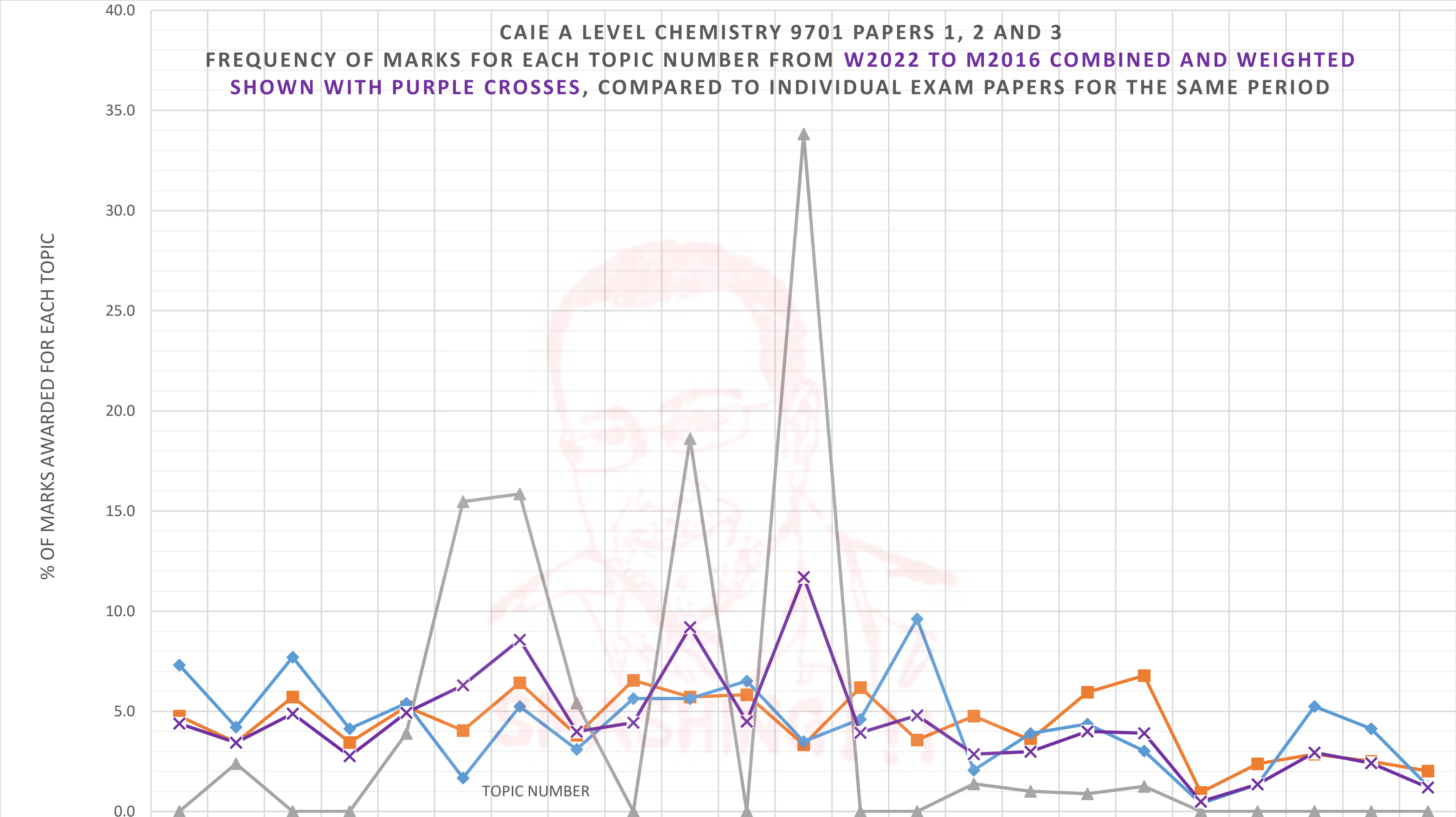
Experiment Name	Code	SAMPLE Data %	P3 09s-22w %
Qualitative: Inorganic ions test	Qi	49.6	28.4
Titration 1: Acid/base	T1	17.8	9.9
Titration 2: Redox of $KMnO_4$ and a reductant	T2	10.8	9.1
Titration 3: Thiosulfate and	T3	0.0	6.6
Gravimetric: Thermal decomposition	G1	8.5	7.4
Gravimetric 2: Water of crystallisation	G2	0.0	1.5
Gravimetric 3: Gas mass lost	G3	0.0	1.1
Rate 1: Thiosulfate and acid	R1	0.0	5.8
Rate 2: Thiosulfate and iodine	R2	9.8	2.9
Qualitative: Organic reactions	Qo	3.5	1.9
Thermometric Titrations	ThT	0.0	5.7
Gas Collection 1: Carbonate reacting with acid	GC1	0.0	2.0
Gas Collection 2: Decomposition of H_2O_2	GC2	0.0	0.8
Gas Collection 3: Metal reacting with acid	GC3	0.0	0.6
Enthalpy 1: Metal displacement	H1	0.0	5.9
Enthalpy 2: Carbonate reacting with acid	H2	0.0	1.8
Enthalpy 3: Decomposition of H_2O_2	H3	0.0	0.8
Enthalpy 4: Heat changes of salts dissolving	H4	0.0	1.5

	G1	G2	G3	GC1	GC2	GC3	H1	H2	H3	H4	R1	R2	T1	T2	T3	Qi	Qo	ThT
P3 09s-22w	7.4	1.5	1.1	2.0	0.8	0.6	5.9	1.8	0.8	1.5	5.8	2.9	9.9	9.1	6.6	28.4	1.9	5.7
SAMPLE Data	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	17.8	10.8	0.0	49.6	3.5	0.0



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Chem X
P3 09s-15w	0.0	2.1	0.0	0.0	2.5	26.5	15.7	15.5	0.0	2.8	0.0	24.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	10.0
P3 16m-22m	0.0	2.4	0.0	0.0	3.9	15.5	15.8	5.4	0.0	18.6	0.0	33.8	0.0	0.0	1.4	1.0	0.9	1.3	0.0	0.0	0.0	0.0	0.0
P3 09s-22m	0.0	2.3	0.0	0.0	3.3	20.2	15.9	9.6	0.0	12.2	0.0	30.0	0.0	0.0	0.8	0.6	0.9	0.7	0.0	0.0	0.0	0.0	3.5

SMASHING!!!



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Chem X
P1 16m-22w	4.8	3.5	5.7	3.5	5.2	4.0	6.4	3.8	6.5	5.7	5.8	3.3	6.2	3.6	4.8	3.6	6.0	6.8	1.0	2.4	2.9	2.5	2.0
P2 16m-22w	7.3	4.2	7.7	4.1	5.4	1.7	5.2	3.1	5.6	5.6	6.5	3.5	4.6	9.6	2.1	3.9	4.4	3.0	0.4	1.4	5.2	4.1	1.3
P3 16m-22m	0.0	2.4	0.0	0.0	3.9	15.5	15.8	5.4	0.0	18.6	0.0	33.8	0.0	0.0	1.4	1.0	0.9	1.3	0.0	0.0	0.0	0.0	0.0
P1,2,3	4.4	3.4	4.9	2.8	4.9	6.3	8.6	4.0	4.4	9.2	4.5	11.7	3.9	4.8	2.9	3.0	4.0	3.9	0.5	1.4	2.9	2.4	1.2

Analysis – Tables

Experiment Name	Code	SAMPLE Data %	P3 09s-22w %
Qualitative: Inorganic ions test	Qi	49.6	28.4
Titration 1: Acid/base	T1	17.8	9.9
Titration 2: Redox of $KMnO_4$ and a reductant	T2	10.8	9.1
Titration 3: Thiosulfate and	T3	0.0	6.6
Gravimetric: Thermal decomposition	G1	8.5	7.4
Gravimetric 2: Water of crystallisation	G2	0.0	1.5
Gravimetric 3: Gas mass lost	G3	0.0	1.1
Rate 1: Thiosulfate and acid	R1	0.0	5.8
Rate 2: Thiosulfate and iodine	R2	9.8	2.9
Qualitative: Organic reactions	Qo	3.5	1.9
Thermometric Titrations	ThT	0.0	5.7
Gas Collection 1: Carbonate reacting with acid	GC1	0.0	2.0
Gas Collection 2: Decomposition of H_2O_2	GC2	0.0	0.8
Gas Collection 3: Metal reacting with acid	GC3	0.0	0.6
Enthalpy 1: Metal displacement	H1	0.0	5.9
Enthalpy 2: Carbonate reacting with acid	H2	0.0	1.8
Enthalpy 3: Decomposition of H_2O_2	H3	0.0	0.8
Enthalpy 4: Heat changes of salts dissolving	H4	0.0	1.5
No longer on the syllabus	X	0.0	6.3

Experiment Name	02s to 23s
Gravimetric	10.0
Gas collection	3.4
Thermometric	10.0
Rate	8.7
Titration	25.6
Qualitative ions	28.4
Qualitative organic	1.9
Therm. Titrn	5.7
Old content	6.3
Total	100.0

Experiment Name	Code	P3 09s-22w
Gravimetric: Thermal decomposition	G1	7.4
Gravimetric 2: Water of crystallisation	G2	1.5
Gravimetric 3: Gas mass lost	G3	1.1
Gravimetric Total		10.0
Gas Collection 1: Carbonate reacting with acid	GC1	2.0
Gas Collection 2: Decomposition of H2O2	GC2	0.8
Gas Collection 3: Metal reacting with acid	GC3	0.6
Gas Collection Total		3.4
Enthalpy 1: Metal displacement	H1	5.9
Enthalpy 2: Carbonate reacting with acid	H2	1.8
Enthalpy 3: Decomposition of H2O2	H3	0.8
Enthalpy 4: Heat changes of salts dissolving	H4	1.5
Enthalpy Total		10.0
Rate 1: Thiosulfate and acid	R1	5.8
Rate 2: Thiosulfate and iodine	R2	2.9
Rate Total		8.7
Titration 1: Acid/base	T1	9.9
Titration 2: Redox of KMnO4 and a reductant	T2	9.1
Titration 3: Thiosulfate and	T3	6.6
Titration Total		25.6
Qualitative: Inorganic ions test	Qi	28.4
Qualitative: Organic reactions	Qo	1.9
Qualitative Total		30.3
Thermometric Titrations	ThT	5.7
No longer on the syllabus	X	6.3

Notes on analysis of Paper 3

Generally, as with Paper 5, it is harder to assign topic numbers to these kinds of skill-based exam questions. As a result, topics like 12, which includes sulfates, nitrates and the ammonium ions have an outsized impact on these statistics, even though there is very little chemistry syllabus content that these would be directly assessing. Similarly, most marks that are assigned to the electrochemistry topic, Topic 6, can be accessed without knowing much or any theory from this topic, as most of the marks relate to using moles in calculations and redox titrations.

A different approach, to assign marks instead to an experiment type makes it harder to compare the 3 different exam question papers with each other and with the syllabus. But it has also been used here and allows a way to organise and order the questions in a way that allows patterns to be more visible.

SAMPLE Data exists for most of the experiment types that are most frequently assigned marks.

Qualitative experiments, almost always on ions, are always included in every exam paper. The sample data provided should be used to deliver the conclusions about what these results tell you about the identity of the unknown substance. Titrations, both acid base and redox using the MnO_4^- ion as the oxidizer and the indicator are very common and included here, as are gravimetric analysis investigating the thermal decomposition of carbonates. Notably absent in the sample data are thermometric titrations and thermometric (enthalpy experiments). A more comprehensive and systematic approach to Sample Data will be attempted, possibly for the November 2024 exams.

Alternate sample data and exercises

You can use this data, which is slightly incorrect for the questions shown.

This will help you get a better understanding of how, even if an experiment does not go to plan, you can still use the data you do end up with to get many, if not most of the marks available for the exam.

REDOX TITRATIONS Alternate Sample data and Notes

For a comprehensive explanation of the chemistry for this type of experiment go here:

https://www.chemguide.co.uk/inorganic/transition/manganese.html

For alternate sample data that will be slightly incorrect:

Sample data for 2002/s/TZ 5/Q1.a-c

During the experiment you have these titres:

- 27, 24, 24.2, 24.1

Sample data for 2011/s/TZ 3/Q1

During the experiment you have these titres:

- 32, 31, 29.8

Sample data for 2014/s/TZ 3/Q1

During the experiment you have these titres:

- 32, 33, 26.7, 29, 28, 36

Sample data for 2015/s/TZ 1/Q1

During the experiment you have these titres:

- 29.8

Sample data for 2015/s/TZ 1/Q1

During the experiment you have these titres:

- 32.0, 31, 30.05 and 30.1

Sample data for 2010/w/TZ 4/Q1

During the experiment you have these titres:

- 29, 32, 25.9, 15.05

Activities and Questions for Redox Titrations

1. After you have used the corre3ct values at the start of each question, repeat the question but use instead the values above, which are slightly incorrect.
2. Work through the calculations for each exam question using these values. How differently do the correct values make things?
3. Are the calculations any easier or harder if you don't get the titration exactly right?
4. Is there any way to increase the number of marks awarded by presenting the data you have been given better?

Questions and Things to Think About for Redox Titrations

1. You will never be able to know how much exactly the correct volume for the titre.
2. What is the direction of error for this experiment, are you likely to add too much from the burette or too little?
3. Which of these sets of results would have taken the most time in the real exam? Do you think they were more accurate?
4. How many marks are awarded for getting the amount added correct?
5. What usually goes into the burette?
6. What is the end point? How do you know when all of the limiting reactant has been used up?
7. If you have limited results, how can you maximise your marks (analyse at the mark schemes!)?
8. What proportion of the marks are awarded for calculations?
9. What is the most common volume for a titre?

THERMAL DECOMPOSITION Sample data and Notes

For a background that goes a little beyond AS level:

https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Instrumental_Analysis_(LibreTexts)/31%3A_Thermal_Methods/31.01%3A_Thermogravimetric_Methods

Table 1: Use the following data to complete the 4 thermal decomposition questions that follow (they include the kinds of mistakes you could make):

Paper ID	Marks	Measured initial mass	Measured final mass
2022/s/TZ 3/Q2	12	42	41.42
2019/s/TZ 1/Q2	14	42.98	41.52
2017/s/TZ 1/Q2	10	43.60	42.76
2016/s/TZ 4/Q2	14	35.8	41.29

THERMAL DECOMPOSITION activities and things to think about

1. Mark your first experiments using the mark scheme at the back and the exact values given in Table 2 above.
2. Complete the 4 exam questions again, using the values in Table 2 instead.
3. Describe and explain any differences you notice between values you might measure in the lab and the exact values given in Table 2. Think about the kinds of mistakes that you could make in an experiment like this and how they could either make the measured mass larger or smaller than it should be.
4. Identify which experiment had an incorrect initial mass.
5. Describe and explain this error in initial mass.
6. Identify which experiment had the largest error.
7. Describe and explain what could have caused this error.
8. Identify which carbonate is most often used for thermal decompositions.
9. Calculate the average exact starting mass for these 4 experiments.
10. Calculate the average exact mass lost for the 4 experiments.
11. Sometimes the crucible cracks, if for instance it is very hot and gets wet. Describe and explain a strategy to deal with this problem in the actual exam so that you can maximise your marks after this mistake.

RATE OF REACTION (thiosulfate and acid) notes on experiments

For a background that covers the chemistry behind this experiment type:

https://www.chemguide.co.uk/physical/basicrates/concentration.html

For a background that goes a little beyond AS level:

https://chem.libretexts.org/Courses/University_of_British_Columbia/UBC_CHEM_154%3A_Chemistry_for_Engineering/10%3A_Chemical_Kinetics/10.02%3A_Measuring_Reaction_Rates

For a YouTube video on this experiment type:

https://www.youtube.com/watch?v=J8zyMnMzbLA

https://www.youtube.com/watch?v=r4IZDPpN-bk

Answers to the questions about the Thermal Decomposition Sample Data:
Mark your first experiments using the mark scheme at the back and the exact values given in the exam questions.

1. Complete the 4 exam questions again, now using the values in Table 1 instead.
2. Describe and explain any differences you notice between values you might measure in the lab and the exact values and those given in Table 1. Think about the kinds of mistakes that you could make in an experiment like this and how they could either make the measured mass larger or smaller than it should be.

Mistakes and experimenter error fall into 2 categories:

More mass is measured than should be. For instance, if the crucible is wet, or if a different, heavier lid is used, or if some other substance, for instance from the pipe-clay triangles gets on the crucible. Or the thermal decomposition was not complete, so some carbonate remains.

Less mass is measured than should be. For instance, the compound used was wet (so the water is lost). Some of the residue was lost, for instance because of 'spitting' and crackling, where the heated solid changes shape suddenly causing it to fly out of the crucible. Residue could also be lost from the crucible if some substance, like soot, gets wiped off after the initial mass has been measured.

3. Identify which experiment had an incorrect initial mass.

Paper ID	Marks	Measured initial mass	Measured final mass	Mass of crucible and lid	Initial mass	Final mass
2017/s/TZ 1/Q2	10	43.60	42.76	40.76	43.51	42.74

4. Describe and explain this error in initial mass.

Crucible could have gotten wet, or the balance had contaminants on it.

5. Identify which experiment had the largest error.

Paper ID	Marks	Measured initial mass
2016/s/TZ 4/Q2	14	35.8

6. Describe and explain what could have caused this error.

The crucible lid was not measured with the crucible.

7. Identify which carbonate is most often used for thermal decompositions.

Magnesium carbonate

8. Calculate the average exact starting mass for these 4 experiments.

1.66g; average of 1.30g for $MgCO_3$ and 2.75 for the single experiment with $CuCO_3$.

9. Calculate the average exact mass lost for the 4 experiments.

0.71g for all 4 experiments; average of 0.69g for $MgCO_3$ and 0.77g for the single experiment with $CuCO_3$.

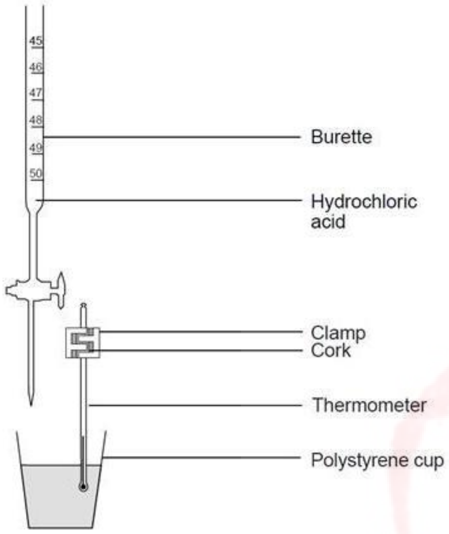
Sometimes the crucible cracks, if for instance it is very hot and gets wet. Describe and explain a strategy to deal with this problem in the actual exam so that you can maximise your marks after this mistake.

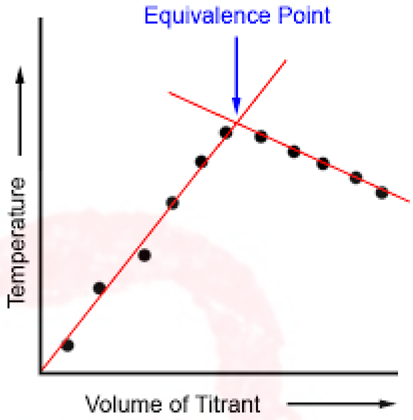
Use an estimated value of 0.71g as the mass lost in your calculations.

For a background that covers the chemistry behind this experiment type:

https://edu.rsc.org/experiments/a-thermometric-titration/429.article

If you really wanted to, you could try using some of this data in a thermometric titration question, which would get you some more practice on some of the questions that followed. Often you are looking at around 25 to 35cm^3 as being the necessary volume needed to reach the end point (the middle of the range given in the exam question). Both intersecting lines would need at least 2 data points each, so there should always be two points which have a lower temperature than the theoretical temperature where the two lines intersect.





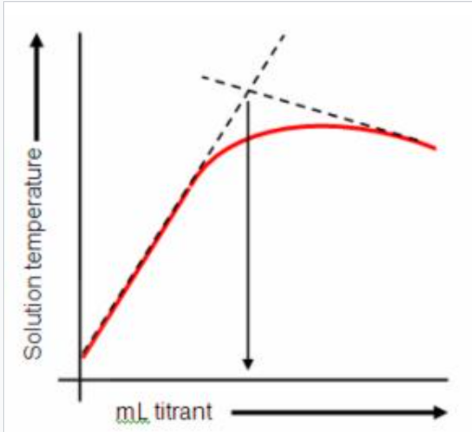
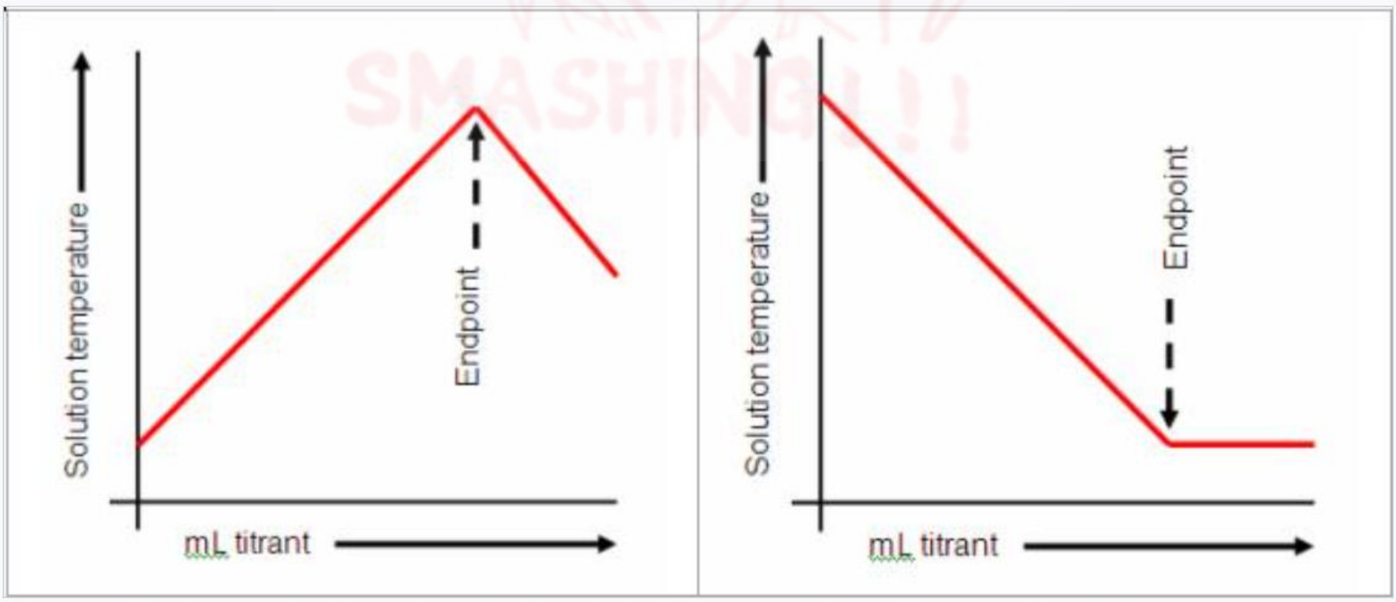
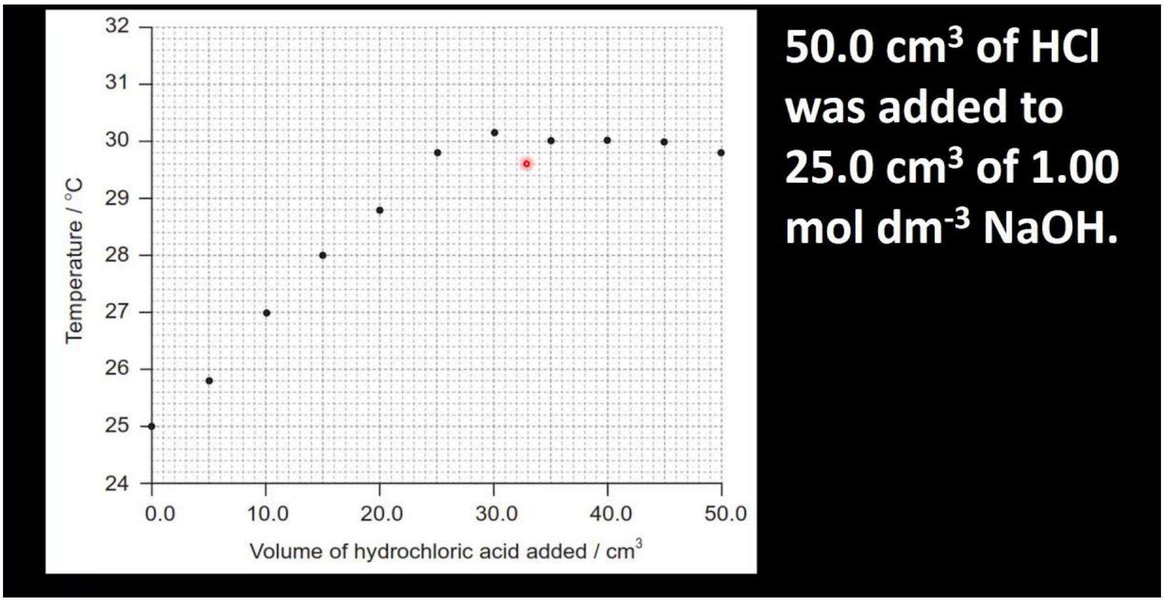


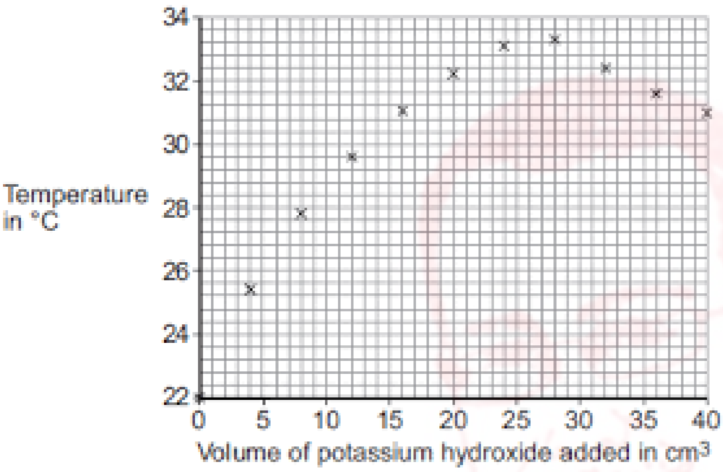
Fig. 2. Representation of a thermometric titration curve for a reaction with a non-stoichiometric equilibrium

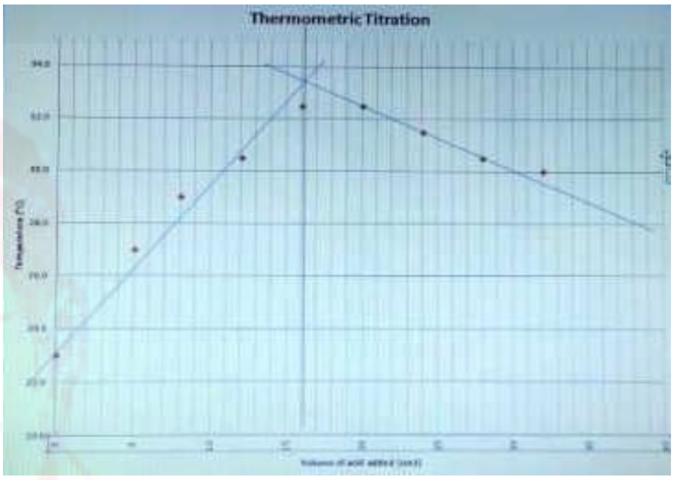
Total volume of sodium hydroxide added /cm^3	0.00	5.00	10.00	15.00	20.00	25.00	30.00
Temperature / °C	20.4	22.8	25.5	28.0	27.2	24.1	20.8

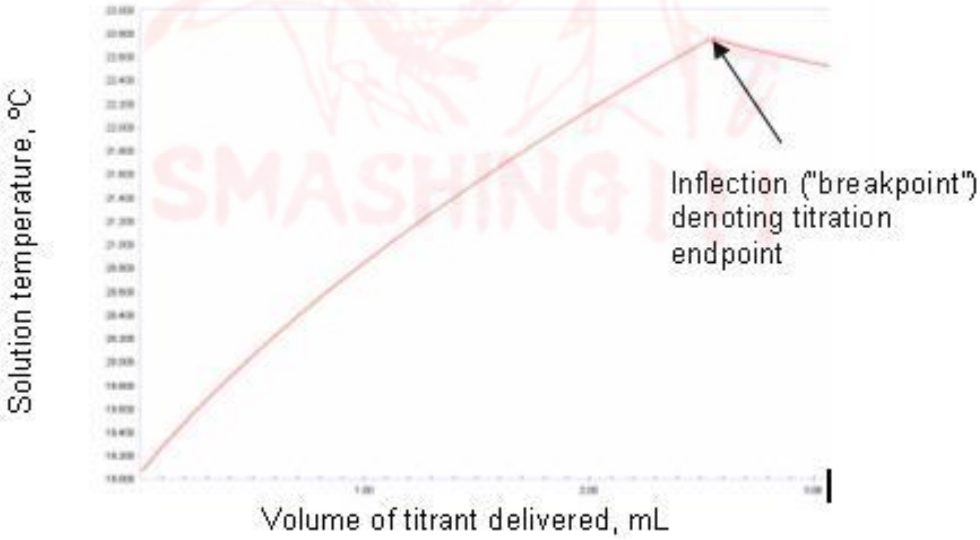


Figs. 1a & 1b. Idealized thermometric titration plots of exothermic (left) and endothermic (right) reactions


Temperature / °C
Volume of hydrochloric acid added / cm^3
50.0 cm^3 of HCl was added to 25.0 cm^3 of 1.00 mol dm^{-3} NaOH.


Temperature in °C
Volume of potassium hydroxide added in cm^3


Thermometric Titration


Solution temperature, °C
Inflection ("breakpoint") denoting titration endpoint
Volume of titrant delivered, mL

Organising your months in 2024

January						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

February						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29		

March						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

April						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

May						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

June						
S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

CAMBRIDGE
International Education

Cambridge IGCSE™
Cambridge O Level
Cambridge International AS & A Level

Cambridge Final Exam Timetable June 2024

Administrative zone 5

CAIE Chemistry 9701 A Level Chemistry Exam Timetable for *Administrative Zone 5 (Time Zone 2)*:

Paper 1 – AS Chemistry

Tuesday 04 June

	Syllabus/Component	Code	Duration	Session
IG	Drama	0411/13	2h 30m	AM
IG	Design & Technology	0445/33	1h	AM
IG	Design & Technology	0445/43	1h	AM
IG	Design & Technology	0445/53	1h	AM
AS	Accounting (Multiple Choice)	9706/13	1h	AM

	Syllabus/Component	Code	Duration	Session
AS	Chemistry (Multiple Choice)	9701/12	1h 15m	PM

Paper 2 - AS Chemistry

Wednesday 15 May

	Syllabus/Component	Code	Duration	Session
IG	Literature in English	0475/23	1h 30m	AM
IG	Literature in English	0475/33	45m	AM
IG	Literature in English	0475/43	1h 15m	AM
OL	Literature in English	2010/23	1h 30m	AM
AL	Mathematics (Pure Mathematics 3)	9709/33	1h 50m	AM

	Syllabus/Component	Code	Duration	Session
IG	Computer Science	0478/12	1h 45m	PM
IG	French	0520/22	1h	PM
OL	Computer Science	2210/12	1h 45m	PM
OL	French	3015/02	1h	PM
AS	Chemistry	9701/22	1h 15m	PM
AL	Chemistry	9701/52	1h 15m	PM

Paper 3 - AS Chemistry

Thursday 02 May

	Syllabus/Component	Code	Duration	Session
IG	Geography	0460/13	1h 45m	AM

	Syllabus/Component	Code	Duration	Session
IG	Sanskrit	0499/22	1h 30m	PM
IG	Biology (Core)	0610/32	1h 15m	PM
IG	Biology (Extended)	0610/42	1h 15m	PM
IG	Combined Science (Core)	0653/32	1h 15m	PM
IG	Combined Science (Extended)	0653/42	1h 15m	PM
IG	Co-ordinated Sciences (Double Award) (Core)	0654/32	2h	PM
IG	Co-ordinated Sciences (Double Award) (Extended)	0654/42	2h	PM
OL	Biology	5090/22	1h 45m	PM
OL	Combined Science	5129/22	1h 45m	PM
AS	Global Perspectives & Research	9239/12	1h 30m	PM
AS	Chemistry (Practical - Advanced)	9701/33	2h	PM

Thursday 30 May

	Syllabus/Component	Code	Duration	Session
OL	Commerce	7100/23	2h	AM
AL	Sociology	9699/43	1h 45m	AM

	Syllabus/Component	Code	Duration	Session
IG	Accounting (Multiple Choice)	0452/12	1h 15m	PM
OL	Accounting (Multiple Choice)	7707/12	1h 15m	PM
AS	Law	9084/22	1h 30m	PM
AS	Chemistry (Practical - Advanced)	9701/34	2h	PM

Paper 4 (A2 Chemistry)

Wednesday 08 May

	Syllabus/Component	Code	Duration	Session
IG	Information & Communication Technology	0417/13	1h 30m	AM
IG	Global Perspectives	0457/13	1h 15m	AM
AS	Computer Science	9618/13	1h 30m	AM
AS	Information Technology	9626/13	1h 45m	AM

	Syllabus/Component	Code	Duration	Session
IG	English (as an Additional Language)	0472/22	1h	PM
IG	English (as an Additional Language)	0472/42	1h	PM
IG	First Language English (Oral Endorsement)	0500/12	2h	PM
IG	English as a Second Language (Speaking Endorsement)	0510/12	2h	PM
IG	English as a Second Language (Count-in Speaking)	0511/12	2h	PM
OL	English Language	1123/12	2h	PM
AL	Chemistry	9701/42	2h	PM
IG	Latin	0480/13	1h 30m	EV
AS	Thinking Skills	9694/23	1h 45m	EV

Paper 5 (A2 Chemistry)

Wednesday 15 May

	Syllabus/Component	Code	Duration	Session
IG	Literature in English	0475/23	1h 30m	AM
IG	Literature in English	0475/33	45m	AM
IG	Literature in English	0475/43	1h 15m	AM
OL	Literature in English	2010/23	1h 30m	AM
AL	Mathematics (Pure Mathematics 3)	9709/33	1h 50m	AM

	Syllabus/Component	Code	Duration	Session
IG	Computer Science	0478/12	1h 45m	PM
IG	French	0520/22	1h	PM
OL	Computer Science	2210/12	1h 45m	PM
OL	French	3015/02	1h	PM
AS	Chemistry	9701/22	1h 15m	PM
AL	Chemistry	9701/52	1h 15m	PM

Syllabus view (A–Z)

CAMBRIDGE International Education

Cambridge International AS Level

Syllabus/Component	Code	Duration	Date	Session
A				
Accounting (Multiple Choice)	9706/13	1h	Tuesday 04 June 2024	AM
Accounting	9706/23	1h 45m	Thursday 09 May 2024	AM
B				
Biology (Multiple Choice)	9700/12	1h 15m	Tuesday 11 June 2024	PM
Biology	9700/22	1h 15m	Tuesday 14 May 2024	PM
Biology (Practical - Advanced)	9700/33	2h	Thursday 09 May 2024	PM
Biology (Practical - Advanced)	9700/34	2h	Tuesday 28 May 2024	PM
Business	9609/13	1h 15m	Monday 06 May 2024	AM
Business	9609/23	1h 30m	Friday 10 May 2024	AM
C				
Chemistry (Multiple Choice)	9701/12	1h 15m	Tuesday 04 June 2024	PM
Chemistry	9701/22	1h 15m	Wednesday 15 May 2024	PM
Chemistry (Practical - Advanced)	9701/33	2h	Thursday 02 May 2024	PM
Chemistry (Practical - Advanced)	9701/34	2h	Thursday 30 May 2024	PM
Chinese Language (Listening - Multiple Choice)	8238/12	1h	Monday 27 May 2024	PM
Chinese Language (Multiple Choice)	8238/22	1h 30m	Wednesday 29 May 2024	PM
Chinese Language	8238/32	1h 30m	Friday 26 April 2024	PM
Computer Science	9618/13	1h 30m	Wednesday 08 May 2024	AM
Computer Science	9618/23	2h	Friday 17 May 2024	AM
D				
Drama	9482/13	2h	Friday 24 May 2024	AM
E				
Economics (Multiple Choice)	9708/12	1h	Friday 07 June 2024	PM
Economics	9708/22	2h	Friday 10 May 2024	PM
English General Paper	8021/12	1h 15m	Thursday 25 April 2024	PM
English General Paper	8021/22	1h 45m	Monday 29 April 2024	PM
English Language	9093/12	2h 15m	Friday 03 May 2024	PM
English Language	9093/22	2h	Monday 06 May 2024	PM
Environmental Management	8291/13	1h 45m	Friday 26 April 2024	EV
Environmental Management	8291/23	1h 45m	Wednesday 01 May 2024	EV
F				
French Language	8682/23	1h 45m	Wednesday 01 May 2024	AM
French Language	8682/33	1h 30m	Wednesday 29 May 2024	AM
Further Mathematics	9231/13	2h	Monday 06 May 2024	AM
Further Mathematics	9231/33	1h 30m	Friday 24 May 2024	AM
Further Mathematics	9231/43	1h 30m	Wednesday 29 May 2024	AM
G				
Geography (Core)	9696/12	1h 30m	Friday 03 May 2024	PM
Geography (Core)	9696/22	1h 30m	Friday 17 May 2024	PM
Global Perspectives & Research	9239/12	1h 30m	Thursday 02 May 2024	PM
H				
History	9489/13	1h 15m	Friday 03 May 2024	AM
History	9489/23	1h 45m	Friday 10 May 2024	AM

Syllabus/Component	Code	Duration	Date	Session
I				
Information Technology	9626/13	1h 45m	Wednesday 08 May 2024	AM
L				
Language & Literature in English	8695/12	2h	Monday 06 May 2024	PM
Language & Literature in English	8695/22	2h	Wednesday 01 May 2024	PM
Law	9084/12	1h 30m	Tuesday 28 May 2024	PM
Law	9084/22	1h 30m	Thursday 30 May 2024	PM
Literature in English	9695/12	2h	Wednesday 01 May 2024	PM
Literature in English	9695/22	2h	Monday 13 May 2024	PM
M				
Marine Science	9693/13	1h 45m	Friday 26 April 2024	EV
Marine Science	9693/23	1h 45m	Wednesday 01 May 2024	AM
Mathematics (Pure Mathematics 1)	9709/13	1h 50m	Monday 29 April 2024	AM
Mathematics (Pure Mathematics 2)	9709/23	1h 15m	Tuesday 07 May 2024	EV
Mathematics (Mechanics)	9709/43	1h 15m	Tuesday 07 May 2024	AM
Mathematics (Probability & Statistics 1)	9709/53	1h 15m	Monday 13 May 2024	AM
Media Studies	9607/22	2h	Tuesday 07 May 2024	PM
Music (Listening)	9483/13	2h	Monday 20 May 2024	AM
P				
Physics (Multiple Choice)	9702/12	1h 15m	Thursday 06 June 2024	PM
Physics	9702/22	1h 15m	Thursday 16 May 2024	PM
Physics (Practical - Advanced)	9702/33	2h	Tuesday 30 April 2024	PM
Physics (Practical - Advanced)	9702/34	2h	Thursday 23 May 2024	PM
Portuguese Language	8684/02	1h 45m	Tuesday 30 April 2024	EV
Portuguese Language	8684/03	1h 30m	Monday 20 May 2024	EV
Psychology	9990/12	1h 30m	Thursday 25 April 2024	PM
Psychology	9990/22	1h 30m	Tuesday 30 April 2024	PM
S				
Sociology	9699/13	1h 30m	Thursday 09 May 2024	AM
Sociology	9699/23	1h 30m	Friday 17 May 2024	AM
Spanish Language (Listening - Multiple Choice)	8022/13	1h	Monday 13 May 2024	AM
Spanish Language (Multiple Choice)	8022/23	1h 30m	Wednesday 22 May 2024	EV
Spanish Language	8022/33	1h 30m	Monday 06 May 2024	EV
Sport & Physical Education	8386/13	1h 45m	Friday 24 May 2024	AM
T				
Thinking Skills	9694/13	1h 30m	Monday 29 April 2024	EV
Thinking Skills	9694/23	1h 45m	Wednesday 08 May 2024	EV
Travel & Tourism	9395/13	2h	Tuesday 30 April 2024	AM
U				
Urdu Language	8686/02	1h 45m	Monday 29 April 2024	EV
Urdu Language	8686/03	1h 30m	Wednesday 22 May 2024	EV

Cambridge Final Exam Timetable June 2024

Syllabus view (A–Z)

CAMBRIDGE International Education

Cambridge International A Level

Syllabus/Component	Code	Duration	Date	Session
A				
Accounting	9706/33	1h 30m	Tuesday 14 May 2024	AM
Accounting	9706/43	1h	Tuesday 21 May 2024	AM
B				
Biology	9700/42	2h	Tuesday 07 May 2024	PM
Biology	9700/52	1h 15m	Tuesday 14 May 2024	PM
Business	9609/33	1h 45m	Thursday 16 May 2024	AM
Business	9609/43	1h 15m	Monday 20 May 2024	AM
C				
Chemistry	9701/42	2h	Wednesday 08 May 2024	PM
Chemistry	9701/52	1h 15m	Wednesday 15 May 2024	PM
Chinese Language & Literature (Multiple Choice)	9868/12	1h 30m	Monday 27 May 2024	PM
Chinese Language & Literature	9868/22	2h	Friday 26 April 2024	PM
Chinese Language & Literature	9868/32	2h	Monday 29 April 2024	PM

Syllabus/Component	Code	Duration	Date	Session
L				
Law	9084/32	1h 30m	Monday 03 June 2024	PM
Law	9084/42	1h 30m	Wednesday 05 June 2024	PM
Literature in English	9695/32	2h	Tuesday 21 May 2024	PM
Literature in English	9695/42	2h	Thursday 23 May 2024	PM
M				
Marine Science	9693/33	1h 45m	Monday 06 May 2024	AM
Marine Science	9693/43	1h 45m	Friday 24 May 2024	EV
Mathematics (Pure Mathematics 3)	9709/33	1h 50m	Wednesday 15 May 2024	AM
Mathematics (Probability & Statistics 2)	9709/63	1h 15m	Tuesday 07 May 2024	AM
Media Studies	9607/42	2h	Wednesday 22 May 2024	PM
P				
Physics	9702/42	2h	Monday 13 May 2024	PM
Physics	9702/52	1h 15m	Thursday 16 May 2024	PM

Organising your weeks

Week Starting	Wk #	Events	Topic Focus
25-Mar	11		
1-Apr	12		
8-Apr	13	MOCK EXAM(?)	
15-Apr	14		
22-Apr	15		
29-Apr	16	Thur 2nd PM Paper 33 (TZ2)	
6-May	17	Wed 8th PM Paper 4 (TZ2)	
13-May	18	Wed 15th PM Paper 2 (TZ2) Wed 15th PM Paper 5 (TZ2)	
20-May	11		
27-May	12	Thur 30th PM Paper 34 (TZ2)	
3-Jun	13	Tues 4th PM Paper 1 (TZ2)	
10-Jun	14		
17-Jun	15		
24-Jun	16		

V1.0 – Continue to refine these to find and RECORD times you study best (and when you never study)

Period	Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	5:00 am							
	5:30 am							
	6:00 am							
	6:30 am							
	7:00 am							
Regstn	7:25 am							
1	7:50 am							
2	8:40 am							
3	9:30 am							
4	10:20 am							
5	11:00 am							
Lunch	11:50 pm							
6	1:10 pm							
7	2:00pm							
8	2:50 pm							
9	3:40 pm							
	4:20 pm							
	5:00 pm							
	5:30 pm							
	6:00 pm							
	6:30 pm							
	7:00 pm							
	7:30 pm							
	8:00 pm							
	8:30 pm							
	9:00 pm							
	9:30 pm							
	10:00 pm							
	10:30 pm							

Planning your days – v2.0

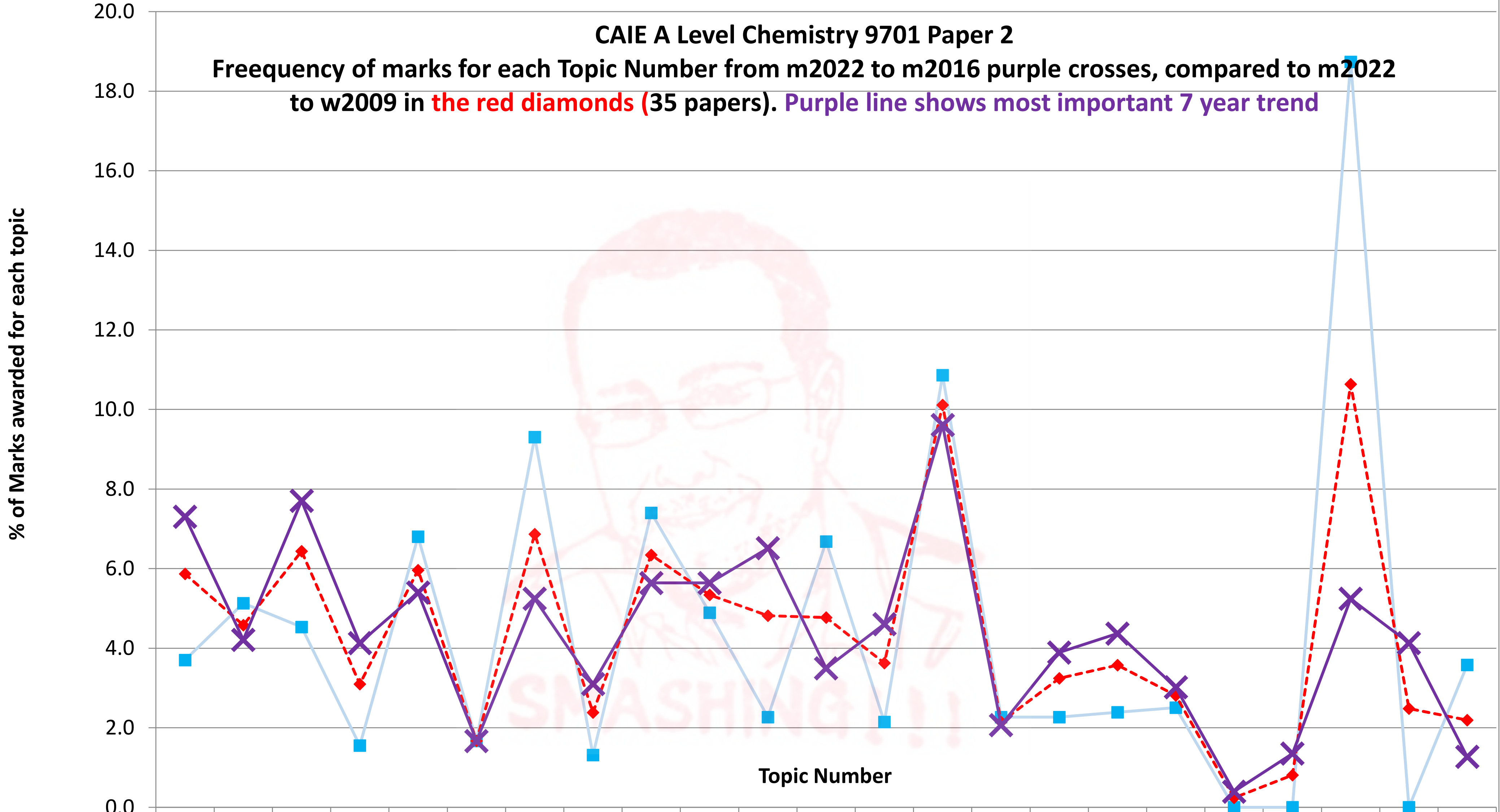
Period	Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	5:00 am							
	5:30 am							
	6:00 am							
	6:30 am							
	7:00 am							
Regstn	7:25 am							
1	7:50 am							
2	8:40 am							
3	9:30 am							
4	10:20 am							
5	11:00 am							
Lunch	11:50 pm							
6	1:10 pm							
7	2:00pm							
8	2:50 pm							
9	3:40 pm							
	4:20 pm							
	5:00 pm							
	5:30 pm							
	6:00 pm							
	6:30 pm							
	7:00 pm							
	7:30 pm							
	8:00 pm							
	8:30 pm							
	9:00 pm							
	9:30 pm							
	10:00 pm							
	10:30 pm							

Planning your days – v3.0

Period	Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	5:00 am							
	5:30 am							
	6:00 am							
	6:30 am							
	7:00 am							
Regstn	7:25 am							
1	7:50 am							
2	8:40 am							
3	9:30 am							
4	10:20 am							
5	11:00 am							
Lunch	11:50 pm							
6	1:10 pm							
7	2:00pm							
8	2:50 pm							
9	3:40 pm							
	4:20 pm							
	5:00 pm							
	5:30 pm							
	6:00 pm							
	6:30 pm							
	7:00 pm							
	7:30 pm							
	8:00 pm							
	8:30 pm							
	9:00 pm							
	9:30 pm							
	10:00 pm							
	10:30 pm							

Planning your days – v4.0

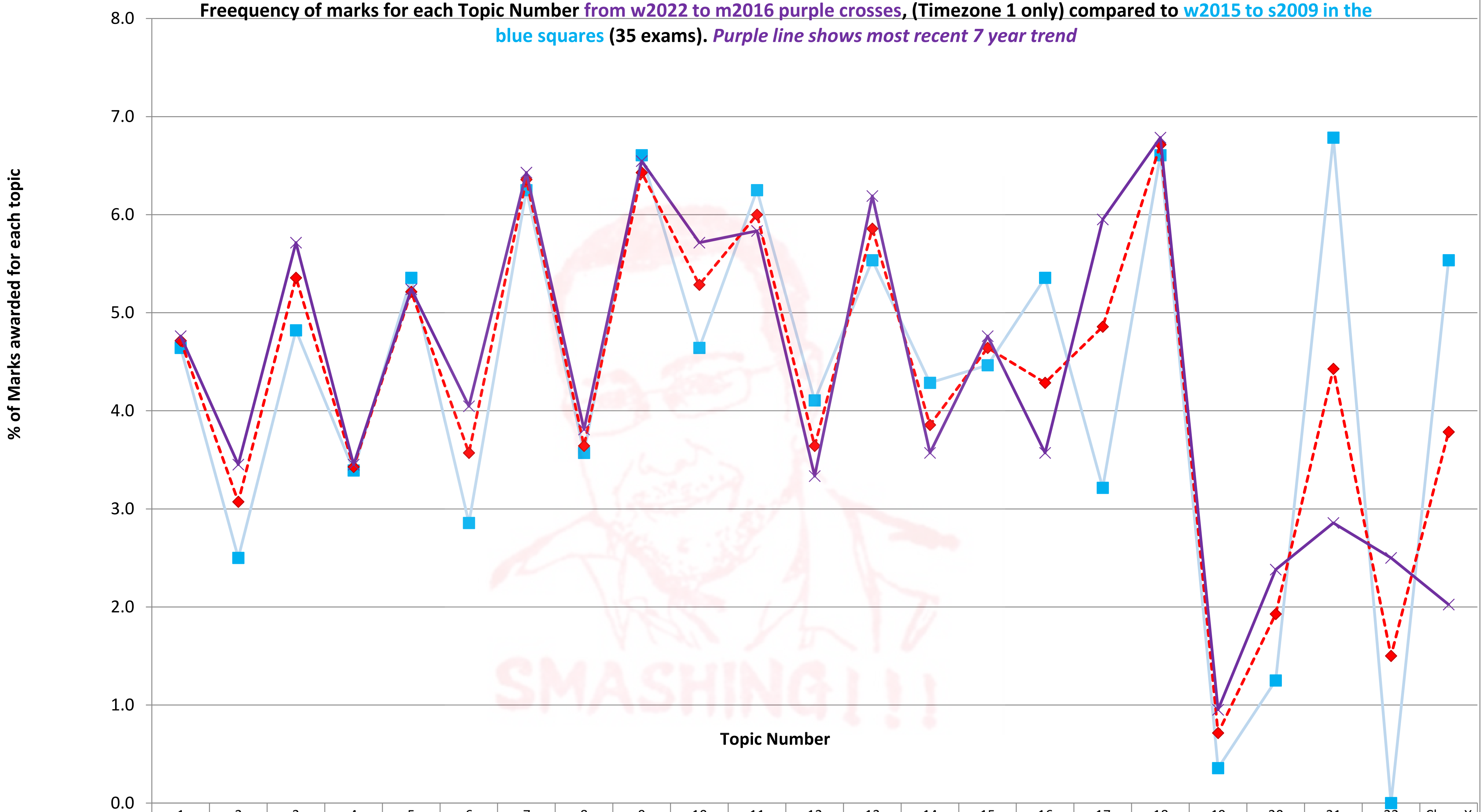
Period	Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	5:00 am							
	5:30 am							
	6:00 am							
	6:30 am							
	7:00 am							
Regstn	7:25 am							
1	7:50 am							
2	8:40 am							
3	9:30 am							
4	10:20 am							
5	11:00 am							
Lunch	11:50 pm							
6	1:10 pm							
7	2:00pm							
8	2:50 pm							
9	3:40 pm							
	4:20 pm							
	5:00 pm							
	5:30 pm							
	6:00 pm							
	6:30 pm							
	7:00 pm							
	7:30 pm							
	8:00 pm							
	8:30 pm							
	9:00 pm							
	9:30 pm							
	10:00 pm							
	10:30 pm							



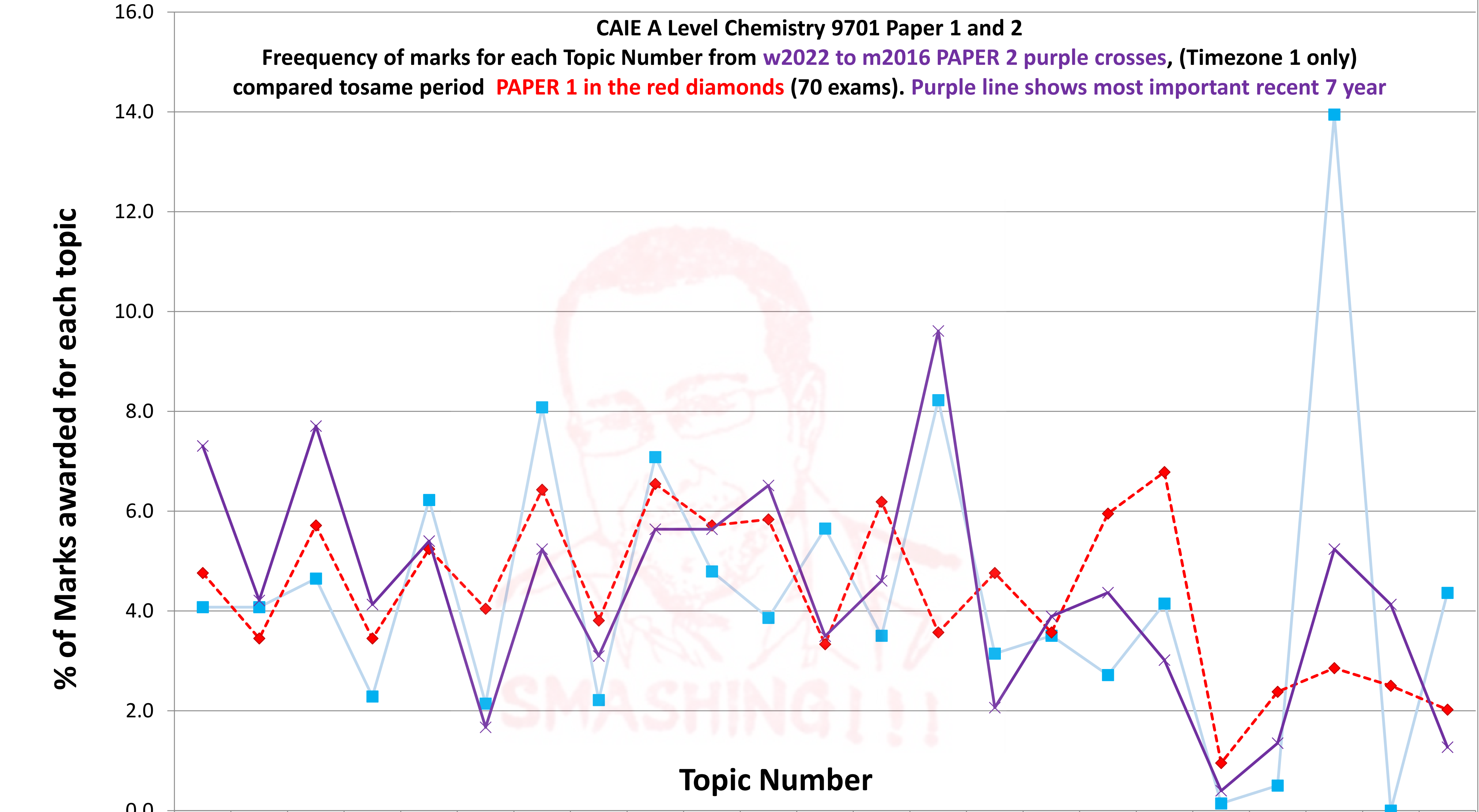
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Chem X
P2 09s-15w	3.7	5.1	4.5	1.6	6.8	1.7	9.3	1.3	7.4	4.9	2.3	6.7	2.1	10.9	2.3	2.3	2.4	2.5	0.0	0.0	18.7	0.0	3.6
P2 09w-22m	5.9	4.6	6.4	3.1	6.0	1.7	6.9	2.4	6.3	5.3	4.8	4.8	3.6	10.1	2.1	3.2	3.6	2.8	0.2	0.8	10.6	2.5	2.2
P2 16m-22w	7.3	4.2	7.7	4.1	5.4	1.7	5.2	3.1	5.6	5.6	6.5	3.5	4.6	9.6	2.1	3.9	4.4	3.0	0.4	1.4	5.2	4.1	1.3

CAIE A Level Chemistry 9701 **Paper 1: Multiple Choice**

Freequency of marks for each Topic Number from w2022 to m2016 purple crosses, (Timezone 1 only) compared to w2015 to s2009 in the blue squares (35 exams). ***Purple line shows most recent 7 year trend***



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Chem X
9w-15w	4.6	2.5	4.8	3.4	5.4	2.9	6.3	3.6	6.6	4.6	6.3	4.1	5.5	4.3	4.5	5.4	3.2	6.6	0.4	1.3	6.8	0.0	5.5
9w-22m	4.7	3.1	5.4	3.4	5.2	3.6	6.4	3.6	6.4	5.3	6.0	3.6	5.9	3.9	4.6	4.3	4.9	6.7	0.7	1.9	4.4	1.5	3.8
16m-22m	4.8	3.5	5.7	3.5	5.2	4.0	6.4	3.8	6.5	5.7	5.8	3.3	6.2	3.6	4.8	3.6	6.0	6.8	1.0	2.4	2.9	2.5	2.0



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Chem X
09w-15w P1+2	4.1	4.1	4.6	2.3	6.2	2.1	8.1	2.2	7.1	4.8	3.9	5.7	3.5	8.2	3.1	3.5	2.7	4.1	0.1	0.5	13.9	0.0	4.4
P1 16m-22w	4.8	3.5	5.7	3.5	5.2	4.0	6.4	3.8	6.5	5.7	5.8	3.3	6.2	3.6	4.8	3.6	6.0	6.8	1.0	2.4	2.9	2.5	2.0
P2 16m-22w	7.3	4.2	7.7	4.1	5.4	1.7	5.2	3.1	5.6	5.6	6.5	3.5	4.6	9.6	2.1	3.9	4.4	3.0	0.4	1.4	5.2	4.1	1.3

Paper 2: Notes and points of interest

Paper 2 By Chemistry Branch	P2 09s-15w	P2 16m-22w	16m-22w P1+2
Physical Chemistry			
1 Atomic structure	3.7	7.3	6.3
2 Atoms, molecules and stoichiometry	5.1	4.2	3.9
3 Chemical bonding	4.5	7.7	6.9
4 States of matter	1.6	4.1	3.9
5 Chemical energetics	6.8	5.4	5.3
6 Electrochemistry	1.7	1.7	2.6
7 Equilibria	9.3	5.2	5.7
8 Reaction kinetics	1.3	3.1	3.4
Physical Chemistry Totals	34.0	38.8	38.0
Inorganic Chemistry			
9 The Periodic Table: chemical periodicity	7.4	5.6	6.0
10 Group 2	4.9	5.6	5.7
11 Group 17	2.3	6.5	6.2
12 Nitrogen and sulfur	6.7	3.5	3.4
Inorganic Chemistry Totals	21.2	21.3	21.3
Organic Chemistry			
13 An introduction to AS Level organic chemistry	2.1	4.6	5.2
14 Hydrocarbons	10.9	9.6	7.2
15 Halogen compounds	2.3	2.1	3.1
16 Hydroxy compounds	2.3	3.9	3.8
17 Carbonyl compounds	2.4	4.4	5.0
18 Carboxylic acids and derivatives	2.5	3.0	4.5
19 Nitrogen compounds	0.0	0.4	0.6
20 Polymerisation	0.0	1.4	1.8
21 Organic synthesis	18.7	5.2	4.3
Organic Chemistry Totals	41.2	34.6	35.5
Analytical Techniques			
22 Analytical techniques	0.0	4.1	3.5
No longer assessed	3.6	1.3	1.6
AS Total (if <100, then because some material moved to A2)	100.0	100.0	100.0

Physical Chemistry Totals	34.0	38.8	38.0
Inorganic Chemistry Totals	21.2	21.3	21.3
Organic Chemistry Totals	41.2	34.6	35.5
22 Analytical techniques	0.0	4.1	3.5

The main change was in Topic 21 Organic Synthesis, which in 2015 and before was a larger part of the course (18.7% of all marks in 2015 and before, to 5.2% in Paper 2 from 2016 onwards). Questions that required several answers from various parts to solve an unknown compound tended to be broken down into smaller steps in 2016 and afterwards and the marks were therefore easier to assign to individual organic topics instead. This is line with a decades long trend away from thrilling subject-specific esoteric riddles towards an increasingly prosaic, quantised and rational assessment approach.

One of the most substantial changes in A2 was a move away from organic chemistry towards allocating a larger share of marks to the other branches of chemistry with the new 2016 syllabus. This change was not really seen at AS level, though organic chemistry is less common.

The 11 topics most frequently given marks in both Paper 1 and Paper 2 were more important from 2016 and onwards, representing almost 2 in 3 of all marks.

Mark were assigned based on when a student, learning in topic order, ought be able to produce an answer that would be awarded that mark, so sometimes material which the examiner may have intended to cover in one topic, say Topic 12 Nitrogen and Sulfur, may have been assigned to a different topic here, for instance Topic 3 Chemical Bonding instead because drawing a dot cross diagram of the triple covalent bond in N_2 is fully covered in Topic 3. But explaining why N_2 is unreactive, but CO, also with a triple covalent bond, is reactive, would be placed in Topic 12 because although bond polarity is covered earlier, this specific example isn't obviously fully covered in Topic 3. This difference between the topics assigned in these workbooks and what part of the syllabus the examiner was intending to assess was somewhat evident in Paper 1, where questions assess topics largely in syllabus order, though this general rule is not at all always followed in Paper 1.

Paper 1 and 2 By Frequency	P1 16m-22w	P2 16m-22w	09w-15w P1+2	16m-22w P1+2
Physical Chemistry				
14 Hydrocarbons	3.6	9.6	8.2	7.2
3 Chemical bonding	5.7	7.7	4.6	6.9
1 Atomic structure	4.8	7.3	4.1	6.3
11 Group 17	5.8	6.5	3.9	6.2
9 The Periodic Table: chemical periodicity	6.5	5.6	7.1	6.0
7 Equilibria	6.4	5.2	8.1	5.7
10 Group 2	5.7	5.6	4.8	5.7
5 Chemical energetics	5.2	5.4	6.2	5.3
13 An introduction to AS Level organic chemistry	6.2	4.6	3.5	5.2
17 Carbonyl compounds	6.0	4.4	2.7	5.0
18 Carboxylic acids and derivatives	6.8	3.0	4.1	4.5
Top half most represented topics totals	62.7	64.9	57.3	64
21 Organic synthesis	2.9	5.2	13.9	4.3
2 Atoms, molecules and stoichiometry	3.5	4.2	4.1	3.9
4 States of matter	3.5	4.1	2.3	3.9
16 Hydroxy compounds	3.6	3.9	3.5	3.8
22 Analytical techniques	2.5	4.1	0.0	3.5
8 Reaction kinetics	3.8	3.1	2.2	3.4
12 Nitrogen and sulfur	3.3	3.5	5.7	3.4
15 Halogen compounds	4.8	2.1	3.1	3.1
6 Electrochemistry	4.0	1.7	2.1	2.6
20 Polymerisation	2.4	1.4	0.5	1.8
19 Nitrogen compounds	1.0	0.4	0.1	0.6
No longer assessed	2.0	1.3	4.4	1.6
AS Total (if <1000, then because some material moved to A2)	99.9	100.0	99.4	100.0

Paper 1 and 2 By Chemistry Branch	P1 16m-22w	P2 16m-22w	09w-15w P1+2	16m-22w P1+2
Physical Chemistry				
1 Atomic structure	4.8	7.3	4.1	6.3
2 Atoms, molecules and stoichiometry	3.5	4.2	4.1	3.9
3 Chemical bonding	5.7	7.7	4.6	6.9
4 States of matter	3.5	4.1	2.3	3.9
5 Chemical energetics	5.2	5.4	6.2	5.3
6 Electrochemistry	4.0	1.7	2.1	2.6
7 Equilibria	6.4	5.2	8.1	5.7
8 Reaction kinetics	3.8	3.1	2.2	3.4
Physical Chemistry Totals	36.9	38.8	33.8	38.0
Inorganic Chemistry				
9 The Periodic Table: chemical periodicity	6.5	5.6	7.1	6.0
10 Group 2	5.7	5.6	4.8	5.7
11 Group 17	5.8	6.5	3.9	6.2
12 Nitrogen and sulfur	3.3	3.5	5.7	3.4
Inorganic Chemistry Totals	21.4	21.3	21.4	21.3
Organic Chemistry				
13 An introduction to AS Level organic chemistry	6.2	4.6	3.5	5.2
14 Hydrocarbons	3.6	9.6	8.2	7.2
15 Halogen compounds	4.8	2.1	3.1	3.1
16 Hydroxy compounds	3.6	3.9	3.5	3.8
17 Carbonyl compounds	6.0	4.4	2.7	5.0
18 Carboxylic acids and derivatives	6.8	3.0	4.1	4.5
19 Nitrogen compounds	1.0	0.4	0.1	0.6
20 Polymerisation	2.4	1.4	0.5	1.8
21 Organic synthesis	2.9	5.2	13.9	4.3
Organic Chemistry Totals	37.0	34.6	39.8	35.5
Analytical Techniques				
22 Analytical techniques	2.5	4.1	0.0	3.5
No longer assessed	2.0	1.3	4.4	1.6
AS Total (if <100, then because some material moved to A2)	99.9	100.0	99.4	100.0

Physical Chemistry Totals	36.9	38.8	33.8	38.0
Inorganic Chemistry Totals	21.4	21.3	21.4	21.3
Organic Chemistry Totals	37.0	34.6	39.8	35.5
22 Analytical techniques	2.5	4.1	0.0	3.5

Exam Papers, their marks and their weighting towards the AS and A2 years and the A Level qualification:

\

Exam Paper	% of AS/ A2	% of ALvl	Marks	Time in min	secs/ marks	% YEAR	% ALL A-Level/ mark (weighting)
1	31	15.5	40	75	112.5	0.78	0.39
2	46	23	60	75	75	0.77	0.38
3	23	11.5	40	120	180	0.58	0.29
4	77	38.5	100	120	72	0.77	0.39
5	23	11.5	30	75	150	0.77	0.38

SECTION 1: Past Exam Questions with SAMPLE Data Provided

T1 Acid Base Titration Chem 7 Q# 1/ ALvl Chemistry/2022/s/TZ 1/Paper 3/Q# 1 :o)

www.SmashingScience.org

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 27.25,

27.3

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will identify a straight-chain carboxylic acid by titrating an aqueous solution of this acid with aqueous sodium hydroxide. 1 mole of the carboxylic acid reacts with 1 mole of sodium hydroxide. The carboxylic acid contains C, H and O atoms only and has no C=C bonds.

FA 1 is an aqueous solution of the carboxylic acid, containing 10.50 $g\,dm^{-3}$.
FA 2 is 0.110 $mol\,dm^{-3}$ sodium hydroxide, NaOH.
FA 3 is thymolphthalein indicator.

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Add approximately 8 drops of **FA 3**.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm^3 of **FA 1** required .... cm^3 of **FA 2**. [1]

(c) Calculations

(i) Calculate the amount, in mol, of sodium hydroxide present in the volume of **FA 2** calculated in **(b)**.

amount of NaOH = ... mol [1]

(ii) Use your answer to **(c)(i)** and the information on page 2 to calculate the relative formula mass of the carboxylic acid in **FA 1**.

M_r of carboxylic acid = ... [1]

(iii) Identify the carboxylic acid in **FA 1**.
Draw its skeletal formula.

skeletal formula

name of acid ....
[2]

(d) A student carries out a similar titration to the titration you carried out in **(a)**. The only difference is that a solution of aminoethanoic acid, $NH_2CH_2CO_2H$, containing 10.50 $g\,dm^{-3}$ is used instead of the acid in **FA 1**.

(i) Construct an equation for the reaction taking place in the student's titration.
Include state symbols.

.... [1]

(ii) State whether the student's titre will be larger or smaller than your titre. Explain your answer.

The student's titre will be .... than mine.

explanation ....

....

.... [1]

[Total: 14]

T1 Acid Base Titration Chem 7 **Q# 2/** ALvl Chemistry/2021/w/TZ 1/Paper 3/Q# 2 :o) www.SmashingScience.org

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30.0, 25, 24.95

2 In this experiment you will titrate a solution of the hydroxide of a Group 1 element, **Z**, with sulfuric acid. The equation for the reaction is shown.

Z may or may not be the same as **X**.

$$2ZOH(aq) + H_2SO_4(aq) \rightarrow Z_2SO_4(aq) + 2H_2O(l)$$

FA 2 is 26.3 g dm^{-3} aqueous hydroxide of metal **Z**, **Z**OH.
FA 3 is 0.0500 mol dm^{-3} sulfuric acid, H_2SO_4.
bromophenol blue indicator

(a) Method

- Pipette 25.0 cm^3 of **FA 2** into the 250 cm^3 volumetric flask.
- Add distilled water to the flask to make 250 cm^3 of solution. Shake the flask thoroughly to ensure complete mixing. Label this solution **FA 4**.
- Rinse the pipette with a little distilled water and then a little **FA 4**.
- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure your recorded results show the accuracy of your practical work.
- Record in a suitable form in the space below all of your burette readings and the volume of **FA 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 3**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the appropriate number of significant figures. [1]

(ii) Calculate the number of moles of sulfuric acid present in the volume of **FA 3** you calculated in **(b)**.

moles of H_2SO_4 = ... mol [1]

(iii) Use your answer to **(c)(ii)** and the information on page 4 to calculate the concentration, in mol dm^{-3}, of **Z**OH present in **FA 4**.

concentration of **FA 4** = ... mol dm^{-3} [1]

(iv) Calculate the concentration, in mol dm^{-3}, of **Z**OH in **FA 2**.

concentration of **FA 2** = ... mol dm^{-3} [1]

(v) Use your answer to **(c)(iv)** and the information on page 4 to calculate the relative atomic mass, A_r, of **Z**. Hence identify **Z**.
Show your working.

Z is .... [2]

(d) Using the value for the relative atomic mass of **Z** that you calculated in **(c)(v)**, calculate the percentage difference of your value from that shown in the Periodic Table.

(If you did not obtain a value for the A_r of **Z**, assume it is 32.0. Note, this is **not** the correct value.)

percentage difference = ... % [1]

[Total: 15]

T1 Acid Base Titration Chem 7 **Q# 3/** ALvl Chemistry/2021/m/TZ 3/Paper 3/Q# 1 :o) www.SmashingScience.org

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30.00, 24.9,

24.95

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will carry out a titration to identify the Group 1 metal, **M**, present in a metal hydrogencarbonate, **M**HCO_3.

FA 1 is 0.0550 mol dm^{-3} sulfuric acid, H_2SO_4.
FA 2 is the metal hydrogencarbonate, **M**HCO_3.
bromophenol blue indicator

(a) Method

Preparing a solution of FA 2

- Weigh the stoppered container of **FA 2**. Record the mass in the space below.
- Tip all the **FA 2** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FA 2** used.
- Add approximately 100 cm^3 of distilled water to **FA 2** in the beaker.
- Stir the mixture with a glass rod until all the **FA 2** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of **M**HCO_3 is **FA 3**. Label the flask **FA 3**.

Titration

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add a few drops of bromophenol blue indicator to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 1** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 1**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)**, **(c)(iv)** and **(c)(v)** to the appropriate number of significant figures. [1]

(ii) Calculate the number of moles of sulfuric acid present in the volume of **FA 1** calculated in **(b)**.

moles of H_2SO_4 = ... mol [1]

(iii) Complete the equation for the reaction of sulfuric acid and **M**HCO_3.
State symbols are not required.

.....**M**HCO_3 + ...H_2SO_4 → .....**M**$_2SO_4$ + ... + ...

Use your answer to **(c)(ii)** to deduce the number of moles of **M**HCO_3 used in each titration.

moles of **M**HCO_3 = ... mol [1]

(iv) Use your answer to **(c)(iii)** and your data on page 2 to calculate the relative formula mass, M_r, of **M**HCO_3.

M_r of **M**HCO_3 = ... [1]

(v) Calculate the relative atomic mass, A_r, of **M**.

A_r of **M** = ...

Suggest the identity of **M**.

M is ....
[1]

(d) **(i)** A student used a pipette that was labelled 25.0 ± 0.06 cm^3 to measure **FA 3**.

Show how you calculate the maximum percentage error in the volume of **FA 3**.

[1]

(ii) The student suggested that it would have been more accurate to measure the volume of **FA 3** with a burette instead of the pipette.

State and explain whether you agree with the student.

....

.... [1]

[Total: 16]

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 24.5, 24.45

2 In this experiment you will determine the concentration of **FA 2** by titration using aqueous sodium hydroxide.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

FA 2 is hydrochloric acid, HCl.
FA 3 is 0.100 mol dm^{-3} sodium hydroxide, NaOH.
methyl orange indicator

(a) **Method**

Dilution of FA 2

- Fill the burette with **FA 2**.
- Run between 40.00 and 45.00 cm^3 from the burette into the 250 cm^3 volumetric flask.
- Record the volume used.
- Make the solution up to the 250 cm^3 mark by adding distilled water.
- Shake the flask thoroughly to ensure mixing.
- Label this solution of hydrochloric acid **FA 4**.

volume of **FA 2** used = ... cm^3

Titration

- Rinse the burette with distilled water and then with a little **FA 4**.
- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add several drops of methyl orange indicator.
- Perform a rough titration and record your burette readings.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form all of your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) From your accurate titration results, obtain a value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 4**.
[1]

(c) Calculations

(i) Give your answers to **(ii)**, **(iii)** and **(iv)** to the appropriate number of significant figures. [1]

(ii) Calculate the number of moles of hydrochloric acid that reacted with 25.0 cm^3 of **FA 3**.

moles of HCl = ... mol
[1]

(iii) Calculate the concentration of hydrochloric acid in **FA 4**.

concentration of HCl in **FA 4** = ... mol dm^{-3}
[1]

(iv) Calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = ... mol dm^{-3}
[1]

(d) Calculate the maximum percentage error in the volume of **FA 2** you added to the volumetric flask.

maximum percentage error = ... %
[1]

(e) In **Question 1** and **Question 2** you have determined the concentration of **FA 2** by two different methods. Each method used has possible sources of error, for example in **Question 1** the largest source of error is escape of gas.

Apart from this error, state and explain a source of error for each method.

Question 1 ....

....

Question 2 ....

....
[2]

[Total: 16]

T1 Acid Base Titration Chem 15 **Q# 5/** ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# 2 :o) www.SmashingScience.org

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 25, 25.95

2 In this question you will determine the identity of the halogen in compound **W**. Compound **W** is the halogenoethanoic acid CH_2XCO_2H, where X is a halogen.

4 g of **W** were heated with 250 cm^3 of 0.400 mol dm^{-3} aqueous sodium hydroxide. Some of the sodium hydroxide reacted with compound **W**. The solution that remained after this reaction is **FA 3**.

By titrating **FA 3** with hydrochloric acid, you will determine how much of the sodium hydroxide remained after reaction with **W**. You will then calculate how much sodium hydroxide had reacted and use this to determine the identity of X in CH_2XCO_2H.

FA 3 is aqueous sodium hydroxide after reaction with **W**.
FA 4 is 0.100 mol dm^{-3} hydrochloric acid, HCl.
bromophenol blue indicator

(a) Method

- Fill the second burette with **FA 4**.
- Rinse the pipette with distilled water followed by a little **FA 3**.
- Use the pipette to transfer 25.0 cm^3 of **FA 3** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	

- From your accurate titration results, obtain a suitable value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 4**.
[3]

(b) Calculations

A halogenoethanoic acid reacts with aqueous sodium hydroxide in two reactions.

The alkali neutralises the carboxylic acid.

$$NaOH + CH_2XCO_2H \rightarrow CH_2XCO_2Na + H_2O$$

The halogenoalkyl group then undergoes a substitution reaction.

$$NaOH + CH_2XCO_2Na \rightarrow CH_2(OH)CO_2Na + NaX$$

(i) Calculate the number of moles of hydrochloric acid, **FA 4**, present in the volume calculated in **(a)**.

moles of HC*l* = ... mol

Hence deduce the number of moles of sodium hydroxide present in 25.0 cm^3 of **FA 3**.

moles of NaOH in 25.0 cm^3 **FA 3** = ... mol
[1]

(ii) Calculate the number of moles of sodium hydroxide added to the 4 g of **W**.

moles of NaOH added to 4 g **W** = ... mol

Calculate the number of moles of sodium hydroxide that **remain after** the reaction with compound **W**.

moles of NaOH remaining after reaction with **W** = ... mol
[1]

(iii) Calculate the number of moles of sodium hydroxide that reacted with **W**.

moles of NaOH that reacted with **W** = ... mol

Hence calculate the number of moles of **W** that reacted with this number of moles of sodium hydroxide.

moles of **W** that reacted = ... mol
[1]

(iv) Use your answer to **(iii)**, and the mass of **W** used to make **FA 3**, to calculate the M_r of **W**.

M_r of **W** = ... [1]

(v) **W** is a halogenoethanoic acid, CH_2XCO_2H. Use your answer to **(iv)** to determine the identity of X. Explain how you reached your conclusion.

....

....

.... [2]

(c) Apart from any inaccuracies in reading the volumes of solutions, suggest a significant source of error in this practical exercise.
Explain how you could minimise this error.

....

....

.... [1]

(d) State at what M_r value of **W**, closest to the one calculated in **(b)(iv)**, you would have concluded that X was a different halogen.

M_r value = ... [1]

[Total: 11]

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 24.5, 24.45

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will use a solution of sodium carbonate, Na_2CO_3, to determine the concentration of a solution of hydrochloric acid, HCl, by carrying out a titration.

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

FA 1 is a solution of sodium carbonate containing 1.30 g Na_2CO_3 in each 250 cm^3.
FA 2 is hydrochloric acid, HCl.
methyl orange indicator

(a) Method

- Fill a burette with **FA 2**.
- Use the pipette to transfer 25.0 cm^3 of **FA 1** into a conical flask.
- Add a few drops of methyl orange indicator.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 2** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 1** required .... cm^3 of **FA 2**. [1]

(c) Calculations

(i) Give your answer to **(ii)**, **(iii)** and **(iv)** to an appropriate number of significant figures. [1]

(ii) Calculate the number of moles of sodium carbonate present in 25.0 cm^3 of **FA 1**.

moles of Na_2CO_3 = ... mol [1]

(iii) Calculate the number of moles of hydrochloric acid that reacted with the number of moles of sodium carbonate you calculated in **(ii)**.

moles of HCl = ... mol [1]

(iv) Use your answers to **(b)** and **(c)(iii)** to calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = ... $mol\,dm^{-3}$ [1]

[Total: 12]

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 27.35, 27.3

2 You will determine the amount of hydrochloric acid remaining in flask **X** after the reaction with the marble chips in **Question 1**. You will do this by titration with sodium hydroxide of known concentration.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

The impurities in the calcium carbonate will not react with the alkali.

FA 3 is 0.140 mol dm^{-3} sodium hydroxide, NaOH.
bromophenol blue indicator

(a) Method

- Transfer **all** the contents of flask **X** into the 250 cm^3 volumetric flask.
- Rinse flask **X** with distilled water and add the washings to the volumetric flask. Add distilled water up to the mark.
- Stopper the volumetric flask and mix the contents thoroughly. Label this solution **FA 4**.
- Rinse the pipette then use it to transfer 25.0 cm^3 of **FA 4** into a conical flask.
- Add about 10 drops of bromophenol blue indicator.
- Fill the burette with **FA 3**.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 3** added in each accurate titration.
- Make certain any recorded results show the precision of your practical work.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 3** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 3**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of sodium hydroxide, NaOH, present in the volume of **FA 3** you calculated in **(b)**.

moles of NaOH = ... mol

(ii) Use your answer to **(i)** and the equation on page 4 to determine the number of moles of hydrochloric acid, HC*l*, present in the 25.0 cm^3 of **FA 4** pipetted in **(a)**.

moles of HC*l* = ... mol

(iii) Use your answer to **(ii)** to calculate the number of moles of hydrochloric acid, HC*l*, remaining in flask **X** after the reaction in **1(a)**.

moles of HC*l* remaining = ... mol

(iv) Use the relevant information on page 2 to calculate the number of moles of hydrochloric acid, HC*l*, pipetted into flask **X** in **1(a)**.

moles of HC*l* pipetted into flask **X** = ... mol

(v) Use your answers to **(iii)** and **(iv)** to calculate the number of moles of hydrochloric acid, HC*l*, which reacted with the marble chips in flask **X**.

moles of HC*l* which reacted in flask **X** = ... mol

(vi) Use your answer to **(v)**, the equation in **Question 1** and the Periodic Table on page 12 to calculate the mass of pure calcium carbonate, $CaCO_3$, in the sample of industrial grade calcium carbonate, **FA 1**.

mass of $CaCO_3$ = ... g

(vii) Use your answer to **(vi)** and the mass of marble chips recorded in **1(a)** to calculate the percentage purity of **FA 1**.

percentage purity of **FA 1** = ... %

[5]

(d) You have carried out two different methods to find the percentage purity of industrial grade calcium carbonate.

A source of error in **Question 1** is that some carbon dioxide escapes before the bung can be inserted.

How would this affect the percentage purity of **FA 1** calculated in the two questions? Explain your answers.

Question 1

....

....

....

Question 2

....

....

....

[3]

[Total: 16]

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 24.9, 25

2 In this experiment you will determine the concentration of the hydrochloric acid, **FA 2**, used in **Question 1**. You will first dilute the reaction mixture that you prepared in **Question 1** and then titrate this diluted solution against sodium hydroxide, NaOH.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

FA 3 is 0.0400 $mol\,dm^{-3}$ sodium hydroxide, NaOH.
methyl orange indicator

(a) Method

Dilution

- Transfer all the reaction mixture that you prepared in **1(a)** from the 250 cm^3 beaker to the 250 cm^3 volumetric flask.
- Rinse the beaker with a little distilled water and add these washings to the volumetric flask.
- Fill the volumetric flask to the line with distilled water. Stopper the flask and shake it to ensure thorough mixing.
- Label this solution **FA 4**.

Titration

- Fill the burette with **FA 4**.
- Use a pipette to transfer 25.0 cm^3 of **FA 3** into a conical flask.
- Add a few drops of methyl orange.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	
IV	

[4]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 4**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of sodium hydroxide, NaOH, present in 25.0 cm^3 of **FA 3**.

moles of NaOH = ... mol

(ii) Calculate the number of moles of hydrochloric acid, HC*l*, present in 250 cm^3 of **FA 4**.

moles of HC*l* in 250 cm^3 of **FA 4** = ... mol

(iii) Use your answers to **1(b)(i)** and **1(b)(ii)** to calculate the number of moles of HC*l* that reacted with **FA 1** in the experiment you carried out in **Question 1**.

moles of HC*l* that reacted with **FA 1** = ... mol

(iv) Use your answers to **2(c)(ii)** and **2(c)(iii)** to calculate the concentration of **FA 2**.

concentration of **FA 2** = ... mol dm^{-3}

[5]

(d) (i) One of the sources of error in determining the concentration of **FA 2** involves measuring volumes of solutions in both **Questions 1** and **2**.

State which volume of solution that you have measured has the greatest percentage error. How could you have reduced this error?

....

....

....

(ii) A student suggested that a greater mass of **X**CO_3 should be used so that the average titre calculated in **2(b)** would be a greater volume.

Explain whether you agree with the student that this would lead to a greater volume for the average titre.

....

....

....

[2]

[Total: 12]

SAMPLE DATA

Use these burette readings to fill in the table you have created: 35, 30, 29.9

For Examiner's Use

2 A second way to determine the concentration of an acid is by volumetric titration. In this experiment you will first dilute the sample of **FA 2** that you used in **Question 1** and then titrate this diluted solution using aqueous sodium hydroxide.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

FA 2 is dilute sulfuric acid, H_2SO_4.
FA 3 is 0.150 mol dm^{-3} sodium hydroxide, NaOH.
distilled water

(a) Method

Dilution of FA 2

- Use the burette labelled **FA 2** to transfer 25.00 cm^3 of **FA 2** into the 250 cm^3 graduated (volumetric) flask, labelled **FA 4**.
- Make up the contents of the flask to the 250 cm^3 mark with distilled water.
- Stopper the flask and mix the contents thoroughly. This is solution **FA 4**.

Titration

- Fill the burette labelled **FA 3** with **FA 3**.
- Use a clean pipette to transfer 25.0 cm^3 of **FA 4** into a conical flask.
- Add to the flask a few drops of the acid-base indicator provided.
- Titrate the acid in the flask with the alkali, **FA 3**.

You should perform a rough titration.
In the space below record your burette readings for this rough titration.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 3** added in each accurate titration. Make certain that any recorded results show the precision of your practical work.

I	
II	
III	
IV	
V	

[5]

For Examiner's Use

(b) From your titration results obtain a suitable value to be used in your calculation. Show clearly how you have obtained this value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 3**.
[1]

(c) (i) Calculate how many moles of NaOH are contained in the volume recorded in **(b)**.

moles of NaOH = ... mol

(ii) Hence, calculate how many moles of H_2SO_4 are contained in 25.0 cm^3 of **FA 4**.

moles of H_2SO_4 = ... mol

(iii) Calculate the concentration of the sulfuric acid, **FA 2**.

concentration of **FA 2** = ... mol dm^{-3}
[3]

I	
II	
III	

(d) You have used two methods to determine the concentration of the sulfuric acid in **FA 2**. Use your answers to **1(d)(iii)** and **2(c)(iii)** to calculate the difference in these values as a percentage of the value found by the volumetric titration method.

percentage difference = ... %
[1]

[Total: 10]

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 29.3, 29.4

1 **FA 1** is sulfuric acid, H_2SO_4, of approximate concentration 0.7 mol dm^{-3}.
FA 2 is 0.150 mol dm^{-3} sodium hydroxide.
You are also provided with phenolphthalein (indicator).

You will determine the exact concentration of **FA 1** by titration.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(a) Method

Dilution

- Pipette 25.0 cm^3 of **FA 1** into the 250 cm^3 graduated (volumetric) flask labelled **FA 3**.
- Make the solution up to the mark using distilled water.
- Shake the flask to mix the solution of **FA 3**.

Titration

- Rinse out the pipette with distilled water and then with **FA 3**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add 5 drops of phenolphthalein indicator to the flask. The indicator should remain colourless.
- Fill the burette with **FA 2**.
- Titrate **FA 3** with **FA 2**, until a permanent pale pink colour is obtained.

You should perform a **rough titration**.
In the space below record your burette readings for this rough titration.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record in a suitable form below all of your burette readings and the volume of **FA 2** added in each accurate titration.
- Make sure that your recorded results show the precision of your practical work.

[7]

For Examiner's Use

I	
II	
III	
IV	
V	
VI	
VII	

(b) From your accurate titration results, obtain a suitable value to be used in your calculations.
Show clearly how you have obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 2**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate how many moles of NaOH were present in the volume of **FA 2** calculated in **(b)**.

.... mol of NaOH

(ii) Calculate how many moles of H_2SO_4 were present in 25.0 cm^3 of **FA 3**.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

.... mol of H_2SO_4

(iii) Calculate how many moles of H_2SO_4 were present in 25.0 cm^3 of the undiluted solution **FA 1**.

.... mol of H_2SO_4

(iv) Calculate the concentration, in mol dm^{-3}, of H_2SO_4 in **FA 1**.

The concentration of H_2SO_4 in **FA 1** was .... mol dm^{-3}. [4]

[Total: 12]

For Examiner's Use

I	
II	
III	
IV	

T2 Redox Titration ($KMnO_4$) Chem 6 Q# 11/ AS Chemistry/2015/s/TZ 1/Paper 3/ :o)

SAMPLE DATA

Use these burette readings to fill in the table you have created: 35, 30, 30.05

1 In this question you will determine the concentration of iron(II) ions in **FA 2**. To do this you will do a titration using potassium manganate(VII) solution. The iron(II) ions, Fe^{2+}, are oxidised by the manganate(VII) ions, MnO_4^-.

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

When all the Fe^{2+} ions have been oxidised, the presence of unreacted MnO_4^- ions causes the solution to become a permanent pink colour.

FA 1 contains 0.0200 mol dm^{-3} manganate(VII) ions, MnO_4^-.
FA 2 is a solution containing iron(II) ions, Fe^{2+}.
FA 3 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Method

- Fill the burette with **FA 1**.
- Use the pipette to transfer 25.0 cm^3 of **FA 2** into the conical flask.
- Use the 25 cm^3 measuring cylinder to add 10 cm^3 of **FA 3** to the conical flask.
- Add **FA 1** from the burette into the conical flask until the solution becomes a permanent pink colour.
- Perform a **rough titration** and record your burette readings in the space below.

The rough titre is .... cm^3.

- Do as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 1** added in each accurate titration.

Keep FA 2 to use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 2** required .... cm^3 of **FA 1**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of manganate(VII) ions present in the volume of **FA 1** calculated in **(b)**.

moles of MnO_4^- = ... mol

(ii) Calculate the number of moles of iron(II) ions present in 25.0 cm^3 of **FA 2**.

moles of Fe^{2+} = ... mol

(iii) Calculate the concentration, in mol dm^{-3}, of iron(II) ions in **FA 2**.

concentration of Fe^{2+} in **FA 2** = ... mol dm^{-3}

(iv) **FA 2** was prepared by dissolving hydrated ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2.6H_2O$ in distilled water. Calculate the mass of salt that would have to be dissolved in 1.00 dm^3 of water to prepare **FA 2**.
(A_r: H, 1.0; N, 14.0; O, 16.0; S, 32.1; Fe, 55.8)

I	
II	
III	
IV	

mass of $(NH_4)_2Fe(SO_4)_2.6H_2O$ = ... g
[4]

[Total: 12]

T2 Redox Titration (KMnO4) Chem 6 **Q# 12/** AS Chemistry/2014/s/TZ 3/Paper 3/ :o) www.SmashingScience.com

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 26.45, 26.5

1 You are to determine, by titration, the change in oxidation number of a transition metal ion, M^{2+}, when reacted with acidified potassium manganate(VII).

FA 1 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 2 is 0.0530 mol dm^{-3} transition metal salt, MSO_4.
FA 3 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Method

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 2** into the conical flask.
- Use the measuring cylinder to add 25 cm^3 of **FA 3** into the conical flask.
- Carry out a **rough titration** and record your burette readings in the space below. Add **FA 1** until the contents of the flask turn a permanent pale pink colour.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record below, in a suitable form, all of your burette readings and the volume of **FA 1** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value to be used in your calculations. Show clearly how you have obtained this value.

25.0 cm^3 of **FA 2** required .... cm^3 of **FA 1**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 1** calculated in **(b)**.

moles of $KMnO_4$ = ... mol

(ii) Calculate the number of moles of $\mathbf{MSO_4}$ in 25.0 cm^3 of **FA 2**.

moles of $\mathbf{MSO_4}$ in 25.0 cm^3 = ... mol

(iii) Use your answers to **(i)** and **(ii)** to calculate the number of moles of $\mathbf{MSO_4}$ that react with 1 mole of $KMnO_4$.

moles of $\mathbf{MSO_4}$ = ... mol

(iv) Two possible equations for the reaction of acidified $KMnO_4$ with $\mathbf{MSO_4}$ are below.

equation 1 $2KMnO_4 + 10MSO_4 + 8H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 5M_2(SO_4)_3 + 8H_2O$
equation 2 $2KMnO_4 + 5MSO_4 + 8H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 5M(SO_4)_2 + 8H_2O$

State and explain which of these two equations is consistent with your answer to **(iii)**.

....

....

(v) Use your answer to **(iv)** to state the oxidation number of the transition metal **M** in the product of the reaction.

....

[5]

[Total: 13]

I	
II	
III	
IV	
V	

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 29.8, 29.85

1 **FA 1** is an iron salt in which all the iron is present as Fe^{2+} cations. You will work out the percentage of iron in this salt by titrating a solution of this salt with a standard solution aqueous potassium manganate(VII).

FA 1 is an unknown iron(II) salt.
FA 2 is 1.00 mol dm^{-3} sulfuric acid.
FA 3 is 0.0100 mol dm^{-3} potassium manganate(VII).

(a) **Method**

Weighing out the salt

- Weigh the tube containing **FA 1**.
- Tip the contents of the tube into a 250 cm^3 beaker.
- Re-weigh the empty tube.
- Record all your readings in a suitable form in the space below.

Preparing the solution

- To the salt in the beaker use a measuring cylinder to add approximately 200 cm^3 of **FA 2** and stir until the salt has dissolved.
- Pour the contents of the beaker carefully into the 250 cm^3 graduated (volumetric) flask using the small funnel.
- Rinse the contents of the beaker twice with a little distilled water and add these washings to the graduated flask.
- Fill the graduated flask to the line with distilled water. Shake carefully to ensure adequate mixing.

Titration

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of the solution of **FA 1** from the graduated flask into a conical flask.
- Titrate the solution of **FA 1** in the flask with **FA 3** until the first appearance of a permanent pink colour.

You should perform a **rough titration**.
In the space below record your burette readings for this rough titration.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think are necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in an appropriate form below all of your burette readings and the volume of **FA 3** added in each accurate titration.

For Examiner's Use

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value to be used in your calculations. Show clearly how you have obtained this value.

25.0 cm^3 of the solution of **FA 1** required .... cm^3 of **FA 3**.
[2]

For Examiner's Use

(c) **Calculations**

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate how many moles of MnO_4^-(aq) were present in the volume of **FA 3** calculated in **(b)**.

moles of MnO_4^-(aq) = ... mol

(ii) Use the following equation to calculate how many moles of Fe^{2+}(aq) were present in the conical flask.

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 8H_2O(aq)$$

moles of Fe^{2+}(aq) in the conical flask = ... mol

(iii) Calculate the number of moles of Fe^{2+} in your weighed sample of **FA 1**.

moles of Fe^{2+} in the weighed sample = ... mol

I	
II	
III	
IV	
V	

(iv) Calculate the percentage of iron in **FA 1**.
[A_r: Fe, 55.8]

the percentage of iron in **FA 1** = ... %
[5]

(d) There are a number of sources of potential error in this experiment. One of these involves the readings taken using the balance.

(i) State the maximum individual error in any single balance reading.

maximum individual error = ... g

(ii) Calculate the maximum percentage error in the mass of **FA 1** used in your experiment.

maximum percentage error = ... % [2]

[Total: 16]

T2 Redox Titration (KMnO4) Chem 6 **Q# 14/** AS Chemistry/2010/w/TZ 4/Paper 3/ :o) www.SmashingScience.com

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 25.8, 25.85

There are three questions on this paper. Question 2 should not be the last question attempted.

For Examiner's Use

1 **FB 1** is an aqueous solution containing 21.50 g dm^{-3} of a mixture of iron(II) sulfate, $FeSO_4$ and iron(III) sulfate, $Fe_2(SO_4)_3$.
FB 2 is an aqueous solution containing 2.00 g dm^{-3} potassium manganate(VII), $KMnO_4$.

In the presence of acid, the iron(II) sulfate is oxidised by potassium manganate(VII).

$$2KMnO_4(aq) + 8H_2SO_4(aq) + 10FeSO_4(aq) \rightarrow 5Fe_2(SO_4)_3(aq) + 2MnSO_4(aq) + K_2SO_4(aq) + 8H_2O(l)$$

(a) Method

- Fill a burette with **FB 2**.
- Pipette 25 cm^3 of **FB 1** into the conical flask.
- Use a 25 cm^3 measuring cylinder to add 10 cm^3 of dilute sulfuric acid to the flask.
- Place the flask on a white tile.
- Carefully titrate with **FB 2** until the first permanent pink colour is obtained.

You should perform a **rough titration**.
In the space below record your burette readings for this rough titration.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record in a suitable form below all of your burette readings and the volume of **FB 2** added in each accurate titration.
- Make certain any recorded results show the precision of your practical work.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results obtain a suitable value to be used in your calculation. Show clearly how you have obtained this value.

For Examiner's Use

25.0 cm^3 of **FB 1** required .... cm^3 of **FB 2**. [1]

Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(c) **(i)** Calculate the concentration, in $mol\,dm^{-3}$, of the potassium manganate(VII) in **FB 2**.
FB 2 contains 2.00 $g\,dm^{-3}$ $KMnO_4$.
[A_r: O, 16.0; K, 39.1; Mn, 54.9]

The concentration of potassium manganate(VII) in **FB 2** is .... $mol\,dm^{-3}$.

(ii) Calculate how many moles of $KMnO_4$ were present in the volume calculated in **(b)**.

.... mol of $KMnO_4$.

(iii) Calculate how many moles of iron(II) sulfate, $FeSO_4$, reacted with the potassium manganate(VII) in **(ii)**.

$$2KMnO_4(aq) + 8H_2SO_4(aq) + 10FeSO_4(aq) \longrightarrow 5Fe_2(SO_4)_3(aq) + 2MnSO_4(aq) + K_2SO_4(aq) + 8H_2O(l)$$

I	
II	
III	
IV	
V	

.... mol of $FeSO_4$ reacted with the potassium manganate(VII).

(iv) Calculate the concentration, in $mol\,dm^{-3}$ of $FeSO_4$ in **FB 1**.

The concentration of $FeSO_4$ in **FB 1** is .... $mol\,dm^{-3}$.

(v) Calculate the concentration, in $g\,dm^{-3}$, of $FeSO_4$ in **FB 1**.
[A_r: O, 16.0; S, 32.1; Fe, 55.8]

FB 1 contains .... $g\,dm^{-3}$ of $FeSO_4$.

(vi) **FB 1** is an aqueous solution containing 21.50 $g\,dm^{-3}$ of $FeSO_4$ and $Fe_2(SO_4)_3$.
Calculate the percentage, by mass, of $FeSO_4$ in this mixture.

The mixture contains .... % $FeSO_4$.
[5]

[Total: 13]

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 24.95, 25

1 You are required to determine the concentration in g dm^{-3} of hydrated ammonium iron(II) sulphate, $(NH_4)_2SO_4.FeSO_4.6H_2O$, in the solution **FB 1**.

FB 1 contains hydrated ammonium iron(II) sulphate.
FB 2 is 0.0120 mol dm^{-3} potassium manganate(VII), $KMnO_4$.

(a) Dilution of FB 1

By using a burette measure between 36.00 cm^3 and 37.00 cm^3 of **FB 1** into the 250 cm^3 graduated flask labelled **FB 3**.
Record your burette readings and the volume of **FB 1** added to the flask in the space below.

Make up the contents of the flask to the 250 cm^3 mark with distilled water. Place the stopper in the flask and mix the contents thoroughly by slowly inverting the flask a number of times.

Titration

Fill a second burette with **FB 2**.

Pipette 25.0 cm^3 of **FB 3** into a conical flask. Use a measuring cylinder to add approximately 10 cm^3 of 1.0 mol dm^{-3} sulphuric acid, H_2SO_4, and titrate with **FB 2** until the first permanent pink colour remains in the solution.

Perform one rough (trial) titration and sufficient further titrations to obtain accurate results.

Record your titration results in the space below. Make certain that your recorded results show the precision of your working.

Use	
i	
ii	
iii	
iv	
v	
vi	

[6]

(b) From your titration results obtain a suitable volume of **FB 2** to be used in your calculations.
Show clearly how you obtained this volume.

[1]

Calculations

Show your working and appropriate significant figures in all of your calculations.

(c) Calculate how many moles of $KMnO_4$ were run from the burette during the titration.

.... mol of $KMnO_4$ were run from the burette.

Calculate how many moles of Fe^{2+} ions reacted with the $KMnO_4$ run from the burette.

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \longrightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

.... mol of Fe^{2+} reacted with the $KMnO_4$ run from the burette.

Calculate the concentration, in mol dm^{-3}, of Fe^{2+} in **FB 3**.

Concentration of Fe^{2+} in **FB 3** = ... mol dm^{-3}.

Calculate the concentration, in mol dm^{-3}, of Fe^{2+} in **FB 1**.

Concentration of Fe^{2+} in **FB 1** = ... mol dm^{-3}.

Calculate, to **4 significant figures**, the concentration of $(NH_4)_2SO_4.FeSO_4.6H_2O$ in **FB 1** in g dm^{-3}.
[A_r: Fe, 55.8; H, 1.0; N, 14.0; O, 16.0; S, 32.1]

FB 1 contains .... g dm^{-3} of $(NH_4)_2SO_4.FeSO_4.6H_2O$.
[5]

i	
ii	
iii	
iv	
v	

(d) A student learns that the solution of the iron(II) salt has been prepared by dissolving the solid in distilled water that has absorbed air from the laboratory.
Suggest a way in which the distilled water can be prepared and stored in the laboratory to ensure that it contains a minimum of dissolved air.

....

....

....[1]

(e) Estimate the error in reading a volume from a burette.

smallest division on burette scale = ... cm^3

estimated error in reading a volume = ± .... cm^3 [1]

(f) A titre value is obtained by the difference between final and initial burette readings.

What is the **maximum** possible error in obtaining a titre reading?

estimated **maximum** error in the titre = ± .... cm^3 [1]

(g) During one titration a student reads the burette twice.
Each reading has an error but the titre has no error. Explain how this can happen.

....

....

....[1]

[Total: 16]

SAMPLE DATA

Use these burette readings to fill in the table you have created: 30, 24.25, 24.3

1 **FB 1** is 0.02 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FB 2 is a solution containing iron(II) ions, Fe^{2+}.
FB 3 is an aqueous solution of a substance, **X**.

Under acid conditions **X** oxidises iron(II) to iron(III).

You are required to determine
- the concentration of iron(II) ions in **FB 2** and, by a graphical method,
- the volume of **FB 3** that will oxidise the iron(II) ions in 25.0 cm^3 of **FB 2**.

(a) *Experiment 1*

Fill a burette with potassium manganate(VII), **FB 1**.

Pipette 25.0 cm^3 of **FB 2** into a conical flask and add, using the measuring cylinder provided, 10 cm^3 of 1 mol dm^{-3} sulphuric acid.

Run **FB 1** from the burette into the conical flask until the first permanent pale pink colour remains. This is the end point of the titration.

Record your burette readings in Table 1.1.

Repeat the titration as many times as you think necessary to obtain accurate results.
Make certain that the recorded results show the precision of your practical work.

Table 1.1 Titration of FB 2 with FB 1

Final burette reading / cm^3				
Initial burette reading / cm^3				
Volume of **FB 1** used / cm^3				

[8]

Summary

25.0 cm^3 of **FB 2** reacted with .... cm^3 of **FB 1**.

Show which results you used to obtain this volume of **FB 1** by placing a tick (✓) under the readings in Table 1.1.

You are advised to show full working in all parts of the calculations.

(b) Calculate how many moles of potassium manganate(VII) were run from the burette into the conical flask during the titration of **FB 2** with **FB 1**.

[1]

(c) Use the half equations for the reaction

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$
$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$$

and your answer to **(b)** to calculate the concentration of Fe^{2+}, in mol dm^{-3}, in **FB 2**.

[2]

G1 Gravimetric Thermal Decomposition Chem 10 Q# 17/ AS Chemistry/2022/s/TZ 3/Paper 3/ :o)

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SAMPLE DATA

Paper ID	Marks	Measured initial mass	Measured final mass	Mass of crucible and lid	Initial mass	Final mass
2022/s/TZ 3/Q2	12	42	41.42	40.76	42.06	41.38
2019/s/TZ 1/Q2	14	42.98	41.52	41.58	42.98	42.24
2017/s/TZ 1/Q2	10	43.60	42.76	40.76	43.51	42.74
2016/s/TZ 4/Q2	14	35.8	41.29	41.58	42.78	42.10

2 In this experiment you will identify the metal, **M**, in a metal carbonate, MCO_3, by thermal decomposition.

$$MCO_3(s) \rightarrow MO(s) + CO_2(g)$$

FA 4 is the metal carbonate, MCO_3.

(a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the **FA 4** from the container into the crucible.
- Weigh the crucible, lid and **FA 4**. Record the mass.
- Calculate and record the mass of **FA 4** used.
- Place the crucible and contents on a pipe-clay triangle.
- Heat the crucible gently, with the lid on, for approximately 1 minute.
- Heat strongly, with the lid off, for a further 4 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.

During the cooling period, you may wish to begin work on Question 3.

- When the crucible has cooled, weigh the crucible with its lid and contents. Record the mass.
- Heat strongly, with the lid off, for a further 2 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.
- When the crucible has cooled, reweigh the crucible with its lid and contents. Record the mass.
- Calculate and record the total loss of mass and the mass of residue obtained.
- This residue is **FA 5**.

Keep FA 5 for use in 2(d).

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

(i) Calculate the amount, in mol, of carbon dioxide given off in your experiment.

amount of CO_2 = ... mol [1]

(ii) Calculate the relative formula mass, M_r, of $\mathbf{M}CO_3$.

M_r of $\mathbf{M}CO_3$ = ... [1]

(iii) From your results, deduce the identity of **M**.
Show your reasoning.

M is = ... [1]

(c) A student carries out the same procedure, using the same mass of solid. However, the student uses the basic carbonate, $\mathbf{M}CO_3{\bullet}\mathbf{M}(OH)_2$, instead of the pure carbonate, $\mathbf{M}CO_3$.

When the metal hydroxide part of the basic carbonate decomposes, metal oxide and steam are produced. The metal carbonate part decomposes in the usual way.

State how the loss of mass from the student's solid compares with the loss of mass you obtained when you carried out your experiment. Explain your reasoning.

....

.... [2]

(d) Use a spatula to transfer a small quantity of your cold residue, **FA 5**, into a test-tube.
Add about a 1 cm depth of dilute hydrochloric acid to the **FA 5** in the test-tube.

Record what you observe.

....

....

State whether or not the thermal decomposition of $\mathbf{M}CO_3$ is complete.

Justify your answer based on your observations.

....

....

....

[2]

[Total: 12]

SAMPLE DATA

Paper ID	Marks	Measured initial mass	Measured final mass	Mass of crucible and lid	Initial mass	Final mass
2022/s/TZ 3/Q2	12	42	41.42	40.76	42.06	41.38
2019/s/TZ 1/Q2	14	42.98	41.52	41.58	42.98	42.24
2017/s/TZ 1/Q2	10	43.60	42.76	40.76	43.51	42.74
2016/s/TZ 4/Q2	14	35.8	41.29	41.58	42.78	42.10

2 When hydrated copper hydroxycarbonate, $CuCO_3.Cu(OH)_2.\mathbf{y}H_2O$ is heated, it decomposes as shown.

$$CuCO_3.Cu(OH)_2.\mathbf{y}H_2O(s) \rightarrow 2CuO(s) + CO_2(g) + (1 + \mathbf{y})H_2O(g)$$

In this experiment, you will heat hydrated copper hydroxycarbonate to decompose it. You will use your results to investigate the value of **y**.

FB 4 is hydrated copper hydroxycarbonate, $CuCO_3.Cu(OH)_2.\mathbf{y}H_2O$.

(a) Method

- Weigh the crucible with its lid and record the mass.
- Add all the **FB 4** from the container into the crucible.
- Weigh the crucible and lid with **FB 4** and record the mass.
- Place the crucible and contents on the pipe-clay triangle.
- Heat the crucible and contents gently for approximately two minutes with the lid on.
- Use tongs to remove the lid and heat strongly for approximately three minutes.
- Replace the lid and leave the crucible and residue to cool for several minutes.

While the crucible is cooling, you may wish to begin work on Question 3.

- When the crucible is cool, reweigh it with its lid and contents. Record the mass.
- Calculate and record the mass of **FB 4** and the mass of residue obtained.

Results

I	
II	
III	
IV	

State the observations made while the decomposition of **FB 4** was taking place.

....

....

[4]

(b) Calculations

(i) Calculate the number of moles of copper oxide, CuO, obtained as residue.

moles of CuO obtained = ... mol [1]

(ii) Use your results to calculate the relative formula mass, M_r, of hydrated copper hydroxycarbonate, $CuCO_3.Cu(OH)_2.\mathbf{y}H_2O$.

M_r of $CuCO_3.Cu(OH)_2.\mathbf{y}H_2O$ = ... [2]

(iii) Use the Periodic Table to calculate the relative formula mass of $CuCO_3.Cu(OH)_2$.

M_r of $CuCO_3.Cu(OH)_2$ = ...

Use your answer to **(ii)** and this M_r to comment on the value of **y** in the formula of hydrated copper hydroxycarbonate.

....

.... [2]

(c) State **one** way to improve the accuracy of the experiment, using the same mass of **FB 4**.

....

.... [1]

[Total: 10]

SAMPLE DATA

Paper ID	Marks	Measured initial mass	Measured final mass	Mass of crucible and lid	Initial mass	Final mass
2022/s/TZ 3/Q2	12	42	41.42	40.76	42.06	41.38
2019/s/TZ 1/Q2	14	42.98	41.52	41.58	42.98	42.24
2017/s/TZ 1/Q2	10	43.60	42.76	40.76	43.51	42.74
2016/s/TZ 4/Q2	14	35.8	41.29	41.58	42.78	42.10

2 In **Question 1** you measured the volume of carbon dioxide produced by a metal carbonate, $\mathbf{M}CO_3$, in order to identify **M**. In **Question 2** you will identify another Group 2 metal, **Q**, by using a gravimetric method.

When Group 2 carbonates are heated they decompose.

$$\mathbf{Q}CO_3(s) \rightarrow \mathbf{Q}O(s) + CO_2(g)$$

FA 3 is the metal carbonate, $\mathbf{Q}CO_3$.

(a) Method

- Weigh the crucible with its lid and record the mass.
- Add between 1.30 g and 1.50 g of **FA 3** into the crucible. Record the mass of crucible, lid and **FA 3**.
- Place the crucible on the pipe-clay triangle on the tripod. Put the lid on the crucible and heat gently for approximately 1 minute.
- Use tongs to remove the lid and heat the crucible strongly for approximately 5 minutes. Replace the lid and then leave to cool.
- While the crucible is cooling, begin work on **Question 3**.
- When cool, reweigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass of **FA 3** placed in the crucible.
- Calculate and record the mass of residue left after heating.

Keep the crucible and its contents for use in Question 3(b).

Results

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the number of moles of carbon dioxide produced during heating of **FA 3**.

moles CO_2 = ... mol [1]

(ii) Use the mass of **FA 3** in **(a)** and your answer to **(b)(i)** to calculate the relative atomic mass, A_r, of **Q** and hence identify **Q**. You should assume complete decomposition of **Q**CO_3.

A_r of **Q** is ....

Q is ....

[4]

(c) Explain why the lid was placed on the crucible when the residue was left to cool.

....

.... [1]

(d) In order to decompose Group 2 carbonates, the solid must be heated strongly. In this experiment **Q**CO_3 was heated for a few minutes.

(i) Suggest an improvement to the method used that would ensure that decomposition was complete.

....

.... [1]

(ii) Suggest a chemical test to determine whether the decomposition of **Q**CO_3 was complete. State the expected observation if the decomposition was incomplete.

Do not carry out this test.

....

.... [1]

(e) (i) In your calculation in **(b)** you used the mass of **Q**CO_3 and assumed that it was all decomposed during the heating.

Explain what effect incomplete decomposition would have on the calculated value of the A_r of **Q**.

....

....

.... [1]

(ii) A student suggested that you could use the mass of the residue, **Q**O, rather than the mass of **Q**CO_3 in a calculation to identify **Q**.

Explain why this method of calculating the A_r of **Q** is valid.

....

.... [1]

[Total: 14]

SAMPLE DATA

Paper ID	Marks	Measured initial mass	Measured final mass	Mass of crucible and lid	Initial mass	Final mass
2022/s/TZ 3/Q2	12	42	41.42	40.76	42.06	41.38
2019/s/TZ 1/Q2	14	42.98	41.52	41.58	42.98	42.24
2017/s/TZ 1/Q2	10	43.60	42.76	40.76	43.51	42.74
2016/s/TZ 4/Q2	14	35.8	41.29	41.58	42.78	42.10

2 Malachite is a basic form of copper carbonate in which copper hydroxide is also present. The accepted chemical formula of malachite is $CuCO_3.Cu(OH)_2.H_2O$.

When malachite is heated, it decomposes as shown.

$$CuCO_3.Cu(OH)_2.H_2O(s) \rightarrow 2CuO(s) + CO_2(g) + 2H_2O(g)$$

In this experiment, you will heat malachite to decompose it and use your results to obtain evidence about the accepted formula of malachite.

FA 5 is malachite, $CuCO_3.Cu(OH)_2.H_2O$.

(a) Method

Read through the method before starting any practical work.
In the space below prepare a **single** table for your results of **Experiments 1** and **2**.

Experiment 1

- Weigh a crucible with its lid and record the mass.
- Add between 2.5 g and 3.0 g of **FA 5** to the crucible. Weigh the crucible with **FA 5** and lid and record the mass.
- Place the crucible on the pipe-clay triangle.
- Heat the crucible and contents gently for about two minutes, with the lid on.
- Remove the lid and continue heating gently for about three minutes.
- Replace the lid and leave the crucible and residue to cool for at least five minutes. Then reweigh the crucible and contents with the lid on. Record the mass.
- **While the crucible is cooling, you may wish to begin work on Question 3.**
- Calculate and record the mass of **FA 5** used and the mass of residue obtained.
- State the observation(s) you made while the reaction was taking place.

....

....

Experiment 2

Repeat the method used in **Experiment 1**, using between 1.5 g and 2.0 g of **FA 5** in the second crucible.

Results

I	
II	
III	
IV	
V	
VI	

[6]

(b) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Use your results from **Experiment 1** to calculate the number of moles of copper oxide, CuO, obtained as residue.
Use the Periodic Table on page 12 for any data you may require.

moles of CuO obtained in **Experiment 1** = ... mol

(ii) Use your answer to **(i)**, the equation on page 4 and the mass of **FA 5** you used in **Experiment 1**, to calculate the relative formula mass, M_r, of malachite.

M_r of malachite (from **Experiment 1**) = ...

(iii) Use your results from **Experiment 2** to calculate another value for the relative formula mass, M_r, of malachite.

M_r of malachite (from **Experiment 2**) = ...

(iv) Use data from the Periodic Table to calculate the relative formula mass, M_r, of malachite from its accepted formula, $CuCO_3.Cu(OH)_2.H_2O$.

M_r of malachite (from formula) = ...

(v) If the relative formula mass of malachite obtained from **either** of your experiments is within 2.5% of the answer in **(iv)**, this is good evidence that the accepted formula, $CuCO_3.Cu(OH)_2.H_2O$, is correct.

Show by calculation whether either of your experiments supports the accepted formula.

[5]

(c) (i) State **one** way of improving the accuracy of the experimental method, using the same masses of **FA 5**.
Explain the benefit of your improvement.

....

....

....

....

(ii) Explain why you would expect **Experiment 1** to be more accurate than **Experiment 2**.

....

....

....

[3]

[Total: 14]

SAMPLE DATA

Paper ID	Marks	Measured initial mass	Measured final mass	Mass of crucible and lid	Initial mass	Final mass
2022/s/TZ 3/Q2	12	42	41.42	40.76	42.06	41.38
2019/s/TZ 1/Q2	14	42.98	41.52	41.58	42.98	42.24
2017/s/TZ 1/Q2	10	43.60	42.76	40.76	43.51	42.74
2016/s/TZ 4/Q2	14	35.8	41.29	41.58	42.78	42.10

2 Some metal carbonates cannot be obtained in a pure state. For example magnesium carbonate exists in a 'basic' form, in which magnesium hydroxide is also present.

One possible chemical formula of basic magnesium carbonate is $MgCO_3.Mg(OH)_2.2H_2O$.

When basic magnesium carbonate is heated, if the possible formula were correct, it would decompose as shown below.

$$MgCO_3.Mg(OH)_2.2H_2O(s) \rightarrow 2MgO(s) + CO_2(g) + 3H_2O(g)$$

In this experiment, you will decompose basic magnesium carbonate by heating it, and you will use your results to determine whether this possible formula is correct.

FB 4 is basic magnesium carbonate.

(a) Method

Read through the method before starting any practical work and prepare a table for your results in the space below.

- Weigh a crucible with its lid and record the mass.
- Add 1.1-1.3 g of **FB 4** to the crucible. Weigh the crucible and lid with **FB 4** and record the mass.
- Place the crucible on the pipe-clay triangle and remove the lid.
- Heat the crucible and contents **gently** for about one minute.
- Then heat the crucible and contents strongly for about four minutes.
- Replace the lid and allow the crucible to cool for at least five minutes.
- **While the crucible is cooling, you may wish to begin work on Question 3**.
- Re-weigh the crucible and contents with lid. Record the mass.
- Calculate, and record, the mass of **FB 4** used and the mass of residue obtained.

I	
II	
III	
IV	
V	

[5]

(b) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Use your results to calculate the number of moles of magnesium oxide, MgO, obtained as residue.

moles of MgO obtained = ... mol

(ii) Use your answer to **(i)**, with the equation on page 4 and the mass of **FB 4** you used, to calculate the relative formula mass, M_r, of basic magnesium carbonate.

M_r of basic magnesium carbonate (from experiment) = ...

(iii) Use data from the Periodic Table to calculate the relative formula mass, M_r, of basic magnesium carbonate from its possible formula, $MgCO_3.Mg(OH)_2.2H_2O$.

M_r of basic magnesium carbonate (from formula) = ...

(iv) If the relative formula mass of basic magnesium carbonate obtained from your experiment is within 2.5% of the answer in **(iii)**, this is good evidence that the possible formula, $MgCO_3.Mg(OH)_2.2H_2O$, is correct.
Does your experiment support the possible formula? Give a reason for your answer.

....

.... [5]

(c) Evaluation

(i) State **one** way in which the accuracy of the experimental procedure could have been improved using the same mass of **FB 4**.
Explain your answer.

....

....

....

....

....

(ii) A student carried out the experiment twice using different masses of **FB 4**. He used the mean mass of **FB 4** and the mean mass of magnesium oxide obtained to calculate the relative formula mass of basic magnesium carbonate.

Instead of doing this, he could have calculated the relative formula mass of basic magnesium carbonate from his two experiments separately.

Suggest **one** advantage of carrying out separate calculations for each experiment.

....

....

....

....

(iii) State the error when making **one** reading on your balance.

error = ... g

Calculate the maximum percentage error in the mass of **FB 4** used.

percentage error = ... %
[4]

[Total: 14]

SAMPLE DATA

	Var	Exp1	Time/s	Exp2	Time/s	Exp3	Time/s	Exp4	Time/s	Exp5	Time/s
2018/m/TZ 3/Q1	TEMP (degrees C)	25 °C	78	55 °C	12	47 °C	20	35 °C	44	30 °C	61
2021/w/TZ 4/Q1	Volume of Sodium thiosulfate	45cm³	35	20 cm³	120	25 cm³	90	30 cm³	67	35 cm³	52

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 The thiosulfate ion, $S_2O_3^{2-}$, is unstable in the presence of acid. The following reaction occurs.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(aq) + H_2O(l)$$

The rate of this reaction can be measured by timing how long it takes for the solid sulfur that is formed to make the mixture too cloudy to see through.

You will investigate how the concentration of the thiosulfate ions affects the rate of this reaction.

Throughout these experiments care must be taken to avoid inhaling any SO_2 that is produced. It is very important that as soon as each experiment is complete, the contents of the beaker are emptied into the quenching bath and the beaker is rinsed thoroughly.

FB 1 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FB 2 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.
distilled water

(a) Method

Experiment 1

- Label one burette **FB 1** and fill it with **FB 1**.
- Run 45.00 cm³ of **FB 1** from the burette into the 100 cm³ beaker.
- Use the 25 cm³ measuring cylinder to measure 10.0 cm³ of **FB 2**.
- Add **FB 2** to **FB 1** and start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the print on the insert from above the mixture.
- Stop timing when the print on the insert is no longer visible.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 2**.

Experiment 2

- Fill the second burette with distilled water.
- Refill the burette labelled **FB 1** with **FB 1**.
- Run 20.00 cm³ of **FB 1** into the 100 cm³ beaker.
- Run 25.00 cm³ of distilled water into the same beaker.
- Use the 25 cm³ measuring cylinder to measure 10.0 cm³ of **FB 2**.
- Add **FB 2** to the beaker and start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the print on the insert from above the mixture.
- Stop timing when the print on the insert is no longer visible.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in the next experiment.

Experiments 3–5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of **FB 1**.

The combined volume of **FB 1** and distilled water must always be 45.00 cm³.
Do not use a volume of **FB 1** that is less than 20.00 cm³.

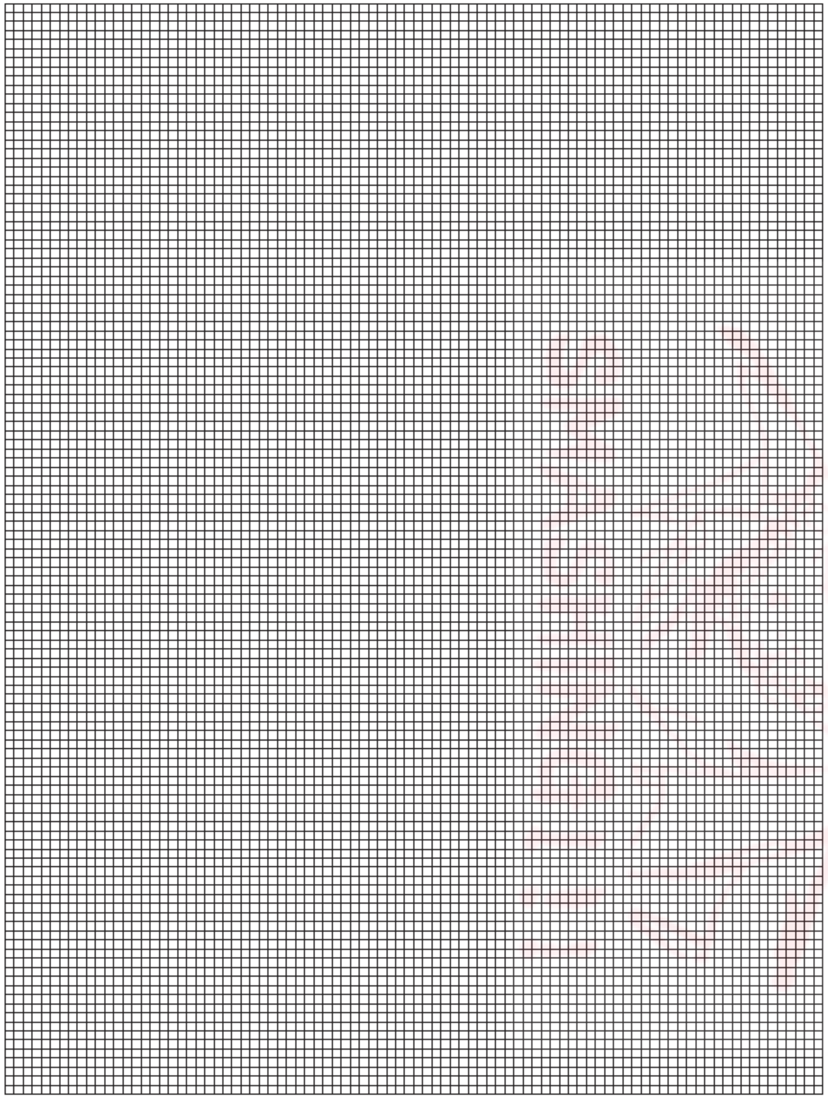
Record all your results in a table.
You should include the volume of **FB 1**, the volume of distilled water, the reaction time and the reaction rate for each of your five experiments.
Calculate the rate of reaction using the following formula.

$$\text{rate} = \frac{1000}{\text{reaction time}}$$

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) On the grid opposite, plot the rate on the *y*-axis against the volume of **FB 1** on the *x*-axis. Identify any anomalous points. Draw a line of best fit.



[4]

I	
II	
III	
IV	

(c) In these experiments, the volume of **FB 1** is related to the concentration of the thiosulfate ions.

Use your graph to suggest the relationship between the rate of reaction and the concentration of the thiosulfate ions.

....

.... [1]

(d) The quenching bath contains an aqueous mixture of sodium carbonate and universal indicator.

(i) How does the quenching bath prevent the further production of SO_2 from the reaction?

....

.... [1]

(ii) Suggest why the mixture contains universal indicator.

....

.... [1]

(e) **(i)** In each experiment the acid is in large excess.

Show, by calculation, that the acid is in large excess in **Experiment 1**.

[2]

(ii) Suggest a reason why the acid used should be in large excess.

....

.... [1]

[Total: 18]

SAMPLE DATA

	Var	Exp1	Time/s	Exp2	Time/s	Exp3	Time/s	Exp4	Time/s	Exp5	Time/s
2018/m/TZ 3/Q1	TEMP (degrees C)	25 °C	78	55 °C	12	47 °C	20	35 °C	44	30 °C	61
2021/w/TZ 4/Q1	Volume of Sodium thiosulfate	45cm^3	35	20 cm^3	120	25 cm^3	90	30 cm^3	67	35 cm^3	52

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 You will investigate how increasing temperature affects the rate of a reaction.

Sodium thiosulfate reacts with acid to form a pale yellow precipitate of sulfur.
The ionic equation for the reaction is given.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(g) + H_2O(l)$$

You will measure the time it takes for the sulfur formed in the reaction to obscure the print on the Insert supplied.

Record your results in a table on page 4. Your table should include the rate of reaction for each experiment.

FA 1 is an 18.1 g dm^{-3} solution of hydrated sodium thiosulfate, $Na_2S_2O_3.5H_2O$.
FA 2 is a 0.050 mol dm^{-3} solution of a strong monoprotic acid, H**Z**.

(a) Method

- Approximately half fill the 250 cm^3 beaker with tap water and place it on the tripod and gauze over the Bunsen burner.
- Heat the water in the beaker to about 55 °C and then switch off the Bunsen burner. This will be your hot water bath.
- Use the 25 cm^3 measuring cylinder to transfer 10 cm^3 of **FA 1** into boiling tube **1**. Place boiling tube **1** into your hot water bath.
- Use the 50 cm^3 measuring cylinder to transfer 20 cm^3 of **FA 2** into boiling tube **2**. Place boiling tube **2** into your hot water bath.
- Leave boiling tubes **1** and **2** in the hot water bath to heat up for use in **Experiment 2**.
- Start **Experiment 1**.

Experiment 1

- Use the 50 cm^3 measuring cylinder to transfer 20 cm^3 of **FA 2** into the 100 cm^3 beaker.
- Measure and record the temperature of **FA 2**.
- Use the 25 cm^3 measuring cylinder to transfer 10 cm^3 of **FA 1** into the same beaker and start timing **immediately**.
- Swirl the beaker once to mix the solutions and place the beaker on the Insert.
- Look down through the beaker and contents onto the Insert.
- Stop timing as soon as the precipitate of sulfur obscures the print on the Insert.
- Record the reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 2**.

Experiment 2

- Measure and record the temperature of **FA 2** in boiling tube **2**.
- Carefully transfer the hot contents of boiling tube **2** into the 100 cm^3 beaker.
- Carefully transfer the hot contents of boiling tube **1** into the same beaker and start timing **immediately**.
- Swirl the beaker once to mix the solutions and place the beaker on the Insert.
- Look down through the beaker and contents onto the Insert.
- Stop timing as soon as the precipitate of sulfur obscures the print on the Insert.
- Record the reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 3**.

Experiment 3

- Use the 25 cm^3 measuring cylinder to transfer 10 cm^3 of **FA 1** into boiling tube **1**. Place boiling tube **1** into your hot water bath.
- Use the 50 cm^3 measuring cylinder to transfer 20 cm^3 of **FA 2** into boiling tube **2**. Place boiling tube **2** into your hot water bath.
- Place the thermometer in boiling tube **2**. When the temperature of **FA 2** is about 8 °C lower than that for **Experiment 2** record the temperature. Remove the thermometer and transfer the contents of boiling tube **2** into the 100 cm^3 beaker.
- Transfer the contents of boiling tube **1** into the same beaker and start timing **immediately**.
- Swirl the beaker once to mix the solutions and place the beaker on the Insert.
- Look down through the beaker and contents onto the Insert.
- Stop timing as soon as the precipitate of sulfur obscures the print on the Insert.
- Record the reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiments 4 and 5**.

Experiments 4 and 5

- Repeat the method for **Experiment 3** but at **two** different temperatures.
- Keep the temperature of **FA 2** between room temperature and 55 °C. Do **not** exceed 55 °C.

Record all your results in your table on page 4.

Results

The rate of reaction can be calculated as shown.

$$\text{rate} = \frac{1000}{\text{reaction time}}$$

Calculate the rate of reaction for each of your **five** experiments. Record these rates in your table.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) On the grid plot a graph of rate of reaction on the *y*-axis, starting at zero, against temperature on the *x*-axis. Select a scale for the *x*-axis which includes a temperature of 15.0 °C. Label your axes and any points you consider anomalous.

Draw a line of best fit and extrapolate it to 15.0 °C.

I	
II	
III	
IV	

[4]

(c) **Use your graph** to calculate the **time** to the nearest second that the reaction would have taken if you had carried it out at 17.5 °C. Show **on the grid** how you obtained your answer.

time = ... s [2]

(d) Explain, by referring to your graph or your table of results, how the rate of reaction is affected by increasing temperature.

....

....

.... [2]

(e) **Calculations**

(i) Calculate the concentration of hydrated sodium thiosulfate, $Na_2S_2O_3.5H_2O$, in **FA 1** in $mol\,dm^{-3}$.

concentration of $Na_2S_2O_3.5H_2O$ in **FA 1** = ... $mol\,dm^{-3}$ [1]

(ii) Calculate the concentration of the strong monoprotic acid, H**Z**, in the solution immediately **after FA 1** was added to **FA 2** in the beaker.

concentration of HZ = ... $mol\,dm^{-3}$ [1]

(iii) Use the equation on page 2 to determine which reagent, **FA 1** or **FA 2**, was in excess.

The reagent in excess was .... [2]

(f) **(i)** Calculate the maximum percentage error in measuring the reaction time you recorded for **Experiment 2**. Assume that the maximum error of the timer is ±0.5 s.

maximum percentage error in the reaction time = ... % [1]

(ii) A student suggested that the error in measuring the reaction time in **Experiment 1** was greater than for **Experiment 2**.

Give **one** reason why the student could be correct.

....

.... [1]

(g) Suggest **two** ways to improve the accuracy of the results of these experiments.

1 ....

....

2 ....

....

[2]

[Total: 24]

Qo Qualitative: Organic compounds test Chem 17 Q# 24/ ALvl Chemistry/2022/w/TZ 1/Paper 3/Q# 3 :o) www.SmashingScience.org

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

(b) Half fill the 250 cm^3 beaker with water and heat to approximately 80 °C. Turn off the Bunsen burner. This will be your hot water bath.

FA 7 is an organic compound with an M_r between 40–57.

(i) Carry out **Test 2** and **Test 3** on **FA 7** and record your observations. The result for **Test 1** is shown in the table.

test	*observations*
Test 1 Add a small piece of sodium.	no change
Test 2 To a 0.5 cm depth of aqueous iodine in a test-tube add aqueous sodium hydroxide dropwise until the yellow colour just disappears. Then add a few drops of **FA 7** and shake the test-tube. If no change is seen, warm the test-tube in your hot water bath.	
Test 3 To a 1 cm depth of **FA 7** in a test-tube add a few drops of acidified potassium manganate(VII). Warm the test-tube in your hot water bath.	

[2]

SAMPLE DATA:

3(b)(i)	M1: Test 2 (triiodomethane test) (Pale) yellow ppt M2: Test 3 add (acidified aqueous) potassium manganate(VII) purple / $KMnO_4$ decolourised

(ii) Using the observations in **(b)(i)** suggest what can be deduced from each test about the functional groups present in **FA 7**.

Test 1 ....

Test 2 ....

Test 3 ....

[2]

(iii) Use your deductions in **(b)(ii)** to suggest the identity of **FA 7**.

FA 7 is .... [1]

[Total: 15]

Qo Qualitative: Organic compounds test Chem 16 **Q# 25/** ALvl Chemistry/2020/s/TZ 1/Paper 3/Q# 3 :o)
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Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

(b) **FA 7** and **FA 8** are aqueous solutions of covalently bonded compounds.

Half fill the beaker with water and place it on a tripod and gauze. Heat until the water begins to boil and then turn off the Bunsen burner. This will be used as a hot water bath.

(i) Complete the table by carrying out the tests described.
Use a 1 cm depth of **FA 7** or **FA 8** in a test-tube for each test.

test	*observation(s)*	
	FA 7	**FA 8**
Test 1 Add an equal volume of dilute sulfuric acid and a **few** drops of **FA 3**, aqueous acidified potassium manganate(VII), then		
place in the hot water bath for several minutes.		
Test 2 Add an equal volume of dilute sulfuric acid and an equal volume of aqueous potassium iodide, then		
add a few drops of aqueous starch.		
Test 3 Add an equal volume of aqueous iodine, then add aqueous sodium hydroxide until no further change occurs. Leave the tube to stand.		
Test 4 Add a few drops of **FA 4**, then		
add aqueous ammonia.		

[5]

Sample Data:

test	observation(s)	
	FA 5	FA 6
Test 1	$KMnO_4$ decolorised*. fizzing/bubbling/effervescence or gas relights glowing spill* .... No (further) change	no reaction $KMnO_4$ not decolorised and .... $KMnO_4$ goes from purple to colourless (solution)*
Test 2	Red-brown/ brown solution formed* .... Mixture goes to (dark) blue / blue-black*	No change and .... No change*
Test 3	Yellow or colourless solution formed*	(On standing) off-white / pale yellow precipitate formed*.
Test 4	No change / pale yellow (solution) formed* .... Red-brown / brown / rust precipitate (formed)* *Ignore fizzing*	

(ii) **FA 8** contains an organic compound.

From your observation(s), suggest one **possible** identity for this compound.
Explain your answer.

name ....

reason ....

....

.... [2]

(iii) State the type of reagent **FA 7** acts as in its reaction with aqueous potassium iodide.
Explain your answer.

....

....

.... [1]

[Total: 18]

Qo Qualitative: Organic compounds test Chem 18 **Q# 26/** ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# 3 :o)
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Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** Half fill the 250 cm^3 beaker with water. Heat to approximately 70 °C, then turn off the Bunsen burner. This will be used as a water bath.

(i) **FA 5** is an aqueous solution of an organic compound. Carry out the following tests on **FA 5** and record your observations in the table.

test	*observations*
To a 1 cm depth of **FA 5** in a test-tube add a small spatula measure of sodium carbonate.	
To a 1 cm depth of **FA 5** in a test-tube add two drops of acidified potassium manganate(VII). Leave to stand in the water bath.	
To a 1 cm depth of **FA 5** in a test-tube add a few drops of aqueous silver nitrate.	
To a 1 cm depth of aqueous silver nitrate in a test-tube add a few drops of aqueous sodium hydroxide and then add aqueous ammonia slowly until the grey precipitate that forms **just** dissolves. This is Tollens' reagent. To this solution add a 1 cm depth of **FA 5** and leave to stand in the water bath. **Care: rinse the tube as soon as you have completed this test.**	

[4]

Sample Data:

3(a)(i)	+ Na_2CO_3: fizz / effervescence / bubbling
	+ $KMnO_4$: purple (allow pink) to colourless (allow pale yellow)
	+ $AgNO_3$: no (visible) reaction / no change / no ppt / solution remains colourless
	+ Tollens': silver mirror / black ppt / grey ppt

(ii) Suggest **two** functional groups that could be present in **FA 5**.

.... and ....

[2]

Qo Qualitative: Organic compounds test Chem 17 **Q# 27/** ALvl Chemistry/2016/s/TZ 1/Paper 3/Q# 3 :o)
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3 **Qualitative Analysis**

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(d) **FA 6** and **FA 7** are different organic liquids. Their possible identities are listed below.

- 2-methylpropan-2-ol
- propanal
- propanone

Half fill the 250 cm^3 beaker with water and heat to about 50 °C. You will use this as a hot water bath.

Turn off the Bunsen burner.

Carry out the following tests and record your observations.

test	observations
To a 1 cm depth of **FA 6** in a test-tube, add a few drops of acidified potassium manganate(VII). If no reaction is seen, warm the solution in the hot water bath.	
To a 1 cm depth of **FA 7** in a test-tube, add a few drops of acidified potassium manganate(VII). If no reaction is seen, warm the solution in the hot water bath.	

Sample Data

(d)	**Both observations required** **FA6** no reaction/solution turns pink **and** **FA7** turns colourless/decolourises the $KMnO_4$	1

Suggest the identity of **FA 6** and **FA 7** with an explanation.

FA 6 ....

FA 7 ....

[2]

[Total: 13]

Qi Qualitative: Inorganic ions test Chem 17 Q# 28/ ALvl Chemistry/2010/s/TZ 1/ Paper 3/Q# 2/ :o)

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Read through the remainder of question 2 before starting further practical work.

Heat a half-full 250 cm^3 beaker of water for use as a hot water-bath.

(g) **FA 7**, **FA 8**, **FA 9** and **FA 10** are organic compounds. Each contains one of the following different functional groups.

- primary alcohol
- tertiary alcohol
- aldehyde
- ketone

You are to react some of these compounds with some of the following reagents.

- acidified aqueous potassium dichromate(VI)
- 2,4-dinitrophenylhydrazine (2,4-DNPH) reagent
- ammoniacal silver nitrate (Tollens' reagent)

You are provided with the first two reagents. You must prepare the last of these reagents, Tollens' reagent, immediately before use. Follow the instructions in the box below.

To 2 cm depth of aqueous silver nitrate in a boiling-tube add ½ cm depth of aqueous sodium hydroxide. This will produce a brown precipitate of silver(I) oxide.
Add aqueous ammonia a little at a time, with continuous shaking, until the brown precipitate **just** dissolves. **Do not add an excess of aqueous ammonia**.

In each of the following tests add a few drops of the reagent to 1 cm depth of **FA 7**, **FA 8**, **FA 9** and **FA 10** in separate test-tubes.

In the tests using acidified potassium dichromate(VI) and Tollens' reagent, if no initial reaction is seen, warm that tube and its contents in your hot water-bath. There is no need to heat any tube to which you have added 2,4-DNPH reagent.

Do **not** heat any tube with a naked flame.

Record your results in the table below.

Do **not** carry out tests for the shaded boxes.

reagent	observations			
	FA 7	**FA 8**	**FA 9**	**FA 10**
acidified potassium dichromate(VI)				
2,4-DNPH reagent				
Tollens' reagent				

[3]

Sample Data:

reagent	observations			
	FA 7	FA 8	FA 9	FA 10
acidified dichromate	no reaction		no reaction	(colour change to) green/blue-green/ cyan/turquoise (solution **not** ppt)
2,4-DNPH	~~no reaction~~	~~yellow ppt~~	~~yellow ppt~~	
Tollens' reagent	no reaction	silver mirror **or** black/grey solution or ppt		no reaction

(h) State which of the solutions contains a tertiary alcohol. Explain the observations leading to your conclusion.

FA .... contains the tertiary alcohol.

explanation ....

....

State which of the solutions contains the aldehyde. Explain the observations leading to your conclusion.

FA .... contains the aldehyde.

explanation ....

....

[2]

[Total: 14]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **(a)** **FA 6** is an aqueous solution that contains one cation and two anions. The three ions are listed in the Qualitative analysis notes.

(i) Carry out the following tests on **FA 6** and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 6** in a boiling tube add aqueous sodium hydroxide, then	
heat gently.	
Test 2 To a 1 cm depth of **FA 6** in a boiling tube add a 1 cm depth of aqueous sodium hydroxide and a piece of aluminium foil. Heat gently.	
Test 3 To a 1 cm depth of **FA 6** in a test-tube add a few drops of hydrogen peroxide.	

[4]

Sample Data

3(a)(i)	**observations** **Test 1** M1: NaOH: white ppt and soluble in excess M2: Heat: no change / no (visible) reaction / litmus stays red **Test 2** M3: Al: fizz and NH_3 / gas turns (damp red) litmus blue **Test 3** M4: H_2O_2: brown / (darker) yellow / yellow-brown / orange-brown / red-brown (solution)

(ii) From your observations suggest **two** possible identities for the cation in **FA 6**.

possible cations: .... and .... [1]

(iii) Suggest a test that would allow you to determine which of the cations you suggested in **(a)(ii)** is present in **FA 6**.

Carry out this test, record the result and hence identify the cation in **FA 6**.

test ....

result ....

The cation present is ....

[2]

(iv) From your observations in **(a)(i)** suggest **two** anions that could be present in **FA 6** and give their formulae.

possible anions: .... or .... [1]

(v) Suggest an additional test that could be carried out to confirm the presence of **one** of the anions you suggested in **(a)(iv)**.

Carry out this test, record the result and hence state the identity of the anion.

test ....

result ....

The anion present is ....

[2]

[After you have suggested the additional tests, the sample data you will need to identify the unknown ions will be found at the end of the next question]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **(a)** **FA 5** is an ionic solid containing two ions. It contains one or more ions that contain nitrogen.

(i) Carry out suitable tests to identify the anion. Reserve a small amount of **FA 5** for use in **(a)(ii)**.

Record the tests you carry out and the observations you make, in a table, in the space below.

You **must** use a boiling tube if any liquid is heated.

anion in **FA 5** = ... [4]

[Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(ii) Heat a small spatula measure of **FA 5** in a hard-glass test-tube.
When no further change occurs, allow the tube and its contents to cool completely.

Record **all** the observations you make and any subsequent conclusions.

....

....

....

.... [2]

(b) **FA 6** is a solution of a compound containing one cation and one anion, both of which are in the Qualitative analysis notes.
FA 7 is an aqueous mixture of two substances. **FA 7** contains one potassium-containing compound and one other substance. All substances are listed in the Qualitative analysis notes.

(i) Carry out the following tests. Complete the table below.
Use a 1 cm depth of **FA 6** or **FA 7** in a test-tube for each test.

Table 3.1

test	*observations*	
	FA 6	**FA 7**
Test 1 Add aqueous sodium hydroxide.		
Test 2 Add aqueous barium chloride or aqueous barium nitrate, then		
add dilute hydrochloric acid.		
Test 3 Add a few drops of aqueous starch, then		
add aqueous sodium thiosulfate.		
Test 4 Add a few drops of aqueous silver nitrate, then		
add a few drops of aqueous sodium hydroxide.		
Test 5 Add aqueous ammonia.		

[5]

Sample Data

3(b)(i)	*test*	*FA 6*	*FA 7*
	Test 1 NaOH	White ppt / solid (formed) * Soluble in excess *	Decolourises / turns (pale) yellow * (ppt is CON)
	Test 2 Ba^{2+}	White ppt	No change / no reaction
	+ HC*l*	AND ppt insoluble / remains / no change / no reaction *	AND no change / no reaction *
	Test 3 starch		Dark blue / blue-black / black (colour formed) (ignore state)
	+ thio		AND colourless solution (forms) ALLOW turns colourless / decolourises *
	Test 4 Ag^+	No change / no reaction / no ppt	Yellow / brown ppt (forms) *
	+ NaOH	AND ppt (forms) (ignore colour) *	Pale yellow ppt ALLOW ppt turns paler yellow * IGNORE use of excess NaOH
	Test 5 + NH_3	White ppt AND ppt is insoluble in excess (NH_3) *	

(ii) Give the formulae of the substances in **FA 6** and **FA 7**.

FA 6 is ....

FA 7 contains .... and .... [3]

(iii) Give the ionic equation for **one** of the reactions taking place in **Test 1**.
Include state symbols.

.... [1]

[Total: 15]

Sample data for previous question where you need to suggest a suitable test/s (2022/w/TZ 1/Paper 3/Q# 3):

3(a)(iii)	identifying the cation M1: cation test: add (aqueous) ammonia M2: white ppt soluble in excess $NH_3(aq)$ shows

3(a)(v)	identifying the anion **if iodide in (iv)** M1: test: add (aqueous) silver nitrate / $AgNO_3$ M2: yellow ppt (insol in NH_3) shows I^- **if nitrite and nitrate (no iodide) in (iv)** M1: test: add (acidified aqueous) potassium manganate(VII) / $KMnO_4$ M2: purple / $KMnO_4$ solution turns (dark) yellow / yellow-brown / orange-brown / red-brown / brown / decolourised shows nitrite OR M1: add named (dilute) acid M2: no fizzing / no brown gas shows nitrate

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **FA 7** and **FA 8** are solutions containing a total of three cations and two anions. Two of the cations and both of the anions are listed in the Qualitative analysis notes.

(a) **(i)** Carry out the following tests and record your observations. Use a fresh 1 cm depth of solution in a test-tube for each test.

test	*observations*	
	FA 7	**FA 8**
Test 1 Add a 1 cm depth of dilute nitric or hydrochloric acid and allow to stand for 2 minutes, then		
add a few drops of aqueous barium nitrate or aqueous barium chloride.		
Test 2 Add a few drops of acidified aqueous potassium manganate(VII).		
Test 3 Add a few drops of aqueous iron(III) chloride and allow to stand for 1 minute.		

[4]

Sample Data:

3(a)(i)		**FA 7**	**FA 8**
	Test 1 + H^+	(slow formation of) white / off-white / cream / pale yellow ppt *	no change / no (visible) reaction / no ppt*
	+ Ba^{2+}	no change (provided ppt reported with H^+) / ppt remains / insoluble *	white ppt *
	Test 2 + MnO_4^-	purple to colourless / $KMnO_4$ decolourises*	no change / no (visible) reaction / stays purple * *Not 'no ppt' alone*
	Test 3 + $FeCl_3$	purple colour fades / turns colourless (on standing) *	no change / no (visible) reaction / solution stays yellow *
	2 x * = 1 mark		

(ii) From your test results, give the formulae of the anions present in **FA 7** and **FA 8**. If the tests do not allow you to positively identify an anion, write 'unknown'.

anion in **FA 7** = ...

anion in **FA 8** = ...

[2]

(b) **(i)** Select reagents for tests to identify as many of the cations as possible in **FA 7** and **FA 8**. Carry out your tests and record your reagents, conditions and observations.

[4]

[Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(ii) From your test results, give the formulae of as many cations as possible in **FA 7** and **FA 8**. If the tests do not allow you to positively identify a cation, write 'unknown'.

FA 7 contains ....

FA 8 contains ....

[2]

(iii) Write an ionic equation for **one** reaction you observed in **(b)(i)**. Include state symbols.

.... [1]

[Total: 13]

Qi Qualitative: Inorganic ions test Chem 18 **Q# 32/** ALvl Chemistry/2021/w/TZ 1/Paper 3/Q# 3 :o)
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Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

(b) **FA 8** is an aqueous solution.

(i) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 8** in a test-tube, add a few drops of acidified potassium manganate(VII). Place the tube in the hot water-bath.	
Test 2 To a 1 cm depth of **FA 8** in a test-tube, add a 1 cm length of magnesium ribbon.	

[2]

Sample Data

3(b)(i)	M1: Test 1 purple / pink to colourless / (pale) yellow / pale brown OR $KMnO_4$ is decolourised M2: Test 2 effervescence / fizzing / bubbles **AND** gas/ H_2 pops with a lighted splint / burns with a pop

(ii) For each observation, state what you can conclude about the chemical properties of **FA 8**.

Test 1 ....

Test 2 ....

[2]

[Total: 14]

Sample data for previous question where you need to suggest a suitable test/s (2022/m/TZ 3/Paper 3/Q# 3):

3(b)(i) selects NaOH and NH_3
AND
uses both NaOH and NH_3 to excess / warms at least one NaOH mixtures

	FA 7	**FA 8**
+ NaOH	no change / no (visible) reaction / no ppt *	white ppt * soluble in excess *
+ warm	no change to (red) litmus / * *ignore no reaction* *ignore bubbling*	gas / NH_3 turns (red) litmus blue *
+ NH_3	Ignore	white ppt * insoluble in excess *

Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 Half-fill the 250 cm^3 beaker with water and place it on a tripod and gauze above a heatproof mat. Heat the water until boiling and then turn off the Bunsen burner. You will use this as a hot water-bath in **3(b)(i)**.

(a) **FA 5**, **FA 6** and **FA 7** are solutions. Each solution contains one cation and one anion. Carbonate, CO_3^{2-}, is **not** present in any of the solutions.

(i) Carry out the following tests and record your observations. Use a 1 cm depth of solution in a test-tube for each test.

test	*observations* FA 5	FA 6	FA 7
Test 1 Add an equal depth of dilute sulfuric acid.			
Test 2 Add an equal depth of aqueous sodium carbonate.			
Test 3 Add an equal depth of aqueous magnesium chloride.			

[5]

Sampel Data

3(a)(i)		FA 5	FA 6	FA 7
	H_2SO_4	white ppt / solid *	no (visible) reaction / no change / no ppt / solution remains colourless *	no (visible) reaction / no change / no ppt / solution remains colourless *
	Na_2CO_3	white ppt / solid *	effervescence / fizzing / bubbles * gas / CO_2 turns limewater milky / cloudy white / forms white ppt *	no (visible) reaction / no change / no ppt / solution remains colourless *
	$MgCl_2$	no (visible) reaction / no change / no ppt / solution remains colourless *	no (visible) reaction/ no change / no ppt / solution remains colourless *	white ppt / solid *

(ii) Use your observations in **(a)(i)** to suggest a **possible** formula for each of the following:

The cation in **FA 5** is ....

The cation in **FA 6** is ....

The anion in **FA 7** is ....

[3]

(iii) Apart from using an indicator, suggest a further test that would confirm the identity of the anion in **FA 7**.

Carry out this test and record the result.

....

....

.... [1]

[After you have suggested the additional tests, the sample data you will need to identify the unknown ions will be found at the end of the next question]

(iv) Did the result of your test in **(a)(iii)** confirm the identity of the anion in **FA 7**? Explain your answer.

....

....

.... [1]

Qi Qualitative: Inorganic ions test Chem 12 **Q# 34/** ALvl Chemistry/2021/s/TZ 1/Paper 3/Q# 3 :o)
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Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** Aqueous ammonium thiocyanate reacts with aqueous iron(III) ions to form an orange or red coloured compound. Iron(II) ions do not react in this way. The darker the orange or red colour, the more iron(III) ions are present in the solution.

(i) For each test use a 1 cm depth of **FA 1** in a test-tube. Record all your observations.

test	*observations*
Test 1 Add a few drops of aqueous ammonium thiocyanate.	
Test 2 Add a few drops of aqueous sodium hydroxide and leave for at least two minutes, then	
add dilute sulfuric acid dropwise until there is no further change, then	
add a few drops of aqueous ammonium thiocyanate.	

[3]

Sampel Data:

3(a)(i)	**Test 1** no change / (pale) orange / (pale) red / (pale) pink solution *Allow solution becomes colourless / paler*	
	Test 2	
	+ NaOH	green / dirty green / pale green / dark green ppt * ppt turns brown (at surface) *
	+ H_2SO_4	ppt dissolves or yellow / yellow-brown / orange-brown solution formed *
	+ SCN^-	(solution) turns dark(er) orange / blood-red / red / dark(er) red / deep red / red-brown * colour must be more intense than in **Test 1**

(ii) Suggest a reason for any difference in observation when you added aqueous ammonium thiocyanate in **Test 2** compared with **Test 1**.
Your answer should refer to the type of reaction that occurred in **Test 2**.

....

....

.... [2]

(iii) The charge on the thiocyanate ion, SCN^-, is –1.

Determine the formula of ammonium thiocyanate.

.... [1]

(iv) A solution containing Fe^{2+} reacts with aqueous ammonia to form a green precipitate.

Write the ionic equation for this reaction.
Include state symbols.

.... [2]

(b) **FA 4** contains one cation and one anion, both of which are listed in the Qualitative Analysis Notes. The anion in **FA 4** contains sulfur.

(i) Carry out appropriate tests to allow you to identify the cation and anion in **FA 4**.

Record each test and your observations in a suitable form below.

[7]

[Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(ii) Give the formula of the ions present in **FA 4**.

cation ....

anion ....

[1]

[Total: 16]

Sample data for previous question where you need to suggest a suitable test/s (2021/w/TZ 1/Paper 3/Q# 3)

3(a)(iii)	**Test for OH^-** Add specified (aqueous) metal compound gives appropriate (coloured) ppt OR Add a specified nitrate and Al and warm Positive test for ammonia OR Add a specified ammonium compound and warm Positive test for ammonia

Qi Qualitative: Inorganic ions test Chem 12 **Q# 35/** ALvl Chemistry/2021/m/TZ 3/Paper 3/Q# 3 :o)
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Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** **FA 6** contains one cation and one anion both of which are listed in the Qualitative analysis notes.

(i) Heat **FA 6** gently for one minute in the hard-glass test-tube in which it is supplied. Then heat strongly until no further change occurs.

Record **all** of your observations.

....

....

....

....

.... [2]

(ii) Identify the ion that **must** be present in **FA 6**.

.... [1]

Sample Data

3(a)(i)	1 mark for correct gas test: (gas / vapour / fumes) turn (moist red) litmus to blue *Reject if incorrect gas identified* 1 mark for any two bulleted observations correct: • solid sublimes / white solid forms near top of tube *(owtte; allow residue for solid)* *Reject 'solid evaporated'* *Allow 'white layer formed around glass tube' (bod)* • white and smoke / vapour / fumes produced *Reject 'effervescence'* *Reject 'gas'* • no residue (at bottom of tube) *Allow 'crystals disappear completely'* • after heating for some time, gas turns (moist blue) litmus to red

(b) (i) **FA 7** and **FA 8** are aqueous solutions.
Each solution contains one cation and one anion both of which are listed in the Qualitative analysis notes.
Use 1 cm depths of **FA 7** or **FA 8** in test-tubes for the following tests.
Complete the table by recording your observations.

test	*observations*	
	FA 7	**FA 8**
Test 1 Add a few drops of aqueous acidified potassium manganate(VII), then		
add a few drops of starch indicator.		
Test 2 Add a few drops of aqueous silver nitrate, then		
add aqueous ammonia.		
Test 3 Add aqueous sodium hydroxide, then		
pour the mixture into a boiling tube. Warm gently and **carefully**, then		
add a piece of aluminium foil.		
Test 4 Add a few drops of dilute sulfuric acid.		

[6]

Sample Data:

3(b)(i)	14 observations. Two * = 1 mark (round down) *Reject 'no observation' (for 'no change') the first time seen, then allow*	6

test	reagent	FA 7	FA 8
1	$KMnO_4$	Solution / turns and yellow / red-brown / orange-brown / brown * *Reject any reference to purple colour at end* *Reject ppt*	*Ignore*
	starch	black / dark blue / blue-black / black-purple * *Reject purple on its own*	*Ignore*
2	$AgNO_3$	(pale) yellow precipitate (formed) * *Reject creamish-yellow*	white precipitate (formed) * *Reject off-white*
	NH_3	ppt does not dissolve / insoluble / no change *	ppt (mostly) dissolves or partially dissolves or (slightly) cloudy mixture forms or <u>some</u> white ppt remains * *Reject 'clear solution'*
3	NaOH (cold)	no reaction / no change / no precipitate * *Allow 'no visible observation'*	white precipitate and insoluble in excess * *Reject any variation on white, e.g. off-white*
	NaOH (hot)	<u>gas / NH_3</u> turns (red) litmus to blue *	*Ignore observations when heated* *(but reject litmus goes blue at any stage of this test)*
	Al	*Ignore observation(s) with Al*	fizzing / bubbling / effervescence or gas / H_2 pops with lighted spill *
4	H_2SO_4	no change / no reaction or solution <u>remains</u> colourless * *Reject 'no ppt'*	white precipitate (formed) *

(ii) Deduce the chemical formulae of **FA 7** and **FA 8**.

FA 7 is .... and **FA 8** is ....
[2]

(iii) Give the ionic equation for the reaction of **FA 8** with sulfuric acid.
Include state symbols.

.... [1]

[Total: 12]

Sample data for previous question where you need to suggest a suitable test/s (2021/s/TZ 1/Paper 3/Q# 3)

3(b)(i)	prepare solution of FA 4	
	prepare a suitable table(s) minimum 2 tests and columns/ rows for tests and for observations	
	2 asterisks = 1 mark (round down)	
	+NaOH *	white ppt * insoluble in excess *
	+ NH_3 *	white ppt* insoluble in excess *
	$BaCl_2$/$Ba(NO_3)_2$* HC*l* / HNO_3 *	white ppt * insoluble in excess suitable named acid *
	OR dilute acid * + $KMnO_4$ *	no change / no reaction / solution remains purple **

Qi Qualitative: Inorganic ions test Chem 12 **Q# 36/** ALvl Chemistry/2020/w/TZ 1/Paper 3/Q# 3 :o)
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Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 (a) **FA 6** is a salt containing one cation and one anion. The anion is listed in the Qualitative Analysis Notes.
Add all the sample of **FA 6** to the 100 cm^3 beaker. Dissolve the solid in approximately 50 cm^3 of distilled water.
Label this solution **FA 7**.

(i) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 7** in a test-tube, add a 3 cm depth of aqueous silver nitrate.	
Pour approximately half the contents of the test-tube into a clean test-tube.	
Test 2 To the first test-tube add aqueous ammonia.	
Test 3 To the second test-tube add **FA 5**, aqueous sodium thiosulfate.	

[2]

(ii) From the results of your tests in **(a)(i)** suggest which anion is present in **FA 6**.

.... [1]

Sample Data

3(a)(i)	+ $AgNO_3$ gives a white ppt
	soluble in both $NH_3(aq)$ and **FA 5** / thio

(iii) It is suggested that **FA 6** could be sodium sulfite, Na_2SO_3, or sodium sulfate, Na_2SO_4.

Carry out tests using solution **FA 7** in order to decide whether **FA 6** is sodium sulfite or sodium sulfate.
Record the reagents selected, the results of your tests and your conclusions in the space below.

FA 6 is sodium .... [2]

(iv) Using your conclusion from **(a)(iii)**, write an ionic equation for the reaction between silver nitrate and **FA 7**.
Include state symbols.

.... [1]

[Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(b) **FA 8** is a solution containing one of the cations listed in the Qualitative Analysis Notes.

(i) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 8** in a test-tube, add aqueous ammonia until there is no further change, then	
pour the contents into a boiling tube and add a few drops of aqueous hydrogen peroxide.	

[3]

(ii) Identify the cation in **FA 8**.

cation = ... [1]

(iii) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 8** in a test-tube, add a 1 cm depth of aqueous potassium iodide, then	
add **FA 5**, aqueous sodium thiosulfate.	

[2]

Sample Data:

3(b)(i)	(Pale) blue ppt dissolves in excess to give a dark blue solution.
	+ H_2O_2 solution turns black / dark green OR black / dark green solid produced AND Effervescence / fizzing / bubbling
	gas / oxygen relights a glowing splint

3(b)(iii)	+ KI(aq) (turns) brown / yellow-brown / orange-brown / grey-brown Ignore state Allow mustard (brown) Reject red-brown
	+ FA 5 then (brown solution becomes paler) ppt is off-white / white Allow cream / pale grey ppt. Ignore effect of excess thio / FA 5.

(iv) Explain your observations in **(b)(iii)**.

....

....

.... [2]

[Total: 14]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** **FA 6** is a hydrated salt. It contains two cations and one anion, all of which are listed in the Qualitative Analysis Notes.

(i) Describe and carry out tests to identify the cations in **FA 6**.

Record your tests and observations in the space below.

The cations in **FA 6** are .... and ....

[5]

[Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(ii) The anion in **FA 6** is a sulfite, sulfate or a halide.

Carry out a test to identify the anion in **FA 6**.
Record your tests and observations in the space below.

Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.

The anion in **FA 6** is .... [2]

(iii) Give the ionic equation for **one** reaction you have carried out in **(a)(i)** or **(a)(ii)**.
Include state symbols.

.... [1]

(iv) The formula of **FA 6** is $XY_2Z_2{\bullet}wH_2O$ where

- **X** and **Y** are the cations present and **Z** is the anion present
- **w** is the number of moles of water of crystallisation in the hydrated salt.

The relative formula mass of this compound is 392.0.

Using your conclusions from **(a)(i)** and **(a)(ii)**, calculate the value of **w**, the number of moles of water of crystallisation.

w = ... [2]

Sample data for previous question where you need to suggest a suitable test/s (2020/w/TZ 1/Paper 3/Q# 3)

3(a)(iii)	Selects $BaCl_2$ OR $Ba(NO_3)_2$ **and** HCl OR HNO_3 **OR** selects acidified (aqueous) $KMnO_4$ **OR** add named mineral acid and test for SO_2 (e.g. blue litmus turns red; acidified aqueous manganate(VII) paper turns colourless)
	Clear display of results to show: white ppt and (partially) soluble in acid OR $KMnO_4$ decolourises OR positive result for SO_2 **AND** FA 6 = sodium sulfite

Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 (a) **FA 3** is aqueous hydrogen peroxide, H_2O_2.
FA 6 is a solution containing two cations and one anion from those listed in the Qualitative analysis notes.

(i) To a 1 cm depth of **FA 6** in a boiling tube, add aqueous sodium hydroxide until it is in excess. Then heat the tube, gently and carefully.
Keep the mixture obtained in the boiling tube for the test in **(a)(ii)**.

Record **all** your observations.
Identify the cations in **FA 6**.

observations ....

....

....

....

....

FA 6: cations are .... and ....
[4]

(ii) To the mixture obtained from **(a)(i)**, carefully add a 1 cm depth of **FA 3**.
Record your observations.

....

.... [1]

Sample Data:

3(a)(i)	Green precipitate and insoluble / no change in excess (NaOH)
	(Green) precipitate darkens and / or goes brown
	(When mixture heated) gas / ammonia turns (red) litmus blue
	Both cations in FA 6 identified • Fe^{2+} ions / iron(II) • Ammonium / NH_4^+
3(a)(ii)	Goes brown / rust / red-brown / orange-brown AND bubbles / fizzing / effervescence

(iii) One reaction taking place in **(a)(ii)** involves oxidation of one of the cations in **FA 6**.

Give the half-equation to show this oxidation reaction. State symbols are not required.

.... [1]

(b) **FA 1** is aqueous potassium manganate(VII).
FA 2 is dilute sulfuric acid.
FA 7 and **FA 8** are solutions, each containing one cation and one anion.

(i) Carry out the following tests and record your observations in the table.

test	*observations*	
	FA 7	**FA 8**
Test 1 To a 1 cm depth of solution in a test-tube, add a small spatula measure of solid sodium carbonate.		
Test 2 To a 1 cm depth of solution in a test-tube, add an equal volume of **FA 2** and a few drops of **FA 1**, then		
add a few drops of aqueous starch.		
Test 3 To a 1 cm depth of solution in a test-tube, add a few drops of aqueous silver nitrate, then		
add aqueous ammonia.		

[5]

Sample Data

3(b)(i)	Award one mark for every two correct observations (*) as shown in table below		
	test	*observations*	
		FA 7	FA 8
	Test 1 + Na_2CO_3(s)	no (visible) reaction / no change / no precipitate / solid (carbonate) dissolves / no effervescence *	effervescence / fizzing / bubbles * gas / CO_2 gives a white ppt with limewater / turns limewater milky / cloudy white / chalky *
	Test 2 + $H^+/KMnO_4$(aq)	solution turns yellow / brown / orange-brown / red-brown / yellow-brown *	no (visible) reaction / no change / $KMnO_4$ / solution stays purple / colourless solution turns purple / purple solution formed *
	+ starch(aq)	(turns) dark blue / deep blue / blue-black / black *	*ignore*
	Test 3 + $AgNO_3$(aq)	(pale) yellow ppt (formed) *	white ppt (formed) *
	+ NH_3(aq)	(ppt) insoluble / does not dissolve / no change *	(ppt) dissolves / soluble / gives a colourless solution *

(ii) Identify the anion in **FA 7**.

anion .... [1]

(iii) Identify **FA 8**.

FA 8 is .... [1]

(iv) Carry out one further test to confirm the identity of the cation in **FA 8**.
State the name of the reagent you used and record the observation(s) you made.

reagent ....

[After you have suggested the additional tests, the sample data you will need to identify the unknown ions will be found at the end of the next question]

observation(s) ....

....

[1]

[Total: 14]

Sample data for previous question where you need to suggest a suitable test/s 2020/s/TZ 1/Paper 3/Q# 3

3(a)(i)	Reagents used are NaOH and NH_3
	FA 6 dissolved in (distilled) water (before carrying out tests)
	Observations with both cold alkalis • With NaOH: green ppt, insoluble in excess • With NH_3: green ppt, insoluble in excess OR • If only one of NaOH or NH_3 was selected, award this mark if the observation is correct, but it must include 'ppt turns brown'.
	Observation when heated with NaOH Fizzing/bubbling and gas/NH_3 turns (moist red) litmus to blue

3(a)(ii)	**Anion test and first observation** • Add barium nitrate/chloride • White precipitate
	Observation with acid and conclusion: • white ppt is insoluble in specified mineral acid (not H_2SO_4)

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** **FA 5** is a salt that contains two different cations and a single anion from those listed in the Qualitative Analysis Notes.

(i) Place a small spatula measure of **FA 5** in a hard-glass test-tube and heat **gently**.
Do not inhale the fumes.
Record **all** your observations.

....

....

....

.... [2]

(ii) Pour a 4 cm depth of distilled water into a boiling tube. Add the remaining **FA 5** and stir carefully until the solid has dissolved. This solution is **FA 6**.
Carry out the following tests on **FA 6** and record your observations.

test	*observations*
To a 1 cm depth in a test-tube, add aqueous ammonia.	
To a 1 cm depth in a boiling tube, add aqueous sodium hydroxide, then	
warm the mixture.	
To a 1 cm depth in a test-tube, add aqueous barium nitrate or aqueous barium chloride, then	
add dilute hydrochloric acid or dilute nitric acid.	

[4]

Sample Data:

3(a)(i)	• melts / dissolves • condensation / moisture on the walls of the test-tube / steam produced • white smoke / fumes (NOT gas) • (gas) turns red litmus blue • gas turns blue litmus red • white residue Award 1 mark for two correct observations from the list, award 2 marks for three or more correct observations. If both gas observations are given they must be in the correct order for both to be credited.
3(a)(ii)	NH_3 White ppt and insoluble in excess
	NaOH White ppt and sol in excess Allow 1 mark for white ppt with both NH_3 and NaOH
	hot NaOH Gas / NH_3 (on warming) turns red litmus blue
	Ba^{2+} White ppt insoluble in acid / white ppt no reaction with acid Reject white ppt formed when acid added

(iii) Identify the three ions in **FA 5**.

FA 5 contains .... , ... and ....

[2]

(b) A student carried out Qualitative Analysis tests on a hydrated salt, **FA 7**, and concluded that it contained the ions K^+, Cr^{3+} and SO_4^{2-}.
The relative formula mass of **FA 7** is 499.3.

Determine the formula of **FA 7**.

The formula of **FA 7** is ....

[2]

(c) **FA 8** is a solution containing a single cation and a single anion, both of which are listed in the Qualitative Analysis Notes.

(i) Carry out the following tests and record your observations.

test	*observations*
To a 1 cm depth in a test-tube, add a few drops of aqueous acidified potassium manganate(VII), then	
add starch indicator.	
To a 1 cm depth in a test-tube, add aqueous sodium hydroxide.	

[2]

Sample Data:

3(c)(i)	Red-brown (allow yellow / yellow-brown / orange / orange-brown / brown) (solution) or $KMnO_4$ / purple decolourises and turns blue-black / dark blue / black (on adding starch)
	Green ppt and insoluble in excess / turns brown (on standing) Reject grey-green

(ii) Identify the two ions in **FA 8**.

FA 8 contains .... and .... [1]

(iii) Suggest an additional test you could carry out to confirm the presence of the anion in **FA 8**.

Carry out this test and record your result.

[After you have suggested the additional tests, the sample data you will need to identify the unknown ions will be found at the end of the next question]

[2]

(iv) Give the ionic equation for the reaction you carried out using **FA 8** and sodium hydroxide. Include state symbols.

.... [1]

[Total: 16]

Sample data for previous question where you need to suggest a suitable test/s (2020/m/TZ 3/Paper 3/Q# 3)

3(b)(iv)	One suitable test for H^+ (reagent and observation) in any acid identified in (b)(iii) • named pH indicator and correct final colour OR • add magnesium and fizzes or gas / H_2 pops with a lighted splint

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Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** **FA 4** and **FA 5** are aqueous solutions each containing one anion and one cation.

(i) Carry out the following tests and record your observations. For each test use a 1 cm depth of **FA 4** or **FA 5** in a test-tube.

test	*observations*	
	FA 4	**FA 5**
Add a 1 cm depth of dilute hydrochloric acid. Leave to stand.		
Add a 1 cm depth of aqueous copper(II) sulfate. Leave to stand.		
Add a few drops of aqueous silver nitrate, then		
add aqueous ammonia.		
Add a 1 cm depth of aqueous chlorine, then		
add a 1 cm depth of **FA 5**.		

[5]

Sample Data:

3(a)(i)

	FA 4	FA 5
HCl	No (visible) reaction / no change * *Allow pale yellow solution / colourless solution*	Pale yellow / cream / white / off-white ppt *(ignore excess)
$CuSO_4$	Brown (ppt/ colour / soln) * *Do not allow orange/-brown or red-brown*	Green soln * allow blue-green / cyan / turquoise ppt is CON
$AgNO_3$	(pale) Yellow ppt *	Yellow ppt / black ppt / grey ppt / (allow solid/ particles for ppt) *
+ NH_3	Insol in NH_3 * *Allow no change*	ignore NH_3
Cl_2	Yellow or brown or red-brown / orange-brown / *yellow-brown soln* * *Do not allow orange. Ppt is CON*	No (visible) reaction / no change * *Allow colourless solution.*
+ FA 5	Decolourised * If Cl_2 reaction is incorrect then allow ecf e.g. colourless solution	

For every two correct observations (*) award 1 mark (round down)
Allow no observation for no (visible) change.

(ii) From your observations in **(a)(i)** identify one of the ions present in either **FA 4** or **FA 5**.

Ion present in .... is .... [1]

(iii) Apart from the reaction with **FA 5** suggest a test that could be used to identify the coloured product formed in the reaction between aqueous chlorine and **FA 4**. You should include the reagent used and the expected observation.

Do not carry out this test.

reagent ....

expected observation .... [1]

(b) (i) Place the cooled crucible and residue from **Question 2** onto a heatproof mat and add approximately 5 cm^3 of water.

Test the solution with litmus papers.
Record your observations.

....

.... [1]

Sample Data:

3(b)(i)	(Red) litmus turns blue Gas turns litmus blue is CON

(ii) Using QO as the formula of the residue, write the equation for the reaction with water that occurs in **(b)(i)**. Include state symbols.

.... [1]

(c) In **Questions 1** and **2** you identified the Group 2 metals present in **M**CO_3 and **Q**CO_3.

You will now plan and carry out tests to confirm, or not confirm, the identities of **M** and **Q**. Both **M** and **Q** are listed in the Qualitative Analysis Notes.

(i) Group 2 carbonates are insoluble in water. In order to test for the cations present (**M**$^{2+}$ and **Q**$^{2+}$) they must be in solution.

Name a reagent you could use to prepare solutions of the cations from solid samples of **M**CO_3 and **Q**CO_3.

.... [1]

(ii) You are provided with the following solutions.
FA 6 contains **M**$^{2+}$(aq).
FA 7 contains **Q**$^{2+}$(aq).

Choose reagents that could be used to confirm the identity of **M** and **Q**.
Carry out the tests. Record the tests, observations and conclusions.

[5]

[Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(iii) Do your conclusions confirm your identification of **M** and **Q** in **Questions 1** and **2**? Explain your answer.

....

....

.... [1]

[Total: 16]

Sample data for previous question where you need to suggest a suitable test/s (2019/w/TZ 1/Paper 3/Q# 3)

3(c)(iii)	Uses silver nitrate and yellow ppt
	ppt insoluble in HNO_3 or ppt insoluble in NH_3 (nitric acid may be added initially)

Qi Qualitative: Inorganic ions test Chem 12 **Q# 41/** ALvl Chemistry/2019/m/TZ 3/Paper 3/Q# 3 :o)
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Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **FA 4** is a solid containing one cation and one anion.
FA 5 is a solution containing one cation and one anion.
Carry out the following tests and record your observations.

(a) (i) Warm (do **not** boil) a 5 cm depth of **FA 5** in a boiling tube. Stop warming the **FA 5**, add all of the **FA 4** and shake the boiling tube.

....

Filter the mixture into a second boiling tube. The filtrate will be used in the tests in **(ii)**.

....

[2]

(ii) Use a 1 cm depth of the filtrate from **(i)** in separate test-tubes for each of the following tests.

test	*observations*
Add aqueous ammonia.	
Add a 1 cm depth of aqueous potassium iodide, then	
add aqueous sodium thiosulfate. (Rinse the test-tube when you have completed this test.)	
Add a 1 cm depth of dilute nitric acid followed by a 1 cm depth of aqueous silver nitrate.	
Add a 1 cm depth of dilute hydrochloric or dilute nitric acid followed by a 1 cm depth of aqueous barium chloride or aqueous barium nitrate.	

[5]

(iii) **FA 6** is a dry sample of the residue obtained by filtration in **(i)**.

test	*observations*
Add a 1 cm depth of dilute nitric acid to all of the **FA 6** in its test-tube. Allow the mixture to stand for about 1 minute, then	
add aqueous sodium hydroxide.	

[2]

Sample Data:

3(a)(i)	FA 4 + FA 5 observations may be in either order blue solution formed / colourless to blue / solution turns blue / blue filtrate
	pink / brown / red-brown **AND** residue / solid

3(a)(ii)

test	*observations*	*marks*
+ NH_3	((pale) blue ppt) forming deep / dark blue solution in excess	1
+ KI, then	turns brown / yellow-brown	1
+ $Na_2S_2O_3$	white ppt	1
+ HNO_3, then + $AgNO_3$	no (visible) reaction / no change / no ppt / remains a blue solution	1
+ HCl / HNO_3, then + $BaCl_2$ / $Ba(NO_3)_2$	white ppt	1

3(a)(iii)	FA 6 + nitric acid: (pale) blue solution
	then + NaOH: (pale) blue ppt

(b) (i) From your observations in **(a)**, suggest the identity of the cation and the anion present in the filtrate produced in **(a)(i)**.

cation present in the filtrate ....

anion present in the filtrate ....

[1]

(ii) Write an ionic equation for **one** reaction in **(a)(ii)** where a precipitate was formed. Include state symbols.

.... [1]

(iii) State the type of reaction that occurred in the first part of **(a)(iii)**.

.... [1]

(c) A student suggested that **FA 5** is an acid.

Apart from using an indicator, suggest and carry out a chemical test to determine whether the student was correct.

Record the name of the reagent you used, your observations and your conclusion.

[3]

[Total: 15]

[Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

Sample data for previous question where you need to suggest a suitable test/s (2019/s/TZ 1/Paper 3/Q# 3)

3(c)(ii)	Clear layout to show tests, observations and conclusions.
	(Chooses) NH_3 Ignore NaOH / named sulfate / H_2SO_4 Any other reagent is CON
	FA 6: no ppt / no (visible) change / no reaction / colourless solution. (allow no observation)
	FA 7: white ppt insoluble in excess Ignore observations with other reagents

Qualitative Analysis

Where reagents are selected for use in a test, the **full name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

2 (a) (i) **FA 4** is a sodium compound that was the impurity in the **FA 1** and **FA 3** that you used in **Question 1**. The anion in **FA 4** is one of those listed in the Qualitative Analysis Notes.

Carry out appropriate tests to allow you to positively identify the anion in **FA 4**.

For the test that gives a positive result, record the test and the results of it.
State the name of the anion in **FA 4**.

[Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

anion in **FA 4** = ... [2]

(ii) Write the ionic equation for the reaction that you have used to identify the anion in **FA 4**. Include state symbols.

.... [1]

(b) **FA 5** is a mixture that contains two cations and three anions from those listed in the Qualitative Analysis Notes.

A sample of **FA 5** was added to water and the water stirred. The mixture produced was filtered to give a solid residue, **FA 6**, and a filtrate, **FA 7**.

(i) Carry out the following tests on **FA 6** and record your observations.

test	*observations*
To a small spatula measure of **FA 6** in a test-tube add dilute hydrochloric acid, then	
add aqueous ammonia.	
Place a small spatula measure of **FA 6** in a hard-glass test-tube and heat gently.	

[4]

(ii) Carry out the following tests on **FA 7** and record your observations.

test	*observations*
To a 1 cm depth of **FA 7** in a test-tube add aqueous sodium hydroxide.	
To a 1 cm depth of **FA 7** in a test-tube add aqueous ammonia.	
To a 1 cm depth of **FA 7** in a test-tube add a few drops of aqueous silver nitrate.	
To a 1 cm depth of **FA 7** in a test-tube add a few drops of aqueous barium nitrate or aqueous barium chloride, then	
add dilute nitric acid.	
To a 0.5 cm depth of **FA 7** in a boiling tube add a 2 cm depth of aqueous sodium hydroxide and warm, then	
add a small piece of aluminium foil.	

[5]

Sample Data:

2(b)(i)	**Hydrochloric acid** Effervescence / bubbling and blue / green / cyan / turquoise solution formed
	gas / CO_2 turns limewater milky / cloudy white / chalky / forms a white ppt
	Ammonia (pale) blue ppt and dark blue solution with excess
	Heating (FA 6) turns black / black solid formed / it turns black

2(b)(ii)	2 * = 1 mark		
		NaOH	White ppt * sol in excess *
		NH_3	White ppt * sol in excess *
		$AgNO_3$	No reaction / no ppt *
		$Ba(NO_3)_2$	White ppt *
		HNO_3	Ppt remains / no change*
		NaOH and warm	No gas / no reaction *
		+ Al /	Gas / NH_3 / effervescence / fizzing / bubbles* turns litmus blue *

(iii) From your observations, identify the two cations present in **FA 5**.

cations .... and .... [1]

(iv) From your observations, identify two anions present in **FA 5**.

.... [1]

(v) From your observations, identify two anions that could be present in **FA 5**.

.... [1]

[Total: 15]

Sample data for previous question where you need to suggest a suitable test/s (2019/m/TZ 3/Paper 3/Q# 3)

3(c)	Na_2CO_3 (or other named carbonate) / Mg / Al / Zn / Fe / sodium thiosulfate
	+ CO_3^{2-}: effervescence / gas turns limewater milky / chalky / cloudy white / white ppt + appropriate metal: effervescence / gas pops with lighted splint + thio: white / off-white / pale yellow ppt
	Student is correct / FA 5 is an acid from correct observation

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

(b) **FA 6** is a mixture that contains two cations and two anions from the Qualitative Analysis Notes. Distilled water was added to **FA 6**, the mixture was stirred and then filtered. You are provided with the dried residue, **FA 7**, and the filtrate, **FA 8**, from this process.

(i) Tests on the residue, FA 7

Carry out the following tests and record your observations in the table.

test	*observations*
Place a spatula measure of **FA 7** in a boiling tube. Add dilute hydrochloric acid until no further reaction occurs, then	
transfer a 1 cm depth of the solution into a test-tube. To this add aqueous sodium hydroxide.	

[3]

(ii) Tests on the filtrate, FA 8

Carry out the following tests and record your observations in the table.

test	*observations*
To a 1 cm depth of **FA 8** in a boiling tube add a 1 cm depth of aqueous sodium hydroxide, then	
warm gently.	
To a 1 cm depth of **FA 8** in a boiling tube add a piece of aluminium foil and a 1 cm depth of aqueous sodium hydroxide. Warm gently.	

[3]

Sample Data

3(b)(i)	+ acid: fizz / effervescence / bubbling
	Gas / CO_2 / fizz turns limewater milky / cloudy white / forms white ppt
	+ NaOH: white ppt soluble in excess NaOH

3(b)(ii)	+ NaOH: (pale) blue ppt (reference to dark blue or dissolving is CON)
	Warming: goes black / brown / grey
	+ *Al* & NaOH: gas / ammonia turns litmus blue
3(b)(iii)	Cu^{2+} / copper(II) definitely present
	Zn^{2+} or Al^{3+} / aluminium or zinc could be present
	Add (aqueous) ammonia – give (white) ppt but **only** (that from) zinc dissolves in excess
3(b)(iv)	CO_3^{2-} / carbonate definitely present
	NO_3^- or NO_2^- / nitrate or nitrite could be present

(iii) Conclusions about cations

State **one** cation that is **definitely** present in **FA 6**.

....

State **two** possible identities for the other cation present in **FA 6**.

.... or ....

Suggest how you could determine which of these two possible cations is present.
Do not carry out this test.

....

....

....

[3]

(iv) Conclusions about anions

State **one** anion that is **definitely** present in **FA 6**.

....

State **two** possible identities for the other anion present in **FA 6**.

.... or ....

[2]

[Total: 17]

Sample data for previous question where you need to suggest a suitable test/s (2018/w/TZ 1/Paper 3/Q# 2)

2(a)(i)	Make a solution of FA 4 and add aqueous $AgNO_3$

	white ppt shows anion is

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Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

2 (a) **FA 3** is a more concentrated solution of the strong monoprotic acid, H**Z**, used for **Question 1**.

Select **two** sets of reagents and suitable apparatus to use in **two** separate tests, **Test 1** and **Test 2**, to investigate the identity of the anion, Z^-, present in **FA 3**. The anion is one of those listed in the Qualitative Analysis Notes.

Complete the '*test*' boxes in the table **before** starting any practical work by circling whether you would use a test-tube or a boiling tube, and stating which reagents you would use.

Carry out your tests and record your observations. You must carry out both **Test 1** and **Test 2**.

test	*observations*
Test 1 To a 1 cm depth of **FA 3** in a *test-tube/boiling tube* add .... *(reagent(s))*	
Test 2 To a 1 cm depth of **FA 3** in a *test-tube/boiling tube* add .... *(reagent(s))*	

[4]

(b) Identify the anion present in H**Z** from your observations in **(a)**.

Z^- is .... [1]

Sample Data:

2(a)	Test: selects $AgNO_3$ and NH_3 and test-tube or boiling tube used
	Observation: no reaction / no change / no ppt / (solution) remains colourless *This mark may be awarded without NH_3 being specified in test.*
	Test: selects NaOH + A*l* (and warm) and boiling tube used *Penalise lack of test-tube/boiling tube only once*
	Observation: effervescence / gas / NH_3 turns (damp) red litmus blue
	If the Devarda's test has been carried out first then allow Test: selects (aqueous acidified) $KMnO_4$ and test-tube or boiling tube used (1) Observation: stays purple / does not decolourise (1) *Allow the observation:* no reaction / no ppt / no change *if $BaCl_2$ or $Ba(NO_3)_2$ selected as a test.*

(c) **FA 4** and **FA 5** both contain one cation and one anion. The ions present in **FA 4** are different from the ions present in **FA 5**. All four ions are listed in the Qualitative Analysis Notes. You are to identify the **four** different ions.

Carry out the following tests and record your observations.

test	*observations*
To a small spatula measure of **FA 4** in a boiling tube, add a 4 cm depth of **FA 3** and shake the tube well. Leave the tube to stand for at least five minutes. Label the solution formed **FA 6**.	
To a 1 cm depth of **FA 5** in a test-tube, add aqueous sodium carbonate.	
To a 1 cm depth of **FA 5** in a test-tube, add aqueous sodium hydroxide.	
To a 1 cm depth of **FA 5** in a test-tube, add aqueous ammonia.	
To a 1 cm depth of **FA 5** in a test-tube, add a few drops of aqueous silver nitrate.	
To a 1 cm depth of **FA 5** in a test-tube, add a few drops of aqueous barium chloride or aqueous barium nitrate, then	
add a 1 cm depth of a suitable acid.	
To a 1 cm depth of **FA 6** in a test-tube, add aqueous sodium hydroxide.	
To a 1 cm depth of **FA 6** in a test-tube, add aqueous ammonia.	
To a 1 cm depth of **FA 6** in a test-tube, add dilute sulfuric acid.	
To a 1 cm depth of **FA 6** in a test-tube, add a 1 cm depth of **FA 5**.	

[8]

Sample Data:

2(c)	Gas / CO_2 / **effervescence** turns limewater milky / cloudy white / (forms) white ppt
	2* = 1 mark Do not penalise 'no observation', 'transparent', 'clear', '–' for 'no visible reaction' more than once.
	FA 4 + FA 3 effervescence / fizzing / bubbling * colourless solution formed *
	FA 5 + Na_2CO_3 white ppt * (soluble in excess is CON)
	FA 5 + NaOH white ppt * insoluble in excess *
	FA 5 + NH_3 white ppt * insoluble in excess *
	FA 5 + Ag^+ no reaction / no ppt / no change *
	FA 5 + Ba^{2+} white ppt * insoluble in acid * *(addition of H_2SO_4 shown in observation table negates second point)*
	FA 6 + NaOH no change / no visible reaction / no ppt / faint / slight white ppt *
	FA 6 + NH_3 no change / no visible reaction / no ppt / faint / slight white ppt *
	FA 6 + H_2SO_4 white ppt * (soluble in excess is CON)
	FA 6 + FA 5 white ppt * (soluble in excess is CON)

(d) Give the formula of the acid you added to the mixture of **FA 5** and aqueous barium chloride or aqueous barium nitrate in **(c)**.

The acid added was .... [1]

(e) Identify the ions present in **FA 4** and **FA 5** from your observations in **(c)**.

	cation	anion
FA 4		
FA 5		

[2]

[Total: 16]

3 Qualitative Analysis

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate;
- the solubility of such precipitates in an excess of the reagent added.

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.
Rinse and reuse test-tubes and boiling tubes where possible.

FA 6, **FA 7** and **FA 8** are solutions of salts.

Information about **FA 6**, **FA 7** and **FA 8**
• Each salt contains one cation and one anion. • One of the ions is sodium; the other five ions are listed in the Qualitative Analysis Notes. • Each salt contains a different nitrogen-containing ion. • **FA 7** or **FA 8** contains a halide ion.

(a) You will identify the **cations** present in **FA 6**, **FA 7** and **FA 8**.

To do this you will carry out **six** separate tests. You will use dilute sulfuric acid and aqueous sodium hydroxide separately with **FA 6**, **FA 7** and **FA 8**.

Use a 1 cm depth of each salt solution in a suitable tube for each test you carry out.

Record **all** of your observations in a table in the space below.

[4]

[Once you have described the test you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(b) Name the reagents you would use to identify the halide ion present in either **FA 7** or **FA 8**. Test **FA 7** and **FA 8** with these reagents and record your observations.

reagents used ....

unknown	observations	halide ion present ✓ / ✗
FA 7		
FA 8		

[2]

(c) (i) Name the reagents you would use to confirm the presence of the nitrogen-containing **anions** in the two solutions that do **not** contain a halide ion. Test both solutions with these reagents and record your observations.

reagents used ....

unknown	observations
FA	
FA	

(ii) Name the reagent you would use to positively identify one of the nitrogen-containing anions in the two solutions tested in **(i)**. Test both solutions with this reagent. Record all your observations.

reagent used ....

unknown	observations
FA	
FA	

[4]

[Once you have described the test you intend to carry out, you can find the sample data to fill in your table at the end of the next question.]

(d) Use the information given in **(a)** and your observations in all tests to deduce the chemical formulae of the three salts.

FA 6 is .... **FA 7** is .... **FA 8** is ....

[2]

[Total: 12]

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.
Rinse and reuse test-tubes and boiling tubes where possible.

(a) **FA 6** is another salt of copper. The anion present is one of those listed in the Qualitative Analysis Notes.

(i) Transfer a **small** spatula measure of **FA 6** into a hard-glass test-tube. Heat gently at first, then heat strongly, until no further change occurs.

Record **all** your observations below.

....

....

....

....

....

....

....

....

Sample Data:

3(a)(i)	• melts *or* dissolves *or* blue liquid / solution formed • condensation *or* steam / vapour produced • black residue / solid • brown gas / fumes • gas / oxygen relights a glowing spill *4 or 5 observations correct = 2 marks* *2 or 3 observations correct = 1 mark*

(ii) Suggest the chemical formula of **FA 6**.

.... [3]

(b) **(i)** Dissolve the remainder of **FA 6** in an approximately 10 cm depth of distilled water in a boiling tube.

FA 7 is a solution of a salt containing one anion from those listed in the Qualitative Analysis Notes.
Two cations are also present.

Carry out the tests described below using separate portions of solutions **FA 6** and **FA 7**.
Record your observations in the table.

test	*observations*	
	FA 6	**FA 7**
To a 1 cm depth of solution in a test-tube, add an equal volume of **FA 3**, aqueous potassium iodide, followed by a few drops of starch indicator.		
To a 1 cm depth of solution in a boiling tube, add aqueous sodium hydroxide, then		
heat **gently and carefully**.		
To a 1 cm depth of solution in a test-tube, add a few drops of aqueous silver nitrate.		
To a 1 cm depth of solution in a test-tube, add aqueous ammonia.		
To a 1 cm depth of solution in a test-tube, add a folded 3 cm length of magnesium ribbon.		

Sample Data:

3(b)(i)	• with KI, FA 7 gives a brown / red-brown / red / orange solution • with starch, blue / blue-black / dark colour
	• with FA 6, blue precipitate (formed) • on heating, (blue precipitate) turns black • With FA 7, red-brown / brown / rust ppt. (formed)
	• With FA 6, no reaction / no change / no ppt. • With FA 7, white precipitate formed
	• With FA 6, (pale) blue precipitate, then • deep/dark blue (solution) with excess • With FA 7, red-brown / brown / rust precipitate (forms)
	Mg test **Both observations correct** With FA 6, brown / black precipitate / solid formed **or** blue colour fades / disappears With FA 7, fizzing / bubbling / effervescence
	Test for hydrogen: (gas) "pops" with lighted splint

(ii) What can you deduce about solution **FA 7** from its reaction with magnesium? Explain your answer.

....

....

(iii) Give the ionic equation for the reaction of the metal cation in **FA 7** with aqueous sodium hydroxide. Include state symbols.

....

(iv) What **type** of reaction took place when aqueous potassium iodide was added to **FA 7**? Use your observations to help you explain your answer.

....

....

....

(v) The observation you made when aqueous silver nitrate was added to **FA 7** does not allow the anion in **FA 7** to be identified with certainty.

Explain why you cannot be certain about the identity of the anion.

....

....

....

(vi) A student suggested that the anion in **FA 7** could be identified with more certainty if excess ammonia solution was added after the aqueous silver nitrate.

Explain why this suggestion is **not** correct.

....

....

....

[11]

[Total: 14]

Sample data for previous question where you need to suggest a suitable test/s (2017/w/TZ 1/Paper 3/Q# 3)

3(a)	**Tabulation of observations** Clear presentation of results to show **FA 6**, **FA 7** and **FA 8** with the reagents specified.

	H_2SO_4	NaOH
FA 6	fizzing / bubbling or pale brown gas (formed) or yellow solution (formed) or goes yellow	no reaction / no change / no ppt
FA 7	no reaction / no change	on warming, gas / NH_3 turns litmus blue
FA 8	white precipitate	no reaction / no change / no ppt **or** (faint) white ppt **and** insoluble in excess NaOH

2 correct boxes for each mark

3(b)	Add silver nitrate followed by ammonia **or** silver nitrate and nitric acid (and ammonia)
	FA 7 cream ppt **and FA 8** no reaction / no change / no ppt

3(c)(i)	For **FA 6** and **FA 7** or **FA 8** not identified in **(b)** as a halide uses NaOH + A*l* **and** there is evidence of heating mixture
	Observations for **both** compounds tested gas / ammonia turns (red) litmus blue
3(c)(ii)	Uses the same unknowns as **(i)** and adds a named dilute acid or correct formula Allow if "acid" on reagent line and correct formula given in table, or adds (acidified) potassium manganate(VII)
	Observations: both must be correct for the reagent selected. **If HC*l* or HNO_3 used** • with **FA 6**, fizzing / bubbling or pale brown gas (formed) or yellow solution (formed) or goes yellow • with **FA 7**, no reaction • with **FA 8**, no reaction **If H_2SO_4 used** • with **FA 6**, fizzing / bubbling or pale brown gas (formed) or yellow solution (formed) or goes yellow • with **FA 7**, no reaction • with **FA 8**, white precipitate **If acidified $KMnO_4$ used** • with **FA 6**, decolourised / goes colourless / loses purple colour • with **FA 7**, no reaction / $KMnO_4$ not decolourised (or stays purple) • with **FA 8**, white / pink (allow "pale purple") precipitate formed

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3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 5**, **FA 6** and **FA 7** are solutions, **some** of which contain ions that are listed on pages 10 and 11.

test	*observations*		
	FA 5	**FA 6**	**FA 7**
(i) To a 0.5 cm depth of solution in a boiling tube add aqueous sodium hydroxide, then			
warm gently.			
Allow to cool, add a piece of aluminium foil and warm again.			
(ii) To a 1 cm depth of solution in a test-tube add two or three drops of acidified aqueous potassium manganate(VII). (Do **not** use **FA 3**.)			
If no reaction occurs, pour the mixture into a boiling tube and warm gently.			
(iii) To a 1 cm depth of solution in a test-tube add a 2 cm depth of '10 volume' hydrogen peroxide and leave to stand. (Do **not** use **FA 1**.)			
(iv) To a 1 cm depth of solution in a test-tube add a 1 cm depth of dilute hydrochloric acid, then			
add a 1 cm depth of aqueous barium chloride or aqueous barium nitrate.			

[11]

Sample Data:

3(a)(i)–(iv)	see below		11

test	FA 5	FA 6	FA 7
(i) aqueous sodium hydroxide, then	no reaction / no ppt. AND	green ppt. AND insol in excess / turning brown 1	no reaction / no change / no ppt. AND
warm gently	solution turns yellow / yellow-brown / brown 1	gas / NH_3 turns (damp red) litmus (paper) blue 1	no reaction / solution remains colourless 1
aluminium foil and warm	effervescence with FA 5 or FA 7	AND	gas / NH_3 turns (damp red) litmus (paper) blue 1
(ii) acidified aqueous potassium manganate (VII)	no reaction AND	purple decolourises / solution turns yellow AND	purple decolourises / turns colourless 1
warm gently	purple decolourises / turns colourless 1		
(iii) hydrogen peroxide		solution turns yellow / effervescence AND	no reaction / no change 1
		gas relights glowing splint 1	
(iv) hydrochloric acid, then		no reaction / no change / no ppt.	brown gas / colourless bubbles / gas turning brown in air / blue solution
Ba^{2+} (aq)		AND white ppt. 1	AND no reaction 1

(b) (i) Identify as many ions present in **FA 5**, **FA 6** and **FA 7** as possible from your observations. If an ion cannot be identified from the tests, write 'unknown' in the space.

	cation(s)	anion(s)
FA 5		
FA 6		
FA 7		

(ii) Describe another test you could carry out to confirm the identity of a cation you have identified in **(i)**. Record the reagent(s) and expected observation(s) in the space below.
Do not carry out this test.

(iii) Write an ionic equation for the reaction that would occur in **(ii)**. Include state symbols.

....

[6]

[Total:17]

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 5** and **FA 6** are solids each containing one cation and one anion.
Carry out the following tests and record your observations in the table below.

test	*observations*	
	FA 5	**FA 6**
(i) Place a spatula measure of solid in a hard-glass test-tube and heat gently at first, then		
heat strongly until no further change takes place.		
Leave the tube to cool completely then add a 2 cm depth of dilute sulfuric acid to the solid residue. Shake the contents of the tube then leave it to stand.		

test	observations	
	FA 5	**FA 6**
(ii) Place a spatula measure of solid in a boiling tube and add a 2 cm depth of dilute sulfuric acid.		
Keep the solutions formed in (ii) for tests (iii) and (iv).		
(iii) To a 1 cm depth of solution from **(ii)** in a test-tube, add aqueous sodium hydroxide.		
(iv) To a 1 cm depth of solution from **(ii)** in a test-tube, add aqueous ammonia.		

Sample Data:

3(a)(i)

FA 5	FA 6
(goes to) colourless or yellow liquid/ solution	(green) powder / solid (turns) black / black residue
gas relights glowing splint	or gas turns limewater milky / cloudy white / chalky / forms white ppt
gas (turns) brown / brown gas or solution turns blue	(pale) blue solution / liquid formed

3(a)(ii)–(iv)

FA 5	FA 6
(iii) solid dissolves / colourless solution allow no reaction / no change / no effervescence	effervescence / fizzing / bubbling and blue solution / liquid formed
(iv) no reaction / no change / no ppt / remains colourless	blue ppt and insoluble in excess
(v) no reaction / no change / no ppt / remains colourless	(pale) blue ppt and soluble in excess to give deep / dark blue (solution)

(v) Identify as many ions as you can from your observations. Write 'unknown' where you have not been able to identify an ion.

FA 5: cation .... anion ....

FA 6: cation .... anion ....

(vi) Write an equation, including state symbols, for the reaction between **FA 6** and dilute sulfuric acid.

....

[12]

(b) **FA 7** is a solution containing one anion from those listed on page 11. The anion is either a halide or contains nitrogen.

(i) You are to select suitable reagents to determine the identity of this anion. Record these in a suitable form below.

(ii) Use these reagents to carry out tests to identify the anion in **FA 7**.

Record your observations and conclusions in the space below.

[5]

[Total: 17]

[Once you have described the test/s you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

Qi Qualitative: Inorganic ions test Chem 12 **Q# 49/** ALvl Chemistry/2016/s/TZ 1/Paper 3/Q# 3 :o)
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3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

FA 5 is a mixture of two different salts. Each of these salts contains one cation and one anion from those listed on pages 12 and 13. You will identify the cations and anions present.

(a) (i) Carry out the following test and record your observations.

test	*observations*
Place a small spatula measure of **FA 5** in a hard-glass test-tube and heat strongly. Test any gases that are given off.	

(ii) Identify one of the cations in **FA 5**.

One of the cations in **FA 5** is ....

[2]

Sample Data:

3 (a) (i)	Red litmus turns blue (then red)
	Condensation or sublimation/white smoke/white fumes

(b) Place the remaining sample of **FA 5** in the 100 cm^3 beaker. Half fill the beaker with distilled water and stir until **FA 5** has fully dissolved. This may take some time. You will use this solution in the remaining tests.

(i) Select reagents to identify the other cation present in **FA 5**. Carry out tests using these reagents and record your results in the space below.
Identify the cation.

The other cation in **FA 5** is ....

[Once you have described the test/s you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(ii) Carry out the following tests and record your observations.
Identify one of the anions in **FA 5**.

test	*observations*
To a 1 cm depth of the solution of **FA 5** in a test-tube add aqueous barium chloride or aqueous barium nitrate, then	
add dilute hydrochloric acid.	

One of the anions in **FA 5** is ....

Sample Data:

(ii)	white precipitate and insoluble in acid	1

(iii) The remaining ion is a halide.

Select a pair of reagents which can be used to identify the halide present. Carry out a test using these reagents and record your observations below. Suggest the identity of the halide anion present in **FA 5**. Explain why this test is not conclusive in this particular case.

[Once you have described the test/s you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

The other anion in **FA 5** is ....

....

....

....

.... [8]

(c) Suggest the formulae of the two salts that could have been mixed to make **FA 5**.

.... and .... [1]

Sample data for previous question where you need to suggest a suitable test/s (2016/w/TZ 1/Paper 3/Q# 3)

3(b)(i)	Selects $AgNO_3$ and NH_3 Selects NaOH and *Al* and $HCl/HNO_3/H_2SO_4$
3(b)(ii)	Clearly defined test | observation | conclusion sections **FA 7** + $AgNO_3$ cream ppt partially soluble in NH_3 **FA 7** is bromide / Br^- from cream ppt

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 6** is a sodium compound containing one anion listed on page 11.

Dissolve the **FA 6** provided in about 15 cm^3 of distilled water in a boiling tube.
Carry out the following tests and record your observations in the table below.

test	*observations*
(i) To a 1cm depth of the solution of **FA 6** in a test-tube, add a few drops of aqueous barium chloride or aqueous barium nitrate, then	
add dilute hydrochloric acid.	
(ii) To a 1cm depth of the solution of **FA 6** in a test-tube, add an equal volume of aqueous hydrogen peroxide, then	
add a few drops of aqueous barium chloride or aqueous barium nitrate, then	
add dilute hydrochloric acid.	

test	observations
(iii) To a 1 cm depth of the solution of **FA 6** in a boiling tube, add an equal volume of **FA 2**, sulfuric acid, then	
heat the mixture **gently and cautiously**.	
(iv) To a 1 cm depth of the solution of **FA 6** in a test-tube, add an equal volume of aqueous sodium hydroxide, then	
add a few drops of **FA 1**, aqueous potassium manganate(VII), then	
add **FA 2**, sulfuric acid.	

Sample Data:

3 (a) (i)	**Both observations required** • white precipitate with Ba^{2+} ion • Precipitate dissolves / partially dissolves in (excess) HC*l*	1
(ii)	**Both observations required** • white precipitate with Ba^{2+} ion • precipitate insoluble / no change with HC*l*	1
(iii)	When heated, gas produced decolourises $KMnO_4$ paper.	1
(iv)	No change (when NaOH added) / no ppt / no reaction **and** green (solution) formed when $KMnO_4$ added	1
	Colourless solution(with acid)	1

(v) Identify the anion in **FA 6**, and state **one** piece of evidence for your identification.

anion ....

evidence ....

....

....

(vi) Give the chemical equation for the reaction between **FA 6** and hydrogen peroxide, H_2O_2, in test **(ii)**. State symbols are **not** required.

....

[7]

(b) **FA 7**, **FA 8**, **FA 9** and **FA 10** each contain one cation from the list on page 10.
You will attempt to identify the cations by testing with aqueous sodium hydroxide and aqueous ammonia.
In each case, use a 1 cm depth of the solution in a test-tube.

(i) Complete the table below.

test	observations			
	FA 7	**FA 8**	**FA 9**	**FA 10**
add sodium hydroxide				
add aqueous ammonia				

Sample Data:

(b) (i)

	FA 7	FA 8	FA 9	FA 10
NaOH	white ppt	white ppt	white ppt	off-white / buff / beige / light brown ppt
excess NaOH	no change **or** insoluble in excess	no change **or** insoluble in excess	(ppt) dissolves **or** soluble in excess	insoluble in excess **or** ppt darkens *(owtte)*
NH_3	no ppt **or** no reaction	white ppt	white ppt	off-white / buff / beige / light brown ppt
excess NH_3	*(ignore)*	no change **or** insoluble in excess	no change **or** insoluble in excess	insoluble in excess **or** ppt darkens *(owtte)*

5

(ii) Use your observations to identify, as far as possible, the cation present in each solution. If alternative identities are possible, state this clearly.

FA 7 cation ....

FA 8 cation ....

FA 9 cation ....

FA 10 cation ....

(iii) Give the ionic equation for the reaction of **one** of your cations with a few drops of sodium hydroxide. State symbols are **not** required.

....

(iv) The precipitates obtained when alkalis are added to solutions of certain cations are sometimes difficult to see. Suggest how, using no additional apparatus, the experiment could be repeated in a way that would make these precipitates more visible.

....

....

[9]

[Total: 16]

Sample data for previous question where you need to suggest a suitable test/s (2016/s/TZ 1/Paper 3/Q# 3)

(b) (i)	Selects NaOH and NH_3	1
	Off-white / beige / light brown precipitate with both NaOH **and** NH_3	1
	Both precipitates turns brown / darkens	1

(iii)	Selects $AgNO_3$ / silver nitrate **and** NH_3 / ammonia	1
	White precipitate **and** insoluble / partially soluble in ammonia	1
	Cannot see if precipitate dissolves in ammonia / Mn^{2+} causes (off-white) precipitate (so cannot be used to distinguish between halides).	1

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) In **Question 1** you used **FA 2**. This solution was prepared from hydrated ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2.6H_2O$.
To a 1 cm depth of **FA 2** in a test-tube, add a small spatula measure of sodium carbonate.
Record your observations.

Sample Data:

3 (a)	Fizzing

Solutions containing Fe^{2+} ions can quickly be oxidised in air if they are prepared by dissolving the solid in distilled water.
Use your observations to suggest what other substance was added to solid $(NH_4)_2Fe(SO_4)_2.6H_2O$ to prepare **FA 2**.

.... [2]

(b) **FA 6** is a mixture of two salts, each of which contains a single cation and a single anion from those listed in the Qualitative Analysis Notes on pages 10 and 11.
Do the following tests and record your observations in the table below.

test	*observations*
(i) Place a small spatula measure of **FA 6** in a hard-glass test-tube and heat strongly.	
(ii) Place a small spatula measure of **FA 6** in a test-tube and carefully add dilute sulfuric acid until the reaction is complete, then	
add aqueous sodium hydroxide.	
(iii) To a 3 cm depth of distilled water in a boiling tube, add the remaining sample of **FA 6**. Stir and then filter the mixture into a clean boiling tube. You will use this solution for tests **(iv)** – **(vi)**.	
(iv) To a 1 cm depth of the solution from **(iii)** in a test-tube, add aqueous sodium hydroxide.	
(v) To a 1 cm depth of the solution from **(iii)** in a test-tube, add aqueous ammonia.	
(vi) To a 1 cm depth of the solution from **(iii)** in a test-tube, add aqueous barium chloride or aqueous barium nitrate.	

Sample Data:

(b)(i)–(vi)	In (i) (solid goes from green) to black/grey	1
	In (i) condensation/water/water vapour/steam/steamy fumes	1
	In (ii) fizzing **and** forms a (light) blue solution .	1
	Cloudy with limewater in (i) or (ii) or (a)	1
	In (ii) blue ppt with sodium hydroxide and insoluble in excess.	1
	Any 2 from: In (iv) white ppt insoluble in excess	1
	In (v) white ppt insoluble in excess In (vi) white ppt	1

(vii) Suggest possible identities for the ions present in **FA 6**.

cations ....

anions ....

(viii) Describe a further test that would allow you to determine exactly which anions are present. Explain your choice. Do **not** do this test.

....

....

....

[11]

[Total: 13]

2 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 6** is a solid that contains one cation and one anion. One of the ions present is included in the lists on pages 14 and 15. This ion contains the element nitrogen.

(i) State which nitrogen-containing ions could be present. Select reagents for use in tests that would distinguish between them.

....

....

....

(ii) Carry out tests on **FA 6** using the reagents selected in **(i)** to identify the nitrogen-containing ion. Record your tests and observations in the space below.

[Once you have described the test/s you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(iii) Identify the nitrogen-containing ion in **FA 6**.

Ion present is ....

[5]

(b) Half fill the 250 cm^3 beaker with water and heat the water to about 60 °C. This is the water bath to be used in one of the following tests.

Carry out the following tests on **FA 7** and complete the table below.

test	*observations*
To a 1 cm depth of **FA 7** in a test-tube, add a few drops of dilute hydrochloric acid.	
To a 1 cm depth of **FA 7** in a test-tube, add a few drops of aqueous potassium iodide, then	
add aqueous ammonia.	
To a 1 cm depth of **FA 7** in a test-tube, add a few drops of aqueous sodium hydroxide and then add aqueous ammonia dropwise, with gentle shaking, until the precipitate **just** dissolves, then	No observation required.
add one spatula measure of glucose and leave to stand in the hot water bath. When you have completed this test, dispose of the solution and rinse the test-tube.	

[4]

Sample Data:

(b)	+ HCl (aq): white ppt	1
	+ KI: yellow ppt	1
	+ NH_3: no effect/ppt insol	1
	+ glucose: silver mirror/black/(dark) grey ppt	1

(c) Solid **FA 8** contains one cation and one anion from those included in the lists on pages 14 and 15.

Carry out the following tests on **FA 8**. For each test record your observations.

(i) In a hard-glass test-tube heat approximately half of the **FA 8**, gently at first and then more strongly. Leave to cool.

....

....

....

(ii) To a 2 cm depth of dilute nitric acid in a boiling tube, add the remaining **FA 8**.

Keep the solution obtained for tests (iii) and (iv).

....

....

....

(iii) To a 1 cm depth of the solution from **(ii)** in a test-tube, add aqueous sodium hydroxide until no further change occurs.

....

....

....

(iv) To a 1 cm depth of the solution from **(ii)** in a test-tube, add aqueous ammonia until no further change occurs.

....

....

....

Sample Data:

(c)	**(i)**	(Solid is) yellow when heated	1
		Goes white/paler on cooling	1
	(ii)	effervescence/fizzing/rapid bubbling **and** limewater turns milky	1
	(iii)	White ppt **and** soluble in excess NaOH	1
	(iv)	White ppt **and** soluble in excess NH_3	1

(v) Use your observations from **(i)** to **(iv)** to identify the ions present in **FA 8**.

Ions present .... and ....

[6]

[Total: 15]

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 6** is a solution of two different salts. It contains two different cations, one of which is listed in the Qualitative Analysis Notes on page 10. It contains two anions, both of which are listed in the Qualitative Analysis Notes on page 11.

(i) Choose reagents that will allow you to identify one of the cations. Carry out suitable tests using these reagents and record your results in the space below.

I	
II	
III	
IV	
V	

One of the cations in **FA 6** is ....

[Once you have described the test/s you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(ii) Carry out the following tests to identify the two anions present in **FA 6**.

test	*observations*
To a 1 cm depth of **FA 6** in a test-tube add a 1 cm depth of aqueous silver nitrate, then	
add aqueous ammonia.	
To a 1 cm depth of **FA 6** in a test-tube add a 1 cm depth of aqueous barium chloride (or aqueous barium nitrate), then	
add dilute nitric acid.	

Sample Data:

(ii)	MMO Collection	**VI** Cream ppt with $AgNO_3$ **and** partially sol / insol in NH_3	1
		VII White ppt with $BaCl_2$/$Ba(NO_3)_2$ **and** insol in nitric acid.	1

The anions in **FA 6** are .... and ....

[9]

VI	
VII	
VIII	
IX	

(b) **FA 7** is an acidified solution of iron(II) sulfate, $FeSO_4(aq)$.

Carry out the following tests and record your observations.

test	*observations*
(i) To a 1 cm depth of **FA 7** in a test-tube add aqueous sodium hydroxide and leave for a few minutes.	
(ii) To a 1 cm depth of **FA 7** in a boiling tube add a 1 cm depth of dilute sulfuric acid followed by a 1 cm depth of '20 vol' hydrogen peroxide. Stir the mixture, then	
(iii) pour a 1 cm depth of the mixture into a clean boiling tube and add a 3 cm depth of aqueous sodium hydroxide.	

I	
II	
III	
IV	
V	
VI	

Sample Date:

(b) (i)	MMO Collection	**I** Green ppt turning brown (in contact with air)	1
(ii)		**II** No reaction/no change or yellow or green solution	1
(iii)		**III** Red-brown/brown/green-brown ppt and effervescence	1
		IV Gas relights a glowing splint	1

(iv) What type of reaction takes place in **(ii)**?

....

....

(v) Explain your observations in **(iii)**.

....

.... [6]

[Total: 15]

Sample data for previous question where you need to suggest a suitable test/s (2014/w/TZ 1/ Paper 3/Q# 2/)

2	**(a)**	**(i)**	Chooses NaOH(aq) (+ heat) (to distinguish NH_4^+/ammonium) Chooses named (allow name from **(ii)**) dilute acid/(acidified) $KMnO_4$ (to distinguish between NO_2^-/nitrite and NO_3^-/nitrate) 2 ions chosen: NH_4^+ & NO_3^- : NaOH (and warm) NO_2^- & NO_3^- : named (dilute) acid NH_4^+ & NO_2^- : either of the above	1 1
		(ii)	Correct obs with relevant tests With NaOH **and** warming/heating: no ammonia/no change/no reaction With acid(aq): no brown fumes/no change/no reaction *'No observation' is not credited anywhere in the observations.*	1 1

Qi Qualitative: Inorganic ions test Chem 12 **Q# 54/** ALvl Chemistry/2013/w/TZ 1/ Paper 3/Q# 3/ :o)
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3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 5** is hydrated barium chloride.
FA 6 is the same iron(II) salt used in Question 1. It contains **one other** cation and **one** anion.

(i) Place a small spatula measure of **FA 6** into a test-tube. Dissolve the solid in about a 5 cm depth of distilled water. Use the solution for the following tests.

test	*observations*
To a 1 cm depth of aqueous **FA 6** in a boiling tube, add aqueous sodium hydroxide until no further change occurs, then	
heat the mixture carefully.	
Dissolve a few crystals of **FA 5** in a 1 cm depth of distilled water in a test-tube. Add a 1 cm depth of **FA 6**, then	
add excess dilute hydrochloric acid to the mixture.	

Sample Data:

3 (a) (i)	MMO Collection	Green precipitate **and** ppt insoluble in excess NaOH/ppt turning brown (in air / on standing).	1
	MMO Decision	(When heated with NaOH) **gas** / NH_3 turns red litmus to blue.	1
	MMO Collection	(With $BaCl_2$), white precipitate forms **and** insoluble in HCl.	1

(ii) Identify the ions present in **FA 6**.

cations: Fe^{2+} and .... anion: ....

(iii) Give the ionic equation for the reaction of iron(II) ions with hydroxide ions.

....

(iv) Place a **small** spatula measure of **FA 6** into a **hard-glass** test-tube.
Heat gently, then strongly, until no further change is observed.
Record your observations in the space below.

[7]

Sample Data:

(iv)	MMO collection	**Any two of** • Solid goes paler / loses green colour (at first) **and then** becomes brown (on strong heating) • Condensation / water vapour / steam produced • (Gas/NH_3) turns red litmus blue.	1 1

Sample data for previous question where you need to suggest a suitable test/s (2014/s/TZ 1/ Paper 3/Q# 3/)

3 (a) (i)	MMO Decisions	**I** Selects NaOH(aq) and NH_3(aq), and uses each in excess	1
	PDO Layout	**II** Unambiguous layout of all 4 observations (excess must be stated).	1
	MMO Collection	**III** White ppt with NaOH and soluble in excess.	1
		IV White ppt with NH_3 soluble in excess.	1

2 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

Solutions **FA 3**, **FA 4**, **FA 5** and **FA 6** each contain one cation and one anion from those listed on pages 12 and 13.

(a) Some cations interfere with tests for anions and have to be removed from the solution before the tests for anions present can be performed. One way in which this can be carried out is to precipitate the cation in the form of its insoluble carbonate.

Carry out the following tests on both **FA 3** and **FA 5**.

test	*observation*	
	FA 3	**FA 5**
To 5 cm depth of solution in a boiling tube, add all of the sodium carbonate, Na_2CO_3, from one of the tubes provided. Stir the mixture.		

Retain the mixture from **FA 3** for use in **(b)**.

[4]

Sample Data:

2 (a)	MMO Collection	Records a blue/greenish-blue ppt/solid with **FA 3** and Na_2CO_3.	1
		Records a brown/rust/orange-brown/red-brown ppt/solid with **FA 5** and Na_2CO_3.	1
		Records effervescence with **FA 5** (or **FA 3**).	1
	MMO Decisions	Tests gas evolved with limewater. Allow from effervescence.	1

(b) Filter the mixture from **FA 3** from **(a)** into another boiling tube. Ignore any colour in the filtered solution.
Add 5 cm depth of dilute nitric acid. This removes any excess of carbonate ions.

Carry out the following tests on the acidified filtrate from **FA 3**.

test	*observation*
To 2 cm depth of the acidified filtrate from **FA 3** in a test-tube, add 1 cm depth of aqueous silver nitrate, then	
add an excess of aqueous ammonia.	

[1]

(c) Carry out the following test on **FA 4**.

test	*observation*
To 1 cm depth of **FA 4** in a test-tube, add 1 cm depth of **FA 3**, then	
add a few drops of starch solution.	

[2]

Sample Data:

2	(a)	MMO Collection	Records a blue/greenish-blue ppt/solid with **FA 3** and Na_2CO_3.	1
			Records a brown/rust/orange-brown/red-brown ppt/solid with **FA 5** and Na_2CO_3.	1
			Records effervescence with **FA 5** (or **FA 3**).	1
		MMO Decisions	Tests gas evolved with limewater. Allow from effervescence.	1
	(b)	MMO Collection	Records a white precipitate with silver nitrate solution **and** soluble in aqueous ammonia.	1
	(c)	MMO Collection	Records yellow-brown/orange-brown/brown/tan colour (solid/solution) (formed on mixing **FA 4** and **FA 3**). Allow dark brown for solution **only**. Allow (qualified) brown solution with white/off-white/grey ppt.	1
			Dark/deep blue/blue-black/black/purple colour on adding starch solution	1

(g) By considering the results of **all** your tests, enter one of the following responses in each of the boxes below.

- chloride
- bromide
- iodide
- no halide ion is present
- insufficient tests (have been performed to identify any halide ion)

FA 3	
FA 4	
FA 5	

[1]

[Total 15]

Qi Qualitative: Inorganic ions test Chem 12 **Q# 56/** ALvl Chemistry/2011/w/TZ 1/ Paper 3/Q# 2/ :o)
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2 Qualitative Analysis

For Examiner's Use

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) You are provided with three sodium salts **FA 3**, **FA 4** and **FA 5**. Each salt contains **one** of the ions carbonate, CO_3^{2-}, sulfite, SO_3^{2-} or sulfate, SO_4^{2-}.

(i) Using your knowledge of the reactions of these ions, suggest **one** reagent you could add to the solid to find out which ion is present in each of the solids.

....

(ii) Use the reagent you selected in **(i)** to identify which of these ions is present in **FA 3**, **FA 4** and **FA 5**.

Carry out suitable tests on a small amount of each solid and record the results of your experiments in an appropriate form in the space below.

I	
II	
III	
IV	
V	
VI	

[Once you have described the test/s you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

Identify the anions in **FA 3**, **FA 4** and **FA 5**.

FA 3 contains the .... ion.

FA 4 contains the .... ion.

FA 5 contains the .... ion. [6]

3 **Qualitative Analysis**

For Examiner's Use

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

When gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and re-use test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) **FA 7** contains one cation and one anion from those listed in the Qualitative Analysis Notes on pages 10 and 11.

Put two spatula measures of **FA 7** into a test-tube.
Add about two-thirds of a test-tube of distilled water and dissolve the solid.
For each test that you carry out, use 1 cm depth of the solution of **FA 7**.

(i) Carry out the following tests and complete the table below.

test	*observation(s)*
Add 5 drops of aqueous barium chloride (or barium nitrate) to your solution of **FA 7**.	
Add 5 drops of aqueous silver nitrate to your solution of **FA 7**.	

I	
II	
III	

Sample Data:

3 (a) (i)	MMO Collection	No change (*or* no precipitate **or** no reaction) both with barium chloride and silver nitrate.	1
	MMO Collection	**Gentle** heat: solid melts **or** dissolves **or** gives a colourless liquid	1

(ii) Put a **very small** spatula measure of solid **FA 7** into a hard glass test-tube.
Hold the test-tube horizontally and heat it gently for a few seconds, then heat it strongly until no further change takes place.
Leave the test-tube to cool to room temperature.
While cooling takes place, move on to (iv).
In the space below record the observations made at each stage in an appropriate form.

For Examiner's Use

Sample Data:

(ii)		Brown fumes/gas produced (allow 'qualified' brown e.g. red/brown, do not allow orange).	1
		(Gas produced) that relights a glowing splint **or** yellow solid, goes white on cooling. (Allow precipitate).	1

(iii) State what deductions you can make about the identity of the anion in **FA 7** from the tests above.

....

....

(iv) Use the information in the Qualitative Analysis Notes on pages 10 and 11 to select a further test to confirm the identity of the anion in **FA 7**.

test ....

Carry out **this test** and, in the space below, record the observation(s) made in an appropriate form. State your conclusion.

IV	
V	
VI	
VII	
VIII	
IX	

[Once you have described the test/s you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(v) The cation in **FA 7** is aluminium ion, calcium ion or zinc ion.
Select **one reagent** to identify the cation in **FA 7**.

reagent ....

Use this reagent to carry out a test.
Record the observation(s) made and identify the cation.

....

....

....

.... [9]

[Once you have described the test/s you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(b) **FA 8** contains one cation from those listed on page 10 and 11.

Put all of the **FA 8** into a test-tube.
Half fill the test-tube with distilled water and dissolve the solid.

(i) To 1 cm depth of the solution of **FA 8** in a test-tube, add aqueous potassium iodide until the test-tube is half full. Allow the mixture to stand for two minutes.

Use a dropping pipette to transfer about 1 cm^3 of the mixture from the top of the test-tube to another test-tube. Add 5 drops of starch solution.
Record all of your observations.

For Examiner's Use

I	
II	
III	
IV	
V	

(ii) State what **type** of chemical behaviour has been shown by potassium iodide in this reaction. Give an ionic equation to justify your answer.

....

....

....

(iii) To another 1 cm depth of solution of **FA 8** in a test-tube, add aqueous sodium hydroxide.
Record the observation(s) made.
Give the **ionic** equation for the reaction taking place.

....

....

....

.... [5]

[Total: 14]

Sample Data:

(iii)	MMO Collection	Blue (do not allow dark blue) precipitate obtained, which does not dissolve in excess NaOH	1

Sample data for previous question where you need to suggest a suitable test/s (2011/w/TZ 1/ Paper 3/Q# 2/)

2 (a)	MMO Decisions	(i) **I** Any named mineral acid or formula or (acidified) potassium dichromate Do **not** allow any reagent suitable for testing cations or more than one reagent.	1
	PDO Recording	(ii) **II** Tabulates evidence of 3 tests carried out with no repeat headings. **Only** consider observations with acid or dichromate.	1
	MMO Collection	**III** Bubbles/effervescence in **FA 4**.	1
		IV Slower effervescence in **FA 3** than **FA 4** or **FA 3** turns green **and FA 5** stays orange if dichromate used.	1
	MMO Decisions	**V** Appropriate test with positive result used to test for either gas.	1
	ACE Conclusions	**VI** All three ions correct from suitable observations. **FA3** is a sulfite. **FA4** is a carbonate. **FA5** is a sulfate. (or correct formulae)	1

Qi Qualitative: Inorganic ions test Chem 10 **Q# 58/** ALvl Chemistry/2010/s/TZ 1/ Paper 3/Q# 2/ :o)
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2 Solutions **FA 3**, **FA 4** and **FA 5** each contain a Group 2 halide.
Solution **FA 6** contains a potassium salt.

You will carry out tests to deduce the following.

- the anion present in **FA 6**
- the solution containing the chloride ions
- the solution containing barium ions

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate and the colour of the precipitate

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed directly with a Bunsen burner a boiling-tube MUST be used.
Rinse and reuse test-tubes where possible.

(a) Use information from the Qualitative Analysis Notes on page 11 to select a pair of reagents that, **used together**, identify the halide ion present.

The reagents are ....

followed by .... [1]

[Once you have described the test/s you intend to carry out and drawn a suitable results table you can find the sample data to fill in your table at the end of the next question.]

(b) Use your chosen reagents to carry out tests on **FA 3**, **FA 4** and **FA 5**.
Record your results in an appropriate form in the space below.

[2]

(c) From the results of the tests in **(b)** state which solution contains the chloride ion, Cl^-.

Solution .... contains the chloride ion.

Explain the evidence that supports your conclusion.

....

....[1]

(d) Carry out the following tests on each of the solutions **FA 3**, **FA 4** and **FA 5**.
Record your observations below.

test	*observations* FA 3	FA 4	FA 5
To 1 cm depth of solution in a test-tube, add 2 cm depth of aqueous sodium hydroxide.			
To 1 cm depth of solution in a test-tube, add 2 cm depth of aqueous ammonia.			

[2]

Sample Data:

(d)	MMO Collection	Mark each of the boxes and see whether correct columns or rows give the better mark. Award the better mark. See table below for the expected observations	1 1 1	[3]

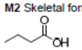
	FA 3	FA 4	FA 5
+ NaOH(aq)	**ignore**	white ppt	white ppt **or** "cloudiness"
+ NH_3(aq)	no ppt *(allow reference to "cloudiness"/"slight white ppt")*	white ppt	no ppt/no change/ no reaction

Sample data for previous question where you need to suggest a suitable test/s (2011/s/TZ 1/ Paper 3/Q# 3)

(iv)	MMO Decisions	(Heat) **FA 7** with *Al* foil and NaOH/ecf from anion given.	1
	MMO Collection	Gas/vapour/NH3 produced ***and*** it turns red litmus to blue ***and*** confirms that **FA 7** contains nitrate/nitrite ions.	1
(v)	MMO Decisions	Adds ammonia. *(This mark is **not** awarded if a second test is also used)*	1
	ACE Conclusions	Zinc ions are present. (No ecf) *(Deduction **must** be consistent with observations recorded – white ppt soluble in excess).*	1

SECTION 1: Mark Scheme for Questions with SAMPLE Data

Q# 1/ T1 Acid Base Titration ALvl Chemistry/2022/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

1(a)	**I** All the following data are recorded: • two burette readings **and** titre for the rough titration • initial and final burette readings for two (or more) accurate titrations	1
	II Appropriate headings and units in the accurate titration table and titre values recorded for accurate titrations • initial / start **and** (burette) reading / volume • final / end **and** (burette) reading / volume • titre or volume used / added / or FA 2 added • unit: / cm^3 or (cm^3) or in cm^3 (for each heading) or cm^3 unit given for each volume recorded	1
	III All accurate burette readings are recorded to the nearest 0.05 cm^3	1
	IV The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre	1
	For assessment of accuracy marks, round all burette readings to the nearest 0.05 cm^3. Check and correct subtractions where necessary. Then select the 'best' titres using the hierarchy: • two (or more) accurate identical titres (ignoring any that are labelled 'rough'), *then* • two (or more) accurate titres within 0.05 cm^3, *then* • two (or more) accurate titres within 0.10 cm^3, *etc.* These best titres should be used to calculate the mean titre, expressed to nearest 0.01 cm^3. Write the Supervisor's [corrected] mean titre in a ring on each candidate script. Calculate the difference (**δ**) between the candidate's mean titre and the Supervisor's. Write the value of **δ** on each script. Award the accuracy marks as shown below.	
	Award **V** if $\delta \leqslant 0.50$ (cm^3) Award **VI** if $\delta \leqslant 0.30$ Award **VII** if $\delta \leqslant 0.20$	3
1(b)	Candidate must average two (or more) titres that are within a total spread of not more than 0.20 cm^3 **AND** working / explanation must be shown or ticks must be put next to the two (or more) accurate titres selected **AND** mean quoted to 2 decimal places	1
1(c)(i)	Correctly calculates moles of NaOH used = 0.110 × **(b)** / 1000 **AND** answer to 3 or 4 sig fig	1
1(c)(ii)	Correctly uses **(c)(i)** to calculate M_r = $^{10.5}/_{(c)(i)}$ − 40	1
1(c)(iii)	**M1** Identity of carboxylic acid [must be consistent with the M_r in **(c)(ii)**] **M2** Skeletal formula (must correspond to candidate's name of acid) 	2
1(d)(i)	Correct equation with state symbols $NH_2CH_2COOH(aq) + NaOH(aq) \rightarrow NH_2CH_2COONa(aq) + H_2O(l)$	1
1(d)(ii)	Student's titre would be larger **AND** M_r of amino acid is 75 / is lower than M_r of **FA 1** so more moles of amino acid are present ORA	1

Q# 2/ T1 Acid Base Titration ALvl Chemistry/2021/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** The following data must be shown • burette readings **and** titre for rough titration • 2 × 2 'box' showing both accurate burette readings *'Correct' headings and units are not required for this mark*	1
	II Headings and units correct for accurate titration table and headings match readings. • initial / start **and** (burette) reading / volume + unit • final / end **and** (burette) reading / volume + unit • titre or volume / **FA 3 and** used / added + unit *Units: (cm^3) or / cm^3 or in cm^3 or cm^3 by every entry*	1
	III All accurate burette readings to 0.05 cm^3	1
	IV The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre. *Do **not** award the mark if any 'accurate' burette readings (apart from initial 0) are given to **zero** dp.*	1
	Award **V** if $\delta \leqslant 0.50\ cm^3$ Award **VI** if $\delta \leqslant 0.30\ cm^3$ Award **VII** if $\delta \leqslant 0.20\ cm^3$	3
2(b)	Candidate must average two (or more) titres that are **all** within 0.20 cm^3 and quoted to 2 dp. Working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
2(c)(i)	Answers for **(c)(ii)**, **(c)(iii)**, **(c)(iv)** to 3–4 sf	1
2(c)(ii)	Correctly calculates $n(H_2SO_4)$ = 0.050 × **(b)** / 1000	1
2(c)(iii)	Correctly uses **[FA 4] = (c)(ii)** × 2 × 40 mol dm^{-3}	1
2(c)(iv)	Correctly calculates **[FA 2] = (c)(iii)** × 10 mol dm^{-3}	1
2(c)(v)	Correctly uses M1: $M_r = \frac{26.3}{\textbf{(c)(iv)}}$ = Answer M2: Use of Answer – 17 and identify **Z** $< Li \leqslant 14.9$ $15.0 \leqslant Na \leqslant 31.1$ $31.2 \leqslant K \leqslant 62.3$ $62.3 \leqslant Rb \leqslant 109.2$ $109.2 \leqslant Cs \leqslant 250$	2
2(d)	Correctly uses | A_r from (c)(v) − A_r from periodic table | × 100 / A_r from periodic table Answer from default = 18.16 or 18.2 or 18%	1

Q# 3/ T1 Acid Base Titration ALvl Chemistry/2021/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

1(a)	**I** Headings and data are recorded in the space provided • (mass of) container with **FA 2** • (mass of empty) container • (mass of) **FA 2** (used) Subtraction for the mass of **FA 2** used must be correct *Headings must be unambiguous and include either 'mass' or g for each piece of datum. Reject 'weight'.*	1
	II The following data must be shown: • two burette readings **and** titre for the rough titration • initial and final burette readings for two (or more) accurate titrations	1
	III Titre values recorded for accurate titrations, **and** correct headings and units in the **accurate** titration table • initial/start **and** (burette) reading / volume • final/end **and** (burette) reading / volume • titre or volume / **FA 1 and** used / added *reject 'difference' or 'total' or 'amount' or 'V' but allow 'vol'* • unit: / cm^3 or (cm^3) or in cm^3 for each heading **or** cm^3 unit given for each volume recorded	1
	IV All accurate burette readings are recorded to the nearest 0.05 cm^3, including 0.00. *Reject 50(.00) as an initial burette reading* *Reject if more than one final burette reading is 50.(00)* *Reject any burette reading is greater than 50.(00)*	1
	V: The **final** accurate titre recorded is within 0.10 cm^3 of any other accurate titre *Ignore any titre labelled 'rough'* *Reject if any 'accurate' burette reading is recorded as an integer (apart from an initial 0 cm^3)*	1
	Check and correct titre and mass subtractions where necessary. *Examiner selects the best mean titre.* *Apply hierarchy: 2 identical, titres within 0.05 cm^3, titres within 0.10 cm^3, etc. Examiner calculates supervisor's corrected average titre / supervisor's mass of **FA 2** to 2 dp.* *Examiner calculates candidate's corrected average titre / candidate's mass of **FA 2** to 2 dp.* *Subtract the candidate value from that of the supervisor: δ*	

1(a)	**Award VI** if $0.40 < \delta \leqslant 0.60\ cm^3\ g^{-1}$	1
	Award VI and VII if $0.20 < \delta \leqslant 0.40\ cm^3\ g^{-1}$	1
	Award VI, VII and VIII if $\delta \leqslant 0.20\ cm^3\ g^{-1}$	1
	If there is only one accurate titration award accuracy marks based on that titration without further penalty. If **only** a rough titration is shown award accuracy marks based on this value but cancel one accuracy mark. Apply spread penalty as follows: if titres selected (by examiner) differ $\geqslant 1.00\ cm^3$ then cancel one accuracy mark. *If Supervisor's value $\leqslant 10.00\ cm^3$ then halve tolerances*	
1(b)	Candidate calculates the mean correctly: • Candidate must take the average of two (or more) accurate titres that are within a total spread of not more than $0.20\ cm^3$ • Working/explanation must be shown *or* ticks must be put next to the two (or more) accurate readings selected • The mean should be quoted to **2 dp**, and be rounded to nearest $0.01\ cm^3$	1
1(c)(i)	All answers given to **(c)(ii) – (c)(v)** must be to 3 or 4 sig fig *(Minimum 3 answers required to award the mark)*	1
1(c)(ii)	Correctly calculates: no of moles of H_2SO_4 used = $0.0550 \times {}^{\text{mean titre}}/_{1000}$ *The candidate's mean titre must be used.*	1
1(c)(iii)	Correct equation and correctly uses **(ii)** • **$2MHCO_3 + H_2SO_4 \rightarrow M_2SO_4 + 2CO_2 + 2H_2O$** *Allow multiples and ignore state symbols.* **AND** • no of moles of $MHCO_3$ = 2 × answer **(ii)**	1
1(c)(iv)	Correctly uses **(iii)** $M_r = {}^{\text{mass of FA 2 used}}/_{10 \times \text{answer (iii)}}$	1
1(c)(v)	Correct use of M_r and appropriate identity of M • A_r = answer **(iv)** – 61 **AND** • M identified as Group 1 metal with closest A_r *Li 0–14.9; Na 15.0–31.0; K 31.1–62.2; Rb 62.3–109.1; Cs 109.2–250* *Reject if the A_r calculated is > 250 or if A_r < 0*	1
1(d)(i)	Correct expression % error = ${}^{0.06}/_{25} \times 100$ (= 0.24 %) *No answer needed but reject incorrect answer.* *No mark for just 0.24 without some working.*	1
1(d)(ii)	Student is incorrect **AND** error in burette reading = 2 × 0.05 > 0.06 *(or candidate **compares** the % errors, 0.40 % and 0.24 %)* *Reject suggestion that error in 1 burette reading is 0.1*	1

Q# 4/ T1 Acid Base Titration ALvl Chemistry/2019/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** Uses a volume between 40.00 and 45.00 cm^3 **and** answer to at least 1 dp	1
	II The following data must be shown • burette readings *and* titre for rough titration • 2 × 2 'box' showing both accurate burette readings	1
	III Headings and units correct for accurate titration table and headings match readings. • Initial / start (burette) and reading / volume + unit • Final / end (burette) and reading / volume + unit • titre or volume / **FA 4** and used / added (*not 'difference' amount or 'total'*) + unit	1
	IV All accurate burette readings to $0.05\ cm^3$	1
	V The final accurate titre recorded is within $0.10\ cm^3$ of any other accurate titre.	1
	Award VI if $20 < \delta \leqslant 30\ cm^3$	1
	Award VII if $10 < \delta \leqslant 20\ cm^3$	1
	Award VIII if $\delta \leqslant 10\ cm^3$	1
2(b)	Candidate must average two (or more) titres that are **all** within $0.20\ cm^3$. Working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
2(c)(i)	Answers for **(ii)**, **(iii)** and **(iv)** given to 3–4 sf. Minimum three answers displayed.	1
2(c)(ii)	Correctly calculates 2.50×10^{-3}	1
2(c)(iii)	Correct use of ans **(c)(ii)** × 1000 / ans **(b)**	1
2(c)(iv)	Correct expression: ans **(c)(iii)** × 250 / vol used from **(a)**	1
2(d)	Correctly calculates 0.10 / vol used in (a) × 100.	1

2(e)	**Question 1** • measuring cylinder **greater** error than **burette / pipette** • molar gas volume of 24 dm^3 may not be valid / temperature of the lab may not be known • too much gas for the measuring cylinder (check that vol > 250 cm^3) • use gas syringe (if volume < 100 cm^3)	1
	Question 2 • dilution introduces extra stage / greater cumulative error • methyl orange **end-point** can be difficult to see / **colour change** gradual / difficult to see	1

Q# 5/ T1 Acid Base Titration ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** Initial and final readings and titre recorded for a minimum of two **accurate** titre details tabulated *(minimum 2 × 3 'boxes')*	1
All burette readings should be rounded to the nearest $0.05\ cm^3$. Subtractions should be checked. The 'best' titres should be selected using the hierarchy: two (or more) identical; then 2 (or more) within $0.05\ cm^3$; then two (or more) within $0.1\ cm^3$, etc the mean titre calculated and this then compared with the supervisor's value.		
	II and III Award **II** and **III** for $\delta \leqslant 0.20\ cm^3$ Award **II** for $0.20 < \delta \leqslant 0.40\ cm^3$	2
2(b)(i)	Correctly calculates moles HC*l* = $\dfrac{\text{vol of FA 2 from (a)} \times 0.100}{1000}$ **and** moles NaOH are the same	1
2(b)(ii)	Correctly calculates moles NaOH added to **W** = 0.40 × 250 ÷ 1000 = 0.10 **and** moles NaOH remaining = answer to **(b)(i)** × 10	1
2(b)(iii)	Correctly uses moles NaOH reacting with **W** = 1st answer in **(b)(ii)** – 2nd answer in **(b)(ii)** (0.10 – 2nd answer in **(b)(ii)**) **and** moles **W** = answer ÷ 2	1
2(b)(iv)	Correctly uses M_r of **W** = 4 ÷ answer to **(b)(iii)**	1
2(b)(v)	Expression to show 59 + A_r of X = M_r from **(b)(iv)**	1
	Identification of X as halogen with nearest A_r to that calculated	1
2(c)	Error: Mass was given correct to 1 sig fig / nearest g Modification: Use a more accurate balance or Error: Hydrolysis of halogeno group may be incomplete Modification: Use more concentrated NaOH / heat for longer	1
2(d)	If F chosen then 87 If C*l* chosen then 86 or 117 If Br chosen then 116 or 163 If I chosen then 162	1

Q# 6/ T1 Acid Base Titration ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

1(a)	**I** Initial and final readings and titre recorded for rough titre **and** accurate titre details tabulated *(minimum 2 × 2 'boxes')*	1
	II All **three** headings and units correct for accurate titrations Headings: initial / final (burette) **and** reading / volume / vol **or** reading / volume / vol at start / finish (but not V) **and** volume / **FA 2 and** added/used **or** titre **and** Units: (cm^3) **or** / cm^3 **or** in cm^3 [or cm^3 by every entry]	1
	III All accurate burette readings are recorded to the nearest $0.05\ cm^3$ Do **not** award this mark if: • 50(.00) is used as an initial burette reading; • more than one final burette reading is 50(.00); • any burette reading is greater than 50(.00)	1
	IV The **final** accurate titre recorded is within $0.1\ cm^3$ of any other accurate titre.	1
All burette readings should be rounded to the nearest $0.05\ cm^3$. Subtractions should be checked. The 'best' titres should be selected using the hierarchy: two (or more) identical; then 2 (or more) within $0.05\ cm^3$; then two (or more) within $0.1\ cm^3$, etc, the mean titre calculated and this then compared with the supervisor mean titre.		
	V, VI and VII Award **V, VI and VII** for a difference from supervisor within $0.20\ cm^3$ Award **V and VI** for $0.20 < \delta \leqslant 0.40\ cm^3$ Award **V** for $0.40 < \delta \leqslant 0.60\ cm^3$	3

1(b)	Candidate must average two (or more) titres for which the total spread is not greater than 0.2 cm^3. Working must be shown or ticks must be put next to the two (or more) accurate readings selected. *The mean should normally be quoted to 2 dp rounded to the nearest 0.01. Example: 26.667 must be rounded to 26.67.* *Two special cases where the mean may not be to 2 dp:* *allow mean to 3 dp only for 0.025 or 0.075 e.g. 26.325;* *allow mean to 1 dp if all accurate burette readings were given to 1 dp and the mean is exactly correct e.g. 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.* *Do not award this mark if:* *any selected titre is not within 0.20 cm^3 of any other selected titre;* *the rough titre was used to calculate the mean;* *the candidate carried out only 1 accurate titration;* *burette readings were incorrectly subtracted to obtain any of the accurate titre values.* *All burette readings, excluding initial 0, (resulting in titre values used in calculation of mean) are integers.* *Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the examiner for the purpose of assessing accuracy.*	1
1(c)(i)	All answers to **(c)** correct to 3 or 4 sig figs.	1
1(c)(ii)	Correctly calculates moles Na_2CO_3 in 25.0 cm^3 **FB 1** = $\frac{1.30}{106 \times 10}$	1
1(c)(iii)	Correctly calculates answer to **(c)(ii)** × 2	1
1(c)(iv)	Correctly uses $\frac{\text{answer to (iii)} \times 1000}{\text{Volume from (b)}}$	1

Q# 7/ T1 Acid Base Titration ALvl Chemistry/2016/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** Initial and final burette readings and volume added recorded for rough titre **and** accurate titre details tabulated. [minimum 2 × 2 'boxes' with relevant information] **II** Initial and final burette readings recorded and volume of **FA 3** added recorded for each accurate titration. Headings and units correct for accurate titrations Headings: initial / final (burette) reading / volume or reading / volume at start / finish **and** volume / **FA 3** added / used or titre **[not difference/total]** allow vol but not V **and** Units: (cm^3) or / cm^3 or in cm^3 [or cm^3 by every entry] **III** All accurate burette readings are recorded to the nearest 0.05 cm^3 Do **not** award this mark if: 50(.00) is used as an initial burette reading; more than one final burette reading is 50(.00); any burette reading is greater than 50(.0) **IV** Final uncorrected titre is within 0.10 cm^3 of any previous uncorrected accurate titre. *Do not include a reading if it is labelled rough.* *Do not award the mark if any accurate burette readings (apart from the initial zero) are given as integers.*	1 1 1 1	
2(b)	Check mean titre is correctly calculated from clearly selected values (ticks or working). • Candidate must average two (or more) titres where the **total** spread is ⩽ 0.20 cm^3. • Working must be shown or ticks must be put next to the two (or more) accurate readings selected. • The mean should normally be quoted to 2 dp rounded to the nearest 0.01. [e.g. *26.667 must be rounded to 26.67*] Two special cases where the mean may not be to 2 dp: allow mean to 3 dp only for 0.025 or 0.075, e.g. 26.325; allow mean to 1 dp if **all** accurate burette readings were given to 1 dp and the mean is exactly correct. [e.g. *26.0 and 26.2 = 26.1 is correct* *but 26.0 and 26.1 = 26.1 is incorrect.*] Do **not** award this mark if: • the rough titre was used to calculate the mean; • candidate carried out only 1 accurate titration; • burette readings were incorrectly subtracted to obtain any of the accurate titre values; • **all** burette readings (resulting in titre values used in calculation of mean) are integers. *Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the examiner for the purpose of assessing accuracy.*	1	1
2(c)(i) and (ii) 2(c)(iii) and 2(c)(iv) 2(c)(v) 2(c)(vi)	Correctly calculates $\frac{0.140 \times (\mathbf{b})}{1000}$ **and** same answer in **(ii)** **and** both answers to 3 or 4 sf Correctly uses **(ii)** × 10 **and** Answer = 5.(00) × 10^{-2} Correctly calculates (iv) – (iii) Correctly uses [(v) × 100.1]/2	1 1 1 1	
2(c)(vii)	Correctly uses [(vi) × 100]/(mass in (a)] to a minimum of 2 sf	1	5
2(d)	Question 1: % purity lower as loss of gas means fewer moles / less mass $CaCO_3$ Question 2: no change / % same as same amount of acid reacts / (amount) acid left is same	1 1 1 1	4 max 3
	Total		16

Q# 8/ T1 Acid Base Titration ALvl Chemistry/2016/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2 (a)	**I** Initial and final readings and titre value for rough titre **and** initial and final reading for **two** (or more) accurate titrations	1	
	II Titre values recorded for accurate titrations **and** Appropriate headings for the **accurate** titration table **and** cm^3 units. • initial / start burette reading / volume / value • final / end burette and reading / volume / value • titre **or** volume / **FA4 and** used / added • unit: / cm^3 **or** (cm^3) **or** in cm^3 **or** cm^3 (for each heading)	1	
	III All **accurate** burette readings are recorded to nearest 0.05 cm^3 *Do **not** award this mark if:* • *50.(00) is used as an initial burette reading* • *more than one final burette reading is 50.(00);* • *any burette reading is greater than 50.(00)* • *there is only one accurate titration*	1	
	IV There are **two** uncorrected, **accurate** titres within 0.10 cm^3 • *Do **not** award this mark if, having performed two titres within 0.1 cm^3, a further titration is performed which is more than 0.10 cm^3 from the closer of the two initial titres, **unless** a further titration, within 0.10 cm^3 of any other, has also been carried out.* • *Do **not** award the mark if any "accurate" burette readings (apart from initial 0 cm^3) are given to **zero** dp*	1	[4]
(b)	Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm^3. Working must be shown **or** ticks must be put next to the two (or more) accurate readings selected. The mean should be quoted to **2 dp**, rounded to the nearest 0.01. Two special cases where the mean may not be to 2 dp: • Allow mean expressed to 3 dp **only** for 0.025 or 0.075 (e.g. 26.325) • Allow mean if expressed to 1 dp if **all** accurate burette readings were given to 1 dp **and** the mean is **exactly** correct. *(e.g. 26.0 and 26.2 = 26.1 is allowed)* *(e.g. 26.0 and 26.1 = 26.1 is incorrect – should be 26.05.)* ***Note**: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the examiner for the purpose of assessing accuracy.*	1	[1]
(c) (i)	**I** Correctly calculates n(NaOH) = 0.001	1	
(ii)	**II** Shows use of $\frac{250(\mathbf{c})(\mathbf{i})}{(\mathbf{b})}$	1	
(iii)	**III** Correctly calculates 2 × **1(b)(i)**	1	
(iv)	**IV** Shows use of **2(c)(ii) + 2(c)(iii)** either as expression **or** correct calculation	1	
	V Shows use of / 0.025(0) **or** × 40 **or** × 1000 / 25	1	[5]
(d) (i)	States that the measuring cylinder / volume of **FA2** has the greatest error **and** should be replaced by burette or pipette	1	

(ii)	Student is correct / greater volume HC*l* used **and** greater mass would react with more HC*l* / would leave less HC*l* unreacted	1	[2]
Question 2			**[12]**

Q# 9/ T1 Acid Base Titration ALvl Chemistry/2013/s/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

2 (a)	MMO collection	**I** Initial and final volumes recorded for rough AND initial, final and volume added recorded for accurate titre.	1	
	PDO recording	**II** All accurate readings recorded to 0.05 cm^3. *Do not award if 50(.00) is used as an initial burette reading; more than one final burette reading is 50.(00); any burette reading is greater than 50.(0).*	1	
	MMO decision	**III** Two uncorrected accurate titres within 0.1 cm^3. *Do not award if, having performed 2 titres within 0.1 cm^3, a further titration is performed that is >0.1 cm^3 from the closer of the original 2 titres unless a further titration has been carried out which is within 0.1 cm^3 of any other.*	1	
	MMO quality	**IV + V** Award 2 marks if difference from Supervisor within 0.20 cm^3. Award 1 mark if difference from Supervisor within 0.50 cm^3. Examiner compares candidate mean titre with Supervisor mean titre. If best titres are ≥ 0.5 cm^3, cancel one of the Q marks.	2	[5]
(b)	ACE interpretation	Calculates the mean to appropriate decimal places. *The mean should normally be quoted to 2 dp rounded to the nearest 0.01. Example: 26.667 must be rounded to 26.67.* *Two special cases where the mean may not be to 2 dp: allow mean to 3 dp only for 0.025 or 0.075 e.g. 26.325; allow mean to 1 dp if **all** accurate burette readings were given to 1 dp and the mean is exactly correct. eg 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.* *Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the Examiner for the purpose of assessing accuracy.*	1	[1]
(c)	ACE interpretation	All answers correct. **(i)** 0.15 × **(b)** /1000 **(ii)** (i)/2 **(iii)** (ii) × 400	1	
	PDO display	Working shown in **(i)** and **(iii)**	1	
	PDO display	All answers given to 3 or 4 sig figs (minimum 2).	1	[3]
(d)	ACE interpretation	Correctly works out % difference to min 2 sig figs.	1	[1]
				[Total: 10]

Q# 10/ T1 Acid Base Titration ALvl Chemistry/2011/s/TZ 1/ Paper 3/Q# 1/ :o) www.SmashingScience.org

1 (a)	PDO Layout	**I** Volume given for rough titre **and** accurate titre details tabulated. *Minimum of 2 × 2 boxes.*	1	
	MMO Collection	**II** Initial and final burette readings recorded for rough titre **and** initial and final burette readings and volume of **FA 2** added recorded for each accurate titre. *Headings should match readings.* *Do **not** award this mark if:* *50(.00) is used as an initial burette reading; more than one final burette reading is 50.(00); any burette reading is greater than 50.(00)*	1	
	PDO Recording	**III** All accurate burette readings (initial and final) recorded to nearest 0.05 (cm^3) *Assessed on burette readings only.*	1	
		IV Has two uncorrected, accurate titres within 0.1 cm^3 *Do **not** award this mark if having performed two titres within 0.1 cm^3 a further titration is performed which is more than 0.10 cm^3 from the closer of the initial **two** titres, unless a fourth titration, within 0.1 cm^3 of any of the previous titres has also been carried out.*	1	
Round any burette readings to the nearest 0.05 cm^3. Check and correct subtractions in the titre table. Examiner then selects the "best" titre using the hierarchy: two identical; titres within 0.05 cm^3; titres within 0.1 cm^3; etc				
	MMO Quality	**V, VI** and **VII** Award **V**, **VI** and **VII** for a difference from Supervisor within 0.20 cm^3 Award **V** and **VI** for a difference of > 0.20 – ≤ 0.40 cm^3 Award **V** for a difference of > 0.40 – ≤ 0.60 cm^3 *If the "best" titres are ≥ 0.60 cm^3 apart cancel one of the Q marks.*	3	[7]
(b)	ACE Interpretation	Calculates the mean, correct to 2 decimal places from any accurate titres within 0.20 cm^3. *The third decimal place may be rounded to the nearest 0.05 cm^3.* *A mean of exactly .x25 or .x75 is allowed but the candidate may round up or down to the nearest 0.05 cm^3.* *If **ALL** burette readings are given to 1 decimal place then the mean can be given to 1 decimal place* if numerically correct without rounding. *Mean of 24.3 and 24.4 = 24.35 (✓)* *Mean of 24.3 and 24.4 = 24.4 (×)* ***Titres to be used in calculating the mean must be clearly shown – in an expression or ticked in the titration table.***	1	[1]

(c)	ACE Interpretation	**I** Expression needed in step **(i)** (= mean titre $\times$ $^{0.15}/_{1000}$ mol) **and** step **(ii)** (= answer to step **(i)** / 2) *No irrelevant or incorrect working should be included.*	1	
		II Correctly evaluates step **(iii)** (= answer to step **(ii)** × 10) **and** step **(iv)** (= answer to step **(iii)** × 40)	1	
	PDO Display	**III** Some **relevant working** shown in a minimum of **three** parts in the calculation. (In **(ii)** could be × 2 or ÷ 2, in **(iii)** could × 10 or ÷ 10).	1	
		IV **All** answers given are quoted to 3 or 4 sig figs (must be a **minimum** of three steps)	1	[4]
				[Total: 12]

Q# 11/ T2 Redox Titration ($KMnO_4$) AS Chemistry/2015/s/TZ 1/Paper 3/ :o) www.SmashingScience.com

1 (a)	**I** Initial and final burette readings and titre unambiguously recorded in rough and accurate titrations. *Minimum of 2 × 2 boxes for accurate.*	1	
	II Headings and units correct for accurate titration and headings match readings. *Headings: initial / final (burette) reading / volume or Reading / volume / vol / value at start / finish* ***and*** *Volume / vol / FA 1 added / used or titre [not "difference or "total"]* ***and*** *Units: (cm³) or / cm³ or in cm³ or cm³ by every entry*	1	
	III All accurate burette readings (initial and final) recorded to nearest 0.05 cm³ *Do* ***not*** *award this mark if: 50(.00) is used as an initial burette reading; more than one final burette reading is 50.(00); any burette reading is greater than 50.(00)*	1	
	IV Has two uncorrected, accurate titres within 0.1 cm³ *Do* ***not*** *award this mark if, having performed two titres within 0.1 cm³, a further titration is performed that is more than 0.1 cm³ from the closer of the two initial titres unless further titrations within 0.1 cm³ of any other has also been carried out. Do* ***not*** *award the mark if any 'accurate' burette readings (apart from initial 0) are given to* ***zero*** *dp.*	1	

Examiner rounds all all burette readings to the nearest 0.05 cm³ and checks subtractions. Examiner selects the 'best' titres using the hierarchy:
two (or more) identical,
then two (or more) within 0.05 cm³ ,
then two (or more) within 0.1 cm³, etc.

	Award **V**, **VI** and **VII** if $\delta \leqslant 0.20\,cm^3$ Award **V** and **VI** if $0.20 \leqslant \delta \leqslant 0.40\,cm^3$ Award **V** if $0.40 \leqslant \delta \leqslant 0.60\,cm^3$ *Spread penalty: if the two 'best' titres used by the examiner are more than 0.50 cm³ apart cancel one of the Q marks.*	1 1 1	[7]
(b)	Calculation of mean Candidate must average two (or more) titres that are **all** within 0.20 cm³. Working must be shown or ticks must be put next to the two (or more) accurate readings selected. *The mean should normally be quoted to 2 dp rounded to the nearest 0.01. Example: 26.667 must be rounded to 26.67. Two special cases where the mean may not be to 2 dp: allow mean to 3 dp only for 0.025 or 0.075, e.g. 26.325; allow mean to 1 dp if* ***all*** *accurate burette readings were given to 1 dp and the mean is exactly correct, e.g. 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.*	1	[1]
(c)(i)(ii)	**I** Correctly calculates $\frac{0.0200 \times (b)}{1000}$ in step **(i)** **and** × 5 in **(ii)**	1	
(iii)	**II** Expression **(ii)** / 0.025	1	
(iv)	**III** Expression **(iii)** × 392.0 (or addition of A_rs shown)	1	
	IV Answers to **(i)** to **(iv)** given to 3 or 4 sf (min 3 answers needed)	1	[4]
Qn 1	**Total**		**[12]**

Q# 12/ T2 Redox Titration (KMnO4) AS Chemistry/2014/s/TZ 3/Paper 3/ :o) www.SmashingScience.com

1 (a)	PDO Layout	**I** Initial and final readings and titre value given for rough titre **and** initial and final readings for two (or more) accurate titrations (*minimum of 2 × 2 box*)	1	
	MMO Collection	**II** Appropriate headings and units for all accurate data. **and** volume **FA 1** added recorded for each accurate titre. *Headings should match readings.* • initial/start (burette) reading/volume • final/end (burette) reading/volume • titre **or** volume/**FA 1** used/added (*not "difference"*) unit: /cm^3 **or** (cm^3) **or** in cm^3 **or** cm^3 for **each** entry	1	
	PDO Recording	**III All** accurate burette readings recorded to 0.05 cm^3. *The need to record to 0.05 applies only to the burette readings and **not** to the recorded titres.* *Do **not** award this mark if:* • *50(.00) is used as an initial burette reading* • *more than one final burette reading is 50.(00)* • *any burette reading is greater than 50.(00).*	1	
	MMO Decisions	**IV** Has two uncorrected, accurate titres within 0.1 cm^3. *Do not include a reading labelled 'rough'.* *Do **not** award this mark if, having performed two titres within 0.1 cm^3, a further titration is performed that is more than 0.1 cm^3 from the closer of the two initial titres unless further titrations within 0.1 cm^3 of any other have also been carried out.* *Do **not** award the mark if any 'accurate' burette readings (apart from initial 0) are given to **zero** dp.*	1	
All burette readings should be rounded to the nearest 0.05 cm^3. Subtractions should be checked. The 'best' titres should be selected using the hierarchy: two (or more) identical, then two (or more) within 0.05 cm^3, then two (or more) within 0.1 cm^3, etc. Examiner compares candidate mean titre with Supervisor mean titre.				
(a)	MMO Quality	**V, VI** and **VII** Award **V**, **VI** and **VII** for a difference from Supervisor, $\delta \le 0.20\,cm^3$ Award **V** and **VI** for $0.20 < \delta \le 0.30\,cm^3$ Award **V** only for $0.30 < \delta \le 0.50\,cm^3$ *Spread penalty: if the two 'best' titres used by the Examiner are ≥ 0.50 cm^3 apart cancel one of the Q marks.*	3	[7]
(b)	ACE Interpretation	Candidate must average two (or more) titres that are all within 0.20 cm^3. Working must be shown or ticks must be put next to the two (or more) accurate readings selected. *The mean should normally be quoted to 2 dp rounded to the nearest 0.01.* *Two special cases where the mean may not be to 2 dp: allow mean to 3 dp only for 0.025 or 0.075 e.g. 26.325; allow mean to 1 dp if **all** accurate burette readings were given to 1 dp and the mean is exactly correct. e.g. 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.* *Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the Examiner for the purpose of assessing accuracy.*	1	[1]

(c)	PDO Display	**I** Uses the expression $\frac{0.0200 \times \mathbf{(b)}}{1000}$ in **(i)** (or answer correct to 3 or 4 sf)	1	
	ACE Interpretation	**II** Correctly evaluates $\frac{0.0530 \times 25}{1000}$ in **(ii)** (to 3 or 4 sf)	1	
		III $\frac{\text{answer to } \mathbf{(ii)}}{\text{answer to } \mathbf{(i)}}$ in **(iii)** **and** correct answer to 2, 3 or 4 sf	1	
		IV Equation 2 as ratio is 5:2 or 2½ **and** reference to their answer in **(iii)** *Allow ecf*	1	
	ACE Conclusion	**V** Oxidation state = (+)4 in **(v)** from equation 2 *Allow ecf ((+)3)*	1	[5]
Qn 1	**Total**		**[13]**	

Q# 13/ T2 Redox Titration (KMnO4) AS Chemistry/2011/s/TZ 3/Paper 3/ :o) www.SmashingScience.com

1 (a)	PDO Layout	**I**	Volume given for rough titre **and** accurate titre details tabulated. *Minimum of 2 × 2 "boxes".*	1	
	PDO Recording	**II**	Appropriate headings and units for data given in weighing and accurate titration tables. *Acceptable headings: mass of tube + FA1; mass of tube + residue/mass of empty tube (mass of FA1 used); initial/final or 1[st]/2[nd] (burette) (reading)/(reading at) start/finish; volume added/used/ titre; or wtte [**not** "difference"]* *Acceptable units are solidus: /cm^3; brackets: (cm^3); in words: volume in cubic centimeters, volume in cm^3. Similarly for mass in g, etc* If units are not included in the heading every entry in the table must have the correct unit.	1	
	PDO Recording	**III**	All accurate burette readings are given to the nearest 0.05 cm^3. *Do **not** award this mark if: 50(.00) is used as an initial burette reading; more than one final burette reading is 50.(00); any burette reading is greater than 50.(00)*	1	
	MMO Decision	**IV**	Two uncorrected titres within 0.10 cm^3 *Do not allow the Rough even if ticked.* *Do **not** award this mark if having performed two titres within 0.1 cm^3 a further titration is performed which is more than 0.10 cm^3 from the closer of the initial **two** titres, unless a fourth titration, within 0.1 cm^3 of any other has also been carried out.*	1	

Examiner rounds any burette readings to the nearest 0.05 cm^3, checks subtractions and then selects the "best" titre using the hierarchy: *two identical; titres within 0.05 cm^3; titres within 0.1 cm^3; etc* to calculate mean (ignore any labelled rough). Examiner compares [corrected mean titre/corrected mass of **FA 1**] with Supervisor result. Calculate the ratios to 2 dp.				
	MMO Quality	Award **V**, **VI** and **VII** if $\delta \le 0.05$ (cm^3g^{-1}) Award **V** and **VI** if $0.05 < \delta \le 0.10$ Award **V** only if $0.10 < \delta \le 0.20$ *If the "best" **titres** are ≥ 0.60 cm^3 apart cancel one of the Q marks.*	1 1 1	[7]

(b)	MMO Decision	Selects **correctly subtracted accurate** titre values within 0.20 cm^3. Must use more than one value. If no calculation shown then titres must be indicated (*e.g.* with a tick) in the table	1	
	PDO Display	Correct mean from any values selected (may include rough) by candidate given to same decimal places as most precise burette reading recorded in the table. *The third decimal place may be rounded to the nearest 0.05 cm^3.* *A mean of exactly .x25 or .x75 is allowed but the candidate may round up or down to the nearest 0.05 cm^3.* *If **ALL** burette readings are given to 1 decimal place then the mean may be given to 1 decimal place* if numerically correct without rounding. *Mean of 24.3 and 24.4 = 24.35 (✓)* *Mean of 24.3 and 24.4 = 24.4 (×)* If no working shown allow mean if value identical to that used by Examiner.	1	[2]
(c)	ACE Interpretation	**I** In part **(i)** {titre from **(b)**/1000} × 0.01(0) *If no working shown then answer must be correct.*	1	
		II ans to **(i)** × 5 **and** ans to **(ii)** × 10 *with no additional steps*	1	
		III ans to **(iii)** × 55.8 *If **(iii)** incorrect allow correct **(ii)** × 10 × 55.8*	1	
		IV **correct** (ans to **(iii)** × 55.8/mass of **FA** 1) × 100 to sf shown (*ecf* allowed from **(iii)**) (sf shown may come from **(i)** with no previous rounding) *If **(iii)** incorrect allow correct **(ii)** × 10 × 55.8 ×* 100/mass **FA 1** *(If choice of answer take the one in the answer space.)*	1	
	PDO Display	**V** 3 or 4 significant figures in final answers to all parts attempted (minimum three parts)	1	[5]

(d)	ACE Interpretation	**(i)** Uncertainty either 1 or .5 in final place. **If balance displays to 1 decimal place:** error in balance reading is ±0.05 g ***or*** ±0.1(0) g **If balance displays to 2 decimal places:** error in balance reading is ±0.005 g ***or*** ±0.01 g **If balance displays to 3 decimal places:** error in balance reading is ±0.0005 g ***or*** ±0.001g	1	
		(ii) {2 × **(i)**/mass used} × 100 answer to 2, 3 or 4 sf	1	[2]
				[Total: 16]

Q# 14/ T2 Redox Titration (KMnO4) AS Chemistry/2010/w/TZ 4/Paper 3/ :o) www.SmashingScience.com

1 (a)	PDO layout	**I** Volume given for Rough titre **and** accurate titre details tabulated.	1	
	MMO Collection	**II** In the correct spaces, records initial and final burette readings for Rough titre **and**; Initial and final burette readings **and**, volume of **FB 2** added recorded for each accurate titre *Headings should match readings.* *Do **not** award this mark if:* *50(.00) is used as an initial burette reading;* *More than one final burette reading is 50.(00);* *Any burette reading is greater than 50.(00)*	1	
	MMO Decisions	**III** Has two uncorrected, accurate titres within 0.1 cm^3 *Do **not** award this mark if having performed two titres within 0.1 cm^3 a further titration is performed which is more than 0.10 cm^3 from the closer of the initial **two** titres, unless a fourth titration, within 0.1 cm^3 of the third titration or of either of the pair has also been carried out.*	1	
	PDO Recording	**IV** All accurate burette readings (initial and final) recorded to nearest 0.05 cm^3. *Assessed on burette readings only.*	1	
	MMO Quality	**V, VI and VII** Round any burette readings to the nearest 0.05 cm^3. Check and correct subtractions in the titre table. **Select the "best" titre using the hierarchy**: two identical; titres within 0.05 cm^3, titres within 0.10 cm^3 etc. Award V, VI and VII for a difference to Supervisor within 0.15 cm^3 Award V and VI only for a difference of 0.15+ cm^3 – 0.25 cm^3 Award V only for a difference of 0.25+ cm^3 – 0.40 cm^3 *If the selected "best" titres are > 0.40 cm^3 apart, cancel one of the Q marks awarded.*	3	[7]

(b)	ACE Interpretation	Calculates the mean, correct to 2 decimal places (third decimal place rounded to the nearest 0.05 cm^3) from any accurate titres within 0.20 cm^3. *A mean of exactly .x25 or .x75 is allowed but the candidate may round up or down to the nearest 0.05 cm^3.* *If **ALL** burette readings are given to 1 decimal place then the mean can be given to 1 decimal place* if numerically correct without rounding. *Mean of 24.3 and 24.4 = 24.35 (✓)* *Mean of 24.3 and 24.4 = 24.4 (×)* ***Titres to be used in calculating the mean must be clearly shown – in an expression or ticked in the titration table.***	1	[1]
(c)	ACE Interpretation PDO Display	**No additional factor/expression is allowed in any step** *If an answer, with no working, is given in any section allow if correct.* **I** Uses $^{2.00}/_{158.0}$ in step **(i)** **and** **answer (i)** × $^{cand\ titre}/_{1000}$ in step **(ii)** **II** Uses **answer (ii)** × 5 in step **(iii)** **and** **answer (iii)** × $^{1000}/_{25}$ in step **(iv)** **III** Uses **answer (iv)** × **151.9** in step **(v)**, **and** **answer (v)** × $^{100}/_{21.50}$ in step **(vi)** **IV** Appropriate working shown in a minimum of **four** sections. **V** 3 to 5 significant figures in final answers to all sections attempted – *minimum of **four** final answers required*	1 1 1 1 1	[5]
				[Total: 13]

Q# 15/ T2 Redox Titration (KMnO4) AS Chemistry/2007/s/TZ 2/Paper 3/ :o) www.SmashingScience.com

1 (a) (i)	PDO Layout	Tabulates initial and final burette readings and volume added in each of the tables *Tabulation may be vertical or horizontal.* *Ignore absence of units* *Do NOT award this mark if any final and initial burette readings are inverted or 50 is used as the initial burette reading*	[1]	
(ii)	PDO Recording	Both burette readings in the dilution table and final and initial burette readings for all accurate titres in the titration table recorded to the nearest 0.05 cm^3. *Treat all titres as "accurate" unless labelled rough or trial*	[1]	

(iii)	MMO Collection	Follows instructions – Rough plus sufficient accurate titrations *Award this mark if there are three or more titres OR where two titres only have been recorded they are within 0.20 cm^3 (neither labelled as rough).* *The first titre does not have to be labelled rough*	[1]	
(iv)	MMO Decisions	Has at least two uncorrected titres within 0.1 cm^3 **Accuracy (v) and (vi)** Give 2 marks if difference to Supervisor is **0.3** or less Give 1 of these two marks for a difference of **0.3+ to 0.5** Give 0 marks for a difference greater than **0.5**	[1] [2]	[6]
(b)	ACE Interpretation	Candidate selects/calculates appropriate "average" from any uncorrected titre values within 0.20 cm^3.	[1]	[1]
(c) (i)(ii)	ACE Interpretation	Examiner checks each of the first four steps of the calculation. Award two marks if all steps are chemically correct. Withhold 1 mark for each chemical error – no negative marks. Count non-completed steps as chemical errors. step 1 $\frac{titre}{1000}$ x 0.0120 step 2 x 5 step 3 $\times\frac{1000}{25}$ step 4 $\times\frac{250}{\text{volume diluted}}$	[2]	
(iii)	PDO Display	Working shown in each step attempted	[1]	
(iv)		3 or 4 significant figures in final answer given for each of the first four steps	[1]	
(v)		Answer to last section is correctly evaluated to 4 sf for (candidate's value to 4th step x 392). *(Answer may be from final answer to step 4 or using number carried on calculator).*	[1]	[5]
(d)	ACE Improvement	Candidate suggests heating solution to eliminate air OR suggests practical way of storing water without air re-dissolving • Storing in a full bottle (no air space) • Ignore and reference to vacuum (pump)	[1]	[1]
(e)	ACE Interpretation	Smallest division correctly read from burette and error estimated at ½ smallest division *Burettes are graduated at 0.1 cm^3*	[1]	[1]
(f)	ACE Interpretation	Doubles error in reading to get maximum possible error	[1]	[1]
(g)	ACE Conclusions	Explains that errors are identical (in the same direction) (and cancel).	[1]	[1]
			[Total: 16]	

Q# 16/ T2 Redox Titration (KMnO4) AS Chemistry/2002/s/TZ 5/Paper 3/ :o) www.SmashingScience.com

Page 1	Mark Scheme	Syllabus	Paper
	A Level Examinations – June 2002	9701	5

N.B. Boxed references within this marking scheme relate to the accompanying booklet of Standing Instructions

1 (a) *Experiment 1*

Titration table Standing Instructions (f)
Check the Candidate's subtraction of each titration unless labelled Rough. The subtraction of a Rough titration should be checked if the Candidate has ticked the value and used it in calculating the average titre.
Give **one mark** if all burette readings are in the correct spaces in the table, the volume has been filled in, and all final burette readings are to at least 2 d.p. **Ignore** any titre which has been labelled **Rough**.
Give **one mark** for a sufficient number of titrations (any two titres differing by 0.10 cm^3 or less). Award this mark on uncorrected titres – **Rough** values may be included in assessing sufficient number of titrations.
Give **one mark** for a value of volume used from the burette and quoted in the Summary, which is clearly justified by the Candidate's indication of the results used. **Do not give this mark if no value is quoted in the Summary, no Values are ticked in the titration table or no calculation of the average is shown.** This will usually be the value of two identical titres or any other average provided it is correct to at least 2 d.p. or to the nearest 0.05 cm^3 (first and second d.p.s may be omitted here if they are 0)

3

Accuracy

See section (g).

As soon as the candidate's average titre has been checked or corrected, the titre value transferred to page 4 should be confirmed and corrected as necessary.

Assign accuracy marks by comparing the candidate's average titre (corrected as necessary) with the Supervisor's value.
The Supervisor's Titre, corrected if necessary, should be recorded on the front of the script.
Apply spread penalty as shown below

Accuracy marks	
Mark	Difference from Supervisor / cm^3
5	up to 0.20
4	0.20+ to 0.25
3	0.25+ to 0.30
2	0.30+ to 0.50
1	0.50+ to 1.00
0	Greater than 1.00

Spread Penalty	
Range used / cm^3	Deduction
0.20+ to 0.25	1
0.25+ to 0.30	2
0.30+ to 0.35	3
0.35+ to 0.40	4
greater than 0.40	5

5

Suspect Supervisor Values

Adopt procedure (ii) in (h) for any suspect Supervisor results

If there is not an obvious value from the Candidates' results, use 24.20 as the Standard Value. Report your action to Team Leader on the Centre Accuracy Return.

Calculations

In all calculations, ignore evaluation errors if working is shown

(b) Give one mark for $\frac{\text{titre}}{1000} \times 0.02$ 1

(c) Give two marks for ans (a) × 5 × $\frac{1000}{25}$ 2
(one) (one)

Q# 17/ G1 Gravimetric Thermal Decomposition

AS Chemistry/2022/s/TZ 3/Paper 3/ :o) www.SmashingScience.com

2(a)	**I** Unambiguous headings and units for four weighings and entered in the space provided: • (mass of) crucible, lid (empty) • (mass of) crucible, lid and FA 4 (or 'contents before heating') • (mass of) crucible, lid and FA 5 / residue / contents after first heating • (mass of) crucible, lid and FA 5 / residue / contents after second heating Units: / g or (g) or gram(me)s or in grams	5
	II Readings are appropriately recorded: • all <u>weighings</u> recorded to same number of decimal places (two or more) • mass of FA 4 is within the range 0.80–1.80 g *(from weighings)* • fourth weighing is within +0.02 and –0.05 g of third weighing	
	III Correct subtractions to give: • mass of FA 4 • mass of FA 5 • mass loss	
	For assessment of accuracy marks: calculate supervisor's mass ratio (to 2 d.p.) = $\frac{\text{mass FA 4}}{\text{mass FA 5 (residue)}}$ Write this value in a ring on each script. Calculate the 25% and 10% ranges correct to 2 dp. Calculate the candidate's mass ratio (to 2 dp) = $\frac{\text{mass FA 4}}{\text{mass FA 5 (residue)}}$ Award accuracy marks as shown below.	
	Award IV if δ is within 25% of supervisor AND ratio > 1.00 Award V if δ is within 10% of supervisor AND ratio > 1.00	
2(b)(i)	Correctly calculated amount of CO_2 = $\frac{\text{mass loss}}{44}$ mol AND answer to 2–4 significant figures	1
2(b)(ii)	Correctly uses M_r of FA 4 = $\frac{\text{mass of FA 4 used}}{\text{(b)(i)}}$ AND answer to 2–4 sf	1
2(b)(iii)	A_r of metal = (b)(ii) – 60 **AND** Group 2 metal correctly deduced from A_r *Be if A_r is in range 0 – 12.1: Mg for A_r 12.2 – 32.2: Ca for A_r 32.2 - 63.8: Sr for A_r 63.9 – 112.4: Ba for A_r 112.5 – 250* (Other metals forming white carbonates with formula MCO_3 are acceptable provided the A_r is close to the value given in the periodic table.)	1
2(c)	**M1**: student's mass loss is lower AND M_r H_2O < M_r CO_2 (or values given) **M2**: using Mg as example % loss from $Mg(OH)_2$ = $\left(\frac{18}{58.3}\right) \times 100$ % loss from $MgCO_3$ = $\left(\frac{44}{84.3}\right) \times 100$ (which is greater than % for $Mg(OH)_2$)	2

2(d)	**EITHER** **M1**: solid dissolves OR colourless solution formed **M2**: decomposition is complete AND reason: no gas / no CO_2 / no fizzing produced (when acid added) OR **M1**: effervescence (owtte) OR gas / CO_2 gives white ppt with limewater **M2**: decomposition is not complete AND reason: carbonate reacts / fizzes / gives out CO_2 with acid / oxide does not fizz with acid	2

Specific information for this practical exam

During the exam, the supervisor (**not** the invigilator) must do all the experiments and record the results on a spare copy of the question paper, clearly labelled 'supervisor's results'.
If chemicals are prepared in more than one batch, clearly labelled supervisor's results must be provided for each batch. The candidates using each batch must be listed on the supervisor's report.

Apparatus

1 × 25 cm^3 pipette
1 × pipette filler
1 × 50 cm^3 burette
2 × 150 cm^3 or 250 cm^3 conical flask
1 × burette stand and clamp
2 × 100 cm^3 beaker
1 × funnel (for filling burette)
1 × white tile
1 × glass rod
1 × stop-clock to measure to an accuracy of 1 second
2 × teat/dropping pipette
1 × spatula
1 × crucible with lid (approximate capacity 15 cm^3)
1 × crucible tongs
1 × pipe-clay triangle
1 × tripod
1 × Bunsen burner
1 × heat-proof mat
1 × test-tube holder
2 × boiling tube
1 × hard-glass test-tube
8 × test-tube*
1 × test-tube rack
balance, single-pan, direct reading, minimum accuracy 0.01 g (1 per 8–12 candidates) weighing to 200 g
1 × wash bottle
1 × pen for labelling glassware
paper towels
red and blue litmus papers
aluminium foil for testing nitrate/nitrite
wooden splints
the apparatus normally used in the centre for use with limewater in testing for carbon dioxide

*Candidates are expected to rinse and re-use test-tubes where possible.
Additional tubes should be available.

Where balance provision is limited, some candidates should be instructed to start the exam with different questions. See the current syllabus for balance : candidate ratio.

Materials

The materials listed in the table must be provided to each candidate.

label	per candidate	identity	notes (hazards given in this column are for the raw materials)
FA 1	120 cm^3	0.0700 mol dm^{-3} sulfuric acid	Dilute 70.0 cm^3 of 1.0 mol dm^{-3} H_2SO_4 **[MH]** to 1 dm^3.
FA 2 [MH]	120 cm^3	0.150 mol dm^{-3} sodium hydroxide	Dissolve 6.00 g of NaOH **[C]** in each dm^3 of solution.
FA 3 [F][MH][HH]	10 cm^3	thymolphthalein indicator	See preparation instructions in current syllabus.
FA 4	1.3 g	magnesium carbonate	Provide 1.3–1.4 g of $MgCO_3$ in a stoppered container.
FA 6	20 cm^3	0.2 mol dm^{-3} copper(II) chloride	Dissolve 34.1 g of $CuCl_2 \cdot 2H_2O$ **[MH][N]** in each dm^3 of solution.
FA 7 [MH]	20 cm^3	0.1 mol dm^{-3} iron(III) chloride	Dissolve 27.0 g of $FeCl_3 \cdot 6H_2O$ **[MH][C]** in approximately 500 cm^3 of 2.0 mol dm^{-3} HCl, then make up to 1 dm^3 with distilled water.
FA 8	2.0 g	ammonium sulfate	Provide 2.0–2.1 g of $(NH_4)_2SO_4$ in a stoppered container.
zinc [F][N]	1.0 g	zinc powder	Provide 1.0–1.1 g of zinc powder **[F][N]** in a stoppered container.
potassium iodide	5 cm^3	0.5 mol dm^{-3} potassium iodide	Dissolve 83.0 g of KI in each dm^3 of water.
sodium thiosulfate	20 cm^3	0.2 mol dm^{-3} sodium thiosulfate	Dissolve 49.6 g of $Na_2S_2O_3 \cdot 5H_2O$ in each dm^3 of water.

label	per candidate	identity	notes (hazards given in this column are for the raw materials)
dilute hydrochloric acid	10 cm^3	2.0 mol dm^{-3} HCl	See preparation instructions in the current syllabus. If necessary, each of these reagents can be provided as a communal supply for groups of up to 6 candidates. Invigilators must be alert to the risk of contamination and the opportunity for malpractice when using a communal supply.
dilute nitric acid **[C]**	10 cm^3	2.0 mol dm^{-3} HNO_3	
dilute sulfuric acid **[MH]**	10 cm^3	1.0 mol dm^{-3} H_2SO_4	
aqueous ammonia **[C][MH][N]**	10 cm^3	2.0 mol dm^{-3} NH_3	
aqueous sodium hydroxide **[C]**	20 cm^3	2.0 mol dm^{-3} NaOH	
aqueous barium chloride or aqueous barium nitrate	10 cm^3	0.1 mol dm^{-3} $BaCl_2$ or 0.1 mol dm^{-3} $Ba(NO_3)_2$	
limewater **[MH]**	10 cm^3	saturated aqueous calcium hydroxide, $Ca(OH)_2$	
aqueous silver nitrate	20 cm^3	0.05 mol dm^{-3} $AgNO_3$	
acidified aqueous potassium manganate(VII) **[MH]**	10 cm^3	0.01 mol dm^{-3} $KMnO_4$ in 0.5 mol dm^{-3} H_2SO_4	

- An excess of at least 10% of each material must be prepared to cover accidental loss.
- All solutions must be thoroughly mixed.
- If you are unable to source any of these chemicals, you must contact Cambridge International as far as possible in advance of the exam for advice.
- **Materials must be labelled only as specified in the 'label' column. The identities of chemicals labelled with letter codes, e.g. FA 1, may be different from their descriptions in the question paper. Candidates must use the descriptions given in the question paper.**

Q# 18/ G1 Gravimetric Thermal Decomposition AS Chemistry/2019/s/TZ 2/Paper 3/ :o) www.SmashingScience.com

2(a)	**I: Table / list of data**, to include values and correct headings and units: • Mass of crucible (and lid) • Mass of crucible, (lid) + FB 4 (or 'contents before heating') • Mass of crucible, (lid) + residue / CuO / contents after heating • Mass of FB 4 (used) • Mass of residue / CuO (obtained)	1
	Accuracy (Q) marks in 2(a) • To assess accuracy, check the masses of **FB 4** used and of CuO obtained by the supervisor and by the candidate. • Work out the ratio $^{\text{mass of FB4}}/_{\text{mass of CuO}}$ for the supervisor (to 2 d.p.) • Work out ratio (mass **FB 4**: mass CuO) for the candidate (2 d.p.) • Calculate δ, the difference between these two ratios.	
	Award II and III if δ ⩽ 0.05	1
	Award III if 0.05 < δ ⩽ 0.10	1
	IV: Observations made during heating (Solid changes from) green / turquoise / cyan / blue-green to black *(both colours required)* or black solid / residue (formed)	1

2(b)(i)	**Correctly calculated no. of moles of CuO** • No. of moles CuO = $^{\text{mass of residue}}/_{79.5}$ • Answer must be correct and expressed to 2, 3 or 4 sig. fig.		1

2(b)(ii)	**Correct use of mole ratio 1 : 2** • No. of moles of **FB 4** = $^{\text{answer (i)}}/_{2}$	1
	Correctly uses n to calculate M_r of copper hydroxycarbonate, • M_r = $^{\text{mass of FB 4 used}}/_{\text{no. of moles of FB 4}}$ • Answer (for M_r) must be expressed to 2, 3 or 4 sig. fig. • Some working must be shown to access the second mark	1
2(b)(iii)	M_r = 221	1
	Appropriate comment on the value of y • If answer **2(b)(ii)** is less than 221, candidate should state that y is negative, so the experiment has been inaccurate • If answer **2(b)(ii)** is between 213 and 229, then (within experimental error) there is no water of crystallisation • If answer **2(b)(ii)** is greater than 221, candidate should calculate the value of y **and** state that it should be an integer	1
2(c)	Heat to constant mass (or description of procedure)	1

Apparatus

The apparatus listed must be provided to each candidate.

1 × 25 cm^3 pipette
1 × pipette filler
1 × 50 cm^3 burette
1 × 250 cm^3 volumetric flask
1 × 250 cm^3 beaker
2 × 150 cm^3 or 250 cm^3 conical flask
1 × burette stand and clamp
1 × funnel (for filling burette)
1 × white tile
1 × spatula
2 × teat/dropping pipette
1 × glass rod
1 × crucible, capacity approximately 15 cm^3, with lid
1 × heatproof mat
1 × crucible tongs
1 × tripod
1 × Bunsen burner
1 × pipe-clay triangle
1 × hard-glass test-tube
8 × test-tube*
1 × test-tube rack
1 × test-tube holder
1 × stop-clock or sight of a clock
1 × wash bottle containing distilled water
1 × pen for labelling glassware
access to balance weighing to a **minimum** accuracy of 0.1 g
paper towels
red and blue litmus papers
aluminium foil for testing nitrate/nitrite
wooden splints
the apparatus normally used in the centre for use with limewater in testing for carbon dioxide

*Candidates are expected to rinse and reuse test-tubes where possible.
Additional tubes should be available.

Where balance provision is limited, some candidates should be instructed to start the exam with different questions. See the current syllabus for balance : candidate ratio.

Materials

The materials listed in the table must be provided to each candidate.

Warning: Small amounts of NH_3 **[C][T][N]**, which can cause respiratory distress in some people, may be produced. The laboratory must be well ventilated.

label	per candidate	identity	notes
FB 1 [MH]	3.0–3.1 g	amidosulfonic acid	Provide 3.0–3.1 g of NH_2SO_3H **[MH]** in a stoppered container. Suppliers may name this as sulfamic acid or aminosulfonic acid.
FB 2	120 cm^3	0.110 mol dm^{-3} sodium hydroxide	Dissolve 4.40 g of NaOH **[C]** in each dm^3 of solution.
FB 4 [MH][N]	2.5–2.7 g	basic copper(II) carbonate	2.5–2.7 g of $CuCO_3.Cu(OH)_2.H_2O$ **[MH][N]** in a stoppered container. Any basic copper(II) carbonate is suitable.
FB 5 [MH]	1.3–1.5 g	ammonium carbonate	1.3–1.5 g of $(NH_4)_2CO_3$ **[MH]** in a stoppered container.
FB 6 [MH]	20 cm^3	0.05 mol dm^{-3} barium hydroxide	Dissolve 15.7 g of $Ba(OH)_2.8H_2O$ **[C][MH]** in each dm^3 of solution. The solution obtained will be cloudy. **It should be filtered shortly before distribution to candidates in a stoppered bottle**. Any slight cloudiness in the solution will **not** affect candidates' experiments.
manganese(II) chloride	2 cm^3	0.1 mol dm^{-3} manganese(II) chloride	Dissolve 19.8 g of $MnCl_2.4H_2O$ **[MH]** in each dm^3 of solution.
copper(II) sulfate [MH]	2 cm^3	0.1 mol dm^{-3} copper(II) sulfate	Dissolve 25.0 g of $CuSO_4.5H_2O$ **[C][MH][N]** in each dm^3 of solution.
distilled water	300 cm^3	distilled water	
thymolphthalein [F][HH][MH]	5 cm^3	thymolphthalein	See preparation instructions in the current syllabus.
Universal Indicator [F]	2 cm^3	Universal Indicator solution	Provide each candidate with 2 cm^3 of Universal Indicator solution and the pH colour chart.

label	per candidate	identity	notes
dilute hydrochloric acid	10 cm^3	2.0 mol dm^{-3} HCl	See preparation instructions in the current syllabus. If necessary, each of these reagents can be provided as a communal supply for groups of up to 6 candidates. Invigilators must be alert to the risk of contamination and the opportunity for malpractice when using a communal supply.
dilute nitric acid **[C]**	10 cm^3	2.0 mol dm^{-3} HNO_3	
dilute sulfuric acid **[MH]**	10 cm^3	1.0 mol dm^{-3} H_2SO_4	
aqueous ammonia **[C][MH][N]**	10 cm^3	2.0 mol dm^{-3} NH_3	
aqueous sodium hydroxide **[C]**	10 cm^3	2.0 mol dm^{-3} NaOH	
aqueous barium chloride or aqueous barium nitrate	10 cm^3	0.1 mol dm^{-3} $BaCl_2$ or 0.1 mol dm^{-3} $Ba(NO_3)_2$	
limewater **[MH]**	10 cm^3	saturated aqueous calcium hydroxide, $Ca(OH)_2$	
aqueous silver nitrate	10 cm^3	0.05 mol dm^{-3} $AgNO_3$	
aqueous acidified potassium manganate(VII) **[MH]**	10 cm^3	0.01 mol dm^{-3} $KMnO_4$ in 0.5 mol dm^{-3} H_2SO_4	

- An excess of at least 10% of each material must be prepared to cover accidental loss.
- All solutions must be thoroughly mixed.
- If you are unable to source any of these chemicals, you must contact Cambridge International as far as possible in advance of the exam for advice.
- **Materials must be labelled only as specified in the 'label' column. The identities of chemicals labelled with letter codes, e.g. FB 1, may be different from their descriptions in the question paper. Candidates must use the descriptions given in the question paper.**

2(a)	I Correct headings and units shown. Mass of crucible (+ lid) (Use of lid must be consistent) Mass of crucible (+ lid) + FA 3 Mass of crucible (+ lid) + residue / contents after heating Mass of FA 3 (used) Mass of residue	1
	II All balance readings to same dp and recorded mass QCO_3 between 1.30 g and 1.50 g AND Mass QCO_3 and residue correctly calculated	1
	Award III and IV if $\delta \leqslant 0.10$	1
	Award IV if $\delta \leqslant 0.20$ Do not allow any Q marks if mass of residue $\geqslant$ mass of FA 3.	1
2(b)(i)	Correctly calculates moles = candidate's mass lost / 44 and answer to 2 – 4 sf	1
2(b)(ii)	Correct use of $M_r = \frac{\textit{candidate's mass of } QCO_3}{\textbf{(b)(i)}}$	1
	Use of 60	1
	Use of 3 – 4 sf for *Mr* and correct A_r If no subtraction at step 2 then step 3 cannot be awarded. Identification of Q as Group 2 metal with nearest A_r Do not allow ecf if no evidence to support conclusion.	1
	Be $\leqslant$ 16.65; 16.65 $\leqslant$ Mg $\leqslant$ 32.10; 32.10 $\leqslant$ Ca $\leqslant$ 63.85; 63.85 $\leqslant$ Sr $\leqslant$ 112.45; 112.45 $\leqslant$ Ba	1
2(c)	So that water vapour / carbon dioxide (from air) not absorbed.	1
2(d)(i)	Heat to constant mass.	1
2(d)(ii)	Add an acid **and** it will fizz / bubble / effervesce or Add named acid **and** pass gas through limewater which turns milky / cloudy white / chalky / forms white ppt	1
2(e)(i)	(Mass lost too low $\rightarrow$) **moles CO_2 too low** ($\rightarrow$ moles QCO_3 (or residue) too low $\rightarrow$ M_r too high $\rightarrow$) **A_r too high**	1
2(e)(ii)	Method is valid since 1 mol QCO_3 gives 1 mol QO. OR moles QO : CO_2 = 1 : 1	1

Apparatus

The apparatus listed must be provided to each candidate.

- 1 × 250 cm^3 measuring cylinder
- 2 × stand, clamp and boss
- 1 × 250 cm^3 side-arm conical flask, labelled **X**, with bung and approximately 50 cm of plastic/rubber delivery tube to fit **or**
- 1 × 150 cm^3 or 250 cm^3 conical flask, labelled **X**, with 1-hole bung connected to approximately 50 cm of plastic/rubber delivery tube to fit
- 1 × tub suitable for acting as trough, minimum capacity 1 dm^3
- 1 × crucible, capacity approximately 15 cm^3, with lid
- 1 × spatula
- 1 × pipe-clay triangle
- 1 × tripod
- 1 × stop-clock or sight of clock with seconds display
- 1 × crucible tongs
- 8 × test-tube*
- 1 × test-tube rack
- 2 × teat/dropping pipette
- 1 × Bunsen burner
- 1 × heatproof mat
- 1 × wash bottle of distilled water
- 1 × pen (for labelling glassware)
- access to balance weighing to a **minimum** accuracy of 0.1 g
- paper towels
- red and blue litmus papers
- aluminium foil for testing nitrate/nitrite
- wooden splints
- the apparatus normally used in the centre for use with limewater in testing for carbon dioxide

*Candidates are expected to rinse and reuse test-tubes where possible.
Additional tubes should be available.

Where balance provision is limited, some candidates should be instructed to start the exam with different questions. See the current syllabus for balance : candidate ratio.

Materials

The materials listed in the table must be provided to each candidate.

Warning: small amounts of SO_2 **[C][T]**, which can cause respiratory distress in some people, may be produced. **The laboratory must be well ventilated.**

label	per candidate	identity	notes
FA 1 [MH]	50 cm^3	4.00 mol dm^{-3} hydrochloric acid	Dilute 340 cm^3 of concentrated (35–37%; approximately 11 mol dm^{-3}) HC*l* **[C][MH]** to 1 dm^3.
FA 2	0.6 ± 0.1 g	small marble chips (approx. 2–4 mm)	Provide 0.6 ± 0.1 g of $CaCO_3$ (as small marble chips) in a stoppered container.
FA 3	1.5 ± 0.1 g	magnesium carbonate	Provide 1.5 ± 0.1 g of any powdered form of $MgCO_3$ or $MgCO_3.Mg(OH)_2$ in a stoppered container.
FA 4	15 cm^3	0.2 mol dm^{-3} potassium iodide	Dissolve 33.2 g of KI in each dm^3 of solution.
FA 5	15 cm^3	0.2 mol dm^{-3} sodium thiosulfate	Dissolve 49.6 g of $Na_2S_2O_3.5H_2O$ in each dm^3 of solution.
FA 6	10 cm^3	0.2 mol dm^{-3} calcium chloride	Dissolve 22.2 g of $CaCl_2$ **[MH]** in each dm^3 of solution.
FA 7	10 cm^3	0.5 mol dm^{-3} magnesium sulfate	Dissolve 123.2 g of $MgSO_4.7H_2O$ in each dm^3 of solution.
aqueous chlorine [MH][N]	5 cm^3	0.2 mol dm^{-3} sodium chlorate(I) (may be labelled sodium hypochlorite)	Dilute 200 cm^3 of 1.0 mol dm^{-3} NaC*l*O **[C][N]** to 1 dm^3. This is approximately 3% w/w available chlorine from chlorine-bleaching solutions (may be labelled sodium hypochlorite). Provide in a stoppered container.
aqueous copper(II) sulfate [C][N]	5 cm^3	0.2 mol dm^{-3} copper(II) sulfate	Dissolve 49.9 g of $CuSO_4.5H_2O$ **[C][MH][N]** in each dm^3 of solution.

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label	per candidate	identity	notes
dilute hydrochloric acid	10 cm³	2.0 mol dm⁻³ HCl	
dilute nitric acid **[C]**	10 cm³	2.0 mol dm⁻³ HNO_3	
dilute sulfuric acid **[MH]**	10 cm³	1.0 mol dm⁻³ H_2SO_4	
aqueous ammonia **[C][MH][N]**	10 cm³	2.0 mol dm⁻³ NH_3	See preparation instructions in the current syllabus.
aqueous sodium hydroxide **[C]**	10 cm³	2.0 mol dm⁻³ NaOH	If necessary, each of these reagents can be provided as a communal supply for groups of up to 6 candidates.
aqueous barium chloride or aqueous barium nitrate	10 cm³	0.1 mol dm⁻³ $BaCl_2$ or 0.1 mol dm⁻³ $Ba(NO_3)_2$	Invigilators must be alert to the risk of contamination and the opportunity for malpractice when using a communal supply.
limewater **[MH]**	10 cm³	saturated aqueous calcium hydroxide, $Ca(OH)_2$	
aqueous silver nitrate	10 cm³	0.05 mol dm⁻³ $AgNO_3$	
aqueous acidified potassium manganate(VII) **[MH]**	10 cm³	0.01 mol dm⁻³ $KMnO_4$ in 0.5 mol dm⁻³ H_2SO_4	

- An excess of at least 10% of each material must be prepared to cover accidental loss.
- All solutions must be thoroughly mixed.
- If you are unable to source any of these chemicals, you must contact Cambridge International as far as possible in advance of the exam for advice.
- **Materials must be labelled only as specified in the 'label' column. The identities of chemicals labelled with letter codes, e.g. FA 1, may be different from their descriptions in the question paper. Candidates must use the descriptions given in the question paper.**

Q# 20/ G1 Gravimetric Thermal Decomposition AS Chemistry/2017/s/TZ 1/Paper 3/ :o) www.SmashingScience.com

2(a)	**I: Table of data**, to include: • Unit "covering" all weighings, or given for each weighing • No repeat headings *(i.e. not two lists of weighings)* • Appropriate headings for the three weighings: Mass of crucible and lid Mass of crucible, lid and **FA 5** (or "contents before heating") Mass of crucible, lid and residue / CuO / contents after heating	1
	II: Weighings recorded • Six weighings recorded in the space provided. • All weighings recorded to same number of decimal places (one or more) • Label/heading to indicate which is Expt 1 and Expt 2	1
	III: Both masses of FA 5 and residue, correctly subtracted • Masses of **FA 5** used recorded on page 4, correctly subtracted • Masses of **FA 5** used were between 2.5 – 3.0 g and 1.5 – 2.0 g • Masses of residue recorded on page 4, correctly subtracted	1
	For assessment of accuracy, examiner must check and correct (if necessary) the masses of **FA 5** used and of CuO obtained by the supervisor and by the candidate for Experiment 1. • Examiner works out the ratio $^{\text{mass of FA5}}/_{\text{mass of CuO}}$ for the supervisor (2 dp) • Examiner works out the ratio (mass **FA 5**: mass CuO) for the candidate (2 dp) • Examiner calculates δ the difference between these two ratios. **Award IV and V if δ ⩽ 0.08** **Award IV if 0.08 < δ ⩽ 0.15**	2
	VI: Observations made during heating Solid goes black / black residue (formed) or reference to blue/green flame	1
2(b)(i)	• No of moles CuO = $^{\text{mass of residue}}/_{79.5}$ • Answer must be correct and expressed to 3 or 4 sig fig	1

2(b)(ii)	• No of moles of **FA 5** = $^{\text{answer (i)}}/_2$ • M_r = $^{\text{mass of FA 6 used}}/_{\text{no of moles of FA 6}}$	1
2(b)(iii)	M_r = $^{\text{mass of FA5 used in Expt 2} \times 79.5 \times 2}/_{\text{mass of residue (CuO)}}$	1
2(b)(iv)	M_r of **FA 5** calculated from A_r values = 239	1
2(b)(v)	Candidate should • correctly calculate the 2.5% of M_r in (iv) = 5.98 / 6.0, **and** • make a correct statement about the accuracy of the accepted formula, based on their result(s). or correctly calculate % difference for their result(s) from M_r in (iv) and correct comment	1
2(c)(i)	• heat (crucible and residue) to constant mass • heat more gently for longer period • cool in a desiccator	1
	• to ensure that decomposition (of **FA 5**) is complete or to ensure that all the residue is CuO • to prevent escape of dust / smoke / solid (during heating)	1
2(c)(ii)	Larger masses have lower percentage error in weighing	1
	Total:	**14**

Apparatus

1 In addition to the fittings ordinarily contained in a chemical laboratory, the apparatus and materials specified below will be necessary.

2 Pipette fillers (or equivalent safety devices), suitable eye protection and disposable gloves should be used where necessary.

3 *For each candidate*

1 × 25 cm³ pipette
1 × 50 cm³ burette
2 × 150 cm³ or 250 cm³ conical flask
1 × 25 cm³ measuring cylinder
1 × burette stand and clamp
1 × funnel (for filling burette)
1 × white tile
1 × spatula
2 × teat/dropping pipette
1 × glass rod
2 × crucible with lid, capacity approximately 15 cm³
1 × crucible tongs
1 × heatproof mat
1 × tripod
1 × Bunsen burner
1 × pipe-clay triangle
1 × hard-glass test-tube
3 × boiling tube
8 × test-tube*
1 × test-tube rack
1 × test-tube holder
1 × wash bottle containing distilled water
1 × marker pen (suitable for labelling glassware)
1 × stop clock or sight of a clock
paper towels
access to a balance weighing to a **minimum** accuracy of 0.1 g

*Candidates are expected to rinse and reuse test-tubes and boiling tubes where possible. Additional tubes should be available.

Where balance provision is limited, some candidates should be instructed to start the examination with different questions. See the current syllabus for balance : candidate ratio.

Chemicals required

1 It is ***especially important*** that great care is taken that the confidential information given below does **not** reach the candidates either directly or indirectly.

2 It should be noted that descriptions of substances given in the Question Paper may not correspond with the specifications in these Confidential Instructions.

3 Particular requirements

hazard	label	per candidate	identity	notes (hazards given in this column are for the raw materials)
	FA 1	130 cm^3	0.104 mol dm^{-3} copper(II) sulfate	Dissolve 26.0 g of hydrated copper(II) sulfate, $CuSO_4.5H_2O$, **[MH] [N]** in each dm^3 of solution.
[MH]	**FA 2**	50 cm^3	1.00 mol dm^{-3} sulfuric acid	See preparation instructions in the current syllabus.
	FA 3	100 cm^3	0.500 mol dm^{-3} potassium iodide	Dissolve 83.0 g of potassium iodide, KI, in each dm^3 of solution.
	FA 4	150 cm^3	0.110 mol dm^{-3} sodium thiosulfate	Dissolve 27.3 g of hydrated sodium thiosulfate, $Na_2S_2O_3.5H_2O$, in each dm^3 of solution.
[MH] [N]	**FA 5**	5.5 g	basic copper(II) carbonate (malachite)	5.5–5.6 g of malachite, $CuCO_3.Cu(OH)_2.H_2O$ **[MH] [N]** in a stoppered container. Any kind of basic copper carbonate is suitable.
[MH] [C][N]	**FA 6**	1.5–1.6 g	copper(II) nitrate	1.5–1.6 g of $Cu(NO_3)_2.3H_2O$ **[MH] [C] [N]** in a stoppered container.
[MH]	**FA 7**	10 cm^3	0.1 mol dm^{-3} iron(III) chloride in 0.2 mol dm^{-3} hydrochloric acid	Dissolve 27.0 g of $FeCl_3.6H_2O$ **[MH] [C]** in 100 cm^3 of 2.0 mol dm^{-3} hydrochloric acid. Make this solution up to 1.00 dm^3 with distilled water. See preparation instructions for 2.0 mol dm^{-3} hydrochloric acid in the current syllabus.
	starch indicator	10 cm^3	2% aqueous starch	See preparation instructions in the current syllabus.
[F]	**magnesium ribbon**	2 × 3 cm length	magnesium ribbon	Each candidate will require two strips of Mg **[F]**, each 2.5–3.0 cm in length

NOTE: Small amounts of SO_2 **[C] [T]** and NO_2 **[C] [O] [T]**, which can cause respiratory distress in some people, may be produced. **The laboratory must be well ventilated.**

4 The reagents below should also be provided. Unless otherwise stated, each candidate should require no more than 10 cm^3 of any of these reagents. If necessary, they may be made available from a communal supply: however, the attention of the Invigilators should be drawn to the fact that such an arrangement may lead to contamination of reagents and enhance the opportunity for malpractice between candidates.

hazard	label	notes
	dilute hydrochloric acid	**See identity details and preparation instructions in the current syllabus.**
[C]	**dilute nitric acid**	
[MH]	**dilute sulfuric acid**	
[C] [MH] [N]	**aqueous ammonia**	
[C]	**aqueous sodium hydroxide**	
	0.1 mol dm^{-3} barium chloride or 0.1 mol dm^{-3} barium nitrate	
[N]	**0.05 mol dm^{-3} silver nitrate**	
[MH]	**limewater**	
[MH]	**aqueous acidified potassium manganate(VII)**	

5 The following materials and apparatus should be available.

red and blue litmus papers, aluminium foil for testing nitrate/nitrite, wooden splints and the apparatus normally used in the Centre for use with limewater in testing for carbon dioxide

4

Q# 21/ G1 Gravimetric Thermal Decomposition AS Chemistry/2016/s/TZ 4/Paper 3/ :o) www.SmashingScience.com

2 (a)	**I** Appropriate headings **and** units for the three balance readings • (Mass of) crucible (and lid) • (Mass of) crucible, (lid) and **FB 4** (or "contents before heating") • (Mass of) crucible, (lid) and residue / MgO / contents after heating / **FB 4** after heating • Unit covering **all** balance readings and subtracted values if shown: / g, (g), in g **or** g (for each heading)	1	

	II Masses recorded • Mass of **FB 4** used was claimed to be between 1.1–1.3 g • **All** balance readings recorded to same number of decimal places *(at least one dp)*	1	
	III Mass of **FB 4** and of residue • Mass of **FB 4** used, correctly subtracted • Mass of residue, correctly subtracted	1	
	IV and **V** • Use corrected values • Examiner used corrected values and works out the ratio $^{\text{mass of FB 4}}/_{\text{mass of MgO}}$ to 1 dp for the candidate Accuracy marks are awarded as shown. Award **IV** if ratio between 1.4–2.5 Award **V** if ratio between 1.7–2.3	2	[5]
(b) (i)	Correctly calculates n(MgO) • $^{\text{mass of residue}}/_{40.3}$ • *Answer must be expressed to 2, 3 or 4 significant figures*	1	
(ii)	Correct use of (i) and mass of **FB 4** • n(**FB 4**) = $^{\text{answer (i)}}/_2$ • M_r = $^{\text{mass of FB 4 used}}/_{\text{no of moles of FB 4}}$ • *An answer for M_r must be quoted to 2 or more significant figures*	1	
(iii)	M_r calculated from A_r values in Periodic Table = 178.6	1	
(iv)	Correct expression shown $^{2.5}/_{100} \times M_r$ in **(iii)** (= 4.5, 4.47, 4.465) **or** expresses % difference of the two M_r values = $^{\lvert(iii) - (ii)\rvert}/_{(iii)} \times 100$ **or (iii)** × $^{97.5}/_{100}$ / **(iii)** × $^{102.5}/_{100}$ to give range (= 174(.1) – 183(.1))	1	
	Makes a correct statement (support / does not support / yes / no) about the accuracy of the possible formula, explained by whether the experimental M_r value is close to the answer in **(iii)**. *Numbers must be quoted or reference made to (ii) and (iii)*	1	[5]

(c) (i)	Improvement Heat (crucible and residue) to constant mass *Accept a description of the procedure for the mark* **or** heat more strongly / to a higher temperature **or** heat for longer so more is decomposed If a **1 dp** balance is used allow use a balance weighing to more dp **and** to reduce % error (in weighing) / give more precise mass	1	
(ii)	Conclusion To find out whether the two experiments are reliable / consistent / concordant **or** If the experiments do not agree then carry out a 3rd / another expt **or** If one experiment was inaccurate because it gave a poor M_r value it can be ignored	1	
(iii)	Error is 0.005 g or 0.01 g *(if 2 dp balance was used)* *(If a 3 dp balance was used, error is 0.0005 or 0.001 g)* *(If a 1 dp balance was used, error is 0.05 or 0.1 g)*	1	
	% = 100 × 2 × error / mass of **FB 4** *Accept correct expression* ***or*** *correct answer to 2, 3 or 4 significant figures*	1	[4]
Question 2			**[14]**

Apparatus

1 In addition to the fittings ordinarily contained in a chemical laboratory, the apparatus and materials specified below will be necessary.

2 Pipette fillers (or equivalent safety devices), safety goggles and disposable gloves should be used where necessary.

3 *For each candidate*

1 × 10 cm^3 pipette
1 × 25 cm^3 pipette
1 × 50 cm^3 burette
2 × 150 cm^3 or 250 cm^3 conical flask
1 × 250 cm^3 volumetric (graduated) flask
1 × burette stand and clamp
1 × funnel (for filling burette)
1 × white tile
1 × spatula
2 × teat / dropping pipette
1 × crucible with lid, capacity approximately 15 cm^3
1 × crucible tongs
1 × heat-proof mat
1 × tripod
1 × Bunsen burner
1 × pipe-clay triangle
1 × stop clock or sight of a clock with seconds display
1 × hard-glass test-tube
8 × test-tube*
1 × test-tube rack
1 × test-tube holder
1 × wash bottle containing distilled water
1 × marker or labels (suitable for labelling glassware)
paper towels
access to a balance weighing to **at least** 0.1 g

* Candidates are expected to rinse and re-use test-tubes where possible.
Additional tubes should be available.

Where the provision of balances is limited, some candidates should be instructed to start the examination with Question 2. See page 58 of the current syllabus for balance : candidate ratio.

9701/34/CI/M/J/16

Chemicals Required

1 It is ***especially important*** that great care is taken that the confidential information given below does **not** reach the candidates either directly or indirectly.

2 It should be noted that descriptions of materials given in the question paper may not correspond with the specifications in these Instructions.

3 Particular requirements

hazard	label	per candidate	identity	notes (hazards given in this column are for the raw materials)
	FB 1	150 cm^3	0.0406 mol dm^{-3} hydrated 'borax', disodium tetraborate	Dissolve 15.5 g of hydrated 'borax', $Na_2B_4O_7.10H_2O$ **[HH]** in each dm^3 of solution. The solid should be ground to a fine powder. The solution should be warmed and stirred to aid dissolving.
	FB 2	30 cm^3	2.00 mol dm^{-3} hydrochloric acid	See preparation instructions on page 56 of the current syllabus.
	FB 4	1.5 g	basic magnesium carbonate	1.5 - 1.6 g of $3MgCO_3.Mg(OH)_2.3H_2O$ in a stoppered container. Any type of basic magnesium carbonate is suitable, irrespective of the formula on the container.
	FB 5	10 cm^3	0.2 mol dm^{-3} barium chloride	Dissolve 48.8 g $BaCl_2.2H_2O$ **[T]** in each dm^3 of solution. (Barium nitrate is not a suitable alternative.)
[N]	**FB 6**	10 cm^3	0.05 mol dm^{-3} silver nitrate	See preparation instructions on page 56 of the current syllabus.
[MH]	**FB 7**	10 cm^3	1.0 mol dm^{-3} sulfuric acid	See preparation instructions on page 56 of the current syllabus.
	FB 8	2 g	sodium hydrogencarbonate	Approximately 2 g of $NaHCO_3$ in a stoppered container.
[F]	**magnesium ribbon**	3 × 2 cm strips	magnesium ribbon	Strips of Mg ribbon **[F]** cut to approximate length 2 cm. Ensure that extra strips are available.
	aqueous potassium iodide	10 cm^3	0.2 mol dm^{-3} potassium iodide	Dissolve 33.2 g of KI in each dm^3 of solution.
	distilled water	350 cm^3	distilled water	
[F][MH] [HH]	**methyl orange indicator**	5 cm^3	methyl orange indicator	See preparation instructions on page 56 of the current syllabus.

Q# 22/ R1 Rate (Thiosulfate and acid) AS Chemistry/2021/w/TZ 4/Paper 3/ :o)

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1(a)(i)	**I** Constructs a single 4 × 5 table for results for 5 experiments **AND** at least one experiment attempted	1
	II Correct headings and units for data given. • volume of **FB1 and** in cm^3 or / cm^3 or (cm^3) • volume of water **and** in cm^3 or / cm^3 or (cm^3) • time **and** in seconds or / s or (s) • rate **and** / s^{-1} or (s^{-1})	1
	III All times recorded to the nearest second **AND** all volumes given to nearest 0.05	1
	IV 3 additional volumes chosen with intervals not less than 5.00 cm^3 **AND** all additional volumes of **FB 1** ⩾ 25.00 cm^3 **AND** In all 3 additional experiments water is added to make a total of 45.00 cm^3	1
	V All rates correctly calculated using 1000 / time **AND** all recorded to the same number of dp or same number of sf.	1
	VI All five times increase with decreasing volume of **FB 1**	1
	VII & VIII Compare ratio of time for 20.00 cm^3 of **FB 1** / time for 45.00 cm^3 of **FB 1** to 2 dp. Award **VII** for ratio 2.10 – 2.60 Award **VIII** for ratio 2.20 – 2.50	2

1(b)	I Rate on y axis and volume of FB 1 on the *x* axis With correct labels **and** units. Do not penalise missing / incorrect unit if penalised in **1(a) II** (ecf)	1
	II Linear scales chosen so that the graph occupies more than half the available length for both axes (7 × 5 big squares)	1
	III **All** points recorded plotted correctly to within half a small square and in the correct square or on the line if it should be on the line and not on the line if it shouldn't.	1
	IV Draws a line of best fit. This can be a straight line or smooth curve.	1
1(c)	Rate is proportional to concentration of thiosulfate	1
1(d)(i)	(Carbonate/ quenching bath) removes H^+ / neutralises acidic solution (so reaction stops).	1
1(d)(ii)	To know when all the carbonate has been neutralised / no more carbonate (solution) remains / more carbonate needs to be added OR mixture becomes acidic / pH drops below 7 / pH is no longer ⩾ 7	1
1(e)(i)	M1: moles of H^+ = 2(.00) × 10^{-2} AND moles of $S_2O_3^{2-}$ = 4.5(0) × 10^{-3} M2: 2(.00) × 10^{-2} > 2 × 4.5(0) × 10^{-3} / 9(.0) × 10^{-3} Other valid methods exist (e.g., comparison of volume of acid required to react and volume used).	2
1(e)(ii)	So acid concentration remains (almost) constant throughout the experiment OR only the conc of thiosulfate affects the rate.	1

Q# 23/ R1 Rate (Thiosulfate and acid) AS Chemistry/2018/m/TZ 3/Paper 3/ :o) www.SmashingScience.com

1(a)	**I** Single table to show temperature of FA 2/reactant(s), time and rate for 5 experiments. (*not all experiments need have been done – minimum 2*)	1
	II Headings unambiguous and units correct – displays: (°C), / s, in s^{-1} (*ignore factor of 1000 in rate unit*)	1
	III All temperatures recorded to .0 or .5, all times as integers. (*minimum 4 experiments carried out*)	1
	IV Selects temperatures in experiments 4 and 5 that are ⩾ 4 °C apart from all others and none above 60 °C. (*Paper states 55 °C but T for Expt 2 may be slightly higher.*)	1
	V Rates correctly calculated to 2–4 sf (*minimum 3 results*)	1
	Award **VI** if candidate for expt 1 is within 10% of supervisor (*If expts have been renumbered by candidate then compare time for the expt carried out at the lowest temperature.*)	1
	Award **VII** if **all** times decrease with increasing temperature.	1
	Award **VIII** if all results give an increasing gradient graph (*Allow if 4 out of the 5 points show an increasing gradient line.*) (*Do not award if no graph drawn or fewer than 5 points plotted.*)	1
1(b)	**I** Axes labelled (*name or unit*) and linear scales chosen so graph occupies more than half the available length for both axes including 15 °C on *x*-axis and 0 on *y*-axis.	1
	II All points recorded (*minimum 4 recorded*) accurately plotted *Any point which should be on a line must be on that line.* *Any point not on a line must be in the correct part of the small square.* *If blobs shown then they must be correctly centred and be less than ½ a small square across.*	1
	III Line of best fit drawn (*smooth curve expected but allow suitable straight line*) *Ignore any obviously anomalous points.*	1
	IV Anomalous points indicated and line extrapolated to 15 °C If no points anomalous then smooth line very close to all points	1
1(c)	Both construction lines at 17.5 °C shown *Allow other clear indication linking 17.5 °C with rate*	1
	Correctly calculates time from rate reading (*ignore sf*) Rate must be correctly read from the graph (to within 0.5 s^{-1} of examiner value) If no construction lines are drawn examiner infers rate and checks rate and time given by candidate. *If construction lines / 'point' drawn in wrong place then allow as ecf (i.e. wrong temp selected)*	1
1(d)	Rate of reaction increases with / is proportional to increase in temperature because it / graph **line** curves upwards / has a positive gradient or **figures** from table. Directly proportional is CON	1
	Rate of rate of reaction increases because gradient increases with temperature / rate of reaction increases more / at a greater rate than increase in temperature as gradient increases (or from relevant figures from graph or results table)	1
1(e)(i)	Correctly calculates initial concentration of thio to 2–4 sf. (*Penalise incorrect sf only once in this section.*) $^{18.1}/_{248.2}$ = 0.073 / 0.0729 / 0.07293 mol dm^{-3}	1
1(e)(ii)	Correctly calculates concentration of acid in the mixture to 2–4 sf 0.05 □ $^{2}/_{3}$ = 0.033(3) mol dm^{-3}	1

1(e)(iii)	Shows working to compare concentration of thio in mixture with **(ii)** or moles of thio and of acid in mixture [conc of thio in mixture = 0.073 □ $^{1}/_{3}$ = 0.024(31) mol dm^{-3}] or [moles of thio (in 10 cm^3) = (7.3 / 7.29 / 7.293) □ 10^{-4} mol and moles of acid (in 20 cm^3) = 1(.000) □ 10^{-3} mol]	1
	Comparison using equation moles thio : acid = 1 : 2 ($^{thio}/_{acid}$ = 0.5) and thio / **FA 1** in excess [concentration of $^{thio}/_{acid}$ in mixture = $^{0.024}/_{0.033}$ > 0.5 This may be shown as thio : acid = 0.0243 > 0.0167 or 0.0486 > 0.033] or [moles of $^{thio}/_{acid}$ in mixture = $^{0.00073}/_{0.001}$ > 0.5 This may be shown as thio : acid = 0.00146 > 0.001] *Allow ecf from **(ii)*** (7.29 □ 10^{-2} □ $^{2}/_{3}$ > 3.33 □ 10^{-2} and **FA 1** / thio in excess gains both marks)	1
1(f)(i)	Correct working shown or correct answer to minimum 2 sf ($^{0.5}/_{\text{time for expt 2}}$) □ 100 *If '□ 100' not in working allow if answer shows its use.* (*t_2 must match the time recorded for the expt labelled 2 in the results table*)	1
1(f)(ii)	It is more difficult to distinguish exactly when the printing disappears at the lower temperature (in expt 1) *ora*	1
1(g)	One of Take the temperature on initial mixing and the temperature as soon as the printed sheet is obscured (and calculate a mean T). Take the temperature of **FA 1** / both solutions (and calculate (weighted) mean) Use a thermostatically controlled water bath (to prevent temperature fluctuations)	1
	One of Use (graduated) pipette / burette / measuring cylinders calibrated to greater precision / smaller percentage error to measure volumes. Use (graduated) pipette / burette to measure **FA 1** / thio and **FA 2** / acid / (volumes of) solutions / reactants (instead of the measuring cylinders) Use light sensor/colorimeter (to avoid subjective judgement of turbidity) (*Do not allow use a more accurate thermometer*)	1

Apparatus

1 In addition to the fittings ordinarily contained in a chemical laboratory, the apparatus and materials specified below will be necessary.

2 Pipette fillers (or equivalent safety devices), suitable eye protection and disposable gloves should be used where necessary.

3 *For each candidate*

1 × 25 cm^3 measuring cylinder
1 × 50 cm^3 measuring cylinder
1 × 250 cm^3 beaker
1 × 100 cm^3 beaker (beakers for all candidates and the Supervisor **must** be the same)
1 × thermometer (–10 °C to +110 °C at 1 °C graduations)
1 × boiling tube labelled **1**
1 × boiling tube labelled **2**
1 × stop-watch (timer)
8 × test-tube*
2 × boiling tube*
1 × test-tube rack
1 × test-tube holder
2 × teat / dropping pipette
1 × spatula
1 × Bunsen burner
1 × tripod
1 × gauze
1 × heatproof mat
1 × wash bottle containing distilled water
1 × pen (for labelling glassware)
paper towels

*Candidates are expected to rinse and reuse test-tubes and boiling tubes where possible. Additional tubes should be available.

4 *Per five candidates*

A bucket labelled **Quenching bath** must be provided.

The bucket must contain 1 dm^3 of 5% sodium carbonate solution (made up by dissolving 50 g of Na_2CO_3 or 135 g of $Na_2CO_3.10H_2O$ in 1 dm^3 of water) and Universal Indicator.

The Supervisor must monitor the colour of the Universal Indicator in each quenching bath to check that the solution has **not** become acidic. If the solution becomes acidic, the Supervisor must add more 5% sodium carbonate solution to the quenching bath.

Chemicals required

1 It is ***especially important*** that great care is taken that the confidential information given below does **not** reach the candidates either directly or indirectly.

2 It should be noted that descriptions of substances given in the Question Paper may **not** correspond with the specifications in these Confidential Instructions.

3 Particular requirements

hazard	label	per candidate	identity	notes (hazards given in this column are for the raw materials)
	FA 1	75 cm^3	0.20 mol dm^{-3} sodium thiosulfate	Dissolve 49.6 g $Na_2S_2O_3.5H_2O$ in each dm^3 of solution.
	FA 2	150 cm^3	0.05 mol dm^{-3} nitric acid	Dilute 25.0 cm^3 of 2.0 mol dm^{-3} HNO_3 **[C]** to 1 dm^3.
[C]	**FA 3**	15 cm^3	2.0 mol dm^{-3} nitric acid	See preparation instructions on page 56 of the current syllabus.
[MH]	**FA 4**	1 g	barium carbonate	Provide approximately 1 g $BaCO_3$ **[MH]** in a stoppered container.
	FA 5	10 cm^3	1.0 mol dm^{-3} magnesium sulfate	Dissolve 246.4 g $MgSO_4.7H_2O$ in each dm^3 of solution.

NOTE: Small amounts of SO_2 **[C] [T]**, which can cause respiratory distress in some people, may be produced. **The laboratory must be well ventilated.**

Q# 24/ Qo Qualitative: Organic compounds test ALvl Chemistry/2022/w/TZ 1/Paper 3/Q# :o)
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	FA 6 is aqueous $Zn(NO_3)_2$ and KI; FA 7 gives results for ethanal but is actually **butan-2-ol**	
3(b)(i)	M1: **Test 2** (triiodomethane test) (Pale) yellow ppt M2: **Test 3** add (acidified aqueous) potassium manganate(VII) purple / $KMnO_4$ decolourised	2
3(b)(ii)	any 2 of the following tests correct **Test 1:** does not contain –OH / not an alcohol / not a carboxylic acid / not hydroxyl group **Test 2:** contains $-CH_2C=O$ (or $-CH(OH)CH_3$) group **Test 3:** is an aldehyde (or a 1° or 2° alcohol)	2
3(b)(iii)	FA 7 is ethanal / CH_3CHO	1

Q# 25/ Qo Qualitative: Organic compounds test ALvl Chemistry/2020/s/TZ 1/Paper 3/Q# :o)
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	FA 1/FA 6 is $(NH_4)_2Fe(SO_4)_2.6H_2O$; FA 7 is H_2O_2; FA 8 is ethanol	
3(a)(i)	Reagents used are NaOH and NH_3	1
	FA 6 dissolved in (distilled) water (before carrying out tests)	1
	Observations with both cold alkalis • With NaOH: green ppt, insoluble in excess • With NH_3: green ppt, insoluble in excess OR • If only one of NaOH or NH_3 was selected, award this mark if the observation is correct, but it must include 'ppt turns brown'.	1
	Observation when heated with NaOH Fizzing/bubbling and gas/NH_3 turns (moist red) litmus to blue	1
	Both ions correctly identified Iron(II) and ammonium (Fe^{2+} and NH_4^+)	1

3(a)(ii)	**Anion test and first observation** • Add barium nitrate/chloride • White precipitate	1
	Observation with acid and conclusion: • white ppt is insoluble in specified mineral acid (not H_2SO_4) • sulfate / SO_4^{2-} present	1
3(a)(iii)	**Ionic equation** *Any one of the following equations, provided that the appropriate test was carried out.* • $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ • $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l\ or\ g)$ • $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$	1
3(a)(iv)	**Correct use of M_r to calculate no of moles water.** Mass of water = (392) - 55.8 -192.2 – 36	1
	• $n(H_2O) = {}^{392-284}/_{18}$ (expressed as integer)	1
3(b)(i)	Award one mark for every two correct observations (*) as shown in table below	5

test	observation(s) FA 5	observation(s) FA 6
Test 1	$KMnO_4$ decolorised*. fizzing/bubbling/effervescence or gas relights glowing spill* No (further) change	no reaction $KMnO_4$ not decolorised **and** $KMnO_4$ goes from purple to colourless (solution)*
Test 2	Red-brown/ brown solution formed* Mixture goes to (dark) blue / blue-black*	No change **and** No change*
Test 3	Yellow or colourless solution formed*	(On standing) off-white / pale yellow precipitate formed*.
Test 4	No change / pale yellow (solution) formed* Red-brown / brown / rust precipitate (formed)* *Ignore fizzing*	

3(b)(ii)	FA 8 is ethanol or propan-2-ol or butan-2-ol *(or any secondary 2-ol)* Correct reference to the CHI_3 test or to $CH_3CH(OH)$- or CH_3CO group	1
	Correct reference to the redox reaction with $KMnO_4$ (provided that **FA 8** was identified as an alcohol/aldehyde).	1
3(b)(iii)	FA 7 is an oxidising agent because iodine is formed.	1

Q# 26/ Qo Qualitative: Organic compounds test ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# :o)
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FA 5 is HCOOH ; FA 7 is $ZnCO_3$; FA 8 is $Cu(NO_3)_2$		
3(a)(i)	+ Na_2CO_3: fizz / effervescence / bubbling	1
	+ $KMnO_4$: purple (allow pink) to colourless (allow pale yellow)	1
	+ $AgNO_3$: no (visible) reaction / no change / no ppt / solution remains colourless	1
	+ Tollens': silver mirror / black ppt / grey ppt	1
3(a)(ii)	(Carboxylic) acid	1
	Aldehyde / primary alcohol / secondary alcohol / alkene	1

Q# 27/ Qo Qualitative: Organic compounds test ALvl Chemistry/2016/s/TZ 1/Paper 3/Q# :o)
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	FA5 is $MnSO_4$ and NH_4Cl; **FA6** is propanone; **FA7** is propanal;		
(d)	**Both observations required** **FA6** no reaction/solution turns pink **and** **FA7** turns colourless/decolourises the $KMnO_4$	1	
	FA6 is either 2-methylpropan-2-ol **or** propanone as they cannot be oxidised (only 1 needed) **and** **FA7** is propanal as it can be oxidised.	1	[2]
Question 3			**[13]**

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FA 7 is a tertiary alcohol; FA 8 is an aldehyde; FA 9 is a ketone; FA 10 is a primary alcohol				
(g)	MMO Collection	One mark for two correct observations with **FA 7**	1	
		One mark for correct observations with **FA 8** and **FA 9**	1	
		One mark for two correct observations with **FA 10** See table below for expected observations	1	[3]

reagent	observations			
	FA 7	FA 8	FA 9	FA 10
acidified dichromate	no reaction		no reaction	(colour change to) green/blue-green/ cyan/turquoise (solution **not** ppt)
2,4-DNPH	~~no reaction~~	~~yellow ppt~~	~~yellow ppt~~	
Tollens' reagent	no reaction	silver mirror **or** black/grey solution or ppt		no reaction

(h)	ACE Conclusions	**No ecf from (g)** **FA 7** contains the tertiary alcohol from no reaction with all three reagents **or** no reaction with dichromate **and** 2,4-DNPH **provided** there is no CON in the observation with Tollens'	1	
		FA 8 contains the aldehyde from the silver (mirror), black or grey precipitate or solution with ammoniacal silver nitrate Allow from brown ppt if it is the only positive result with Tollens'.	1	[2]
	Total			**[14]**

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FA 6 is aqueous $Zn(NO_3)_2$ and KI; FA 7 gives results for ethanal but is actually **butan-2-ol**		
3(a)(i)	**observations** **Test 1** M1: NaOH: white ppt **and** soluble in excess M2: Heat: no change / no (visible) reaction / litmus stays red **Test 2** M3: Al: fizz **and** NH_3 / gas turns (damp red) litmus blue **Test 3** M4: H_2O_2: brown / (darker) yellow / yellow-brown / orange-brown / red-brown (solution)	4
3(a)(ii)	possible cations: aluminium / Al^{3+} and zinc / Zn^{2+}	1
3(a)(iii)	identifying the cation M1: cation test: add (aqueous) ammonia M2: white ppt soluble in excess $NH_3(aq)$ shows Zn^{2+}	2
3(a)(iv)	possible anions: any two from NO_3^-, NO_2^-, I^-	1
3(a)(v)	identifying the anion **if iodide in (iv)** M1: test: add (aqueous) silver nitrate / $AgNO_3$ M2: yellow ppt (insol in NH_3) shows I^- **if nitrite and nitrate (no iodide) in (iv)** M1: test: add (acidified aqueous) potassium manganate(VII) / $KMnO_4$ M2: purple / $KMnO_4$ solution turns (dark) yellow / yellow-brown / orange-brown / red-brown / brown / decolourised shows nitrite OR M1: add named (dilute) acid M2: no fizzing / no brown gas shows nitrate	2

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FA 5 is $NaNO_3$; FA 6 is $Al_2(SO_4)_3$; FA 7 is I_2 + KI		
3(a)(i)	M1: 'table' (2 × 2 min) with headings: 'test / experiment / reagents' and 'observations' **AND** two (or more) reagents listed in the space M2: (*eliminating ammonium ion*) heat **FA 5** with (aqueous) NaOH **AND** no effervescence / (damp red) litmus stays red M3: (*identifying NO_2^- / NO_3^-*) add Al to warm NaOH and **FA 5** **AND** fizz / gas / NH_3 turns (damp red) litmus blue M4: (*eliminating NO_2^-*) anion is NO_3^- / nitrate / nitrate(V) **AND** **Either** add (a few drops of) (acidified) $KMnO_4$ / potassium manganate(VII) **AND** no change / no reaction / (solution) remains purple **Or** add (dilute) named mineral acid to (solid or aqueous) **FA 5 AND** no brown fumes / no blue solution / no reaction / no change produced	4
3(a)(ii)	• solid melts / solid dissolves / liquid forms • fizzing / bubbling / effervescence • (gas) re-lights glowing splint / spill • oxygen produced • (on cooling), (pale) yellow solid formed or residue is yellow *3 or more bullets = 2 marks* *2 bullets = 1 mark*	2
3(b)(i)	(see table below) 2 * = 1 mark (round down)	5
3(b)(ii)	FA 6 = $Al_2(SO_4)_3$ [1] FA 7 = I_2 [1] AND KI [1]	3
3(b)(iii)	$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$ OR $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$ OR $I_2(aq) + 6OH^-(aq) \rightarrow I^-(aq) + IO_3^-(aq) + 3H_2O(l)$	1

Table for 3(b)(i):

test	*FA 6*	*FA 7*
Test 1 NaOH	White ppt / solid (formed) * Soluble in excess *	Decolourises / **turns** (pale) yellow * (ppt is CON)
Test 2 Ba^{2+}	White ppt	No change / no reaction
+ HCl	AND ppt insoluble / remains / no change / no reaction *	**AND** no change / no reaction *
Test 3 starch		Dark blue / blue-black / black (colour formed) (ignore state)
+ thio		**AND** colourless solution (forms) ALLOW turns colourless / decolourises *
Test 4 Ag^+	No change / no reaction / no ppt	Yellow / brown ppt (forms) *
+ NaOH	**AND** ppt (forms) (ignore colour) *	Pale yellow ppt ALLOW ppt turns paler yellow * IGNORE use of excess NaOH
Test 5 + NH_3	White ppt **AND** ppt is insoluble in excess (NH_3) *	

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FA 7 is $Na_2S_2O_3$; FA 8 is $AlNH_4(SO_4)_2(aq)$		
3(a)(i)	(see table below) 2 x * = 1 mark	4

	FA 7	FA 8
Test 1 + H^+	(slow formation of) white / off-white / cream / **pale** yellow ppt *	no change / no (visible) reaction / no ppt*
+ Ba^{2+}	no change (provided ppt reported with H^+) / ppt remains / insoluble *	white ppt *
Test 2 + MnO_4^-	purple to colourless / $KMnO_4$ decolourises*	no change / no (visible) reaction / stays purple * *Not 'no ppt' alone*
Test 3 + $FeCl_3$	purple colour fades / turns colourless (on standing) *	no change / no (visible) reaction / solution stays yellow *

3(a)(ii)	FA 7 = $S_2O_3^{2-}$	1
	FA 8 = SO_4^{2-}	1
3(b)(i)	selects NaOH and NH_3 **AND** uses both NaOH and NH_3 to excess / warms at least one NaOH mixtures	1
	(see table below) 2 x * = 1 mark (round down)	3

	FA 7	FA 8
+ NaOH	no change / no (visible) reaction / no ppt *	white ppt * soluble in excess *
+ warm	no change to (red) litmus / * *ignore no reaction* *ignore bubbling*	gas / NH_3 turns (red) litmus blue *
+ NH_3	Ignore	white ppt * insoluble in excess *

3(b)(ii)	**M1 FA 8** = Al^{3+} from fully correct observations **OR** **FA 8** = NH_4^+ from litmus turning blue **M2 FA 7** is unknown and both ions in **FA 8** correct	2
3(b)(iii)	One of: $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$ $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$ $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$ *Allow ecf from* **(b)(ii)** *on incorrect cations*	1

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FA 5 is $BaCl_2(aq)$; FA 6 is $H_2SO_4(aq)$; FA 7 is NaOH(aq); FA 8 is HCOOH(aq)

3(b)(i)	M1: Test 1 purple / pink to colourless / (pale) yellow / pale brown OR $KMnO_4$ is decolourised M2: Test 2 effervescence / fizzing / bubbles **AND** gas/ H_2 pops with a lighted splint / burns with a pop	2
3(b)(ii)	M1: (**FA 8**) can be oxidised / is a reducing agent M2: (**FA 8**) is an acid	2

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FA 5 is $BaCl_2(aq)$; FA 6 is $H_2SO_4(aq)$; FA 7 is NaOH(aq); FA 8 is HCOOH(aq)

3(a)(i) — 5

	FA 5	FA 6	FA 7
H_2SO_4	white ppt / solid *	no (visible) reaction / no change / no ppt / solution remains colourless *	no (visible) reaction / no change / no ppt / solution remains colourless *
Na_2CO_3	white ppt / solid *	effervescence / fizzing / bubbles * gas / CO_2 turns limewater milky / cloudy white / forms white ppt *	no (visible) reaction / no change / no ppt / solution remains colourless *
$MgCl_2$	no (visible) reaction / no change / no ppt / solution remains colourless *	no (visible) reaction/ no change / no ppt / solution remains colourless *	white ppt / solid *

3(a)(ii)	M1: Cation in **FA 5** is Ba^{2+} or Ca^{2+} M2: Cation in **FA 6** is H^+ M3: Anion in **FA 7** is OH^-	3
3(a)(iii)	**Test for OH^-** Add specified (aqueous) metal compound gives appropriate (coloured) ppt OR Add a specified nitrate and Al and warm Positive test for ammonia OR Add a specified ammonium compound and warm Positive test for ammonia	1
3(a)(iv)	Yes, because the test gave a named ppt of specified hydroxide which is insoluble (in water). OR Yes, because it gave ammonia gas (on warming) which is alkaline.	1

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3(a)(i)	**Test 1** no change / (pale) orange / (pale) red / (pale) pink solution *Allow solution becomes colourless / paler*	1
	Test 2 (see table below) 2 asterisks = 1 mark (round down)	2

+ NaOH	green / dirty green / pale green / dark green ppt * ppt turns brown (at surface) *
+ H_2SO_4	ppt dissolves or yellow / yellow-brown / orange-brown solution formed *
+ SCN^-	(solution) turns dark(er) orange / blood-red / red / dark(er) red / deep red / red-brown * colour must be more intense than in **Test 1**

3(a)(ii)	Fe^{3+} is formed (in **Test 2**)	1
	oxidation of Fe^{2+} / redox	1
3(a)(iii)	NH_4SCN	1
3(a)(iv)	$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$	
	correct product formula	1
	balancing and state symbols	1
3(b)(i)	prepare solution of **FA 4**	1
	prepare a suitable table(s) minimum 2 tests and columns/ rows for tests and for observations	1
	2 asterisks = 1 mark (round down) (see table below) *Ignore additional reagents*	5

+NaOH *	white ppt * insoluble in excess *
+ NH_3 *	white ppt* insoluble in excess *
$BaCl_2$/$Ba(NO_3)_2$* HCl / HNO_3 *	white ppt * insoluble in excess suitable named acid *
OR dilute acid * + $KMnO_4$ *	no change / no reaction / solution remains purple **

3(b)(ii)	cation: Mg^{2+} **and** anion: SO_4^{2-}	1

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FA 6 is NH_4Cl; FA 7 is NH_4I; FA 8 is $BaCl_2$

3(a)(i)	1 mark for correct gas test: (gas / vapour / fumes) turn (moist red) litmus to blue *Reject if incorrect gas identified* 1 mark for any two bulleted observations correct: • solid sublimes / white solid forms near top of tube *(owtte; allow residue for solid)* *Reject 'solid evaporated'* *Allow 'white layer formed around glass tube' (bod)* • white **and** smoke / vapour / fumes produced *Reject 'effervescence'* *Reject 'gas'* • no residue (at bottom of tube) *Allow 'crystals disappear completely'* • after heating for some time, gas turns (moist blue) litmus to red	2
3(a)(ii)	ammonium / NH_4^+ *Reject if more than one ion identified*	1
3(b)(i)	14 observations. Two * = 1 mark (round down) *Reject 'no observation' (for 'no change') the first time seen, then allow*	6

test	reagent	FA 7	FA 8
1	$KMnO_4$	Solution / turns and yellow / red-brown / orange-brown / brown * *Reject any reference to purple colour at end* *Reject ppt*	*Ignore*
	starch	black / dark blue / blue-black / black-purple * *Reject purple on its own*	*Ignore*
2	$AgNO_3$	(pale) yellow precipitate (formed) * *Reject creamish-yellow*	white precipitate (formed) * *Reject off-white*
	NH_3	ppt does not dissolve / insoluble / no change *	ppt (mostly) dissolves or partially dissolves or (slightly) cloudy mixture forms or <u>some</u> white ppt remains * *Reject 'clear solution'*
3	NaOH (cold)	no reaction / no change / no precipitate * *Allow 'no visible observation'*	white precipitate **and** insoluble in excess * *Reject any variation on white, e.g. off-white*
	NaOH (hot)	<u>gas / NH_3</u> turns (red) litmus to blue *	*Ignore observations when heated (but reject litmus goes blue at any stage of this test)*
	Al	*Ignore observation(s) with Al*	fizzing / bubbling / effervescence or gas / H_2 pops with lighted spill *
4	H_2SO_4	no change / no reaction or solution <u>remains</u> colourless * *Reject 'no ppt'*	white precipitate (formed) *

3(b)(ii)	FA 7 is NH_4I FA 8 is $BaCl_2$ **ALLOW** $CaCl_2$ / $CaBr_2$ / $BaBr_2$ for FA8 *If both are named correctly award one mark (out of 2).* *If both cations are correct, award one mark (out of 2).*	2
3(b)(iii)	$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ *State symbols are required. Allow ecf for Ca^{2+} or Mg^{2+} in (ii)*	1

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	FA 6 = Na_2SO_3(s); FA 8 = $CuSO_4$(aq)	
3(a)(i)	+ $AgNO_3$ gives a white ppt	1
	soluble in **both** NH_3(aq) and **FA 5** / thio	1
3(a)(ii)	Cl^- / chloride	1
3(a)(iii)	Selects $BaCl_2$ OR $Ba(NO_3)_2$ **and** HCl OR HNO_3 OR selects acidified (aqueous) $KMnO_4$ OR add named mineral acid and test for SO_2 (e.g. blue litmus turns red; acidified aqueous manganate(VII) paper turns colourless)	1
	Clear display of results to show: white ppt **and** (partially) soluble in acid OR $KMnO_4$ decolourises OR positive result for SO_2 **AND** **FA 6** = sodium sulfite	1
3(a)(iv)	$2Ag^+(aq) + SO_3^{2-}(aq) \rightarrow Ag_2SO_3(s)$ Allow sulfate if ppt seen in **(iii)**: $2Ag^+(aq) + SO_4^{2-}(aq) \rightarrow Ag_2SO_4(s)(sic)$	1
3(b)(i)	(Pale) blue ppt dissolves in excess to give a dark blue solution.	1
	+ H_2O_2 solution turns black / dark green OR black / dark green solid produced **AND** Effervescence / fizzing / bubbling	1
	gas / oxygen relights a glowing splint	1
3(b)(ii)	Cu^{2+} / copper(II)	1
3(b)(iii)	+ KI(aq) (turns) brown / yellow-brown / orange-brown / grey-brown Ignore state Allow mustard (brown) Reject red-brown	1
	+ **FA 5** then (brown solution becomes paler) ppt is off-white / white Allow cream / pale grey ppt. Ignore effect of excess thio / FA 5.	1
3(b)(iv)	Any 2 of: • (mixture) turns brown owing to the production of iodine • ppt formed is copper(I) iodide (allow copper(II) iodide) • I^- is oxidised (by Cu^{2+}) OR Cu^{2+} is reduced (by I^-) I_2 is reduced (by $S_2O_3^{2-}$) OR S is oxidised (by I_2) (ignore oxidation state of S)	2

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	FA 1/FA 6 is $(NH_4)_2Fe(SO_4)_2 6H_2O$; FA 7 is H_2O_2; FA 8 is ethanol	
3(a)(i)	Reagents used are NaOH and NH_3	1
	FA 6 dissolved in (distilled) water (before carrying out tests)	1
	Observations with both cold alkalis • With NaOH: green ppt, insoluble in excess • With NH_3: green ppt, insoluble in excess OR • If only one of NaOH or NH_3 was selected, award this mark if the observation is correct, but it must include 'ppt turns brown'.	1
	Observation when heated with NaOH Fizzing/bubbling **and** <u>gas/NH_3</u> turns (moist red) litmus to blue	1
	Both ions correctly identified Iron(II) **and** ammonium (Fe^{2+} and NH_4^+)	1
3(a)(ii)	**Anion test and first observation** • Add barium nitrate/chloride • White precipitate	1
	Observation with acid and conclusion: • white ppt is insoluble in specified mineral acid (**not** H_2SO_4) • sulfate / SO_4^{2-} present	1
3(a)(iii)	**Ionic equation** *Any one of the following equations, provided that the appropriate test was carried out.* • $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ • $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l\ or\ g)$ • $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$	1
3(a)(iv)	**Correct use of M_r to calculate no of moles water.** Mass of water = (392) - 55.8 -192.2 – 36	1
	• $n(H_2O) = {}^{392-284}/_{18}$ (expressed as integer)	1

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	FA 6 is $(NH_4)_2Fe(SO_4)_2$(aq); FA 7 is KI(aq); FA 8 is HCl(aq)	
3(a)(i)	Green precipitate **and** insoluble / no change in excess (NaOH)	1
	(Green) precipitate darkens and / or goes brown	1
	(When mixture heated) gas / ammonia turns (red) litmus blue	1
	Both cations in **FA 6** identified • Fe^{2+} ions / iron(II) • Ammonium / NH_4^+	1
3(a)(ii)	Goes brown / rust / red-brown / orange-brown **AND** bubbles / fizzing / effervescence	1
3(a)(iii)	$Fe^{2+} \rightarrow Fe^{3+} + e^-$ / $Fe^{2+} - e^- \rightarrow Fe^{3+}$	1
3(b)(i)	Award one mark for every two correct observations (*) as shown in table below	5

test	observations	
	FA 7	FA 8
Test 1 + Na_2CO_3(s)	no (visible) reaction / no change / no precipitate / solid (carbonate) dissolves / no effervescence *	effervescence / fizzing / bubbles * gas / CO_2 gives a white ppt with limewater / turns limewater milky / cloudy white / chalky *
Test 2 + $H^+/KMnO_4$(aq)	solution turns yellow / brown / orange-brown / red-brown / yellow-brown *	no (visible) reaction / no change / $KMnO_4$ / solution stays purple / colourless solution turns purple / purple solution formed *
+ starch(aq)	(turns) dark blue / deep blue / blue-black / black *	*ignore*
Test 3 + $AgNO_3$(aq)	(pale) yellow ppt (formed) *	white ppt (formed) *
+ NH_3(aq)	(ppt) insoluble / does not dissolve / no change *	(ppt) dissolves / soluble / gives a colourless solution *

3(b)(ii)	Anion in **FA 7** is iodide (ion) / I^- must be concluded from a (pale) yellow precipitate	1
3(b)(iii)	**FA 8** is hydrochloric acid / HCl	1
3(b)(iv)	One suitable test for H^+ (reagent **and** observation) in any acid identified in **(b)(iii)** • named pH indicator **and** correct final colour OR • add magnesium **and** fizzes or gas / H_2 pops with a lighted splint	1

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	FA 5 is $AlNH_4(SO_4)_2.12H_2O$; FA 8 is KI and $FeSO_4$	
3(a)(i)	• melts / dissolves • condensation / moisture on the walls of the test-tube / steam produced • white smoke / fumes (NOT gas) • (gas) turns red litmus blue • gas turns blue litmus red • white residue Award 1 mark for two correct observations from the list, award 2 marks for three or more correct observations. If both gas observations are given they must be in the correct order for both to be credited.	2
3(a)(ii)	NH_3 White ppt and insoluble in excess	1
	NaOH White ppt and sol in excess **Allow** 1 mark for white ppt with both NH_3 and NaOH	1
	hot NaOH Gas / NH_3 (on warming) turns red litmus blue	1
	Ba^{2+} White ppt insoluble in acid / white ppt no reaction with acid **Reject** white ppt formed when acid added	1
3(a)(iii)	names or correct formulae	1
	NH_4^+ , Al^{3+} , SO_4^{2-} Award 1 mark for two ions, award 2 marks for three ions.	1
3(b)	Any formula (involving all three ions) in which the charges on the ions cancel (e.g. $K_3Cr(SO_4)_3$)	1
	$KCr(SO_4)_2.12H_2O$	1
3(c)(i)	Red-brown (allow yellow / yellow-brown / orange / orange-brown / brown) (solution) or $KMnO_4$ / purple decolourises and turns blue-black / dark blue / black (on adding starch)	1
	Green ppt and insoluble in excess / turns brown (on standing) **Reject** grey-green	1
3(c)(ii)	Fe^{2+} / iron(II) and I^- / iodide This mark is free-standing	1
3(c)(iii)	Uses silver nitrate and yellow ppt	1
	ppt insoluble in HNO_3 or ppt insoluble in NH_3 (nitric acid may be added initially)	1
3(c)(iv)	$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ ecf for Cr^{3+} / Cu^{2+} / Fe^{3+} or any other transition metal ion concluded in **(ii)**.	1

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		FA 4	FA 5	
3(a)(i)	HCl	No (visible) reaction / no change * *Allow pale yellow solution / colourless solution*	Pale yellow / cream / white / off-white ppt *(ignore excess)	5
	$CuSO_4$	Brown (ppt/ colour / soln) * *Do not allow orange/-brown or red-brown*	Green soln * allow blue-green / cyan / turquoise ppt is CON	
	$AgNO_3$	(pale) Yellow ppt *	Yellow ppt / black ppt / grey ppt / (allow solid/ particles for ppt) *	
	+ NH_3	Insol in NH_3 * *Allow no change*	ignore NH_3	
	Cl_2	Yellow or brown or red-brown / orange-brown / yellow-brown soln * *Do not allow orange.* *Ppt is CON*	No (visible) reaction / no change * *Allow colourless solution.*	
	+ FA 5	Decolourised * If Cl_2 reaction is incorrect then allow ecf e.g. colourless solution		
	For every two correct observations (*) award 1 mark (round down) Allow no observation for no (visible) change.			
3(a)(ii)	**FA 4** contains iodide / I^- Or **FA 5** contains thiosulfate / $S_2O_3^{2-}$			1
3(a)(iii)	Reagent: starch Observation expected: dark blue or blue / black colour			1

3(b)(i)	(Red) litmus turns blue Gas turns litmus blue is CON	1
3(b)(ii)	$QO(s) + H_2O(l) \rightarrow Q(OH)_2(s) / (aq)$	1
3(c)(i)	hydrochloric / nitric acid allow sulfuric acid accept correct formula	1
3(c)(ii)	Clear layout to show tests, observations and conclusions.	1
	(Chooses) NH_3 Ignore NaOH / named sulfate / H_2SO_4 Any other reagent is CON	1
	FA 6: no ppt / no (visible) change / no reaction / colourless solution. (allow no observation)	1
	FA 7: white ppt insoluble in excess Ignore observations with other reagents	1
	M is calcium (or barium), **Q** is magnesium	1
3(c)(iii)	Conclusions to follow identification of **M** or **Q** in Questions **1** and **2** and conclusions of tests in **(b)(ii)**	1

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	FA 4 is $Cu_2O(s)$; FA 5 is $H_2SO_4(aq)$; FA 6 is Cu powder	
3(a)(i)	**FA 4** + **FA 5** observations may be in either order blue solution formed / colourless to blue / solution turns blue / blue filtrate	1
	pink / brown / red-brown **AND** residue / solid	1
3(a)(ii)	(see table below)	5

test	*observations*	*marks*
+ NH_3	((pale) blue ppt) forming deep / dark blue solution in excess	1
+ KI, then	turns brown / yellow-brown	1
+ $Na_2S_2O_3$	white ppt	1
+ HNO_3, then + $AgNO_3$	no (visible) reaction / no change / no ppt / remains a blue solution	1
+ HCl / HNO_3, then + $BaCl_2$ / $Ba(NO_3)_2$	white ppt	1

3(a)(iii)	**FA 6** + nitric acid: (pale) blue solution	1
	then + NaOH: (pale) blue ppt	1
3(b)(i)	metal ion: Cu^{2+} / copper(II) **AND** anion: SO_4^{2-} / sulfate	1
3(b)(ii)	$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ OR $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ OR $2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq) / (s)$	1
3(b)(iii)	redox (from some reaction in **(a)(iii)**) OR oxidation of metal / Cu OR reduction of nitrate	1
3(c)	Na_2CO_3 (or other named carbonate) / Mg / Al / Zn / Fe / sodium thiosulfate	1
	+ CO_3^{2-}: effervescence / gas turns limewater milky / chalky / cloudy white / white ppt + appropriate metal: effervescence / gas pops with lighted splint + thio: white / off-white / pale yellow ppt	1
	Student is correct / FA 5 is an acid from correct observation	1

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	FA 4 is sodium chloride; FA 6 is copper(II) carbonate; FA 7 is a mixture of zinc sulfate and zinc nitrate	
2(a)(i)	Make a solution of FA 4 and add aqueous $AgNO_3$	1
	white ppt shows anion is Cl^-	1
2(a)(ii)	$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$	1
2(b)(i)	**Hydrochloric acid** Effervescence / bubbling and blue / green / cyan / turquoise solution formed	1
	gas / CO_2 turns limewater milky / cloudy white / chalky / forms a white ppt	1
	Ammonia (pale) blue ppt and dark blue solution with excess	1
	Heating (FA 6) turns black / black solid formed / it turns black	1

2(b)(ii)	2 * = 1 mark		5
	NaOH	White ppt * sol in excess *	
	NH_3	White ppt * sol in excess *	
	$AgNO_3$	No reaction / no ppt *	
	$Ba(NO_3)_2$	White ppt *	
	HNO_3	Ppt remains / no change*	
	NaOH and warm	No gas / no reaction *	
	+ *Al*	Gas / NH_3 / effervescence / fizzing / bubbles* turns litmus blue *	
2(b)(iii)	Cations: Cu^{2+} and Zn^{2+} / copper(II) and zinc		1
2(b)(iv)	Anions: any two of CO_3^{2-}, NO_3^-, NO_2^-, SO_4^{2-} / carbonate, nitrate, nitrite, sulfate		1
2(b)(v)	NO_3^-, NO_2^- / nitrate and nitrite / nitrate(V) and nitrate(III)		1

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FA 5 is HCOOH ; **FA 7** is $ZnCO_3$; **FA 8** is $Cu(NO_3)_2$

3(b)(i)	+ acid: fizz / effervescence / bubbling	1
	Gas / CO_2 / fizz turns limewater milky / cloudy white / forms white ppt	1
	+ NaOH: white ppt soluble in excess NaOH	1
3(b)(ii)	+ NaOH: (pale) blue ppt (reference to dark blue or dissolving is CON)	1
	Warming: goes black / brown / grey	1
	+ *Al* & NaOH: gas / ammonia turns litmus blue	1
3(b)(iii)	Cu^{2+} / copper(II) definitely present	1
	Zn^{2+} or Al^{3+} / aluminium or zinc could be present	1
	Add (aqueous) ammonia – give (white) ppt but **only** (that from) zinc dissolves in excess	1
3(b)(iv)	CO_3^{2-} / carbonate definitely present	1
	NO_3^- or NO_2^- / nitrate or nitrite could be present	1

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	FA 3 = HNO_3(aq); FA 4 = $BaCO_3$(s); FA 5 = $MgSO_4$(aq)	
2(a)	Test: selects $AgNO_3$ and NH_3 and test-tube or boiling tube used	1
	Observation: no reaction / no change / no ppt / (solution) remains colourless *This mark may be awarded without NH_3 being specified in test.*	1
	Test: selects NaOH + *Al* (and warm) and boiling tube used *Penalise lack of test-tube/boiling tube only once*	1
	Observation: effervescence / gas / NH_3 turns (damp) red litmus blue	1
	If the Devarda's test has been carried out first then allow Test: selects (aqueous acidified) $KMnO_4$ and test-tube or boiling tube used (1) Observation: stays purple / does not decolourise (1) *Allow the observation*: no reaction / no ppt / no change *if $BaCl_2$ or $Ba(NO_3)_2$ selected as a test.*	
2(b)	NO_3^- / nitrate (ion) from evidence of ammonia (*Allow NO_2^- / nitrite*)	1

2(c)	Gas / CO_2 / **effervescence** turns limewater milky / cloudy white / (forms) white ppt	1
	2* = 1 mark Do not penalise 'no observation', 'transparent', 'clear', '–' for 'no visible reaction' more than once.	
	FA 4 + FA 3 effervescence / fizzing / bubbling * colourless solution formed *	
	FA 5 + Na_2CO_3 white ppt * (soluble in excess is CON)	
	FA 5 + NaOH white ppt * insoluble in excess *	
	FA 5 + NH_3 white ppt * insoluble in excess *	
	FA 5 + Ag^+ no reaction / no ppt / no change *	
	FA 5 + Ba^{2+} white ppt * insoluble in acid * (*addition of H_2SO_4 shown in observation table negates second point*)	
	FA 6 + NaOH no change / no visible reaction / no ppt / faint / slight white ppt *	
	FA 6 + NH_3 no change / no visible reaction / no ppt / faint / slight white ppt *	
	FA 6 + H_2SO_4 white ppt * (soluble in excess is CON)	
	FA 6 + FA 5 white ppt * (soluble in excess is CON)	7
2(d)	Selects either HC*l* or HNO_3	1
2(e)	FA 4: Ba^{2+} / barium and CO_3^{2-} / carbonate (*allow Ca^{2+} if white ppt insoluble in excess formed with NaOH – see 8th observation box*)	1
	FA 5: Mg^{2+} / magnesium and SO_4^{2-} / sulfate (*allow Ca^{2+} if no ppt with NH_3 – see 4th observation box*) (*Do not allow Ca^{2+} for both. Anions are stand alone marks.*) 4 ions = 2 marks; 2 or 3 ions = 1 mark	1

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3(a)	**Tabulation of observations** Clear presentation of results to show **FA 6**, **FA 7** and **FA 8** with the reagents specified.	1
	(table below) 2 correct boxes for each mark	3
3(b)	Add silver nitrate followed by ammonia **or** silver nitrate and nitric acid (and ammonia)	1
	FA 7 cream ppt **and FA 8** no reaction / no change / no ppt	1
3(c)(i)	For **FA 6** and **FA 7** or **FA 8** not identified in **(b)** as a halide uses NaOH + *Al* **and** there is evidence of heating mixture	1
	Observations for **both** compounds tested gas / ammonia turns (red) litmus blue	1
3(c)(ii)	Uses the same unknowns as **(i)** and adds a named dilute acid or correct formula Allow if "acid" on reagent line and correct formula given in table, or adds (acidified) potassium manganate(VII)	1
	Observations: both must be correct for the reagent selected. **If HC*l* or HNO_3 used** • with **FA 6**, fizzing / bubbling or pale brown gas (formed) or yellow solution (formed) or goes yellow • with **FA 7**, no reaction • with **FA 8**, no reaction **If H_2SO_4 used** • with **FA 6**, fizzing / bubbling or pale brown gas (formed) or yellow solution (formed) or goes yellow • with **FA 7**, no reaction • with **FA 8**, white precipitate **If acidified $KMnO_4$ used** • with **FA 6**, decolourised / goes colourless / loses purple colour • with **FA 7**, no reaction / $KMnO_4$ not decolourised (or stays purple) • with **FA 8**, white / pink (allow "pale purple") precipitate formed	1

Table for 3(a):

	H_2SO_4	NaOH
FA 6	fizzing / bubbling or pale brown gas (formed) or yellow solution (formed) or goes yellow	no reaction / no change / no ppt
FA 7	no reaction / no change	on warming, gas / NH_3 turns litmus blue
FA 8	white precipitate	no reaction / no change / no ppt **or** (faint) white ppt **and** insoluble in excess NaOH

3(d)	**Correct formulae of unknowns** • **FA 6** is $NaNO_2$ • **FA 7** is NH_4Br • **FA 8** is $Ba(NO_3)_2$ / $Ca(NO_3)_2$ three formulae correct = 2 marks one formula correct = 1 mark	2

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FA 6 is $Cu(NO_3)_2$; FA 7 is $FeCl_3$		
3(a)(i)	• melts *or* dissolves *or* blue liquid / solution formed • condensation *or* steam / vapour produced • black residue / solid • brown gas / fumes • gas / oxygen relights a glowing spill *4 or 5 observations correct = 2 marks* *2 or 3 observations correct = 1 mark*	2
3(a)(ii)	FA 6 is $Cu(NO_3)_2$	1
3(b)(i)	• with KI, **FA 7** gives a brown / red-brown / red / orange solution • with starch, blue / blue-black / dark colour	1
	• with **FA 6**, blue precipitate (formed) • on heating, (blue precipitate) turns black • With **FA 7**, red-brown / brown / rust ppt. (formed)	1
	• With **FA 6**, no reaction / no change / no ppt. • With **FA 7**, white precipitate formed	1
	• With **FA 6**, (pale) blue precipitate, then • deep/dark blue (solution) with excess • With **FA 7**, red-brown / brown / rust precipitate (forms)	1
	Mg test **Both observations correct** With **FA 6**, brown / black precipitate / solid formed or blue colour fades / disappears With **FA 7**, fizzing / bubbling / effervescence	1
	Test for hydrogen: (gas) "pops" with lighted splint	1
3(b)(ii)	FA 7 is acidic, because it fizzes / produces hydrogen with magnesium	1
3(b)(iii)	$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$	1
3(b)(iv)	Redox because iodine was produced (from iodide ions)	1
3(b)(v)	You can't be certain about the colour of the precipitate (with $AgNO_3$) due to the coloured solution / colour of FA 7. or You can't be sure whether the precipitate with $AgNO_3$ is white / $AgCl$ or cream / $AgBr$	1
3(b)(vi)	Ammonia would react with the Fe^{3+} ions in FA 7 (masking the effect of ammonia on $AgCl$) or The cation in FA 7 gives a precipitate with ammonia (so the precipitate of $AgCl$ would not appear to dissolve).	1
	Total:	14

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FA 5 is $C_6H_{12}O_6(aq)$; FA 6 is $(NH_4)_2Fe(SO_4)_2(aq)$; FA 7 is $NaNO_2(aq)$		
3(a)(i)–(iv)	see below	11

test	FA 5	FA 6	FA 7
(i) aqueous sodium hydroxide, then	no reaction / no ppt. **AND**	green ppt. **AND** insol in excess / turning brown 1	no reaction / no change / no ppt. **AND**
warm gently	solution turns yellow / yellow-brown / brown 1	gas / NH_3 turns (damp red) litmus (paper) blue 1	no reaction / solution remains colourless 1
aluminium foil and warm	effervescence with FA 5 or FA 7	**AND**	gas / NH_3 turns (damp red) litmus (paper) blue 1
(ii) acidified aqueous potassium manganate (VII)	no reaction **AND**	purple decolourises / solution turns yellow **AND**	purple decolourises / turns colourless 1
warm gently	purple decolourises / turns colourless 1		
(iii) hydrogen peroxide		solution turns yellow / effervescence **AND**	no reaction / no change 1
		gas relights glowing splint 1	
(iv) hydrochloric acid, then		no reaction / no change / no ppt.	brown gas / colourless bubbles / gas turning brown in air / blue solution
Ba^{2+} (aq)		**AND** white ppt. 1	**AND** no reaction 1

3(b)(i)			3

	cation(s)	anion(s)
FA 5	unknown	unknown
FA 6	Fe^{2+} / iron(II) and NH_4^+ / ammonium	SO_4^{2-} / sulfate
FA 7	unknown	NO_2^- / nitrite

3(b)(ii)	clearly shows the reagent and expected observation(s)	1
	add NH_3 **AND** green ppt. **AND** insoluble in an excess of ammonia / turning brown (on standing)	1
3(b)(iii)	$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ **OR** $[Fe(H_2O)_6]^{2+}(aq) + 2NH_3(aq) \rightarrow [Fe(OH)_2(H_2O)_4](s) + 2NH_4^+(aq)$	1

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FA 5 is $NaNO_3(s)$; FA 6 is $CuCO_3(s)$; FA 7 is $NaBr(aq)$

3(a)(i)

FA 5	FA 6	
(goes to) colourless or yellow liquid/ solution	(green) powder / solid (turns) black / black residue	1+1
gas relights glowing splint	or gas turns limewater milky / cloudy white / chalky / forms white ppt	1
gas (turns) brown / brown gas or solution turns blue	(pale) blue solution / liquid formed	1+1

3(a)(ii)–(iv)

FA 5	FA 6	
(iii) solid dissolves / colourless solution allow no reaction / no change / no effervescence	effervescence / fizzing / bubbling and blue solution / liquid formed	1
(iv) no reaction / no change / no ppt / remains colourless	blue ppt and insoluble in excess	1
(v) no reaction / no change / no ppt / remains colourless	(pale) blue ppt and soluble in excess to give deep / dark blue (solution)	1

3(a)(v)	FA 5: cation unknown; anion nitrate / NO_3^- FA 6: cation Cu^{2+} / copper(II); anion carbonate / CO_3^{2-} 4 correct = 3 marks 3 correct = 2 marks 2 correct = 1 mark	1 1 1	
3(a)(vi)	$CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$	1	12
3(b)(i)	Selects $AgNO_3$ and NH_3 Selects NaOH and Al and HCl / HNO_3 / H_2SO_4	1 1	
3(b)(ii)	Clearly defined test | observation | conclusion sections	1	
	FA 7 + $AgNO_3$ cream ppt partially soluble in NH_3	1	
	FA 7 is bromide / Br^- from cream ppt	1	
			5
	Total		17

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FA5 is $MnSO_4$ and NH_4Cl; **FA6** is propanone; **FA7** is propanal;

3 (a) (i)	Red litmus turns blue (then red)	1	
	Condensation or sublimation / white smoke / white fumes	1	[2]
(a) (ii) and (b) (i)	NH_4^+ / ammonium in **3(a)(ii) and** Mn^{2+} / manganese(II) in **3(b)(i).**	1	
(b) (i)	Selects NaOH and NH_3	1	
	Off-white / beige / light brown precipitate with both NaOH **and** NH_3	1	
	Both precipitates turns brown / darkens	1	
(ii)	white precipitate **and** insoluble in acid	1	

(iii)	Selects $AgNO_3$/silver nitrate **and** NH_3/ammonia	1	
	White precipitate **and** insoluble / partially soluble in ammonia	1	
	Cannot see if precipitate dissolves in ammonia / Mn^{2+} causes (off-white) precipitate (so cannot be used to distinguish between halides).	1	[8]
(c)	$MnCl_2$ **and** $(NH_4)_2SO_4$ **or** $MnSO_4$ **and** NH_4Cl	1	[1]

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FA 6 is Na_2SO_3; FA 7 is $CaCl_2$; FA 8 is $MgSO_4$; FA 9 is $Al_2(SO_4)_3$; FA 10 is $MnSO_4$			
3 (a) (i)	**Both observations required** • white precipitate with Ba^{2+} ion • Precipitate dissolves / partially dissolves in (excess) HCl	1	
(ii)	**Both observations required** • white precipitate with Ba^{2+} ion • precipitate insoluble / no change with HCl	1	
(iii)	When heated, gas produced decolourises $KMnO_4$ paper.	1	
(iv)	No change (when NaOH added) / no ppt / no reaction **and** green (solution) formed when $KMnO_4$ added	1	
	Colourless solution(with acid)	1	
(v)	Anion is sulfite **and** one piece of evidence • **FA 6** with acid – SO_2 / gas which decolourises $KMnO_4$ is formed **or** • **FA 6** with Ba^{2+} – white precipitate / $BaSO_3$ formed which dissolves in acid / partially soluble in acid	1	
(vi)	$Na_2SO_3 + H_2O_2 \rightarrow Na_2SO_4 + H_2O$	1	[7]
(b) (i)	(see table below)	5	
(ii)	Conclusions • **FA 7** – calcium / Ca^{2+} **or** barium/Ba^{2+} • **FA 8** – magnesium / Mg^{2+} • **FA 9** – aluminium / Al^{3+} • **FA 10** – manganese(II)/Mn^{2+} *Four correct = 2 marks* *Two or three correct = 1 mark*	2	

	FA 7	FA 8	FA 9	FA 10
NaOH	white ppt	white ppt	white ppt	off-white / buff / beige / light brown ppt
excess NaOH	no change **or** insoluble in excess	no change **or** insoluble in excess	(ppt) dissolves **or** soluble in excess	insoluble in excess **or** ppt darkens *(owtte)*
NH_3	no ppt **or** no reaction	white ppt	white ppt	off-white / buff / beige / light brown ppt
excess NH_3	*(ignore)*	no change **or** insoluble in excess	no change **or** insoluble in excess	insoluble in excess **or** ppt darkens *(owtte)*

(iii)	$M^{2+} + 2OH^- \rightarrow M(OH)_2$ (for any divalent cation) **or** $M^{3+} + 3OH^- \rightarrow M(OH)_3$ (for any trivalent cation)	1	
(iv)	Use higher concentration	1	[9]
Qn 3			**[Total: 16]**

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FA 5 is $(NH_4)_2Fe(SO_4)_2(aq)$; FA 6 is $CuCO_3 + MgSO_4.7H_2O$			
3 (a)	Fizzing	1	
	Acid or any named acid	1	[2]
(b)(i)–(vi)	In **(i)** (solid goes from green) to black / grey	1	
	In **(i)** condensation / water / water vapour / steam / steamy fumes	1	
	In **(ii)** fizzing **and** forms a (light) blue solution .	1	
	Cloudy with limewater in **(i)** or **(ii)** or **(a)**	1	
	In **(ii)** blue ppt with sodium hydroxide and insoluble in excess.	1	
	Any **2** from: In **(iv)** white ppt insoluble in excess	1	
	In **(v)** white ppt insoluble in excess In **(vi)** white ppt	1	
(vii)	Cation: Cu^{2+}	1	
	Cation: Mg^{2+}	1	
	Anions: CO_3^{2-} **and** SO_4^{2-} **and** SO_3^{2-}	1	
(viii)	Selects acid/ named acid to add to test **(vi)** (**not** H_2SO_4) **or** Selects named acid to add to **FA 6 and** tests with $H^+/Cr_2O_7^{2-}$ or H^+/MnO_4^- **and** SO_4^{2-} insoluble and SO_3^{2-} soluble **or** SO_4^{2-} no change and SO_3^{2-} (orange) turns green or (purple) turns colourless	1	[11]
Qn 3	**Total**		**[13]**

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FA 6 is $NaNO_3(s)$; FA 7 is $AgNO_3(aq)$; FA 8 is $ZnCO_3(s)$			
2 (a) (i)	Chooses NaOH(aq) (+ heat) (to distinguish NH_4^+ / ammonium) Chooses named (allow name from **(ii)**) dilute acid / (acidified) $KMnO_4$ (to distinguish between NO_2^- / nitrite and NO_3^- / nitrate) 2 ions chosen: NH_4^+ & NO_3^- : NaOH (and warm) NO_2^- & NO_3^- : named (dilute) acid NH_4^+ & NO_2^- : either of the above	1 1	
(ii)	Correct obs with relevant tests With NaOH **and** warming / heating: no ammonia / no change / no reaction With acid(aq): no brown fumes / no change / no reaction *'No observation' is not credited anywhere in the observations.*	1 1	
(iii)	**FA 6** contains NO_3^- (*with sufficient obs to eliminate other ion(s) given in* ***(i)***)	1	[5]

(b)	+ HCl(aq): white ppt	1	
	+ KI: yellow ppt	1	
	+ NH_3: no effect/ppt insol	1	
	+ glucose: silver mirror/black/(dark) grey ppt	1	[4]
(c) (i)	(Solid is) yellow when heated	1	
	Goes white/paler on cooling	1	
(ii)	effervescence/fizzing/rapid bubbling **and** limewater turns milky	1	
(iii)	White ppt **and** soluble in excess NaOH	1	
(iv)	White ppt **and** soluble in excess NH_3	1	
(v)	Ions present: Zn^{2+} **and** CO_3^{2-} (from fizz **or** limewater test correct)	1	[6]
Qn 2		**Total**	**[15]**

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FA 6 is $ZnSO_4$(aq) and NaBr(aq); FA 7 is $FeSO_4$(aq)				
3 (a) (i)	MMO Decisions	**I** Selects NaOH(aq) and NH_3(aq), and uses each in excess	1	
	PDO Layout	**II** Unambiguous layout of all 4 observations (excess must be stated).	1	
	MMO Collection	**III** White ppt with NaOH and soluble in excess.	1	
		IV White ppt with NH_3 soluble in excess.	1	
	ACE Conclusion	**V** Zn^{2+}	1	
(ii)	MMO Collection	**VI** Cream ppt with $AgNO_3$ **and** partially sol / insol in NH_3	1	
		VII White ppt with $BaCl_2$/$Ba(NO_3)_2$ **and** insol in nitric acid.	1	
	ACE Conclusion	**VIII** Br^-	1	
		IX SO_4^{2-}	1	[9]
(b) (i)	MMO Collection	**I** Green ppt turning brown (in contact with air)	1	
(ii)		**II** No reaction/no change **or** yellow or green solution	1	
(iii)		**III** Red-brown/brown/green-brown ppt **and** effervescence	1	
		IV Gas relights a glowing splint	1	
(iv)	ACE Conclusion	**V** Redox	1	
(v)		**VI** Decomposition of hydrogen peroxide to give oxygen **or** ppt is $Fe(OH)_3$ / oxidation of Fe^{2+} to Fe^{3+}	1	[6]
Qn 3	**Total**		**[15]**	

Q# 54/ Qi Qualitative: Inorganic ions test ALvl Chemistry/2013/w/TZ 1/ Paper 3/Q# 3/ :o)
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FA 6 is $(NH_4)_2Fe(SO_4)_2$(s); FA 7 is Na_2CO_3(aq); FA 8 is $Pb(NO_3)_2$(aq); FA 9 is K_2CrO_4(aq)				
3 (a) (i)	MMO Collection	Green precipitate **and** ppt insoluble in excess NaOH/ppt turning brown (in air / on standing).	1	
	MMO Decision	(When heated with NaOH) **gas** / NH_3 turns red litmus to blue.	1	
	MMO Collection	(With $BaCl_2$), white precipitate forms **and** insoluble in HCl.	1	
(ii)	ACE Conclusion	**FA 6** contains ammonium ions **and** sulfate ions. *(correct evidence needed for each ion in the observations table).*	1	
(iii)	ACE conclusion	$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$	1	
(iv)	MMO collection	**Any two** of • Solid goes paler / loses green colour (at first) **and then** becomes brown (on strong heating) • Condensation / water vapour / steam produced • (Gas/NH_3) turns red litmus blue.	1 1	[7]

Q# 55/ Qi Qualitative: Inorganic ions test ALvl Chemistry/2012/w/TZ 1/ Paper 3/Q# 2/ :o)
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FA 3 is $CuCl_2$(aq); FA 4 is $AlK(SO_4)_2$(aq) + KI(aq); FA 5 is $FeCl_3$(aq); FA 6 is $Pb(NO_3)_2$(aq)				
2 (a)	MMO Collection	Records a blue/greenish-blue ppt/solid with **FA 3** and Na_2CO_3.	1	
		Records a brown/rust/orange-brown/red-brown ppt/solid with **FA 5** and Na_2CO_3.	1	
		Records effervescence with **FA 5** (or **FA 3**).	1	
	MMO Decisions	Tests gas evolved with limewater. Allow from effervescence.	1	[4]
(b)	MMO Collection	Records a white precipitate with silver nitrate solution **and** soluble in aqueous ammonia.	1	[1]
(c)	MMO Collection	Records yellow-brown/orange-brown/brown/tan colour (solid/solution) (formed on mixing **FA 4** and **FA 3**). Allow dark brown for solution **only**. Allow (qualified) brown solution with white/off-white/grey ppt.	1	
		Dark/deep blue/blue-black/black/purple colour on adding starch solution	1	[2]

Q# 56/ Qi Qualitative: Inorganic ions test ALvl Chemistry/2011/w/TZ 1/ Paper 3/Q# 2/ :o)
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FA 3 is $Na_2S_2O_5$(s); **FA 4** is Na_2CO_3(s); **FA 5** is Na_2SO_4(s); **FA 6** is $Pb(NO_3)_2$(s) and (aq)				
2 (a)	MMO Decisions	(i) **I** Any named mineral acid or formula or (acidified) potassium dichromate. Do **not** allow any reagent suitable for testing cations or more than one reagent.	1	
	PDO Recording	(ii) **II** Tabulates evidence of 3 tests carried out with no repeat headings. **Only** consider observations with acid or dichromate.	1	
	MMO Collection	**III** Bubbles/effervescence in **FA 4**.	1	
		IV Slower effervescence in **FA 3** than **FA 4** or **FA 3** turns green **and FA 5** stays orange if dichromate used.	1	
	MMO Decisions	**V** Appropriate test with positive result used to test for either gas.	1	
	ACE Conclusions	**VI** All three ions correct from suitable observations. **FA3** is a sulfite. **FA4** is a carbonate. **FA5** is a sulfate. (or correct formulae)	1	[6]

Q# 57/ Qi Qualitative: Inorganic ions test ALvl Chemistry/2011/s/TZ 1/ Paper 3/Q# 3/ :o)
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		FA 7 is $Zn(NO_3)_2$(s); **FA 8** is $CuSO_4$(s)		
3 (a) (i)	MMO Collection	No change (*or* no precipitate **or** no reaction) both with barium chloride and silver nitrate.	1	
	MMO Collection	**Gentle** heat: solid melts **or** dissolves **or** gives a colourless liquid	1	
(ii)		Brown fumes/gas produced (allow 'qualified' brown e.g. red/brown, do not allow orange).	1	
		(Gas produced) that relights a glowing splint **or** yellow solid, goes white on cooling. (Allow precipitate).	1	
(iii)	ACE Conclusions	**FA 7** is a nitrate/nitrite (from some evidence)	1	
(iv)	MMO Decisions	(Heat) **FA 7** with *Al* foil and NaOH/ecf from anion given.	1	
	MMO Collection	Gas/vapour/NH3 produced ***and*** it turns red litmus to blue ***and*** confirms that **FA 7** contains nitrate/nitrite ions.	1	
(v)	MMO Decisions	Adds ammonia. *(This mark is **not** awarded if a second test is also used)*	1	
	ACE Conclusions	Zinc ions are present. (No ecf) *(Deduction **must** be consistent with observations recorded – white ppt soluble in excess).*	1	[9]

(b) (i)	MMO Collection	With KI, goes yellow/orange/brown ***and*** gives a blue (blue-black ***or*** purple ***or*** black) colour with starch. *No reference to the state is required, just the colours.*	1	
		Brown/yellow/white/off- white precipitate forms.	1	
(ii)	ACE Conclusions	KI is the reducing agent (**or** it is oxidised) as iodine is formed **or** $2I^- - 2e^- \rightarrow I_2$ **or** $2Cu^{2+} + 2I^- \rightarrow I_2 + 2Cu^+$ *Ignore state symbols.*	1	
(iii)	MMO Collection	Blue (do not allow dark blue) precipitate obtained, which does not dissolve in excess NaOH	1	
	ACE Conclusions	$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$	1	[5]
				[Total: 14]

Q# 58/ Qi Qualitative: Inorganic ions test ALvl Chemistry/2010/s/TZ 1/ Paper 3/Q# 2/ :o)
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Question 2

Question	Sections	Indicative material	Mark	
FA 3 is $BaCl_2$(aq); **FA 4** is $MgBr_2$(aq) *[$MgCl_2$ + NaBr]*; **FA 5** is CaI_2(aq) *[$CaCl_2$ + NaI]*; **FA 6** is K_2CrO_4(aq)				
2 (a)	MMO Decisions	Chooses silver nitrate/Ag^+(aq)/solution containing Ag^+ ions followed by (aqueous) ammonia.	1	[1]
(b)	PDO Recording	Results for three solutions and the two reagents from **(a)** (or three reagents if **(a)**: 'Ag^++ NH_3', Pb^{2+}) if recorded in a single table *(no repetition of solutions or reagents)*	1	
	MMO Collection	Give one mark for correct observations with **FA 3, FA 4** and **FA 5**. **FA 3** – white ppt with Ag^+, soluble in NH3(aq) **FA 4** – cream ppt with Ag^+, partially soluble or insoluble in NH_3(aq) (allow "creamy" not "creamy white") **FA 5** – yellow ppt with Ag^+, insoluble in NH_3(aq) If Ag^+ and Pb^{2+} in **(a)**, all observations must be correct (ignore any 'extra' NH_3 if not in **(a)**) (Pb^{2+}: white, white, yellow ppts respectively)	1	[2]
(c)	ACE Conclusion	Mark consequentially on observations in **(b)** Expected conclusion Identifies **FA 3** as solution containing Cl^- from "white ppt with Ag^+ (soluble in NH_3(aq)) given as evidence. *Mark consequentially – ecf allowed here. (No retrospective to observations)*	1	[1]
(d)	MMO Collection	Mark each of the boxes and see whether correct columns or rows give the better mark. Award the better mark. See table below for the expected observations	1 1 1	[3]

	FA 3	FA 4	FA 5
+ NaOH(aq)	**ignore**	white ppt	white ppt **or** "cloudiness"
+ NH_3(aq)	no ppt *(allow reference to "cloudiness"/"slight white ppt")*	white ppt	no ppt/no change/ no reaction

Qi Qualitative inorganic ions tests Chem 12 Q# 1/ ALvl Chemistry/2022/w/TZ 1/Paper 3/Q# 3 :o)
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Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **(a)** **FA 6** is an aqueous solution that contains one cation and two anions. The three ions are listed in the Qualitative analysis notes.

(i) Carry out the following tests on **FA 6** and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 6** in a boiling tube add aqueous sodium hydroxide, then	
heat gently.	
Test 2 To a 1 cm depth of **FA 6** in a boiling tube add a 1 cm depth of aqueous sodium hydroxide and a piece of aluminium foil. Heat gently.	
Test 3 To a 1 cm depth of **FA 6** in a test-tube add a few drops of hydrogen peroxide.	

[4]

(ii) From your observations suggest **two** possible identities for the cation in **FA 6**.

possible cations: .... and .... [1]

(iii) Suggest a test that would allow you to determine which of the cations you suggested in **(a)(ii)** is present in **FA 6**.

Carry out this test, record the result and hence identify the cation in **FA 6**.

test ....

result ....

The cation present is ....

[2]

(iv) From your observations in **(a)(i)** suggest **two** anions that could be present in **FA 6** and give their formulae.

possible anions: .... or .... [1]

(v) Suggest an additional test that could be carried out to confirm the presence of **one** of the anions you suggested in **(a)(iv)**.

Carry out this test, record the result and hence state the identity of the anion.

test ....

result ....

The anion present is ....

[2]

Qualitative inorganic ions tests **Chem 12 Q# 2/** ALvl Chemistry/2022/s/TZ 1/Paper 3/Q# 3 :o)
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Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **(a)** **FA 5** is an ionic solid containing two ions. It contains one or more ions that contain nitrogen.

(i) Carry out suitable tests to identify the anion. Reserve a small amount of **FA 5** for use in **(a)(ii)**.

Record the tests you carry out and the observations you make, in a table, in the space below.

You **must** use a boiling tube if any liquid is heated.

anion in **FA 5** = ... [4]

(ii) Heat a small spatula measure of **FA 5** in a hard-glass test-tube.
When no further change occurs, allow the tube and its contents to cool completely.

Record **all** the observations you make and any subsequent conclusions.

....

....

....

.... [2]

(b) **FA 6** is a solution of a compound containing one cation and one anion, both of which are in the Qualitative analysis notes.
FA 7 is an aqueous mixture of two substances. **FA 7** contains one potassium-containing compound and one other substance. All substances are listed in the Qualitative analysis notes.

(i) Carry out the following tests. Complete the table below.
Use a 1 cm depth of **FA 6** or **FA 7** in a test-tube for each test.

Table 3.1

test	*observations*	
	FA 6	**FA 7**
Test 1 Add aqueous sodium hydroxide.		
Test 2 Add aqueous barium chloride or aqueous barium nitrate, then		
add dilute hydrochloric acid.		
Test 3 Add a few drops of aqueous starch, then	✕	
add aqueous sodium thiosulfate.	✕	
Test 4 Add a few drops of aqueous silver nitrate, then		
add a few drops of aqueous sodium hydroxide.		
Test 5 Add aqueous ammonia.		✕

[5]

(ii) Give the formulae of the substances in **FA 6** and **FA 7**.

FA 6 is ....

FA 7 contains .... and .... [3]

(iii) Give the ionic equation for **one** of the reactions taking place in **Test 1**.
Include state symbols.

.... [1]

[Total: 15]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **FA 7** and **FA 8** are solutions containing a total of three cations and two anions. Two of the cations and both of the anions are listed in the Qualitative analysis notes.

(a) (i) Carry out the following tests and record your observations. Use a fresh 1 cm depth of solution in a test-tube for each test.

test	*observations*	
	FA 7	**FA 8**
Test 1 Add a 1 cm depth of dilute nitric or hydrochloric acid and allow to stand for 2 minutes, then		
add a few drops of aqueous barium nitrate or aqueous barium chloride.		
Test 2 Add a few drops of acidified aqueous potassium manganate(VII).		
Test 3 Add a few drops of aqueous iron(III) chloride and allow to stand for 1 minute.		

[4]

(ii) From your test results, give the formulae of the anions present in **FA 7** and **FA 8**. If the tests do not allow you to positively identify an anion, write 'unknown'.

anion in **FA 7** = ...

anion in **FA 8** = ...

[2]

(b) (i) Select reagents for tests to identify as many of the cations as possible in **FA 7** and **FA 8**. Carry out your tests and record your reagents, conditions and observations.

[4]

(ii) From your test results, give the formulae of as many cations as possible in **FA 7** and **FA 8**. If the tests do not allow you to positively identify a cation, write 'unknown'.

FA 7 contains ....

FA 8 contains ....

[2]

(iii) Write an ionic equation for **one** reaction you observed in **(b)(i)**. Include state symbols.

.... [1]

[Total: 13]

Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

(b) **FA 8** is an aqueous solution.

(i) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 8** in a test-tube, add a few drops of acidified potassium manganate(VII). Place the tube in the hot water-bath.	
Test 2 To a 1 cm depth of **FA 8** in a test-tube, add a 1 cm length of magnesium ribbon.	

[2]

(ii) For each observation, state what you can conclude about the chemical properties of **FA 8**.

Test 1 ....

Test 2 ....

[2]

[Total: 14]

Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 Half-fill the 250 cm^3 beaker with water and place it on a tripod and gauze above a heatproof mat. Heat the water until boiling and then turn off the Bunsen burner. You will use this as a hot water-bath in **3(b)(i)**.

(a) **FA 5**, **FA 6** and **FA 7** are solutions. Each solution contains one cation and one anion. Carbonate, CO_3^{2-}, is **not** present in any of the solutions.

(i) Carry out the following tests and record your observations.
Use a 1 cm depth of solution in a test-tube for each test.

test	*observations*		
	FA 5	**FA 6**	**FA 7**
Test 1 Add an equal depth of dilute sulfuric acid.			
Test 2 Add an equal depth of aqueous sodium carbonate.			
Test 3 Add an equal depth of aqueous magnesium chloride.			

[5]

(ii) Use your observations in **(a)(i)** to suggest a **possible** formula for each of the following:

The cation in **FA 5** is ....

The cation in **FA 6** is ....

The anion in **FA 7** is ....

[3]

(iii) Apart from using an indicator, suggest a further test that would confirm the identity of the anion in **FA 7**.

Carry out this test and record the result.

....

....

.... [1]

(iv) Did the result of your test in **(a)(iii)** confirm the identity of the anion in **FA 7**? Explain your answer.

....

....

.... [1]

Qualitative inorganic ions tests **Chem 12 Q# 6/** ALvl Chemistry/2021/s/TZ 1/Paper 3/Q# 3 :o)
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Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 (a) Aqueous ammonium thiocyanate reacts with aqueous iron(III) ions to form an orange or red coloured compound. Iron(II) ions do not react in this way. The darker the orange or red colour, the more iron(III) ions are present in the solution.

(i) For each test use a 1 cm depth of **FA 1** in a test-tube. Record all your observations.

test	*observations*
Test 1 Add a few drops of aqueous ammonium thiocyanate.	
Test 2 Add a few drops of aqueous sodium hydroxide and leave for at least two minutes, then	
add dilute sulfuric acid dropwise until there is no further change, then	
add a few drops of aqueous ammonium thiocyanate.	

[3]

(ii) Suggest a reason for any difference in observation when you added aqueous ammonium thiocyanate in **Test 2** compared with **Test 1**.
Your answer should refer to the type of reaction that occurred in **Test 2**.

....

....

.... [2]

(iii) The charge on the thiocyanate ion, SCN^-, is –1.

Determine the formula of ammonium thiocyanate.

.... [1]

(iv) A solution containing Fe^{2+} reacts with aqueous ammonia to form a green precipitate.

Write the ionic equation for this reaction.
Include state symbols.

.... [2]

(b) **FA 4** contains one cation and one anion, both of which are listed in the Qualitative Analysis Notes. The anion in **FA 4** contains sulfur.

(i) Carry out appropriate tests to allow you to identify the cation and anion in **FA 4**.

Record each test and your observations in a suitable form below.

[7]

(ii) Give the formula of the ions present in **FA 4**.

cation ....

anion ....

[1]

[Total: 16]

Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** **FA 6** contains one cation and one anion both of which are listed in the Qualitative analysis notes.

(i) Heat **FA 6** gently for one minute in the hard-glass test-tube in which it is supplied.
Then heat strongly until no further change occurs.

Record **all** of your observations.

....

....

....

....

.... [2]

(ii) Identify the ion that **must** be present in **FA 6**.

.... [1]

(b) (i) **FA 7** and **FA 8** are aqueous solutions.
Each solution contains one cation and one anion both of which are listed in the Qualitative analysis notes.
Use 1 cm depths of **FA 7** or **FA 8** in test-tubes for the following tests.
Complete the table by recording your observations.

test	*observations*	
	FA 7	**FA 8**
Test 1 Add a few drops of aqueous acidified potassium manganate(VII), then		
add a few drops of starch indicator.		
Test 2 Add a few drops of aqueous silver nitrate, then		
add aqueous ammonia.		
Test 3 Add aqueous sodium hydroxide, then		
pour the mixture into a boiling tube. Warm gently and **carefully**, then		
add a piece of aluminium foil.		
Test 4 Add a few drops of dilute sulfuric acid.		

[6]

(ii) Deduce the chemical formulae of **FA 7** and **FA 8**.

FA 7 is .... and **FA 8** is .... [2]

(iii) Give the ionic equation for the reaction of **FA 8** with sulfuric acid.
Include state symbols.

.... [1]

[Total: 12]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 (a) **FA 6** is a salt containing one cation and one anion. The anion is listed in the Qualitative Analysis Notes.
Add all the sample of **FA 6** to the 100 cm^3 beaker. Dissolve the solid in approximately 50 cm^3 of distilled water.
Label this solution **FA 7**.

(i) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 7** in a test-tube, add a 3 cm depth of aqueous silver nitrate.	
Pour approximately half the contents of the test-tube into a clean test-tube.	
Test 2 To the first test-tube add aqueous ammonia.	
Test 3 To the second test-tube add **FA 5**, aqueous sodium thiosulfate.	

[2]

(ii) From the results of your tests in **(a)(i)** suggest which anion is present in **FA 6**.

.... [1]

(iii) It is suggested that **FA 6** could be sodium sulfite, Na_2SO_3, or sodium sulfate, Na_2SO_4.

Carry out tests using solution **FA 7** in order to decide whether **FA 6** is sodium sulfite or sodium sulfate.
Record the reagents selected, the results of your tests and your conclusions in the space below.

FA 6 is sodium .... [2]

(iv) Using your conclusion from **(a)(iii)**, write an ionic equation for the reaction between silver nitrate and **FA 7**.
Include state symbols.

.... [1]

(b) **FA 8** is a solution containing one of the cations listed in the Qualitative Analysis Notes.

(i) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 8** in a test-tube, add aqueous ammonia until there is no further change, then	
pour the contents into a boiling tube and add a few drops of aqueous hydrogen peroxide.	

[3]

(ii) Identify the cation in **FA 8**.

cation = ... [1]

(iii) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 8** in a test-tube, add a 1 cm depth of aqueous potassium iodide, then	
add **FA 5**, aqueous sodium thiosulfate.	

[2]

(iv) Explain your observations in **(b)(iii)**.

....

....

.... [2]

[Total: 14]

Qualitative inorganic ions tests **Chem 12 Q# 9/** ALvl Chemistry/2020/s/TZ 1/Paper 3/Q# 3 :o)
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Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** **FA 6** is a hydrated salt. It contains two cations and one anion, all of which are listed in the Qualitative Analysis Notes.

(i) Describe and carry out tests to identify the cations in **FA 6**.

Record your tests and observations in the space below.

The cations in **FA 6** are .... and ....
[5]

(ii) The anion in **FA 6** is a sulfite, sulfate or a halide.

Carry out a test to identify the anion in **FA 6**.
Record your tests and observations in the space below.

The anion in **FA 6** is .... [2]

(iii) Give the ionic equation for **one** reaction you have carried out in **(a)(i)** or **(a)(ii)**.
Include state symbols.

.... [1]

(iv) The formula of **FA 6** is $XY_2Z_2 \cdot wH_2O$ where

- **X** and **Y** are the cations present and **Z** is the anion present
- **w** is the number of moles of water of crystallisation in the hydrated salt.

The relative formula mass of this compound is 392.0.

Using your conclusions from **(a)(i)** and **(a)(ii)**, calculate the value of **w**, the number of moles of water of crystallisation.

w = ... [2]

Qualitative inorganic ions tests **Chem 12 Q# 10/** ALvl Chemistry/2020/m/TZ 3/Paper 3/Q# 3 :o)
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Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 (a) **FA 3** is aqueous hydrogen peroxide, H_2O_2.
FA 6 is a solution containing two cations and one anion from those listed in the Qualitative analysis notes.

(i) To a 1 cm depth of **FA 6** in a boiling tube, add aqueous sodium hydroxide until it is in excess. Then heat the tube, gently and carefully.
Keep the mixture obtained in the boiling tube for the test in **(a)(ii)**.

Record **all** your observations.
Identify the cations in **FA 6**.

observations ....

....

....

....

....

FA 6: cations are .... and .... [4]

(ii) To the mixture obtained from **(a)(i)**, carefully add a 1 cm depth of **FA 3**.
Record your observations.

....

.... [1]

(iii) One reaction taking place in **(a)(ii)** involves oxidation of one of the cations in **FA 6**.

Give the half-equation to show this oxidation reaction. State symbols are not required.

.... [1]

(b) **FA 1** is aqueous potassium manganate(VII).
FA 2 is dilute sulfuric acid.
FA 7 and **FA 8** are solutions, each containing one cation and one anion.

(i) Carry out the following tests and record your observations in the table.

test	*observations*	
	FA 7	**FA 8**
Test 1 To a 1 cm depth of solution in a test-tube, add a small spatula measure of solid sodium carbonate.		
Test 2 To a 1 cm depth of solution in a test-tube, add an equal volume of **FA 2** and a few drops of **FA 1**, then		
add a few drops of aqueous starch.		
Test 3 To a 1 cm depth of solution in a test-tube, add a few drops of aqueous silver nitrate, then		
add aqueous ammonia.		

[5]

(ii) Identify the anion in **FA 7**.

anion .... [1]

(iii) Identify **FA 8**.

FA 8 is .... [1]

(iv) Carry out one further test to confirm the identity of the cation in **FA 8**.
State the name of the reagent you used and record the observation(s) you made.

reagent ....

observation(s) ....

.... [1]

[Total: 14]

Qualitative inorganic ions tests Chem 12 Q# 11/ ALvl Chemistry/2019/w/TZ 1/Paper 3/Q# 3 :o)
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Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** **FA 5** is a salt that contains two different cations and a single anion from those listed in the Qualitative Analysis Notes.

(i) Place a small spatula measure of **FA 5** in a hard-glass test-tube and heat **gently**.
Do not inhale the fumes.
Record **all** your observations.

....

....

....

.... [2]

(ii) Pour a 4 cm depth of distilled water into a boiling tube. Add the remaining **FA 5** and stir carefully until the solid has dissolved. This solution is **FA 6**.
Carry out the following tests on **FA 6** and record your observations.

test	*observations*
To a 1 cm depth in a test-tube, add aqueous ammonia.	
To a 1 cm depth in a boiling tube, add aqueous sodium hydroxide, then	
warm the mixture.	

test	*observations*
To a 1 cm depth in a test-tube, add aqueous barium nitrate or aqueous barium chloride, then	
add dilute hydrochloric acid or dilute nitric acid.	

[4]

(iii) Identify the three ions in **FA 5**.

FA 5 contains .... , ... and ....

[2]

(b) A student carried out Qualitative Analysis tests on a hydrated salt, **FA 7**, and concluded that it contained the ions K^+, Cr^{3+} and SO_4^{2-}.
The relative formula mass of **FA 7** is 499.3.

Determine the formula of **FA 7**.

The formula of **FA 7** is ....

[2]

(c) **FA 8** is a solution containing a single cation and a single anion, both of which are listed in the Qualitative Analysis Notes.

(i) Carry out the following tests and record your observations.

test	*observations*
To a 1 cm depth in a test-tube, add a few drops of aqueous acidified potassium manganate(VII), then	
add starch indicator.	
To a 1 cm depth in a test-tube, add aqueous sodium hydroxide.	

[2]

(ii) Identify the two ions in **FA 8**.

FA 8 contains .... and ....

[1]

(iii) Suggest an additional test you could carry out to confirm the presence of the anion in **FA 8**.

Carry out this test and record your result.

[2]

(iv) Give the ionic equation for the reaction you carried out using **FA 8** and sodium hydroxide. Include state symbols.

.... [1]

[Total: 16]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 (a) **FA 4** and **FA 5** are aqueous solutions each containing one anion and one cation.

(i) Carry out the following tests and record your observations. For each test use a 1 cm depth of **FA 4** or **FA 5** in a test-tube.

test	*observations*	
	FA 4	**FA 5**
Add a 1 cm depth of dilute hydrochloric acid. Leave to stand.		
Add a 1 cm depth of aqueous copper(II) sulfate. Leave to stand.		
Add a few drops of aqueous silver nitrate, then		
add aqueous ammonia.		
Add a 1 cm depth of aqueous chlorine, then		
add a 1 cm depth of **FA 5**.		

[5]

(ii) From your observations in **(a)(i)** identify one of the ions present in either **FA 4** or **FA 5**.

Ion present in .... is .... [1]

(iii) Apart from the reaction with **FA 5** suggest a test that could be used to identify the coloured product formed in the reaction between aqueous chlorine and **FA 4**. You should include the reagent used and the expected observation.

Do not carry out this test.

reagent ....

expected observation ....
[1]

(b) (i) Place the cooled crucible and residue from **Question 2** onto a heatproof mat and add approximately $5\,cm^3$ of water.

Test the solution with litmus papers.
Record your observations.

....

.... [1]

(ii) Using **Q**O as the formula of the residue, write the equation for the reaction with water that occurs in **(b)(i)**. Include state symbols.

.... [1]

(c) In **Questions 1** and **2** you identified the Group 2 metals present in $\mathbf{M}CO_3$ and $\mathbf{Q}CO_3$.

You will now plan and carry out tests to confirm, or not confirm, the identities of **M** and **Q**. Both **M** and **Q** are listed in the Qualitative Analysis Notes.

(i) Group 2 carbonates are insoluble in water. In order to test for the cations present ($\mathbf{M}^{2+}$ and $\mathbf{Q}^{2+}$) they must be in solution.

Name a reagent you could use to prepare solutions of the cations from solid samples of $\mathbf{M}CO_3$ and $\mathbf{Q}CO_3$.

.... [1]

(ii) You are provided with the following solutions.
FA 6 contains $\mathbf{M}^{2+}$(aq).
FA 7 contains $\mathbf{Q}^{2+}$(aq).

Choose reagents that could be used to confirm the identity of **M** and **Q**.
Carry out the tests. Record the tests, observations and conclusions.

[5]

(iii) Do your conclusions confirm your identification of **M** and **Q** in **Questions 1** and **2**? Explain your answer.

....

....

.... [1]

[Total: 16]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **FA 4** is a solid containing one cation and one anion.
FA 5 is a solution containing one cation and one anion.
Carry out the following tests and record your observations.

(a) **(i)** Warm (do **not** boil) a 5 cm depth of **FA 5** in a boiling tube. Stop warming the **FA 5**, add all of the **FA 4** and shake the boiling tube.

....

Filter the mixture into a second boiling tube. The filtrate will be used in the tests in **(ii)**.

....
[2]

(ii) Use a 1 cm depth of the filtrate from **(i)** in separate test-tubes for each of the following tests.

test	*observations*
Add aqueous ammonia.	
Add a 1 cm depth of aqueous potassium iodide, then	
add aqueous sodium thiosulfate. (Rinse the test-tube when you have completed this test.)	
Add a 1 cm depth of dilute nitric acid followed by a 1 cm depth of aqueous silver nitrate.	
Add a 1 cm depth of dilute hydrochloric or dilute nitric acid followed by a 1 cm depth of aqueous barium chloride or aqueous barium nitrate.	

[5]

(iii) **FA 6** is a dry sample of the residue obtained by filtration in **(i)**.

test	*observations*
Add a 1 cm depth of dilute nitric acid to all of the **FA 6** in its test-tube. Allow the mixture to stand for about 1 minute, then	
add aqueous sodium hydroxide.	

[2]

(b) **(i)** From your observations in **(a)**, suggest the identity of the cation and the anion present in the filtrate produced in **(a)(i)**.

cation present in the filtrate ....

anion present in the filtrate ....

[1]

(ii) Write an ionic equation for **one** reaction in **(a)(ii)** where a precipitate was formed. Include state symbols.

.... [1]

(iii) State the type of reaction that occurred in the first part of **(a)(iii)**.

.... [1]

(c) A student suggested that **FA 5** is an acid.

Apart from using an indicator, suggest and carry out a chemical test to determine whether the student was correct.

Record the name of the reagent you used, your observations and your conclusion.

[3]

[Total: 15]

Qualitative Analysis

Where reagents are selected for use in a test, the **full name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

2 **(a)** **(i)** **FA 4** is a sodium compound that was the impurity in the **FA 1** and **FA 3** that you used in **Question 1**. The anion in **FA 4** is one of those listed in the Qualitative Analysis Notes.

Carry out appropriate tests to allow you to positively identify the anion in **FA 4**.

For the test that gives a positive result, record the test and the results of it.
State the name of the anion in **FA 4**.

anion in **FA 4** = ...

[2]

(ii) Write the ionic equation for the reaction that you have used to identify the anion in **FA 4**. Include state symbols.

.... [1]

(b) **FA 5** is a mixture that contains two cations and three anions from those listed in the Qualitative Analysis Notes.

A sample of **FA 5** was added to water and the water stirred. The mixture produced was filtered to give a solid residue, **FA 6**, and a filtrate, **FA 7**.

(i) Carry out the following tests on **FA 6** and record your observations.

test	*observations*
To a small spatula measure of **FA 6** in a test-tube add dilute hydrochloric acid, then	
add aqueous ammonia.	
Place a small spatula measure of **FA 6** in a hard-glass test-tube and heat gently.	

[4]

(ii) Carry out the following tests on **FA 7** and record your observations.

test	*observations*
To a 1 cm depth of **FA 7** in a test-tube add aqueous sodium hydroxide.	
To a 1 cm depth of **FA 7** in a test-tube add aqueous ammonia.	
To a 1 cm depth of **FA 7** in a test-tube add a few drops of aqueous silver nitrate.	
To a 1 cm depth of **FA 7** in a test-tube add a few drops of aqueous barium nitrate or aqueous barium chloride, then	
add dilute nitric acid.	
To a 0.5 cm depth of **FA 7** in a boiling tube add a 2 cm depth of aqueous sodium hydroxide and warm, then	
add a small piece of aluminium foil.	

[5]

(iii) From your observations, identify the two cations present in **FA 5**.

cations .... and ....
[1]

(iv) From your observations, identify two anions present in **FA 5**.

.... [1]

(v) From your observations, identify two anions that could be present in **FA 5**.

.... [1]

[Total: 15]

Qualitative inorganic ions tests Chem 12 Q# 15/ ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# 3 :o)
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Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

(b) **FA 6** is a mixture that contains two cations and two anions from the Qualitative Analysis Notes. Distilled water was added to **FA 6**, the mixture was stirred and then filtered. You are provided with the dried residue, **FA 7**, and the filtrate, **FA 8**, from this process.

(i) **Tests on the residue, FA 7**

Carry out the following tests and record your observations in the table.

test	*observations*
Place a spatula measure of **FA 7** in a boiling tube. Add dilute hydrochloric acid until no further reaction occurs, then	
transfer a 1 cm depth of the solution into a test-tube. To this add aqueous sodium hydroxide.	

[3]

(ii) Tests on the filtrate, FA 8

Carry out the following tests and record your observations in the table.

test	*observations*
To a 1 cm depth of **FA 8** in a boiling tube add a 1 cm depth of aqueous sodium hydroxide, then	
warm gently.	
To a 1 cm depth of **FA 8** in a boiling tube add a piece of aluminium foil and a 1 cm depth of aqueous sodium hydroxide. Warm gently.	

[3]

(iii) Conclusions about cations

State **one** cation that is **definitely** present in **FA 6**.

....

State **two** possible identities for the other cation present in **FA 6**.

.... or ....

Suggest how you could determine which of these two possible cations is present.
Do not carry out this test.

....

....

.... [3]

(iv) Conclusions about anions

State **one** anion that is **definitely** present in **FA 6**.

....

State **two** possible identities for the other anion present in **FA 6**.

.... or .... [2]

[Total: 17]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

2 (a) **FA 3** is a more concentrated solution of the strong monoprotic acid, H**Z**, used for **Question 1**.

Select **two** sets of reagents and suitable apparatus to use in **two** separate tests, **Test 1** and **Test 2**, to investigate the identity of the anion, Z^-, present in **FA 3**. The anion is one of those listed in the Qualitative Analysis Notes.

Complete the '*test*' boxes in the table **before** starting any practical work by circling whether you would use a test-tube or a boiling tube, and stating which reagents you would use.

Carry out your tests and record your observations. You must carry out both **Test 1** and **Test 2**.

test	*observations*
Test 1 To a 1 cm depth of **FA 3** in a *test-tube/boiling tube* add .... *(reagent(s))*	
Test 2 To a 1 cm depth of **FA 3** in a *test-tube/boiling tube* add .... *(reagent(s))*	

[4]

(b) Identify the anion present in HZ from your observations in **(a)**.

Z^- is .... [1]

(c) **FA 4** and **FA 5** both contain one cation and one anion. The ions present in **FA 4** are different from the ions present in **FA 5**. All four ions are listed in the Qualitative Analysis Notes.
You are to identify the **four** different ions.

Carry out the following tests and record your observations.

test	*observations*
To a small spatula measure of **FA 4** in a boiling tube, add a 4 cm depth of **FA 3** and shake the tube well. Leave the tube to stand for at least five minutes. Label the solution formed **FA 6**.	
To a 1 cm depth of **FA 5** in a test-tube, add aqueous sodium carbonate.	
To a 1 cm depth of **FA 5** in a test-tube, add aqueous sodium hydroxide.	
To a 1 cm depth of **FA 5** in a test-tube, add aqueous ammonia.	
To a 1 cm depth of **FA 5** in a test-tube, add a few drops of aqueous silver nitrate.	
To a 1 cm depth of **FA 5** in a test-tube, add a few drops of aqueous barium chloride or aqueous barium nitrate, then	
add a 1 cm depth of a suitable acid.	
To a 1 cm depth of **FA 6** in a test-tube, add aqueous sodium hydroxide.	
To a 1 cm depth of **FA 6** in a test-tube, add aqueous ammonia.	
To a 1 cm depth of **FA 6** in a test-tube, add dilute sulfuric acid.	
To a 1 cm depth of **FA 6** in a test-tube, add a 1 cm depth of **FA 5**.	

[8]

(d) Give the formula of the acid you added to the mixture of **FA 5** and aqueous barium chloride or aqueous barium nitrate in **(c)**.

The acid added was .... [1]

(e) Identify the ions present in **FA 4** and **FA 5** from your observations in **(c)**.

	cation	anion
FA 4		
FA 5		

[2]

[Total: 16]

Qualitative inorganic ions tests Chem 12 Q# 17/ ALvl Chemistry/2017/w/TZ 1/Paper 3/Q# 3 :o)
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3 Qualitative Analysis

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate;
- the solubility of such precipitates in an excess of the reagent added.

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.
Rinse and reuse test-tubes and boiling tubes where possible.

FA 6, **FA 7** and **FA 8** are solutions of salts.

Information about **FA 6**, **FA 7** and **FA 8**
• Each salt contains one cation and one anion. • One of the ions is sodium; the other five ions are listed in the Qualitative Analysis Notes. • Each salt contains a different nitrogen-containing ion. • **FA 7** or **FA 8** contains a halide ion.

(a) You will identify the **cations** present in **FA 6**, **FA 7** and **FA 8**.

To do this you will carry out **six** separate tests. You will use dilute sulfuric acid and aqueous sodium hydroxide separately with **FA 6**, **FA 7** and **FA 8**.

Use a 1 cm depth of each salt solution in a suitable tube for each test you carry out.

Record **all** of your observations in a table in the space below.

[4]

(b) Name the reagents you would use to identify the halide ion present in either **FA 7** or **FA 8**. Test **FA 7** and **FA 8** with these reagents and record your observations.

reagents used ....

unknown	observations	halide ion present ✓/✗
FA 7		
FA 8		

[2]

(c) (i) Name the reagents you would use to confirm the presence of the nitrogen-containing **anions** in the two solutions that do **not** contain a halide ion. Test both solutions with these reagents and record your observations.

reagents used ....

unknown	observations
FA	
FA	

(ii) Name the reagent you would use to positively identify one of the nitrogen-containing anions in the two solutions tested in **(i)**. Test both solutions with this reagent. Record all your observations.

reagent used ....

unknown	observations
FA	
FA	

[4]

(d) Use the information given in **(a)** and your observations in all tests to deduce the chemical formulae of the three salts.

FA 6 is .... **FA 7** is .... **FA 8** is ....

[2]

[Total: 12]

Qualitative inorganic ions tests Chem 12 Q# 18/ ALvl Chemistry/2017/s/TZ 1/Paper 3/Q# 3 :o)
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3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.
Rinse and reuse test-tubes and boiling tubes where possible.

(a) **FA 6** is another salt of copper. The anion present is one of those listed in the Qualitative Analysis Notes.

(i) Transfer a **small** spatula measure of **FA 6** into a hard-glass test-tube.
Heat gently at first, then heat strongly, until no further change occurs.

Record **all** your observations below.

....

....

....

....

....

....

....

....

(ii) Suggest the chemical formula of **FA 6**.

....

[3]

(b) **(i)** Dissolve the remainder of **FA 6** in an approximately 10 cm depth of distilled water in a boiling tube.

FA 7 is a solution of a salt containing one anion from those listed in the Qualitative Analysis Notes.
Two cations are also present.

Carry out the tests described below using separate portions of solutions **FA 6** and **FA 7**.
Record your observations in the table.

test	*observations*	
	FA 6	**FA 7**
To a 1 cm depth of solution in a test-tube, add an equal volume of **FA 3**, aqueous potassium iodide, followed by a few drops of starch indicator.		
To a 1 cm depth of solution in a boiling tube, add aqueous sodium hydroxide, then		
heat **gently and carefully**.		
To a 1 cm depth of solution in a test-tube, add a few drops of aqueous silver nitrate.		
To a 1 cm depth of solution in a test-tube, add aqueous ammonia.		
To a 1 cm depth of solution in a test-tube, add a folded 3 cm length of magnesium ribbon.		

(ii) What can you deduce about solution **FA 7** from its reaction with magnesium?
Explain your answer.

....

....

(iii) Give the ionic equation for the reaction of the metal cation in **FA 7** with aqueous sodium hydroxide. Include state symbols.

....

(iv) What **type** of reaction took place when aqueous potassium iodide was added to **FA 7**? Use your observations to help you explain your answer.

....

....

....

(v) The observation you made when aqueous silver nitrate was added to **FA 7** does not allow the anion in **FA 7** to be identified with certainty.

Explain why you cannot be certain about the identity of the anion.

....

....

....

(vi) A student suggested that the anion in **FA 7** could be identified with more certainty if excess ammonia solution was added after the aqueous silver nitrate.

Explain why this suggestion is **not** correct.

....

....

....

[11]

[Total: 14]

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 5**, **FA 6** and **FA 7** are solutions, **some** of which contain ions that are listed on pages 10 and 11.

test	*observations* FA 5	FA 6	FA 7
(i) To a 0.5 cm depth of solution in a boiling tube add aqueous sodium hydroxide, then			
warm gently.			
Allow to cool, add a piece of aluminium foil and warm again.		✕	
(ii) To a 1 cm depth of solution in a test-tube add two or three drops of acidified aqueous potassium manganate(VII). (Do **not** use **FA 3**.)			
If no reaction occurs, pour the mixture into a boiling tube and warm gently.			
(iii) To a 1 cm depth of solution in a test-tube add a 2 cm depth of '10 volume' hydrogen peroxide and leave to stand. (Do **not** use **FA 1**.)	✕		
(iv) To a 1 cm depth of solution in a test-tube add a 1 cm depth of dilute hydrochloric acid, then	✕		
add a 1 cm depth of aqueous barium chloride or aqueous barium nitrate.	✕		

[11]

(b) (i) Identify as many ions present in **FA 5**, **FA 6** and **FA 7** as possible from your observations. If an ion cannot be identified from the tests, write 'unknown' in the space.

	cation(s)	anion(s)
FA 5		
FA 6		
FA 7		

(ii) Describe another test you could carry out to confirm the identity of a cation you have identified in **(i)**. Record the reagent(s) and expected observation(s) in the space below. **Do not carry out this test.**

(iii) Write an ionic equation for the reaction that would occur in **(ii)**. Include state symbols.

....

[6]

[Total:17]

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 5** and **FA 6** are solids each containing one cation and one anion.
Carry out the following tests and record your observations in the table below.

test	*observations*	
	FA 5	**FA 6**
(i) Place a spatula measure of solid in a hard-glass test-tube and heat gently at first, then		
heat strongly until no further change takes place.		
Leave the tube to cool completely then add a 2 cm depth of dilute sulfuric acid to the solid residue. Shake the contents of the tube then leave it to stand.		

test	*observations*	
	FA 5	**FA 6**
(ii) Place a spatula measure of solid in a boiling tube and add a 2 cm depth of dilute sulfuric acid.		
Keep the solutions formed in (ii) for tests (iii) and (iv).		
(iii) To a 1 cm depth of solution from **(ii)** in a test-tube, add aqueous sodium hydroxide.		
(iv) To a 1 cm depth of solution from **(ii)** in a test-tube, add aqueous ammonia.		

(v) Identify as many ions as you can from your observations. Write 'unknown' where you have not been able to identify an ion.

FA 5: cation .... anion ....

FA 6: cation .... anion ....

(vi) Write an equation, including state symbols, for the reaction between **FA 6** and dilute sulfuric acid.

....

[12]

(b) **FA 7** is a solution containing one anion from those listed on page 11. The anion is either a halide or contains nitrogen.

(i) You are to select suitable reagents to determine the identity of this anion. Record these in a suitable form below.

(ii) Use these reagents to carry out tests to identify the anion in **FA 7**.

Record your observations and conclusions in the space below.

[5]

[Total: 17]

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

FA 5 is a mixture of two different salts. Each of these salts contains one cation and one anion from those listed on pages 12 and 13. You will identify the cations and anions present.

(a) **(i)** Carry out the following test and record your observations.

test	*observations*
Place a small spatula measure of **FA 5** in a hard-glass test-tube and heat strongly. Test any gases that are given off.	

(ii) Identify one of the cations in **FA 5**.

One of the cations in **FA 5** is ....

[2]

(b) Place the remaining sample of **FA 5** in the 100 cm^3 beaker. Half fill the beaker with distilled water and stir until **FA 5** has fully dissolved. This may take some time. You will use this solution in the remaining tests.

(i) Select reagents to identify the other cation present in **FA 5**. Carry out tests using these reagents and record your results in the space below.
Identify the cation.

The other cation in **FA 5** is ....

(ii) Carry out the following tests and record your observations.
Identify one of the anions in **FA 5**.

test	*observations*
To a 1 cm depth of the solution of **FA 5** in a test-tube add aqueous barium chloride or aqueous barium nitrate, then	
add dilute hydrochloric acid.	

One of the anions in **FA 5** is ....

(b) Place the remaining sample of **FA 5** in the 100 cm^3 beaker. Half fill the beaker with distilled water and stir until **FA 5** has fully dissolved. This may take some time. You will use this solution in the remaining tests.

(i) Select reagents to identify the other cation present in **FA 5**. Carry out tests using these reagents and record your results in the space below.
Identify the cation.

The other cation in **FA 5** is ....

(ii) Carry out the following tests and record your observations.
Identify one of the anions in **FA 5**.

test	*observations*
To a 1 cm depth of the solution of **FA 5** in a test-tube add aqueous barium chloride or aqueous barium nitrate, then	
add dilute hydrochloric acid.	

One of the anions in **FA 5** is ....

(iii) The remaining ion is a halide.

Select a pair of reagents which can be used to identify the halide present. Carry out a test using these reagents and record your observations below. Suggest the identity of the halide anion present in **FA 5**. Explain why this test is not conclusive in this particular case.

The other anion in **FA 5** is ....

....

....

....

.... [8]

(c) Suggest the formulae of the two salts that could have been mixed to make **FA 5**.

.... and .... [1]

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3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 6** is a sodium compound containing one anion listed on page 11.

Dissolve the **FA 6** provided in about 15 cm^3 of distilled water in a boiling tube.
Carry out the following tests and record your observations in the table below.

test	*observations*
(i) To a 1cm depth of the solution of **FA 6** in a test-tube, add a few drops of aqueous barium chloride or aqueous barium nitrate, then	
add dilute hydrochloric acid.	
(ii) To a 1cm depth of the solution of **FA 6** in a test-tube, add an equal volume of aqueous hydrogen peroxide, then	
add a few drops of aqueous barium chloride or aqueous barium nitrate, then	
add dilute hydrochloric acid.	

test	*observations*
(iii) To a 1 cm depth of the solution of **FA 6** in a boiling tube, add an equal volume of **FA 2**, sulfuric acid, then	
heat the mixture **gently and cautiously**.	
(iv) To a 1 cm depth of the solution of **FA 6** in a test-tube, add an equal volume of aqueous sodium hydroxide, then	
add a few drops of **FA 1**, aqueous potassium manganate(VII), then	
add **FA 2**, sulfuric acid.	

(v) Identify the anion in **FA 6**, and state **one** piece of evidence for your identification.

anion ....

evidence ....

....

....

(vi) Give the chemical equation for the reaction between **FA 6** and hydrogen peroxide, H_2O_2, in test **(ii)**. State symbols are **not** required.

....

[7]

(b) **FA 7**, **FA 8**, **FA 9** and **FA 10** each contain one cation from the list on page 10.
You will attempt to identify the cations by testing with aqueous sodium hydroxide and aqueous ammonia.
In each case, use a 1 cm depth of the solution in a test-tube.

(i) Complete the table below.

test	*observations*			
	FA 7	**FA 8**	**FA 9**	**FA 10**
add sodium hydroxide				
add aqueous ammonia				

(ii) Use your observations to identify, as far as possible, the cation present in each solution. If alternative identities are possible, state this clearly.

FA 7 cation ....

FA 8 cation ....

FA 9 cation ....

FA 10 cation ....

(iii) Give the ionic equation for the reaction of **one** of your cations with a few drops of sodium hydroxide. State symbols are **not** required.

....

(iv) The precipitates obtained when alkalis are added to solutions of certain cations are sometimes difficult to see. Suggest how, using no additional apparatus, the experiment could be repeated in a way that would make these precipitates more visible.

....

....

[9]

Qualitative inorganic ions tests Chem 12 **Q# 23/** ALvl Chemistry/2015/s/TZ 1/ Paper 3/Q# 3/ :o)
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3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) In **Question 1** you used **FA 2**. This solution was prepared from hydrated ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2.6H_2O$.
To a 1 cm depth of **FA 2** in a test-tube, add a small spatula measure of sodium carbonate.
Record your observations.

Solutions containing Fe^{2+} ions can quickly be oxidised in air if they are prepared by dissolving the solid in distilled water.
Use your observations to suggest what other substance was added to solid $(NH_4)_2Fe(SO_4)_2.6H_2O$ to prepare **FA 2**.

....

[2]

(b) **FA 6** is a mixture of two salts, each of which contains a single cation and a single anion from those listed in the Qualitative Analysis Notes on pages 10 and 11.
Do the following tests and record your observations in the table below.

test	*observations*
(i) Place a small spatula measure of **FA 6** in a hard-glass test-tube and heat strongly.	
(ii) Place a small spatula measure of **FA 6** in a test-tube and carefully add dilute sulfuric acid until the reaction is complete, then	
add aqueous sodium hydroxide.	
(iii) To a 3 cm depth of distilled water in a boiling tube, add the remaining sample of **FA 6**. Stir and then filter the mixture into a clean boiling tube. You will use this solution for tests **(iv)** – **(vi)**.	
(iv) To a 1 cm depth of the solution from **(iii)** in a test-tube, add aqueous sodium hydroxide.	
(v) To a 1 cm depth of the solution from **(iii)** in a test-tube, add aqueous ammonia.	
(vi) To a 1 cm depth of the solution from **(iii)** in a test-tube, add aqueous barium chloride or aqueous barium nitrate.	

(vii) Suggest possible identities for the ions present in **FA 6**.

cations ....

anions ....

(viii) Describe a further test that would allow you to determine exactly which anions are present. Explain your choice. Do **not** do this test.

....

....

.... [11]

[Total: 13]

Qualitative inorganic ions tests Chem 12 **Q# 24/** ALvl Chemistry/2014/w/TZ 1/ Paper 3/Q# 2/ :o)
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2 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 6** is a solid that contains one cation and one anion. One of the ions present is included in the lists on pages 14 and 15. This ion contains the element nitrogen.

(i) State which nitrogen-containing ions could be present. Select reagents for use in tests that would distinguish between them.

....

....

....

(ii) Carry out tests on **FA 6** using the reagents selected in **(i)** to identify the nitrogen-containing ion. Record your tests and observations in the space below.

(iii) Identify the nitrogen-containing ion in **FA 6**.

Ion present is ....

[5]

(b) Half fill the 250 cm^3 beaker with water and heat the water to about 60 °C. This is the water bath to be used in one of the following tests.

Carry out the following tests on **FA 7** and complete the table below.

test	*observations*
To a 1 cm depth of **FA 7** in a test-tube, add a few drops of dilute hydrochloric acid.	
To a 1 cm depth of **FA 7** in a test-tube, add a few drops of aqueous potassium iodide, then	
add aqueous ammonia.	
To a 1 cm depth of **FA 7** in a test-tube, add a few drops of aqueous sodium hydroxide and then add aqueous ammonia dropwise, with gentle shaking, until the precipitate **just** dissolves, then	No observation required.
add one spatula measure of glucose and leave to stand in the hot water bath. When you have completed this test, dispose of the solution and rinse the test-tube.	

[4]

(c) Solid **FA 8** contains one cation and one anion from those included in the lists on pages 14 and 15.

Carry out the following tests on **FA 8**. For each test record your observations.

(i) In a hard-glass test-tube heat approximately half of the **FA 8**, gently at first and then more strongly. Leave to cool.

....

....

....

(ii) To a 2 cm depth of dilute nitric acid in a boiling tube, add the remaining **FA 8**.

Keep the solution obtained for tests (iii) and (iv).

....

....

....

(iii) To a 1 cm depth of the solution from **(ii)** in a test-tube, add aqueous sodium hydroxide until no further change occurs.

....

....

....

(iv) To a 1 cm depth of the solution from **(ii)** in a test-tube, add aqueous ammonia until no further change occurs.

....

....

....

(v) Use your observations from **(i)** to **(iv)** to identify the ions present in **FA 8**.

Ions present .... and ....

[6]

[Total: 15]

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 6** is a solution of two different salts. It contains two different cations, one of which is listed in the Qualitative Analysis Notes on page 10. It contains two anions, both of which are listed in the Qualitative Analysis Notes on page 11.

(i) Choose reagents that will allow you to identify one of the cations. Carry out suitable tests using these reagents and record your results in the space below.

I	
II	
III	
IV	
V	

One of the cations in **FA 6** is ....

(ii) Carry out the following tests to identify the two anions present in **FA 6**.

test	*observations*
To a 1 cm depth of **FA 6** in a test-tube add a 1 cm depth of aqueous silver nitrate, then	
add aqueous ammonia.	
To a 1 cm depth of **FA 6** in a test-tube add a 1 cm depth of aqueous barium chloride (or aqueous barium nitrate), then	
add dilute nitric acid.	

The anions in **FA 6** are .... and ....

[9]

VI	
VII	
VIII	
IX	

(b) **FA 7** is an acidified solution of iron(II) sulfate, $FeSO_4(aq)$.

Carry out the following tests and record your observations.

test	*observations*
(i) To a 1 cm depth of **FA 7** in a test-tube add aqueous sodium hydroxide and leave for a few minutes.	
(ii) To a 1 cm depth of **FA 7** in a boiling tube add a 1 cm depth of dilute sulfuric acid followed by a 1 cm depth of '20 vol' hydrogen peroxide. Stir the mixture, then	
(iii) pour a 1 cm depth of the mixture into a clean boiling tube and add a 3 cm depth of aqueous sodium hydroxide.	

I	
II	
III	
IV	
V	
VI	

(iv) What type of reaction takes place in **(ii)**?

....

....

(v) Explain your observations in **(iii)**.

....

....

[6]

[Total: 15]

3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 5** is hydrated barium chloride.
FA 6 is the same iron(II) salt used in Question 1. It contains **one other** cation and **one** anion.

(i) Place a small spatula measure of **FA 6** into a test-tube. Dissolve the solid in about a 5 cm depth of distilled water. Use the solution for the following tests.

test	*observations*
To a 1 cm depth of aqueous **FA 6** in a boiling tube, add aqueous sodium hydroxide until no further change occurs, then	
heat the mixture carefully.	
Dissolve a few crystals of **FA 5** in a 1 cm depth of distilled water in a test-tube. Add a 1 cm depth of **FA 6**, then	
add excess dilute hydrochloric acid to the mixture.	

(ii) Identify the ions present in **FA 6**.

cations: Fe^{2+} and .... anion: ....

(iii) Give the ionic equation for the reaction of iron(II) ions with hydroxide ions.

....

(iv) Place a **small** spatula measure of **FA 6** into a **hard-glass** test-tube.
Heat gently, then strongly, until no further change is observed.
Record your observations in the space below.

[7]

Qualitative inorganic ions tests Chem 12 **Q# 27/** ALvl Chemistry/2012/w/TZ 1/ Paper 3/Q# 2/ :o)
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2 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

Solutions **FA 3**, **FA 4**, **FA 5** and **FA 6** each contain one cation and one anion from those listed on pages 12 and 13.

(a) Some cations interfere with tests for anions and have to be removed from the solution before the tests for anions present can be performed. One way in which this can be carried out is to precipitate the cation in the form of its insoluble carbonate.

Carry out the following tests on both **FA 3** and **FA 5**.

test	*observation*	
	FA 3	**FA 5**
To 5 cm depth of solution in a boiling tube, add all of the sodium carbonate, Na_2CO_3, from one of the tubes provided. Stir the mixture.		

Retain the mixture from **FA 3** for use in **(b)**.

[4]

(b) Filter the mixture from **FA 3** from **(a)** into another boiling tube. Ignore any colour in the filtered solution.
Add 5 cm depth of dilute nitric acid. This removes any excess of carbonate ions.

Carry out the following tests on the acidified filtrate from **FA 3**.

test	*observation*
To 2 cm depth of the acidified filtrate from **FA 3** in a test-tube, add 1 cm depth of aqueous silver nitrate, then	
add an excess of aqueous ammonia.	

[1]

(c) Carry out the following test on **FA 4**.

test	*observation*
To 1 cm depth of **FA 4** in a test-tube, add 1 cm depth of **FA 3**, then	
add a few drops of starch solution.	

[2]

(g) By considering the results of **all** your tests, enter one of the following responses in each of the boxes below.

- chloride
- bromide
- iodide
- no halide ion is present
- insufficient tests (have been performed to identify any halide ion)

FA 3	
FA 4	
FA 5	

[1]

[Total 15]

2 Qualitative Analysis

For Examiner's Use

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) You are provided with three sodium salts **FA 3**, **FA 4** and **FA 5**. Each salt contains **one** of the ions carbonate, CO_3^{2-}, sulfite, SO_3^{2-} or sulfate, SO_4^{2-}.

(i) Using your knowledge of the reactions of these ions, suggest **one** reagent you could add to the solid to find out which ion is present in each of the solids.

....

(ii) Use the reagent you selected in **(i)** to identify which of these ions is present in **FA 3**, **FA 4** and **FA 5**.

Carry out suitable tests on a small amount of each solid and record the results of your experiments in an appropriate form in the space below.

I	
II	
III	
IV	
V	
VI	

Identify the anions in **FA 3**, **FA 4** and **FA 5**.

FA 3 contains the .... ion.

FA 4 contains the .... ion.

FA 5 contains the .... ion. [6]

3 **Qualitative Analysis**

For Examiner's Use

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

When gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and re-use test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) **FA 7** contains one cation and one anion from those listed in the Qualitative Analysis Notes on pages 10 and 11.

Put two spatula measures of **FA 7** into a test-tube.
Add about two-thirds of a test-tube of distilled water and dissolve the solid.
For each test that you carry out, use 1 cm depth of the solution of **FA 7**.

(i) Carry out the following tests and complete the table below.

test	*observation(s)*
Add 5 drops of aqueous barium chloride (or barium nitrate) to your solution of **FA 7**.	
Add 5 drops of aqueous silver nitrate to your solution of **FA 7**.	

I	
II	
III	

SMASHING!!!

(ii) Put a **very small** spatula measure of solid **FA 7** into a hard glass test-tube.
Hold the test-tube horizontally and heat it gently for a few seconds, then heat it strongly until no further change takes place.
Leave the test-tube to cool to room temperature.
*While cooling takes place, move on to **(iv)**.*
In the space below record the observations made at each stage in an appropriate form.

For Examiner's Use

(iii) State what deductions you can make about the identity of the anion in **FA 7** from the tests above.

....

....

(iv) Use the information in the Qualitative Analysis Notes on pages 10 and 11 to select a further test to confirm the identity of the anion in **FA 7**.

test ....

Carry out **this test** and, in the space below, record the observation(s) made in an appropriate form. State your conclusion.

IV	
V	
VI	
VII	
VIII	
IX	

(v) The cation in **FA 7** is aluminium ion, calcium ion or zinc ion.
Select **one reagent** to identify the cation in **FA 7**.

reagent ....

Use this reagent to carry out a test.
Record the observation(s) made and identify the cation.

....

....

....

....[9]

SMASHING!!!

(b) **FA 8** contains one cation from those listed on page 10 and 11.

Put all of the **FA 8** into a test-tube.
Half fill the test-tube with distilled water and dissolve the solid.

(i) To 1 cm depth of the solution of **FA 8** in a test-tube, add aqueous potassium iodide until the test-tube is half full. Allow the mixture to stand for two minutes.

Use a dropping pipette to transfer about 1 cm^3 of the mixture from the top of the test-tube to another test-tube. Add 5 drops of starch solution.
Record all of your observations.

(ii) State what **type** of chemical behaviour has been shown by potassium iodide in this reaction. Give an ionic equation to justify your answer.

....

....

....

(iii) To another 1 cm depth of solution of **FA 8** in a test-tube, add aqueous sodium hydroxide.
Record the observation(s) made.
Give the **ionic** equation for the reaction taking place.

....

....

....

....[5]

[Total: 14]

For Examiner's Use

I	
II	
III	
IV	
V	

2 Solutions **FA 3**, **FA 4** and **FA 5** each contain a Group 2 halide.
Solution **FA 6** contains a potassium salt.

You will carry out tests to deduce the following.
- the anion present in **FA 6**
- the solution containing the chloride ions
- the solution containing barium ions

At each stage of any test you are to record details of the following.
- colour changes seen
- the formation of any precipitate and the colour of the precipitate

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed directly with a Bunsen burner a boiling-tube MUST be used.
Rinse and reuse test-tubes where possible.

(a) Use information from the Qualitative Analysis Notes on page 11 to select a pair of reagents that, **used together**, identify the halide ion present.

The reagents are ....

followed by .... [1]

(b) Use your chosen reagents to carry out tests on **FA 3**, **FA 4** and **FA 5**.
Record your results in an appropriate form in the space below.

[2]

(c) From the results of the tests in **(b)** state which solution contains the chloride ion, Cl^-.

Solution .... contains the chloride ion.

Explain the evidence that supports your conclusion.

....

....[1]

(d) Carry out the following tests on each of the solutions **FA 3**, **FA 4** and **FA 5**.
Record your observations below.

test	*observations*		
	FA 3	**FA 4**	**FA 5**
To 1 cm depth of solution in a test-tube, add 2 cm depth of aqueous sodium hydroxide.			
To 1 cm depth of solution in a test-tube, add 2 cm depth of aqueous ammonia.			

[2]

Qualitative inorganic ions tests Chem 12 **Q# 31/** ALvl Chemistry/2009/s/TZ 1/ Paper 3/Q# 3/ :o)
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3 **FA 5**, **FA 6**, **FA 7** and **FA 8** are aqueous solutions each containing one cation and one anion.

For Examiner's Use

You will carry out specified tests to deduce

- the cations present in two of the four solutions,
- the anions present in three of the four solutions.

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.
If any solution is warmed, a boiling-tube MUST be used.

(a) Carry out the following tests. Record your observations in the spaces provided in the table.

	FA 5	**FA 6**	**FA 7**	**FA 8**
To 1 cm depth of solution in a test-tube add aqueous sodium hydroxide, a little at a time, until in excess.				
To 1 cm depth of solution in a test-tube add aqueous ammonia, a little at a time, until in excess.				

Using the qualitative analysis notes printed on page 11 and the observations above it is possible to identify the cation present in one of the solutions and also to identify possible cations in another of the solutions.

Solution .... contains the single cation ....

Solution .... contains one of the following cations, ...

[4]

i	
ii	
iii	
iv	

Rinse and re-use test-tubes.

For Examiner's Use

(b) You are to select suitable reagents and carry out tests on the solutions to identify which solution or solutions contain either a nitrate or a nitrite ion.

Record in an appropriate form below the tests performed and the observations made.

i	
ii	

Nitrate or nitrite ions are contained in solution(s) .... [2]

(c) Carry out the following tests.

	FA 5	FA 6	FA 7	FA 8
To 1 cm depth of solution in a test-tube add 1 cm depth of dilute hydrochloric acid.				

Use these observations to identify the cation or anion present in each solution and complete the table below.

solution	anion/cation present	reason for selecting the ion

[4]

i	
ii	
iii	
iv	

(d) **FA 5** and **FA 7** can be mixed to confirm the identity of one ion in each of the two solutions.

test	*observation*
To 1 cm depth of **FA 5** in a test-tube add 1 cm depth of **FA 7**.	

This observation confirms the presence of .... in **FA 5** and .... in **FA 7**.
[2]

[Total: 12]

For Examiner's Use

i	
ii	

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will identify a straight-chain carboxylic acid by titrating an aqueous solution of this acid with aqueous sodium hydroxide. 1 mole of the carboxylic acid reacts with 1 mole of sodium hydroxide. The carboxylic acid contains C, H and O atoms only and has no C=C bonds.

FA 1 is an aqueous solution of the carboxylic acid, containing 10.50 $g\,dm^{-3}$.
FA 2 is 0.110 $mol\,dm^{-3}$ sodium hydroxide, NaOH.
FA 3 is thymolphthalein indicator.

(a) **Method**

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Add approximately 8 drops of **FA 3**.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm^3 of **FA 1** required .... cm^3 of **FA 2**. [1]

(c) Calculations

(i) Calculate the amount, in mol, of sodium hydroxide present in the volume of **FA 2** calculated in **(b)**.

amount of NaOH = ... mol [1]

(ii) Use your answer to **(c)(i)** and the information on page 2 to calculate the relative formula mass of the carboxylic acid in **FA 1**.

M_r of carboxylic acid = ... [1]

(iii) Identify the carboxylic acid in **FA 1**.
Draw its skeletal formula.

skeletal formula

name of acid ....

[2]

(d) A student carries out a similar titration to the titration you carried out in **(a)**. The only difference is that a solution of aminoethanoic acid, $NH_2CH_2CO_2H$, containing 10.50 g dm^{-3} is used instead of the acid in **FA 1**.

(i) Construct an equation for the reaction taking place in the student's titration.
Include state symbols.

.... [1]

(ii) State whether the student's titre will be larger or smaller than your titre. Explain your answer.

The student's titre will be .... than mine.

explanation ....

....

.... [1]

[Total: 14]

2 In this experiment you will titrate a solution of the hydroxide of a Group 1 element, **Z**, with sulfuric acid.
The equation for the reaction is shown.

Z may or may not be the same as **X**.

$$2\mathbf{Z}OH(aq) + H_2SO_4(aq) \rightarrow \mathbf{Z}_2SO_4(aq) + 2H_2O(l)$$

FA 2 is 26.3 g dm^{-3} aqueous hydroxide of metal **Z**, **Z**OH.
FA 3 is 0.0500 mol dm^{-3} sulfuric acid, H_2SO_4.
bromophenol blue indicator

(a) Method

- Pipette 25.0 cm^3 of **FA 2** into the 250 cm^3 volumetric flask.
- Add distilled water to the flask to make 250 cm^3 of solution. Shake the flask thoroughly to ensure complete mixing. Label this solution **FA 4**.
- Rinse the pipette with a little distilled water and then a little **FA 4**.
- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure your recorded results show the accuracy of your practical work.
- Record in a suitable form in the space below all of your burette readings and the volume of **FA 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to use in your calculations.
Show clearly how you obtained this value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 3**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the appropriate number of significant figures. [1]

(ii) Calculate the number of moles of sulfuric acid present in the volume of **FA 3** you calculated in **(b)**.

moles of H_2SO_4 = ... mol [1]

(iii) Use your answer to **(c)(ii)** and the information on page 4 to calculate the concentration, in $mol\,dm^{-3}$, of **Z**OH present in **FA 4**.

concentration of **FA 4** = ... $mol\,dm^{-3}$ [1]

(iv) Calculate the concentration, in $mol\,dm^{-3}$, of **Z**OH in **FA 2**.

concentration of **FA 2** = ... $mol\,dm^{-3}$ [1]

(v) Use your answer to **(c)(iv)** and the information on page 4 to calculate the relative atomic mass, A_r, of **Z**. Hence identify **Z**.
Show your working.

Z is .... [2]

(d) Using the value for the relative atomic mass of **Z** that you calculated in **(c)(v)**, calculate the percentage difference of your value from that shown in the Periodic Table.

(If you did not obtain a value for the A_r of **Z**, assume it is 32.0. Note, this is **not** the correct value.)

percentage difference = ... % [1]

[Total: 15]

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will carry out a titration to identify the Group 1 metal, **M**, present in a metal hydrogencarbonate, **M**HCO_3.

FA 1 is 0.0550 $mol\,dm^{-3}$ sulfuric acid, H_2SO_4.
FA 2 is the metal hydrogencarbonate, **M**HCO_3.
bromophenol blue indicator

(a) Method

Preparing a solution of FA 2

- Weigh the stoppered container of **FA 2**. Record the mass in the space below.
- Tip all the **FA 2** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FA 2** used.
- Add approximately 100 cm^3 of distilled water to **FA 2** in the beaker.
- Stir the mixture with a glass rod until all the **FA 2** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of **M**HCO_3 is **FA 3**. Label the flask **FA 3**.

Titration

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add a few drops of bromophenol blue indicator to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 1** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 1**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)**, **(c)(iv)** and **(c)(v)** to the appropriate number of significant figures. [1]

(ii) Calculate the number of moles of sulfuric acid present in the volume of **FA 1** calculated in **(b)**.

moles of H_2SO_4 = ... mol [1]

(iii) Complete the equation for the reaction of sulfuric acid and **M**HCO_3.
State symbols are not required.

.....**M**HCO_3 + ...H_2SO_4 → .....**M**$_2SO_4$ + ... + ...

Use your answer to **(c)(ii)** to deduce the number of moles of **M**HCO_3 used in each titration.

moles of **M**HCO_3 = ... mol [1]

(iv) Use your answer to **(c)(iii)** and your data on page 2 to calculate the relative formula mass, M_r, of **M**HCO_3.

M_r of **M**HCO_3 = ... [1]

(v) Calculate the relative atomic mass, A_r, of **M**.

A_r of **M** = ...

Suggest the identity of **M**.

M is ....
[1]

(d) (i) A student used a pipette that was labelled 25.0 ± 0.06 cm^3 to measure **FA 3**.

Show how you calculate the maximum percentage error in the volume of **FA 3**.

[1]

(ii) The student suggested that it would have been more accurate to measure the volume of **FA 3** with a burette instead of the pipette.

State and explain whether you agree with the student.

....

.... [1]

[Total: 16]

2 In this experiment you will determine the concentration of **FA 2** by titration using aqueous sodium hydroxide.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

FA 2 is hydrochloric acid, HCl.
FA 3 is 0.100 mol dm^{-3} sodium hydroxide, NaOH.
methyl orange indicator

(a) Method

Dilution of FA 2

- Fill the burette with **FA 2**.
- Run between 40.00 and 45.00 cm^3 from the burette into the 250 cm^3 volumetric flask.
- Record the volume used.
- Make the solution up to the 250 cm^3 mark by adding distilled water.
- Shake the flask thoroughly to ensure mixing.
- Label this solution of hydrochloric acid **FA 4**.

volume of **FA 2** used = ... cm^3

Titration

- Rinse the burette with distilled water and then with a little **FA 4**.
- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add several drops of methyl orange indicator.
- Perform a rough titration and record your burette readings.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form all of your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) From your accurate titration results, obtain a value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 4**.
[1]

(c) Calculations

(i) Give your answers to **(ii)**, **(iii)** and **(iv)** to the appropriate number of significant figures. [1]

(ii) Calculate the number of moles of hydrochloric acid that reacted with 25.0 cm^3 of **FA 3**.

moles of HCl = ... mol
[1]

(iii) Calculate the concentration of hydrochloric acid in **FA 4**.

concentration of HCl in **FA 4** = ... mol dm^{-3}
[1]

(iv) Calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = ... mol dm^{-3}
[1]

(d) Calculate the maximum percentage error in the volume of **FA 2** you added to the volumetric flask.

maximum percentage error = ... %
[1]

(e) In **Question 1** and **Question 2** you have determined the concentration of **FA 2** by two different methods. Each method used has possible sources of error, for example in **Question 1** the largest source of error is escape of gas.

Apart from this error, state and explain a source of error for each method.

Question 1 ....

....

Question 2 ....

....

[2]

[Total: 16]

Acid/base titrations **Chem 15 Q# 36/** ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# 2 :o) www.SmashingScience.org

2 In this question you will determine the identity of the halogen in compound **W**. Compound **W** is the halogenoethanoic acid CH_2XCO_2H, where X is a halogen.

4 g of **W** were heated with 250 cm³ of 0.400 mol dm⁻³ aqueous sodium hydroxide. Some of the sodium hydroxide reacted with compound **W**. The solution that remained after this reaction is **FA 3**.

By titrating **FA 3** with hydrochloric acid, you will determine how much of the sodium hydroxide remained after reaction with **W**. You will then calculate how much sodium hydroxide had reacted and use this to determine the identity of X in CH_2XCO_2H.

FA 3 is aqueous sodium hydroxide after reaction with **W**.
FA 4 is 0.100 mol dm⁻³ hydrochloric acid, HC*l*.
bromophenol blue indicator

(a) Method

- Fill the second burette with **FA 4**.
- Rinse the pipette with distilled water followed by a little **FA 3**.
- Use the pipette to transfer 25.0 cm³ of **FA 3** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm³.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	

- From your accurate titration results, obtain a suitable value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm³ of **FA 3** required .... cm³ of **FA 4**.
[3]

(b) Calculations

A halogenoethanoic acid reacts with aqueous sodium hydroxide in two reactions.

The alkali neutralises the carboxylic acid.

$$NaOH + CH_2XCO_2H \rightarrow CH_2XCO_2Na + H_2O$$

The halogenoalkyl group then undergoes a substitution reaction.

$$NaOH + CH_2XCO_2Na \rightarrow CH_2(OH)CO_2Na + NaX$$

(i) Calculate the number of moles of hydrochloric acid, **FA 4**, present in the volume calculated in **(a)**.

moles of HC*l* = ... mol

Hence deduce the number of moles of sodium hydroxide present in 25.0 cm³ of **FA 3**.

moles of NaOH in 25.0 cm³ **FA 3** = ... mol
[1]

(ii) Calculate the number of moles of sodium hydroxide added to the 4 g of **W**.

moles of NaOH added to 4 g **W** = ... mol

Calculate the number of moles of sodium hydroxide that **remain after** the reaction with compound **W**.

moles of NaOH remaining after reaction with **W** = ... mol
[1]

(iii) Calculate the number of moles of sodium hydroxide that reacted with **W**.

moles of NaOH that reacted with **W** = ... mol

Hence calculate the number of moles of **W** that reacted with this number of moles of sodium hydroxide.

moles of **W** that reacted = ... mol [1]

(iv) Use your answer to **(iii)**, and the mass of **W** used to make **FA 3**, to calculate the M_r of **W**.

M_r of **W** = ... [1]

(v) **W** is a halogenoethanoic acid, CH_2XCO_2H. Use your answer to **(iv)** to determine the identity of X. Explain how you reached your conclusion.

....

....

.... [2]

(c) Apart from any inaccuracies in reading the volumes of solutions, suggest a significant source of error in this practical exercise.
Explain how you could minimise this error.

....

....

.... [1]

(d) State at what M_r value of **W**, closest to the one calculated in **(b)(iv)**, you would have concluded that X was a different halogen.

M_r value = ... [1]

[Total: 11]

Acid/base titrations **Chem 7 Q# 37/** ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# 1 :o) www.SmashingScience.org

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will use a solution of sodium carbonate, Na_2CO_3, to determine the concentration of a solution of hydrochloric acid, HC*l*, by carrying out a titration.

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

FA 1 is a solution of sodium carbonate containing 1.30 g Na_2CO_3 in each 250 cm^3.
FA 2 is hydrochloric acid, HC*l*.
methyl orange indicator

(a) Method

- Fill a burette with **FA 2**.
- Use the pipette to transfer 25.0 cm^3 of **FA 1** into a conical flask.
- Add a few drops of methyl orange indicator.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 2** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 1** required .... cm^3 of **FA 2**. [1]

(c) Calculations

(i) Give your answer to **(ii)**, **(iii)** and **(iv)** to an appropriate number of significant figures. [1]

(ii) Calculate the number of moles of sodium carbonate present in 25.0 cm^3 of **FA 1**.

moles of Na_2CO_3 = ... mol [1]

(iii) Calculate the number of moles of hydrochloric acid that reacted with the number of moles of sodium carbonate you calculated in **(ii)**.

moles of HCl = ... mol [1]

(iv) Use your answers to **(b)** and **(c)(iii)** to calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = ... mol dm^{-3} [1]

Acid/base titrations **Chem 7 Q# 38/** ALvl Chemistry/2016/w/TZ 1/Paper 3/Q# 2 :o) www.SmashingScience.org

2 You will determine the amount of hydrochloric acid remaining in flask **X** after the reaction with the marble chips in **Question 1**. You will do this by titration with sodium hydroxide of known concentration.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

The impurities in the calcium carbonate will not react with the alkali.

FA 3 is 0.140 mol dm^{-3} sodium hydroxide, NaOH.
bromophenol blue indicator

(a) Method

- Transfer **all** the contents of flask **X** into the 250 cm^3 volumetric flask.
- Rinse flask **X** with distilled water and add the washings to the volumetric flask. Add distilled water up to the mark.
- Stopper the volumetric flask and mix the contents thoroughly. Label this solution **FA 4**.
- Rinse the pipette then use it to transfer 25.0 cm^3 of **FA 4** into a conical flask.
- Add about 10 drops of bromophenol blue indicator.
- Fill the burette with **FA 3**.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 3** added in each accurate titration.
- Make certain any recorded results show the precision of your practical work.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 3** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 3**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of sodium hydroxide, NaOH, present in the volume of **FA 3** you calculated in **(b)**.

moles of NaOH = ... mol

(ii) Use your answer to **(i)** and the equation on page 4 to determine the number of moles of hydrochloric acid, HCl, present in the 25.0 cm^3 of **FA 4** pipetted in **(a)**.

moles of HCl = ... mol

(iii) Use your answer to **(ii)** to calculate the number of moles of hydrochloric acid, HCl, remaining in flask **X** after the reaction in **1(a)**.

moles of HCl remaining = ... mol

(iv) Use the relevant information on page 2 to calculate the number of moles of hydrochloric acid, HCl, pipetted into flask **X** in **1(a)**.

moles of HCl pipetted into flask **X** = ... mol

(v) Use your answers to **(iii)** and **(iv)** to calculate the number of moles of hydrochloric acid, HCl, which reacted with the marble chips in flask **X**.

moles of HCl which reacted in flask **X** = ... mol

(vi) Use your answer to **(v)**, the equation in **Question 1** and the Periodic Table on page 12 to calculate the mass of pure calcium carbonate, $CaCO_3$, in the sample of industrial grade calcium carbonate, **FA 1**.

mass of $CaCO_3$ = ... g

(vii) Use your answer to **(vi)** and the mass of marble chips recorded in **1(a)** to calculate the percentage purity of **FA 1**.

percentage purity of **FA 1** = ... %
[5]

(d) You have carried out two different methods to find the percentage purity of industrial grade calcium carbonate.

A source of error in **Question 1** is that some carbon dioxide escapes before the bung can be inserted.

How would this affect the percentage purity of **FA 1** calculated in the two questions? Explain your answers.

Question 1

....

....

....

Question 2

....

....

....
[3]

[Total: 16]

2 In this experiment you will determine the concentration of the hydrochloric acid, **FA 2**, used in **Question 1**. You will first dilute the reaction mixture that you prepared in **Question 1** and then titrate this diluted solution against sodium hydroxide, NaOH.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

FA 3 is 0.0400 mol dm^{-3} sodium hydroxide, NaOH.
methyl orange indicator

(a) Method

Dilution

- Transfer all the reaction mixture that you prepared in **1(a)** from the 250 cm^3 beaker to the 250 cm^3 volumetric flask.
- Rinse the beaker with a little distilled water and add these washings to the volumetric flask.
- Fill the volumetric flask to the line with distilled water. Stopper the flask and shake it to ensure thorough mixing.
- Label this solution **FA 4**.

Titration

- Fill the burette with **FA 4**.
- Use a pipette to transfer 25.0 cm^3 of **FA 3** into a conical flask.
- Add a few drops of methyl orange.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	
IV	

[4]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 4**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of sodium hydroxide, NaOH, present in 25.0 cm^3 of **FA 3**.

moles of NaOH = ... mol

(ii) Calculate the number of moles of hydrochloric acid, HC*l*, present in 250 cm^3 of **FA 4**.

moles of HC*l* in 250 cm^3 of **FA 4** = ... mol

(iii) Use your answers to **1(b)(i)** and **1(b)(ii)** to calculate the number of moles of HC*l* that reacted with **FA 1** in the experiment you carried out in **Question 1**.

moles of HC*l* that reacted with **FA 1** = ... mol

(iv) Use your answers to **2(c)(ii)** and **2(c)(iii)** to calculate the concentration of **FA 2**.

concentration of **FA 2** = ... mol dm^{-3}
[5]

(d) (i) One of the sources of error in determining the concentration of **FA 2** involves measuring volumes of solutions in both **Questions 1** and **2**.

State which volume of solution that you have measured has the greatest percentage error. How could you have reduced this error?

....

....

....

(ii) A student suggested that a greater mass of **X**CO_3 should be used so that the average titre calculated in **2(b)** would be a greater volume.

Explain whether you agree with the student that this would lead to a greater volume for the average titre.

....

....

....

[2]

[Total: 12]

Acid/base titrations Chem 7 **Q# 40/** ALvl Chemistry/2013/s/TZ 1/ Paper 3/Q# 2/ :o)
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2 A second way to determine the concentration of an acid is by volumetric titration. In this experiment you will first dilute the sample of **FA 2** that you used in **Question 1** and then titrate this diluted solution using aqueous sodium hydroxide.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

FA 2 is dilute sulfuric acid, H_2SO_4.
FA 3 is 0.150 mol dm^{-3} sodium hydroxide, NaOH.
distilled water

(a) Method

Dilution of FA 2

- Use the burette labelled **FA 2** to transfer 25.00 cm^3 of **FA 2** into the 250 cm^3 graduated (volumetric) flask, labelled **FA 4**.
- Make up the contents of the flask to the 250 cm^3 mark with distilled water.
- Stopper the flask and mix the contents thoroughly. This is solution **FA 4**.

Titration

- Fill the burette labelled **FA 3** with **FA 3**.
- Use a clean pipette to transfer 25.0 cm^3 of **FA 4** into a conical flask.
- Add to the flask a few drops of the acid-base indicator provided.
- Titrate the acid in the flask with the alkali, **FA 3**.

For Examiner's Use

You should perform a rough titration.
In the space below record your burette readings for this rough titration.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 3** added in each accurate titration. Make certain that any recorded results show the precision of your practical work.

I	
II	
III	
IV	
V	

[5]

(b) From your titration results obtain a suitable value to be used in your calculation. Show clearly how you have obtained this value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 3**.
[1]

(c) (i) Calculate how many moles of NaOH are contained in the volume recorded in **(b)**.

moles of NaOH = ... mol

(ii) Hence, calculate how many moles of H_2SO_4 are contained in 25.0 cm^3 of **FA 4**.

moles of H_2SO_4 = ... mol

For Examiner's Use

(iii) Calculate the concentration of the sulfuric acid, **FA 2**.

I	
II	
III	

concentration of **FA 2** = ... $mol\,dm^{-3}$ [3]

(d) You have used two methods to determine the concentration of the sulfuric acid in **FA 2**. Use your answers to **1(d)(iii)** and **2(c)(iii)** to calculate the difference in these values as a percentage of the value found by the volumetric titration method.

percentage difference = ... % [1]

Acid/base titrations Chem 7 **Q# 41/** ALvl Chemistry/2011/s/TZ 1/ Paper 3/Q# 1/ :o)

1 **FA 1** is sulfuric acid, H_2SO_4, of approximate concentration 0.7 $mol\,dm^{-3}$.
FA 2 is 0.150 $mol\,dm^{-3}$ sodium hydroxide.
You are also provided with phenolphthalein (indicator).

You will determine the exact concentration of **FA 1** by titration.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

For Examiner's Use

(a) Method

Dilution

- Pipette 25.0 cm^3 of **FA 1** into the 250 cm^3 graduated (volumetric) flask labelled **FA 3**.
- Make the solution up to the mark using distilled water.
- Shake the flask to mix the solution of **FA 3**.

Titration

- Rinse out the pipette with distilled water and then with **FA 3**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add 5 drops of phenolphthalein indicator to the flask. The indicator should remain colourless.
- Fill the burette with **FA 2**.
- Titrate **FA 3** with **FA 2**, until a permanent pale pink colour is obtained.

You should perform a **rough titration**.
In the space below record your burette readings for this rough titration.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record in a suitable form below all of your burette readings and the volume of **FA 2** added in each accurate titration.
- Make sure that your recorded results show the precision of your practical work.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value to be used in your calculations.
Show clearly how you have obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 2**. [1]

For Examiner's Use

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate how many moles of NaOH were present in the volume of **FA 2** calculated in **(b)**.

.... mol of NaOH

(ii) Calculate how many moles of H_2SO_4 were present in 25.0 cm^3 of **FA 3**.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

.... mol of H_2SO_4

I	
II	
III	
IV	

(iii) Calculate how many moles of H_2SO_4 were present in 25.0 cm^3 of the undiluted solution **FA 1**.

.... mol of H_2SO_4

(iv) Calculate the concentration, in $mol\,dm^{-3}$, of H_2SO_4 in **FA 1**.

The concentration of H_2SO_4 in **FA 1** was .... $mol\,dm^{-3}$. [4]

[Total: 12]

Ti2 Redox titrations with KMNO₄ Chem 6 Q# 42/ ALvl Chemistry/2022/w/TZ 1/Paper 3/Q# 1 :o)

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 Group 1 elements form salts with ethanedioic acid. These salts are ethanedioates and have the formula $(COO\mathbf{M})_2 \cdot 2H_2O$, where **M** is the Group 1 metal.

Ethanedioate ions react with manganate(VII) ions as shown.

$$5(COO^-)_2(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

You will determine which metal is present in $(COO\mathbf{M})_2 \cdot 2H_2O$ by titrating a solution of this salt with manganate(VII) ions.

FA 1 is $10.14\,g\,dm^{-3}$ aqueous hydrated ethanedioate of metal **M**, $(COO\mathbf{M})_2 \cdot 2H_2O$.
FA 2 is $0.0200\,mol\,dm^{-3}$ potassium manganate(VII), $KMnO_4$.
FA 3 is $1\,mol\,dm^{-3}$ sulfuric acid, H_2SO_4.

(a) Method

- Fill the burette with **FA 2**.
- Pipette $25.0\,cm^3$ of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately $20\,cm^3$ of **FA 3** into the conical flask.
- Place the conical flask on a tripod and gauze and heat carefully until the temperature of the solution is approximately 70 °C.
- Remove the flame.
- **Carefully** lift the hot conical flask and place it on the white tile under the burette.
- During titrations, add **FA 2**, **slowly at first**, until a permanent pale pink colour is formed. The pink colour on initial addition may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70 °C. If the brown colour disappears, continue with the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- Perform a rough titration with **FA 2**. Record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to be used in your calculations.
Show clearly how you obtained this value.

$25.0\,cm^3$ of **FA 1** required .... cm^3 of **FA 2**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the appropriate number of significant figures. [1]

(ii) Calculate the amount, in mol, of manganate(VII) ions, MnO_4^-, in the volume of **FA 2** calculated in **(b)**.

amount of MnO_4^- = ... mol [1]

(iii) Calculate the amount, in mol, of ethanedioate ions that reacted with the manganate(VII) ions in **(c)(ii)**.

amount of $(COO^-)_2$ = ... mol

Hence calculate the concentration, in $mol\,dm^{-3}$, of ethanedioate ions in **FA 1**.

concentration of $(COO^-)_2$ = ... $mol\,dm^{-3}$ [1]

(iv) Calculate the relative formula mass, M_r, of the hydrated ethanedioate, $(COO\mathbf{M})_2 \cdot 2H_2O$.

M_r = ... [1]

(v) Identify **M**. Show your working.

M is .... [2]

(d) Explain why it is necessary to add **FA 3** in each titration.

....

.... [1]

[Total: 15]

Redox titrations with $KMNO_4$ **Chem 6 Q# 43/** ALvl Chemistry/2021/s/TZ 1/Paper 3/Q# 1 :o)
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Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 Iron(II) sulfate crystals, $FeSO_4 \cdot xH_2O$, contain water of crystallisation. You will carry out a titration to determine the value of x in the formula, where x is an integer. A solution containing a known mass of the crystals will be titrated with acidified aqueous potassium manganate(VII) of known concentration.

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

FA 1 contains $26.52\,g\,dm^{-3}$ of hydrated iron(II) sulfate, $FeSO_4 \cdot xH_2O$.
FA 2 is $0.0200\,mol\,dm^{-3}$ potassium manganate(VII), $KMnO_4$.
FA 3 is dilute sulfuric acid, H_2SO_4.

(a) Method

- Fill the burette with **FA 2**.
- Pipette $25.0\,cm^3$ of **FA 1** into a conical flask.
- Use the $25\,cm^3$ measuring cylinder to transfer $25\,cm^3$ of **FA 3** into the same conical flask.

- Carry out a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the accuracy of your practical work.
- Record in a suitable form below all your burette readings and the volume of **FA 2** added in each accurate titration.

Keep FA 1 for use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value to be used in your calculations. Show clearly how you obtained this value.

$25.0\,cm^3$ of **FA 1** required .... cm^3 of **FA 2**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to an appropriate number of significant figures. [1]

(ii) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 2** calculated in **(b)**.

moles of $KMnO_4$ = ... mol [1]

(iii) Calculate the number of moles of iron(II) sulfate present in $1.00\,dm^3$ of **FA 1**.

moles of $FeSO_4$ = ... mol [1]

(iv) Calculate the mass of iron(II) sulfate present in 1.00 dm^3 of **FA 1**.

mass of $FeSO_4$ = ... g [1]

(v) Calculate the value of x in $FeSO_4{\cdot}xH_2O$.

x = ... [2]

(d) Iron(II) sulfate in solution is readily oxidised by air to form iron(III) sulfate.

State the effect, on the value of x calculated in **(c)(v)**, if some of your sample of **FA 1** had oxidised before you carried out the titration.
Explain your answer.

....

....

....

.... [2]

[Total: 16]

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will carry out a titration to determine the relative formula mass of a hydrated salt, **FA 1**.

FA 1 is a hydrated salt.
FA 2 is dilute sulfuric acid.
FA 3 is 0.0200 mol dm^{-3} potassium manganate(VII).

(a) Method

Preparing a solution of FA 1

- Weigh the stoppered container of **FA 1**. Record the mass in the space below.
- Tip all the **FA 1** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FA 1** used.
- Add approximately 100 cm^3 of **FA 2** to the **FA 1** in the beaker.
- Stir the mixture until all the **FA 1** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Rinse the beaker and glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of the hydrated salt is **FA 4**. Label the flask **FA 4**.

Titration

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Use the 25.0 cm^3 measuring cylinder to add 10 cm^3 of **FA 2** to the **FA 4** in the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 3** added in each accurate titration.

Keep FA 3 and FA 4 for use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 3** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 3**. [1]

(c) Calculations

(i) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 3** calculated in **(b)**.

moles of $KMnO_4$ = ... mol [1]

(ii) 1 mol of $KMnO_4$ reacts with 5 mol of the hydrated salt, **FA 1**.

Calculate the concentration of the hydrated salt, in $mol\,dm^{-3}$, in **FA 4**.

concentration of **FA 4** = ... $mol\,dm^{-3}$ [1]

(iii) Use your answer to **(c)(ii)**, and your data on page 2, to calculate an experimentally determined value for the relative formula mass of the hydrated salt, **FA 1**.
Show your working.

M_r of **FA 1** = ... [1]

[Total: 12]

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 The concentrations of solutions of hydrogen peroxide are often represented in terms of 'volume strength'. In this experiment you will determine the 'volume strength' of a solution of hydrogen peroxide by titration with acidified potassium manganate(VII).

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$

FA 1 is 0.0300 $mol\,dm^{-3}$ potassium manganate(VII), $KMnO_4$.
FA 2 is dilute sulfuric acid, H_2SO_4.
FA 3 is aqueous hydrogen peroxide, H_2O_2.

(a) Method

Dilution of FA 3

- Pipette 25.0 cm^3 of **FA 3** into the 250 cm^3 volumetric flask.
- Make the solution up to the mark using distilled water.
- Shake the flask thoroughly.
- Label this diluted solution of hydrogen peroxide **FA 4**.

Titration

- Fill the burette with **FA 1**.
- Rinse the pipette thoroughly with distilled water and then with a little **FA 4**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 20 cm^3 of **FA 2** into the same conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all of your burette readings and the volume of **FA 1** added in each accurate titration.

Keep FA 1, FA 2 and FA 3 for use in Questions 2 and 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 1**. [1]

(c) Calculations

(i) Give your answers to **(ii)**, **(iii)**, **(iv)** and **(v)** to the appropriate number of significant figures. [1]

(ii) Calculate the number of moles of potassium manganate(VII) present in the volume calculated in **(b)**.

moles of $KMnO_4$ = ... mol [1]

(iii) The equation for the reaction of potassium manganate(VII) with hydrogen peroxide is shown.

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$

Use your answer to **(c)(ii)** to calculate the number of moles of hydrogen peroxide used in each titration.

moles of H_2O_2 = ... mol

Hence calculate the concentration of H_2O_2 in **FA 4**, in mol dm^{-3}.

concentration of H_2O_2 in **FA 4** = ... mol dm^{-3} [1]

(iv) Calculate the concentration of H_2O_2 in **FA 3**, in mol dm^{-3}.

concentration of H_2O_2 in **FA 3** = ... mol dm^{-3} [1]

(v) When hydrogen peroxide decomposes in the presence of a catalyst, oxygen is produced.

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

The 'volume strength' of hydrogen peroxide is equal to the volume of oxygen, in dm^3, produced under room conditions, when 1.00 dm^3 of the solution decomposes.

Use your answer to **(c)(iv)** and the equation above to calculate the volume, in dm^3, of oxygen produced when 1.00 dm^3 of **FA 3** decomposes. This is the 'volume strength', in vol, of **FA 3**.

(Under room conditions 1.00 mol of gas occupies a volume of 24.0 dm^3.
If you were unable to calculate the concentration of H_2O_2 in **FA 3**, assume that it is 1.02 mol dm^{-3}. This may **not** be the correct value.)

'volume strength' of **FA 3** = ... vol [2]

(d) The maximum error in reading a 25.0 cm^3 pipette is ±0.06 cm^3.

Show by calculation that the pipette is more accurate than a burette for measuring 25.0 cm^3 of solution.

....

.... [1]

[Total: 15]

2 You will carry out a second experiment to determine the concentration of hydrogen peroxide, **FA 1**, in $mol\,dm^{-3}$, by titration with acidified aqueous potassium manganate(VII). The equation for the reaction is given below.

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$

FA 1 is a solution of hydrogen peroxide, H_2O_2.
FA 3 is 0.0300 $mol\,dm^{-3}$ potassium manganate(VII), $KMnO_4$.
FA 4 is dilute sulfuric acid.

(a) Method

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add approximately 20 cm^3 of **FA 4** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 3** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 1** required .... cm^3 of **FA 3**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of manganate(VII) ions present in the volume of **FA 3** calculated in **(b)**.

moles of MnO_4^- = ... mol

(ii) Calculate the number of moles of hydrogen peroxide present in 25.0 cm^3 of **FA 1**.

moles of H_2O_2 = ... mol

(iii) Using your answer to **(ii)** calculate the concentration, in $mol\,dm^{-3}$, of hydrogen peroxide in **FA 1**.

concentration of H_2O_2 in **FA 1** = ... $mol\,dm^{-3}$ [4]

Redox titrations with $KMNO_4$ Chem 6 **Q# 47/** ALvl Chemistry/2015/w/TZ 1/ Paper 3/Q# 1/ :o)
www.SmashingScience.org

1 In this experiment you will determine the ionic equation for the reaction of acidified potassium manganate(VII) with potassium iodide. Excess potassium iodide is used and the reaction produces iodine. The amount of iodine produced is measured by titration with sodium thiosulfate.

FA 1 is 0.0180 $mol\,dm^{-3}$ potassium manganate(VII), $KMnO_4$.
FA 2 is 1.00 $mol\,dm^{-3}$ sulfuric acid, H_2SO_4.
FA 3 is 0.500 $mol\,dm^{-3}$ potassium iodide, KI.
FA 4 is 0.100 $mol\,dm^{-3}$ sodium thiosulfate, $Na_2S_2O_3$.
starch indicator

(a) Method

- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the measuring cylinder to add 25 cm^3 of **FA 2** to the conical flask.
- Use the measuring cylinder to add 20 cm^3 of **FA 3** to the conical flask.
- Fill the burette with **FA 4**.
- Carry out a rough titration. When the colour of the mixture becomes yellow/orange, add a few drops of starch indicator. Then titrate until the mixture goes colourless.
- Record all your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 4** added in each accurate titration.

Keep FA 1 and FA 2 for use in Question 3 and FA 4 for use in Question 2.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 4** to be used in your calculations.
Show clearly how you have obtained this value.

Volume of **FA 4** required is .... cm^3. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of sodium thiosulfate in the volume of **FA 4** calculated in **(b)**.

moles of $Na_2S_2O_3$ = ... mol

(ii) Use the equation below to calculate the number of moles of iodine that reacted with the sodium thiosulfate in the titration.

$$I_2 + 2Na_2S_2O_3 \rightarrow Na_2S_4O_6 + 2NaI$$

moles of I_2 = ... mol

(iii) Use information on page 2 to calculate the number of moles of potassium manganate(VII) in **FA 1** used in the titration.

moles of $KMnO_4$ = ... mol

(iv) From your answers to **(ii)** and **(iii)**, calculate the number of moles of iodine produced by the reaction of **2.00** moles of potassium manganate(VII) with excess potassium iodide.

moles I_2 = ... mol

(v) Using your answer to **(iv)**, put a tick next to the ionic equation that represents the reaction between **FA 1** and **FA 3**.

$2MnO_4^- + 2I^- + 16H^+ \rightarrow I_2 + 2Mn^{6+} + 8H_2O$ ....

$2MnO_4^- + 4I^- + 16H^+ \rightarrow 2I_2 + 2Mn^{5+} + 8H_2O$ ....

$2MnO_4^- + 6I^- + 16H^+ \rightarrow 3I_2 + 2Mn^{4+} + 8H_2O$ ....

$2MnO_4^- + 8I^- + 16H^+ \rightarrow 4I_2 + 2Mn^{3+} + 8H_2O$ ....

$2MnO_4^- + 10I^- + 16H^+ \rightarrow 5I_2 + 2Mn^{2+} + 8H_2O$ ....

$2MnO_4^- + 12I^- + 16H^+ \rightarrow 6I_2 + 2Mn^{+} + 8H_2O$ ....

(vi) Prove that the iodide ion has been oxidised in the equation that you selected in **(v)**.

....

....

.... [5]

(d) (i) The error in calibration of the pipette you used is ±0.06 cm^3.
Calculate the percentage error when measuring **FA 1**, using the pipette.

percentage error = ... %

(ii) A student suggested that the experiment would be more accurate if a pipette was used to measure solution **FA 3**.
State and explain whether you agree with the student.

....

....

.... [2]

[Total: 15]

1 In this question you will determine the concentration of iron(II) ions in **FA 2**. To do this you will do a titration using potassium manganate(VII) solution. The iron(II) ions, Fe^{2+}, are oxidised by the manganate(VII) ions, MnO_4^-.

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

When all the Fe^{2+} ions have been oxidised, the presence of unreacted MnO_4^- ions causes the solution to become a permanent pink colour.

FA 1 contains 0.0200 mol dm^{-3} manganate(VII) ions, MnO_4^-.
FA 2 is a solution containing iron(II) ions, Fe^{2+}.
FA 3 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Method

- Fill the burette with **FA 1**.
- Use the pipette to transfer 25.0 cm^3 of **FA 2** into the conical flask.
- Use the 25 cm^3 measuring cylinder to add 10 cm^3 of **FA 3** to the conical flask.
- Add **FA 1** from the burette into the conical flask until the solution becomes a permanent pink colour.
- Perform a **rough titration** and record your burette readings in the space below.

The rough titre is .... cm^3.

- Do as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 1** added in each accurate titration.

Keep FA 2 to use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 2** required .... cm^3 of **FA 1**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of manganate(VII) ions present in the volume of **FA 1** calculated in **(b)**.

moles of MnO_4^- = ... mol

(ii) Calculate the number of moles of iron(II) ions present in 25.0 cm^3 of **FA 2**.

moles of Fe^{2+} = ... mol

(iii) Calculate the concentration, in mol dm^{-3}, of iron(II) ions in **FA 2**.

concentration of Fe^{2+} in **FA 2** = ... mol dm^{-3}

(iv) **FA 2** was prepared by dissolving hydrated ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2.6H_2O$ in distilled water. Calculate the mass of salt that would have to be dissolved in 1.00 dm^3 of water to prepare **FA 2**.
(A_r: H, 1.0; N, 14.0; O, 16.0; S, 32.1; Fe, 55.8)

I	
II	
III	
IV	

mass of $(NH_4)_2Fe(SO_4)_2.6H_2O$ = ... g
[4]

[Total: 12]

1 Hydrogen peroxide, H_2O_2, is unstable and decomposes to give water and oxygen. In addition to the usual units of concentration, mol dm^{-3}, the concentration of a solution of hydrogen peroxide can also be given in 'volume strength' or 'vol'. For example, in **Question 3** you will use a solution of '20 vol' H_2O_2. This term means that when 1 dm^3 of this solution is completely decomposed it generates 20 dm^3 of oxygen at room temperature and pressure.

The aim of the following titration is to determine the volume strength of a solution of hydrogen peroxide. To do this you will titrate an acidified solution of hydrogen peroxide with potassium manganate(VII) solution.

FA 1 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 2 is aqueous hydrogen peroxide, H_2O_2.
FA 3 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Method

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 2** into the conical flask.
- Use the measuring cylinder to add 25 cm^3 of **FA 3** to the conical flask.
- Run **FA 1** from the burette into the conical flask until the pink colour remains.
- Perform a **rough titration** and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 1** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	

[6]

(b) From your accurate titration results obtain a suitable value to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 2** required .... cm^3 of **FA 1**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 1** calculated in **(b)**.

moles of $KMnO_4$ = ... mol

(ii) Use the following equation and your answer to **(i)** to calculate the number of moles of hydrogen peroxide used in each titration.

$$2KMnO_4 + 5H_2O_2 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 5O_2 + 8H_2O$$

moles of H_2O_2 = ... mol

(iii) Calculate the concentration, in mol dm^{-3}, of H_2O_2 in **FA 2**.

concentration of H_2O_2 = ... mol dm^{-3}

(iv) Write an equation for the decomposition of hydrogen peroxide to produce oxygen and water.

....

(v) Calculate the concentration in 'volume strength' of H_2O_2 in **FA 2**. You must assume that the molar volume of oxygen is 24.0 dm^3 mol^{-1} at room temperature and pressure.

concentration of **FA 2** = ... 'vol'
[5]

I	
II	
III	
IV	
V	

[Total: 12]

1 In this experiment you are to determine the relative formula mass of an iron(II) salt by titration with potassium manganate(VII).

FA 1 is the iron(II) salt.
FA 2 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 3 is dilute sulfuric acid, H_2SO_4.

(a) Method

Preparing a solution of FA 1

- Weigh the 250 cm^3 beaker and record the mass in the space below.
- Add all the **FA 1** provided to the beaker. Weigh the beaker with **FA 1** and record the mass.
- Calculate the mass of **FA 1** used and record this in the space below.
- Use a measuring cylinder to add approximately 100 cm^3 of **FA 3** to the beaker. Stir until all the solid has dissolved.
- Transfer the solution into the 250 cm^3 volumetric (graduated) flask labelled **FA 4**.
- Wash out the beaker thoroughly using distilled water and add the washings to the volumetric flask. Make the solution up to the mark using distilled water.
- Shake the flask thoroughly to mix the solution before using it for your titrations.
- This solution of the iron(II) salt is **FA 4**.

Titration

- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Use a measuring cylinder to add 20 cm^3 of **FA 3** to the flask.
- Fill the burette with **FA 2**.
- Titrate **FA 4** with **FA 2** until the solution changes to a permanent pink colour.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 2** added in each accurate titration.

For Examiner's Use

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value to be used in your calculations. Show clearly how you have obtained this value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 2** [1]

For Examiner's Use

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 2** calculated in **(b)**.

moles of $KMnO_4$ = ... mol

(ii) The half-equation for the reduction of a manganate(VII) ion is:

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

Give the half-equation for the oxidation of an iron(II) ion to an iron(III) ion.

....

Therefore, 1 mole of manganate(VII) ions reacts with 5 moles of iron(II) ions.

(iii) Calculate the number of moles of iron(II) ions present in 25.0 cm^3 of solution **FA 4**.

moles of Fe^{2+} in 25.0 cm^3 of **FA 4** = ... mol

(iv) Calculate the number of moles of iron(II) ions present in 250 cm^3 of solution **FA 4**.

moles of Fe^{2+} in 250 cm^3 of **FA 4** = ... mol

(v) In 1 mole of the iron(II) salt, **FA 1**, there is 1 mole of iron(II) ions.
Use the mass of **FA 1** you weighed out to calculate the relative formula mass of the iron(II) salt.

relative formula mass = ...

I	
II	
III	
IV	
V	

[5]

(d) (i) A 25 cm^3 pipette is accurate to ± 0.06 cm^3.
Calculate the maximum percentage error when the pipette was used to measure solution **FA 4**.

percentage error in measuring **FA 4** = ... %

(ii) State the maximum error in the mass of the 250 cm^3 beaker that you recorded in **(a)**.

maximum error = ... g

(iii) Calculate the maximum percentage error in the mass of **FA 1** used in **(a)**.

maximum percentage error = ... %
[2]

[Total: 15]

2 Solid sodium sulfite is often provided as the hydrated salt, $Na_2SO_3 \cdot xH_2O$, where x is an integer. You will determine x by using a solution of this sodium sulfite and reacting it with an excess of aqueous iodine.

$$Na_2SO_3(aq) + I_2(aq) + H_2O(l) \rightarrow Na_2SO_4(aq) + 2I^-(aq) + 2H^+(aq)$$

The amount of iodine remaining will be determined by titration using a known concentration of sodium thiosulfate, $Na_2S_2O_3$.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

FA 3 is a solution containing 31.50 g dm^{-3} of hydrated sodium sulfite, $Na_2SO_3 \cdot xH_2O$.
FA 4 is 0.100 mol dm^{-3} iodine, I_2.
FA 5 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 6 is starch indicator.

(a) Method

- Pipette **10.0** cm^3 of **FA 3** into a conical flask.
- Pipette **25.0** cm^3 of **FA 4** into the same flask.
- Swirl the flask to mix the contents.
- Fill the second burette with **FA 5**.
- Add **FA 5** to the flask until the mixture is yellow.
- Add approximately 10 drops of **FA 6**.
- Complete the rough titration by adding **FA 5** until the mixture is colourless.
- Record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 5** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

10.0 cm^3 of **FA 3** plus 25.0 cm^3 of **FA 4** required .... cm^3 of **FA 5**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(iii)** and **(iv)** to an appropriate number of significant figures. [1]

(ii) Use your answer to **(b)** to calculate the amount, in mol, of sodium thiosulfate, **FA 5**, required to react with the excess iodine which remained in the conical flask.

amount of $Na_2S_2O_3$ = ... mol

Hence calculate the amount, in mol, of iodine, **FA 4**, remaining in the conical flask.

amount of I_2 remaining = ... mol [1]

(iii) Calculate the amount, in mol, of iodine, **FA 4**, added to the conical flask.

amount of I_2 added = ... mol

Hence calculate the amount, in mol, of iodine that reacted with the 10.0 cm^3 of sodium sulfite, **FA 3**.

amount of I_2 that reacted with Na_2SO_3 = ... mol [1]

(iv) Use your final answer to **(c)(iii)** and the information on page 5 to calculate the amount, in mol, of sodium sulfite present in 1.00 dm^3 of **FA 3**.

amount of Na_2SO_3 in 1.00 dm^3 = ... mol [1]

(v) Use your answer to **(c)(iv)** to calculate the value of x in $Na_2SO_3 \cdot xH_2O$.

x = ... [2]

(d) A student suggests that sodium carbonate should be added to each mixture of sodium sulfite and iodine in the conical flask before titrating with sodium thiosulfate.

State whether you agree with the student. Explain your answer.

....

.... [1]

[Total: 15]

Titrations with thiosulfate and iodine **Chem 6 Q# 52/** ALvl Chemistry/2020/w/TZ 1/Paper 3/Q# 1 :o)
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Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will determine the value of x in the formula of hydrated sodium thiosulfate, $Na_2S_2O_3 \cdot xH_2O$, where x is an integer. You will first prepare a solution of the salt and then use this solution in a titration with aqueous iodine. The thiosulfate ions react with iodine as shown.

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

FA 1 is hydrated sodium thiosulfate, $Na_2S_2O_3 \cdot xH_2O$.
FA 3 is 0.0500 mol dm^{-3} iodine, I_2.
starch indicator

(a) Method

Preparation of salt solution

- Weigh the container containing **FA 1**.
- Tip the contents of the container into the 250 cm^3 beaker.
- Weigh the container with any residue.
- Record all your readings in the space below.

- Add approximately 200 cm^3 of distilled water to the salt in the beaker and stir until the salt has dissolved.
- Pour the contents carefully into the 250 cm^3 volumetric flask.
- Rinse the beaker with a little distilled water and add these washings to the flask.
- Fill the flask to the mark with distilled water and shake to ensure thorough mixing.
- Label this solution **FA 2**.

Titration

- Fill a burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 3** into the conical flask.
- Add **FA 2** from the burette until the solution in the flask turns yellow.
- Add 10 drops of starch indicator to the conical flask. The solution will turn blue-black.
- Continue to add more **FA 2** from the burette until the blue-black colour just disappears. This is the end-point of the titration.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure your recorded results show the precision of your practical work.
- Record, in a suitable form in the space below, all of your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
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VIII	

[8]

(b) From your accurate titration results, obtain a value for the volume of **FA 2** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 2**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)** and **(c)(iii)** to the appropriate number of significant figures. [1]

(ii) Calculate the number of moles of iodine in 25.0 cm^3 of **FA 3**.

moles of I_2 = ... mol [1]

(iii) Calculate the number of moles of thiosulfate ions in the volume recorded in **(b)**.

moles of $S_2O_3^{2-}$ = ... mol

Hence calculate the number of moles of hydrated sodium thiosulfate in the mass weighed in **(a)**.

moles of $Na_2S_2O_3 \cdot xH_2O$ = ... mol [1]

(iv) Calculate the value for x in the formula of hydrated sodium thiosulfate, $Na_2S_2O_3 \cdot xH_2O$. Show your working.

x = ...
[3]

(d) (i) State the maximum error in a single reading on the balance used in **(a)**.

maximum error = ± .... g

Calculate the maximum percentage error in the mass of **FA 1** used in **(a)**.
Show your working.

maximum percentage error = ± .... %
[1]

(ii) Assume that the uncertainty in the mass of **FA 1** is the only source of error in your experiment.

Calculate the minimum value for the relative formula mass of **FA 1**.
Show your working.

minimum value for the relative formula mass of **FA 1** = ... [1]

(e) A student prepares **FA 2** using anhydrous sodium thiosulfate salt and the same mass of salt that you used in **(a)**.

State how the student's titre would compare with the average titre value you obtained in **(b)**.
Explain your answer.

....

....

....

.... [1]

(f) In many titrations it is usual to fill the burette with the solution of known concentration.

Suggest why this was not done in **(a)**.

....

.... [1]

[Total: 19]

1 In this experiment you will determine the oxidation number of iodine in one of its compounds by titration.

FA 1 is a 0.0197 mol dm^{-3} solution of the iodine-containing compound.
FA 2 is dilute sulfuric acid, H_2SO_4.
FA 3 is aqueous potassium iodide, KI.
FA 4 is 0.105 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
starch indicator

FA 1 reacts with excess acidified potassium iodide to produce iodine, I_2. This iodine is then titrated with aqueous sodium thiosulfate using starch indicator.

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Using the measuring cylinder, add 10 cm^3 of **FA 2** to the same conical flask.
- Using the same measuring cylinder, add 20 cm^3 of **FA 3** to the mixture in the conical flask. The mixture will now be a red-brown colour, due to iodine produced.
- Carry out a rough titration by adding **FA 4** from the burette until the mixture becomes light brown.
- Then add 10 drops of starch indicator. The mixture will change to a dark blue colour.
- Continue titrating until the mixture becomes colourless. This is the end-point.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
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VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

The iodine produced required .... cm^3 of **FA 4**. [1]

(c) **Calculations**

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of sodium thiosulfate in the volume of **FA 4** calculated in **(b)**.

moles of $Na_2S_2O_3$ = ... mol

(ii) The equation for the reaction of iodine with sodium thiosulfate is shown.

$$I_2(aq) + 2Na_2S_2O_3(aq) \rightarrow Na_2S_4O_6(aq) + 2NaI(aq)$$

Calculate the number of moles of iodine that reacted with the sodium thiosulfate calculated in **(i)**.

moles of I_2 = ... mol

(iii) Use the information on page 2 to calculate the number of moles of iodine-containing compound in the 25 cm³ of **FA 1** used in each titration.

moles of iodine-containing compound in 25 cm³ **FA 1** = ... mol

(iv) Use your answers to **(ii)** and **(iii)** to calculate the number of moles of iodine produced when 1 mole of the iodine-containing compound in **FA 1** reacts with excess **FA 3**. Give your answer as an integer.

moles of I_2 = ... mol

(v) The anion in **FA 1** is IO_x^- where **x** is the number of oxygen atoms present in the formula.

Use your answer to **(iv)** to balance the ionic equation for the reaction between **FA 1** and **FA 3** under acidic conditions.
Hence deduce the value of **x** in the formula IO_x^-.

$$IO_{...}^- + ...I^- + ...H^+ \rightarrow ......I_2 + ...H_2O$$

x = ...

(vi) Calculate the oxidation state of iodine in **FA 1**.
(If you were unable to calculate **x** in part **(v)**, assume that **x** = 4.)

oxidation state of iodine = ...

[6]

[Total: 14]

1 In this experiment you will determine the relative formula mass of a copper salt by titration.

A solution of the copper salt reacts with excess acidified potassium iodide, producing iodine. This iodine is then titrated with aqueous sodium thiosulfate, using starch indicator.

FA 1 is an aqueous solution of the copper salt prepared by dissolving 26.0 g of the salt to make 1.00 dm³ of solution.
FA 2 is dilute sulfuric acid, H_2SO_4.
FA 3 is aqueous potassium iodide, KI.
FA 4 is 0.110 mol dm⁻³ sodium thiosulfate, $Na_2S_2O_3$.
starch indicator

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm³ of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately 10 cm³ of **FA 2** to the same conical flask.
- Use the measuring cylinder to add approximately 20 cm³ of **FA 3** to the mixture in the conical flask. The mixture will now be a brown colour, due to iodine produced in the reaction.
- Begin your rough titration by adding **FA 4** from the burette until the mixture becomes light brown.
- Add 10 drops of starch indicator. The mixture will become darker.
- Continue titrating until the mixture becomes an off-white colour. This is the end-point.
- Add **one** drop of starch indicator to check that no traces of dark colour are produced. If the mixture stays off-white, the titration is finished. If some dark colour is produced, because iodine is still present, continue the titration.
- Record your burette readings and the rough titre in the space below.

The rough titre is .... cm³.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 4** added in each accurate titration.

Keep FA 3 and starch indicator for use in Question 3.

I	
II	
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VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 4** to be used in your calculations.
Show clearly how you obtained this value.

The iodine produced required .... cm³ of **FA 4**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of sodium thiosulfate, $Na_2S_2O_3$, in the volume of **FA 4** calculated in **(b)**.

moles of $Na_2S_2O_3$ = ... mol

(ii) Balance the equation for the reaction of iodine with sodium thiosulfate. State symbols are not required.

......I_2 + ...$Na_2S_2O_3$ → ....$Na_2S_4O_6$ + ...NaI

(iii) Using your answer to **(ii)**, calculate the number of moles of iodine that reacted with the number of moles of $Na_2S_2O_3$ calculated in **(i)**.

moles of I_2 = ... mol

(iv) Iodine, I_2, is produced in the reaction between **FA 1** and **FA 3**. **FA 3** is in excess.

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Using your answer to **(iii)**, calculate the number of moles of copper(II) ions in 25.0 cm^3 of **FA 1**.

moles of Cu^{2+} ions = ... mol

(v) Using your answer to **(iv)** and the information on page 2, calculate the relative formula mass of the copper compound in **FA 1**.

M_r of copper compound = ...

[4]

[Total: 12]

There are three questions on this paper. Question 2 should not be the last question attempted.

For Examiner's Use

1 You are to determine the concentration of hydrochloric acid, which supplies the H^+ ions in the following reaction.

$$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \longrightarrow 3H_2O(l) + 3I_2(aq)$$

In the presence of an excess of IO_3^- ions and an excess of I^- ions, the amount of I_2 liberated is directly proportional to the amount of H^+ ions present and can be determined by titration with sodium thiosulfate, $Na_2S_2O_3$.

You are provided with the following reactants.

FA 1 hydrochloric acid
FA 2 containing 15.0 g dm^{-3} sodium thiosulfate, $Na_2S_2O_3.5H_2O$
aqueous potassium iodate(V), KIO_3
aqueous potassium iodide, KI

(a) Method

- Fill a burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into the conical flask.
- Use a 25 cm^3 measuring cylinder to add to the flask 10 cm^3 of aqueous potassium iodate(V) **and** 10 cm^3 of aqueous potassium iodide. There is an excess of each of these reagents.
- Place the flask on a white tile.
- Titrate the liberated iodine with **FA 2**.
- During the titration the colour of the iodine in the solution will fade from red-brown to orange to yellow. The end-point occurs when the solution just goes colourless with the addition of a single drop of **FA 2**.
- You should perform a **rough titration**.
  In the space below record your burette readings for this rough titration.

The rough titre is .... cm^3

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record in a suitable form below all of your burette readings and the volume of **FA 2** added in each accurate titration.
- Make certain any recorded results show the precision of your practical work.

I	
II	
III	
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VI	
VII	

[7]

(b) From your titration results obtain a suitable value to be used in your calculation. Show clearly how you have obtained this value.

25.0 cm^3 of **FA 1** require .... cm^3 of **FA 2**. [1]

Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(c) (i) Calculate the concentration, in mol dm^{-3}, of the sodium thiosulfate in **FA 2**.
FA 2 contains 15.0 g dm^{-3} $Na_2S_2O_3.5H_2O$.
[A_r: H, 1.0; O, 16.0; Na, 23.0; S, 32.1]

The concentration of sodium thiosulfate in **FA 2** is .... mol dm^{-3}.

(ii) Calculate how many moles of $Na_2S_2O_3$ are contained in the volume of **FA 2** recorded in **(b)**.

.... mol of $Na_2S_2O_3$

(iii) Calculate how many moles of iodine, I_2 reacted with the $Na_2S_2O_3$ in **(ii)**.

$$2Na_2S_2O_3(aq) + I_2(aq) \rightarrow Na_2S_4O_6(aq) + 2NaI(aq)$$

.... mol of iodine reacted with the sodium thiosulfate.

(iv) Calculate how many moles of hydrochloric acid, HC*l*, reacted with an excess of potassium iodate(V) and an excess of potassium iodide to produce the amount of iodine calculated in **(iii)**.

$$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3H_2O(l) + 3I_2(aq)$$

.... mol of HC*l* produced the amount of iodine calculated in **(iii)**.

For Examiner's Use

I	
II	
III	
IV	
V	

(v) Calculate the concentration, in mol dm^{-3}, of HC*l* in **FA 1**.

The concentration of HC*l* in **FA 1** is .... mol dm^{-3}.
[5]

(d)

> Each reading with a burette has a maximum error of ±0.05 cm^3.
> Grade B volumetric (bulb) pipettes are calibrated to ±0.06 cm^3.

(i) Calculate the maximum error in the volume run from the burette recorded in any titration.

The maximum error is .... cm^3.

(ii) Express the maximum error calculated in **(i)** as a percentage error for the volume calculated in **(b)**.

The maximum error is .... %.

(iii) Calculate the percentage error when 25.0 cm^3 of **FA 1** was pipetted into the conical flask.

The error was .... %.
[2]

[Total: 15]

1 You are provided with the following.
FA 1 is 0.15 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 2 is aqueous copper(II) sulfate.
You are also provided with a 10% solution of potassium iodide, KI, and starch indicator.

You are required to determine the concentration, in g dm^{-3}, of hydrated copper(II) sulfate, $CuSO_4.5H_2O$, in **FA 2**.

Dilution of FA 2

(a) By using a burette measure between 47.00 cm^3 and 47.50 cm^3 of **FA 2** into the 250 cm^3 graduated flask labelled **FA 3**.
Record your burette readings and the volume of **FA 2** added to the flask in the space below.

Make up the contents of the flask to the 250 cm^3 mark with distilled water. Place the stopper in the flask and mix the contents thoroughly by slowly inverting the flask a number of times.

Titration

Fill a second burette with **FA 1**.

Perform a rough (trial) titration as follows.

Pipette 25.0 cm^3 of **FA 3** into a conical flask.
Use the measuring cylinder provided to add 10 cm^3 of 10% potassium iodide to the flask.
The Cu^{2+} ions in **FA 3** oxidise the iodide ions to iodine, I_2, which can be titrated with **FA 1**.
The flask will also contain an off-white precipitate of copper(I) iodide, CuI.

Run **FA 1** from the burette, 1 cm^3 at a time, until the brown colour of the iodine solution has changed to pale brown.
Add approximately 10 drops of starch indicator. A blue-black colour should be seen as the starch reacts with the residual iodine.
Continue to add **FA 1** 1 cm^3 at a time until the blue-black colour of the starch-iodine complex disappears and there is no further colour change.

In this rough titration .... cm^3 of **FA 1** were added.

Perform sufficient further titrations to obtain reliable results.

Record your titration results in the space below. Make certain that your recorded results show the precision of your working.

For Examiner's Use

i	
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iii	
iv	
v	
vi	

[6]

(b) From your titration results obtain a volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this volume.

[1]

Calculations
Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(c) Use your answer to **(b)** to calculate how many moles of $Na_2S_2O_3$ were run from the burette into the conical flask.

.... mol of $Na_2S_2O_3$ were run from the burette into the conical flask.

Calculate how many moles of I_2 reacted with the $Na_2S_2O_3$ run from the burette.

$$2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e^-$$

$$I_2 + 2e^- \rightarrow 2I^-$$

.... mol of I_2 reacted with the $Na_2S_2O_3$ run from the burette.

Calculate how many moles of Cu^{2+} ions reacted with iodide ions to produce this amount of I_2.

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

.... mol of Cu^{2+} reacted to form the I_2.

Calculate the concentration, in mol dm^{-3}, of Cu^{2+} in **FA 3**.

The concentration of Cu^{2+} in **FA 3** is .... mol dm^{-3}.

Calculate the concentration, in mol dm^{-3}, of Cu^{2+} in **FA 2**.

The concentration of Cu^{2+} in **FA 2** is .... mol dm^{-3}.

Calculate the concentration, in g dm^{-3}, of $CuSO_4.5H_2O$ in **FA 2**.
[A_r: Cu, 63.5; H, 1.0; O, 16.0; S, 32.1]

FA 2 contains .... g dm^{-3} $CuSO_4.5H_2O$.
[5]

For Examiner's Use

i	
ii	
iii	
iv	
v	

(d) The maximum error in any burette reading is ±0.05 cm^3.

Explain how the maximum error in a titration is therefore ±0.10 cm^3.

....

....

.... [1]

(e) Calculate the maximum percentage error in the average titre given in **(b)**.

The error is .... %. [1]

[Total: 14]

2 In this experiment you will measure the heat given out by the reaction of excess zinc with copper(II) sulfate solution and use this to estimate the concentration of the copper(II) sulfate.

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

FA 4 is zinc powder.
FA 5 is aqueous copper(II) sulfate, $CuSO_4$.

(a) Method

Read through the instructions carefully and prepare a table below for your results before starting any practical work.

- Support the plastic cup in the 250 cm³ beaker.
- Use the 50 cm³ measuring cylinder to transfer 40 cm³ of **FA 5** into the plastic cup.
- Measure and record the initial temperature of the solution in the plastic cup.
- Start the stopwatch. Measure and record the temperature of the solution every 30 seconds up to and including the temperature at 2 minutes. Stir the solution frequently.
- At time $t = 2\frac{1}{2}$ minutes, add **all** the powdered zinc to the solution in the plastic cup and stir the mixture.
- Record the temperature every 30 seconds from $t = 3$ minutes up to and including $t = 9$ minutes. Stir the solution constantly.

I	
II	
III	
IV	

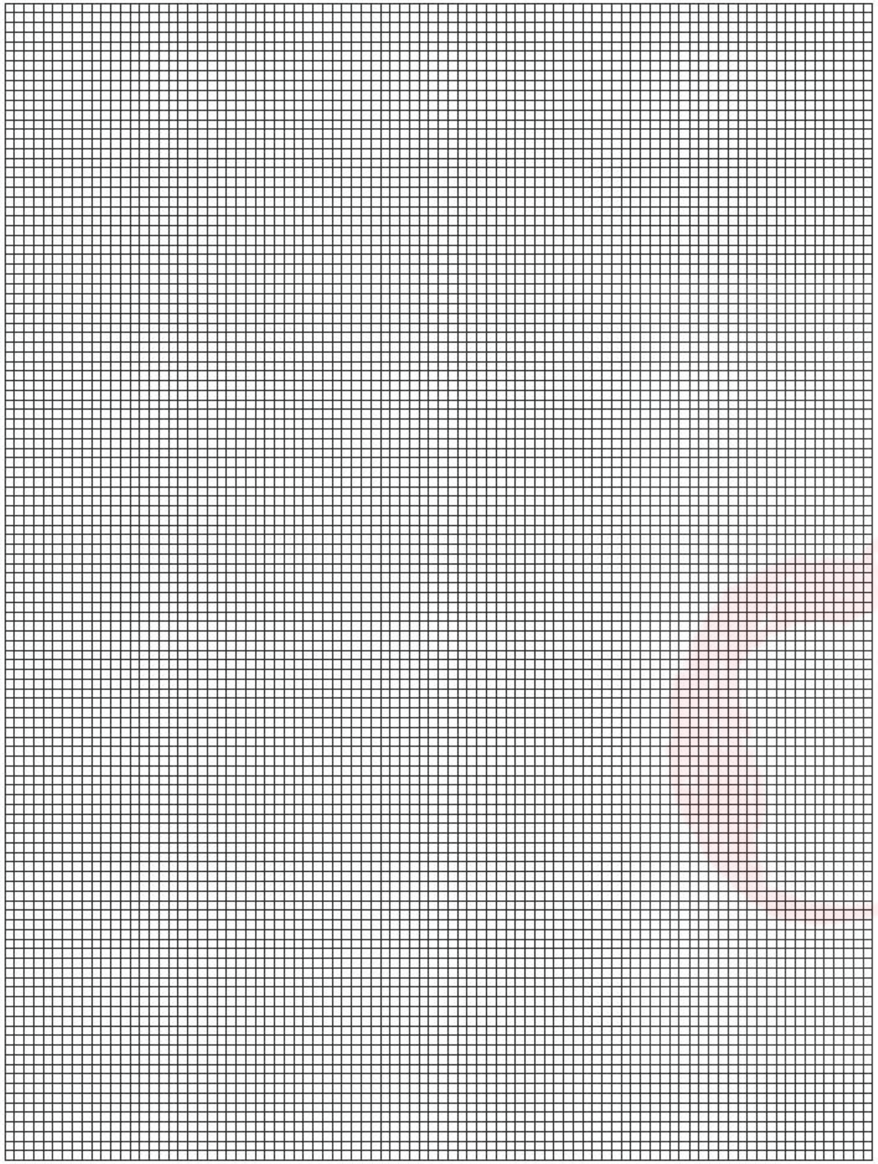
[4]

(b) (i) On the grid opposite, plot the temperature (y-axis) against the time (x-axis). The scale for the temperature axis must allow you to plot a point with a temperature 5 °C greater than the maximum temperature you recorded.

(ii) Draw the following best-fit **straight** lines on the graph.
- a line through the points between time $t = 0$ minutes and time $t = 2$ minutes
- a line through the points between time $t = 5$ minutes and time $t = 9$ minutes
- a vertical line at time $t = 2\frac{1}{2}$ minutes

(iii) Extrapolate the first two straight lines so that they intersect the vertical line at time $t = 2\frac{1}{2}$ minutes.
Use these extrapolated lines to determine the theoretical temperature **change** at time $t = 2\frac{1}{2}$ minutes.

change in temperature = ... °C
[5]



(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Use your answer to **(b)(iii)** to calculate the heat energy produced in the reaction.
(Assume that **4.2 J** are required to increase the temperature of 1 cm^3 of solution by 1 °C.)

heat energy produced = ... J

(ii) The molar enthalpy change, ΔH, for the reaction shown below is –219 kJ mol^{-1}.

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

Use this value and your answer to **(i)** to calculate the number of moles of copper(II) sulfate in your reaction.

moles of $CuSO_4$ = ... mol

(iii) Use your answer to **(ii)**, to calculate the concentration of copper(II) sulfate, in mol dm^{-3}, in **FA 5**.

concentration of $CuSO_4$ = ... mol dm^{-3}
[3]

(d) (i) Calculate the maximum percentage error in the highest temperature that you recorded in your results table.

maximum percentage error = ... %

(ii) A student suggested that the concentration of the copper(II) sulfate could be determined more accurately if a greater mass of zinc had been used.
Explain whether you agree with this student.

(iii) A second student suggested that the concentration of the copper(II) sulfate could be determined more accurately if a smaller volume of copper(II) sulfate was used.
Explain whether you agree with this student.

[3]

[Total: 15]

Thermometric (metal displacement) enthalpy experiments Chem 6 **Q# 58/** ALvl Chemistry/2014/w/TZ 1/ Paper 3/Q# 1/ :o) www.SmashingScience.org

1 You are to determine the enthalpy change of reaction, ΔH, for the reaction shown below.

$$Cu(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2(g)$$

Since copper is an unreactive metal it does not react directly with dilute acids. You will therefore need to find the enthalpy change of reaction for two reactions that do occur. The equations for these two reactions are below.

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g) \qquad \textbf{Reaction 1}$$

$$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s) \qquad \textbf{Reaction 2}$$

You will carry out experiments to find the enthalpy changes for each of **Reaction 1** and **Reaction 2** and use these values to calculate the enthalpy change for the reaction of copper with sulfuric acid.

TURN OVER FOR EXPERIMENTAL METHOD

Determining the enthalpy change for Reaction 1

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g) \qquad \textbf{Reaction 1}$$

(a) Method

FA 1 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4.
FA 2 is magnesium powder, Mg.

Read through the method before you start any practical work and prepare a suitable table for your results.

- Weigh the stoppered tube containing **FA 2**. Record the mass.
- Support the plastic cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25 cm^3 of **FA 1** into the plastic cup.
- Measure the temperature of **FA 1** in the plastic cup and start the stop clock. Record this temperature as being the temperature at time = 0.
- Measure, and record, the temperature of this **FA 1** every half minute for 2 minutes.
- At time = $2\frac{1}{2}$ minutes add the **FA 2** to the acid and stir carefully to reduce acid spray.
- Measure the temperature of the mixture in the cup at time = 3 minutes and then every half minute up to time = 7 minutes.
- Continue stirring occasionally throughout this time.
- Weigh the stoppered tube that had contained **FA 2**. Record the mass.
- Calculate and record the mass of **FA 2** added to the sulfuric acid.
- Rinse the plastic cup with water and shake to dry.

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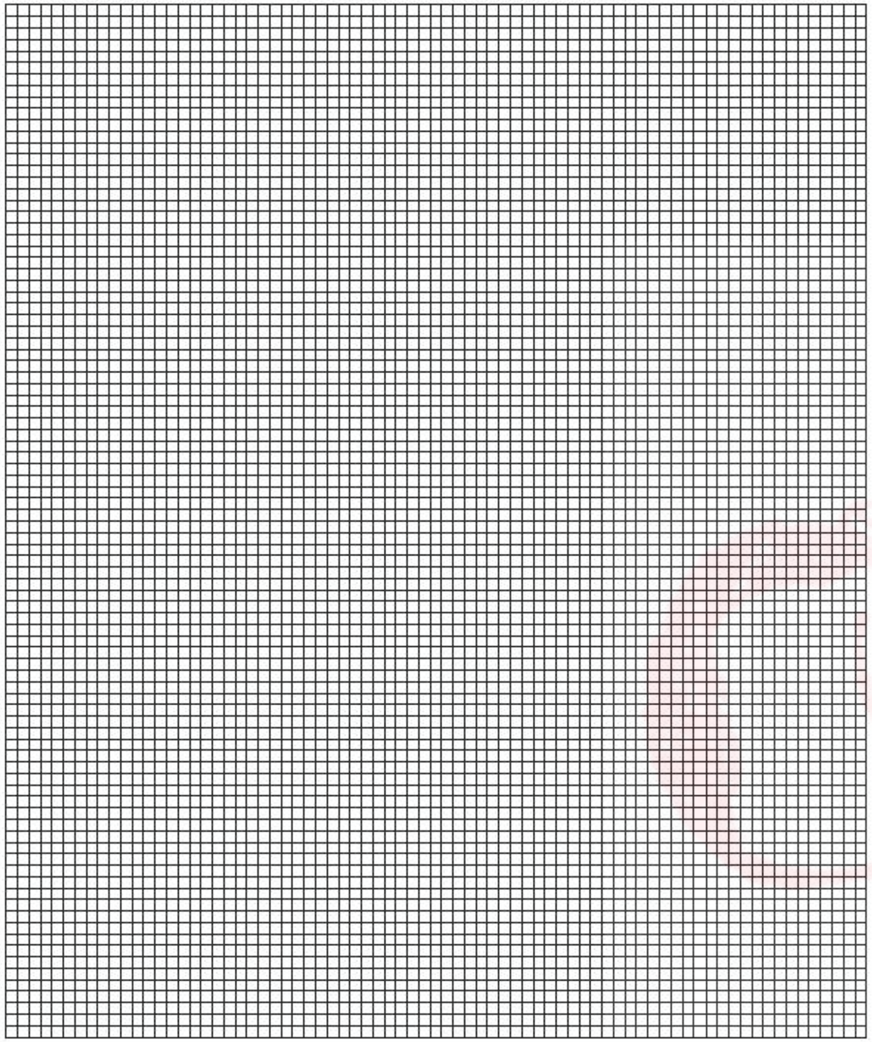
VI	

[6]

(b) (i) On the grid below plot a graph of temperature (*y*-axis) against time (*x*-axis).



(ii) Complete the graph by inserting **two**, **straight** lines of best fit:

- one to show the temperature up to time = $2\frac{1}{2}$ minutes,
- one to show the temperature after time = $2\frac{1}{2}$ minutes.

I	
II	
III	
IV	

(iii) From your graph, use the two straight lines of best fit to calculate the change in temperature at time = $2\frac{1}{2}$ minutes.

temperature change = ... °C

[4]

(c) Calculations

(i) In the reaction in **(a)**, the sulfuric acid was in excess. Without carrying out any additional tests, what observation could you have made during your experiment to confirm this?

....

....

(ii) Calculate the energy change that occurred during the reaction in **(a)**.
[Assume that 4.2 J is needed to raise the temperature of 1.0 cm^3 of solution by 1.0 °C.]

energy change = ... J

(iii) Use your answer to **(ii)** to calculate the enthalpy change, in kJ mol^{-1}, for the reaction between sulfuric acid and magnesium.
[A_r : Mg, 24.3]

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$ **Reaction 1**

enthalpy change for **Reaction 1** = ... (*sign*) .... (*value*) kJ mol^{-1}

[4]

Determining the enthalpy change for Reaction 2

$$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s) \qquad \textbf{Reaction 2}$$

(d) Method

FA 3 is 1.00 mol dm^{-3} copper(II) sulfate, $CuSO_4$.
FA 4 and **FA 5** are magnesium powder, Mg.

Read through the method before you start any practical work and prepare a suitable table for your results.

- Weigh the stoppered tube containing **FA 4**. Record the mass.
- Support the plastic cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25 cm^3 of **FA 3** into the plastic cup.
- Measure the temperature of **FA 3** in the plastic cup and record the temperature.
- Add the **FA 4** to the **FA 3** in the cup and stir the mixture constantly.
- Measure and record the maximum temperature reached during the reaction.
- Calculate and record the maximum temperature change that occurred during the reaction.
- Weigh the stoppered tube that had contained **FA 4**. Record the mass.
- Calculate and record the mass of **FA 4** added to the copper(II) sulfate.
- Empty the contents of the plastic cup into the 100 cm^3 beaker labelled **waste**.
- Rinse the plastic cup and shake to dry.

- Repeat this experiment using **FA 5** in place of **FA 4**.

[2]

(e) Calculations

(i) Using your results from **(d)**, calculate the mean temperature rise.

mean temperature rise = ... °C

(ii) Using your results from **(d)**, calculate the mean mass of magnesium used.

mean mass = ... g

(iii) Show, using a suitable calculation, that the copper(II) sulfate was in excess in these reactions.

(iv) Using your values from **(i)** and **(ii)**, calculate the enthalpy change, in kJ mol^{-1}, for the reaction between magnesium and copper(II) sulfate.
[Assume that 4.2 J is needed to raise the temperature of 1.0 cm^3 of solution by 1.0 °C.]
[A_r : Mg, 24.3]

$$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s) \qquad \textbf{Reaction 2}$$

enthalpy change for **Reaction 2** = ... kJ mol^{-1}
sign *value*

[4]

Enthalpy change for Reaction 3

Reaction 3 is shown below.

$Cu(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2(g)$ **Reaction 3**

(f) Use your values for the enthalpy changes for **Reactions 1** and **2** to calculate the enthalpy change for **Reaction 3**.

$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$ **Reaction 1**

$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s)$ **Reaction 2**

Show clearly how you obtained your answer.

(If you were unable to calculate the enthalpy changes for **Reactions 1** and **2**, you should assume that the value for **Reaction 1** is $-444\,kJ\,mol^{-1}$ and that the value for **Reaction 2** is $-504\,kJ\,mol^{-1}$. Note: these are not the correct values.)

enthalpy change for **Reaction 3** = ... $kJ\,mol^{-1}$
sign value

[2]

(g) (i) The method you used to determine the enthalpy change for **Reaction 1** was more accurate than the method you used to determine the enthalpy change for **Reaction 2**. Suggest **two** reasons why the method used for **Reaction 2** was less accurate. Explain your answers.

1 ....

....

....

2 ....

....

....

(ii) A student suggested that the accuracy of the method used for **Reaction 2** could be improved by using a larger volume of copper(II) sulfate. Is this a correct suggestion? Give a reason for your answer.

....

....

[3]

[Total: 25]

2 You will determine, using Hess' Law, the enthalpy change, ΔH_1, for the reaction of magnesium with oxygen to form magnesium oxide.

For Examiner's Use

$$Mg(s) + \frac{1}{2}O_2(g) \longrightarrow MgO(s)$$

(a) Reaction of magnesium with sulfuric acid

Method

FA 4 is $0.64\,mol\,dm^{-3}$ sulfuric acid.
FA 5 is magnesium turnings. This is supplied in two containers.

You will carry out the experiment **twice**.

- Support the plastic cup in a $250\,cm^3$ beaker.
- Using a measuring cylinder, transfer $25\,cm^3$ of **FA 4** into the plastic cup.
- Tilt the beaker so that the bulb of the thermometer is covered by the solution. Measure and record the initial temperature of the solution.
- **Carefully**, add all the **FA 5** from one of the containers into the plastic cup.
- Stir the mixture constantly with the thermometer.
- Record the highest temperature obtained.
- Empty and rinse the plastic cup and dry it with a paper towel.
- Repeat the experiment using the second portion of **FA 5**.

In the space below, record all your readings in an appropriate form.
Calculate the mean temperature rise.

I	
II	
III	
IV	
V	

mean temperature rise = ... °C [5]

Calculation

Show your working and express your answers to **three** significant figures.

(i) Using the mean temperature rise above, calculate the mean heat energy produced in the reaction.
(You may assume that 4.3 J are required to raise the temperature of $1.0\,cm^3$ of any solution by 1.0 °C.)

heat energy produced = ...
value unit

(ii) Calculate the enthalpy change, ΔH_2, in $kJ\,mol^{-1}$, for the following reaction.

$$Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$$

You should assume that the magnesium in your reaction is in excess.

ΔH_2 = ... (sign) .... (value) $kJ\,mol^{-1}$ [2]

(b) Reaction of magnesium oxide with sulfuric acid

Method

FA 4 is $0.64\,mol\,dm^{-3}$ sulfuric acid.
FA 6 is magnesium oxide.

- Using a measuring cylinder, transfer $50\,cm^3$ of **FA 4** into a $250\,cm^3$ beaker.
- Place the beaker on a tripod and gauze, and heat gently until the temperature of the acid reaches 45 °C–60 °C.
- Support a plastic cup in a $250\,cm^3$ beaker.
- Transfer all the solution of hot **FA 4** into the plastic cup.
- Stir and record the temperature of hot **FA 4**.
- **Immediately** add all the **FA 6** to the **FA 4** in the plastic cup.
- Stir the mixture constantly with the thermometer.
- Record the highest temperature obtained.

In the space below, record all your readings in an appropriate form.

[3]

Calculation

Show your working and express your answers to **three** significant figures.

(i) Calculate the heat energy produced in the reaction.
(You may assume that 4.3 J are required to raise the temperature of $1.0\,cm^3$ of any solution by 1.0 °C.)

heat energy produced = ... (value) .... (unit)

(ii) Calculate the enthalpy change, ΔH_3, in $kJ\,mol^{-1}$, for the following reaction.

$$MgO(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2O(l)$$

You should assume that the magnesium oxide in your reaction is in excess.

ΔH_3 = ... (sign) .... (value) $kJ\,mol^{-1}$

(iii) The enthalpy change for the following reaction is $-286\,kJ\,mol^{-1}$.

$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(l) \qquad \Delta H = -286\,kJ\,mol^{-1}$$

Use the Hess' Law cycle given below to calculate ΔH_1, the enthalpy change for the reaction of magnesium with oxygen.

$$\begin{array}{ccc} Mg(s) + H_2SO_4(aq) + \tfrac{1}{2}O_2(g) & \xrightarrow{\quad \Delta H_1 \quad} & MgO(s) + H_2SO_4(aq) \\ \Delta H_2 \downarrow & & \downarrow \Delta H_3 \\ MgSO_4(aq) + H_2(g) + \tfrac{1}{2}O_2(g) & \xrightarrow{\quad -286\,kJ\,mol^{-1} \quad} & MgSO_4(aq) + H_2O(l) \end{array}$$

ΔH_1 = ... (sign) .... (value) $kJ\,mol^{-1}$ [3]

(c) Suggest **one** improvement to the method by which heat losses from your apparatus could have been reduced.

....

....[1]

[Total: 14]

1 You are provided with the following reagents.

- two weighing bottles labelled **FA 1**, each containing between 2.90 g and 3.00 g of zinc powder
- **FA 2**, 0.80 mol dm^{-3} copper sulfate, $CuSO_4$

You are to determine the enthalpy change, ΔH, for the following reaction.

$$Zn(s) + CuSO_4(aq) \longrightarrow Cu(s) + ZnSO_4(aq)$$

You will carry out the experimental procedure twice.

Read through the instructions below before starting the experiment.

(a) You will weigh each bottle and later in the experiment weigh it again after the zinc powder has been tipped into copper sulfate solution.
In the space below prepare a table to record the weighings and the mass of zinc powder used in **each** experiment.

Weigh accurately, to at least one decimal place, one of the weighing bottles labelled **FA 1**.
Record this mass in the table you have prepared. [1]

(b) Procedure

- Support the plastic cup in the 250 cm^3 beaker and, using a pipette, place 25.0 cm^3 of **FA 2** into the plastic cup.
- Stir gently, taking a temperature reading every ½ minute until a steady temperature has been obtained for a period of at least 2 minutes. You may need to tilt the beaker in order to cover the bulb of the thermometer with solution.
- On a precise minute reading tip the zinc powder from the weighing bottle into the plastic cup.
Do not read the temperature at this time or at the following ½ minute.
- Continue to stir the mixture thoroughly. Starting 1 minute after the addition of the zinc powder, record the temperature every ½ minute until the temperature has reached a maximum value and then decreased steadily for at least 5 minutes.
- Reweigh the empty weighing bottle. Record the mass of the bottle + any residual zinc powder and the mass of zinc powder used in the experiment in the table you prepared in **(a)**.
- Record your results in an appropriate form in the space on the following page.

Repeat the experiment using the contents of the second weighing bottle and 25.0 cm^3 copper sulfate solution pipetted into a clean plastic cup.

(b) continued

Results Make certain your readings of temperature display the precision of the apparatus used.

[11]

(c) Plot your temperature and time readings separately for each experiment on the grids on the next page. Your temperature axis should extend 10 °C **above** the highest temperature you recorded.
Draw lines as instructed below.

On each graph draw a horizontal straight line through the steady initial temperature.

Extrapolate the cooling section of each graph back to the time when you added the zinc powder.
Draw construction lines on the graphs to deduce the "theoretical" **temperature rise** at the moment of mixing the reagents.

experiment 1

experiment 2

[4]

(d) The "theoretical" **temperature rises** are .... °C and .... °C.

The mean "theoretical" **temperature rise** is .... °C. [1]

Calculations

Show working and appropriate significant figures in **all** of your calculations. [2]

(e) Calculate how many moles of copper sulfate, $CuSO_4$, were pipetted into the plastic cup.

.... mol of $CuSO_4$ were pipetted into the cup

For each experiment calculate how many moles of zinc powder were added to the plastic cup.
[A_r: Zn, 65.4]

1st experiment	2nd experiment

In the 1st experiment .... mol of zinc powder were added to the plastic cup.

In the 2nd experiment .... mol of zinc powder were added to the plastic cup. [1]

(f) Use your answers to **(e)** and the equation for the reaction to determine which reagent was in excess and which was the limiting reagent. Explain your answer.

$$Zn(s) + CuSO_4(aq) \longrightarrow Cu(s) + ZnSO_4(aq)$$

....

....

.... [1]

(g) From your mean "theoretical" temperature rise at the time of mixing, calculate the heat energy released in the plastic cup by the reaction of zinc powder with copper sulfate solution.
[You may assume that 4.3 J are required to raise the temperature of 1 cm^3 of any solution by 1 °C and that the mass of any solid may be ignored.]

.... of heat energy are released. [1]

(h) Calculate, correct to 3 significant figures, the enthalpy change in $kJ\,mol^{-1}$ for the following reaction.

$$Zn(s) + CuSO_4(aq) \longrightarrow Cu(s) + ZnSO_4(aq)$$

ΔH = ... $kJ\,mol^{-1}$ [2]

(i) Identify and explain **one** source of error in the experiment you have carried out.

....

....

....

.... [1]

(j) Suggest a way in which the experimental method you used could be improved in a school or college laboratory in order to minimise this error.

....

....

....

.... [1]

[Total: 26]

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will determine the percentage purity of a sample of impure anhydrous sodium carbonate. You will use two different methods to measure the enthalpy change of reaction when a sample of impure anhydrous sodium carbonate reacts with excess dilute hydrochloric acid.

FA 1 is a sample of the impure anhydrous sodium carbonate.
FA 2 is 2.00 $mol\,dm^{-3}$ hydrochloric acid, HCl.
FA 3 is a second sample of the impure anhydrous sodium carbonate used in **FA 1**.

(a) Method 1

- Weigh the container with **FA 1**. Record this mass.

mass of container with **FA 1** = ... g

- Support one of the plastic cups in the 250 cm^3 beaker.
- Use the measuring cylinder to place 25 cm^3 of **FA 2** into the cup.
- Measure the temperature of the **FA 2** in the cup. Tilt the cup if necessary so that the bulb of the thermometer is fully covered. Record this temperature at time $t = 0$.
- Start the stopclock and leave it running for the whole experiment.
- Measure and record the temperature of **FA 2** in the cup every half minute for 2 minutes.
- At $t = 2\frac{1}{2}$ minutes tip all the **FA 1** into the cup. Stir the contents of the cup.
- Measure and record the temperature of the contents of the cup at $t = 3$ minutes and then every half minute up to $t = 9$ minutes.
- Weigh the container with any residual **FA 1**. Record this mass.

I	
II	
III	
IV	
V	

mass of container with residual **FA 1** = ... g [5]

I	
II	
III	
IV	

(b) (i) On the grid on page 3, plot a graph of temperature (*y*-axis) against time (*x*-axis). You should choose a scale that allows you to plot 2 °C above the maximum temperature reached.

On your graph, draw two straight lines of best fit. One line is for the temperature before adding **FA 1** and the other line for the cooling of the solution once reaction is complete.

Extrapolate these two lines to $t = 2\frac{1}{2}$ minutes. [4]

(ii) From your graph, find the theoretical temperature rise at $t = 2\frac{1}{2}$ minutes.

theoretical temperature rise = ... °C [1]

(c) (i) Calculate the energy released in the reaction.

(Assume 4.2 J of heat energy changes the temperature of 1.0 cm^3 of solution by 1.0 °C.)

energy released = ... J [1]

(ii) The equation for the reaction between anhydrous sodium carbonate and hydrochloric acid is shown.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

The literature value for the enthalpy change of this reaction is –27.0 kJ mol^{-1}.

Use this figure, and the value that you found in **(i)**, to find the mass of anhydrous sodium carbonate you used in **(a)**. You should assume that no energy was lost to the surroundings in your experiment.

mass Na_2CO_3 = ... g [2]

(iii) Calculate the percentage of anhydrous sodium carbonate present in **FA 1**.

percentage Na_2CO_3 in **FA 1** = ... % [1]

(d) In your calculation in **(c)**, what assumption have you made about the impurity present in **FA 1**?

....

.... [1]

(e) Method 2

- Weigh a clean, dry plastic cup and record the mass.
- Add between 1.70 g and 1.90 g of **FA 3** to the plastic cup and record the mass.
- Support the plastic cup in the 250 cm^3 beaker.
- Pour 25 cm^3 of **FA 2** into the measuring cylinder.
- Measure and record the initial temperature of **FA 2** in the measuring cylinder.
- Pour the 25 cm^3 of **FA 2** into the plastic cup.
- Stir the contents of the cup and record the maximum temperature. Tilt the cup if necessary so that the bulb of the thermometer is fully covered.
- Calculate and record the mass of **FA 3** used and the change in temperature.

[2]

(f) Use the temperature rise in **(e)**, and the fact that the enthalpy change for the reaction between anhydrous sodium carbonate and hydrochloric acid is –27.0 kJ mol^{-1}, to calculate the percentage of anhydrous sodium carbonate in **FA 3**.

percentage Na_2CO_3 in **FA 3** = ... % [2]

(g) **FA 1** and **FA 3** are both samples of the same impure anhydrous sodium carbonate and so the percentage of anhydrous sodium carbonate found using **Method 1** and **Method 2** should be the same. In practice the percentages are sometimes different from each other.

In both methods, percentage errors occur due to measuring the mass of solid and the temperature rise.

Ignoring these errors, which method is more accurate?
Tick the correct box and explain your answer.

Method 1 more accurate ☐

Method 2 more accurate ☐

Method 1 and Method 2 equally accurate ☐

....

....

....
[1]

(h) A student decided to confirm by experiment the literature value for the enthalpy change of the reaction between anhydrous sodium carbonate and hydrochloric acid. By mistake the student weighed a sample of hydrated sodium carbonate, $Na_2CO_3.10H_2O$, instead of anhydrous sodium carbonate, Na_2CO_3.

State what effect this would have on the calculated value of the enthalpy change for the reaction. Explain your answer.

....

....

....

.... [2]

(i) A student used 3.00 g of anhydrous sodium carbonate that was 80.0% pure by mass.

Calculate the minimum volume of 2.00 mol dm^{-3} hydrochloric acid that would be needed to react completely with this sample of impure anhydrous sodium carbonate.

volume of HC*l* = ... cm^3 [3]

[Total: 25]

H3 Thermometric (decomposition of H_2O_2) enthalpy experiments Chem 5 Q# 62/ ALvl Chemistry/2020/m/TZ 3/Paper 3/Q# 2 :o) www.SmashingScience.org

2 In this experiment you will determine the enthalpy change, ΔH, for the catalytic decomposition of hydrogen peroxide into water and oxygen.

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

FA 3 is aqueous hydrogen peroxide, H_2O_2.
FA 5 is manganese(IV) oxide, MnO_2.

(a) Method

Experiment 1

- Support one of the plastic cups inside the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to add 30 cm^3 of **FA 3** into the plastic cup.
- Measure and record the initial temperature of the solution.
- Add a heaped spatula measure of **FA 5** to the solution in the plastic cup.
- Stir constantly until the maximum temperature is reached and record this temperature.
- Calculate and record the temperature rise.
- Rinse and dry the thermometer.

Experiment 2

- Support the second plastic cup inside the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to add 40 cm^3 of **FA 3** into the plastic cup.
- Measure and record the initial temperature of the solution.
- Add a heaped spatula measure of **FA 5** to the solution in the plastic cup.
- Stir constantly until the maximum temperature is reached and record this temperature.
- Calculate and record the temperature rise.

I	
II	
III	
IV	
V	

[5]

(b) Calculation

(i) Calculate the energy released in **Experiment 1**.
[Assume that 4.2 J changes the temperature of 1.0 cm^3 of solution by 1.0 °C.]

energy released = ... J [1]

(ii) Use your answer to **1(c)(iv)** to calculate the number of moles of hydrogen peroxide used in **Experiment 1**.
(If you were unable to calculate the concentration of H_2O_2 in **FA 3**, assume that it is 1.02 mol dm^{-3}. This may **not** be the correct value.)

moles of H_2O_2 = ... mol [1]

(iii) Calculate the enthalpy change, in kJ mol^{-1}, for the decomposition of 1 mole of hydrogen peroxide into water and oxygen.

enthalpy change = ... (sign) .... (value) kJ mol^{-1} [1]

(c) (i) A student suggested that the experiment would be more accurate if the same mass of **FA 5**, manganese(IV) oxide, had been weighed out for each experiment.

State and explain whether you agree with the student's suggestion.

....

....

....

.... [2]

(ii) The student also suggested that **Experiments 1** and **2** should give the same temperature rise, even though a greater volume of **FA 3** was used in **Experiment 2**.

State and explain whether you agree with the student's suggestion.

....

....

.... [1]

[Total: 11]

2 Hydrated copper(II) sulfate, $CuSO_4{\cdot}5H_2O$, can lose its water of crystallisation to form anhydrous copper(II) sulfate.

The enthalpy change for the dehydration of hydrated copper(II) sulfate is shown in the equation.

$$CuSO_4{\cdot}5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

You will carry out experiments to determine the enthalpy changes for the solution of hydrated and anhydrous copper(II) sulfate and then use Hess's law to determine the enthalpy change of dehydration.

FA 4 is hydrated copper(II) sulfate, $CuSO_4{\cdot}5H_2O$.
FA 5 is anhydrous copper(II) sulfate, $CuSO_4$.

(a) Determination of the enthalpy change of solution of hydrated copper(II) sulfate.

Method

- Weigh the container with **FA 4**. Record the mass.
- Support the cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Measure and record the temperature of the water.
- Tip all the **FA 4** into the water and stir until the solid dissolves.
- Measure and record the lowest temperature reached.
- Rinse and dry the cup ready for the next experiment.
- Weigh the container with any residual **FA 4**. Record the mass.
- Calculate and record the change in temperature.
- Calculate and record the mass of **FA 4** used.

Results

[2]

(b) Calculations

(i) Calculate the energy change during this reaction.

energy change = ... J [1]

(ii) Calculate the amount, in mol, of hydrated copper(II) sulfate, **FA 4**, used in the experiment. Show your working.

amount of $CuSO_4{\cdot}5H_2O$ = ... mol [1]

(iii) Calculate the enthalpy change, in $kJ\,mol^{-1}$, when 1.00 mol of hydrated copper(II) sulfate dissolves in water. This is the enthalpy of solution.

enthalpy change of solution = ... $kJ\,mol^{-1}$ [1]
sign *value*

(c) Determination of the enthalpy change of solution of anhydrous copper(II) sulfate.

Method

- Weigh the container with **FA 5**. Record the mass.
- Support the cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Measure and record the temperature of the water.
- Tip all the **FA 5** into the water and stir until the solid dissolves.
- Measure and record the highest temperature reached.
- Weigh the container with any residual **FA 5**. Record the mass.
- Calculate and record the change in temperature.
- Calculate and record the mass of **FA 5** used.

Results

[1]

(d) Calculations

(i) Calculate the enthalpy change, in $kJ\,mol^{-1}$, for the enthalpy change of solution of anhydrous copper(II) sulfate.

enthalpy change = ... $kJ\,mol^{-1}$ [2]
sign *value*

(ii) Use the enthalpy changes calculated in **(b)(iii)** and **(d)(i)** to calculate the enthalpy change of dehydration of hydrated copper(II) sulfate.

$$CuSO_4{\bullet}5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

Show clearly how you obtained your answer.

enthalpy change = ... $kJ\,mol^{-1}$ [1]
sign *value*

(e) In the experiments in **(a)** and **(c)** you used the same method to determine the enthalpy change of solution of two solids.

Tick the box to indicate which statement is correct.
Ignore the effect of differences in mass used.

The percentage error in **(b)(iii)** is less than the percentage error in **(d)(i)**.	
The percentage errors in **(b)(iii)** and **(d)(i)** are equal.	
The percentage error in **(b)(iii)** is greater than the percentage error in **(d)(i)**.	

Explain your choice.

....

.... [1]

2 In this experiment you will determine the enthalpy change of solution for anhydrous sodium carbonate.

FA 5 is anhydrous sodium carbonate, Na_2CO_3. (You are given approximately 11 g.)

(a) Method

Experiment 1

- Weigh a cup. Record the mass.
- Transfer 4.0–4.2 g of **FA 5** from the container into the cup.
- Reweigh and record the mass of the cup with **FA 5**.
- Calculate and record the mass of **FA 5** used.
- Support the cup in the 250 cm^3 beaker.
- Pour 30 cm^3 of distilled water into the 50 cm^3 measuring cylinder.
- Measure and record the temperature of the distilled water in the measuring cylinder.
- Add the 30 cm^3 of distilled water to the **FA 5** in the cup.
- Stir constantly until the maximum temperature is reached.
- Measure and record the maximum temperature.
- Calculate and record the temperature rise.

Experiment 2

- Repeat **Experiment 1** but this time use 5.0–5.2 g of **FA 5** and the other cup.
- Record all data from **both** experiments in one table.

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the energy produced during **Experiment 1**.
(Assume that 4.2 J change the temperature of 1.0 cm^3 of solution by 1.0 °C.)

energy produced = ... J [1]

(ii) Calculate the number of moles of Na_2CO_3 used in **Experiment 1**.

moles of Na_2CO_3 = ... mol [1]

(iii) Use your answers to **(b)(i)** and **(b)(ii)** to calculate the enthalpy change, in $kJ\,mol^{-1}$, for the reaction below.
Show your working.

$$Na_2CO_3(s) + aq \rightarrow Na_2CO_3(aq)$$

enthalpy change = ... $kJ\,mol^{-1}$
sign value [1]

(c) (i) A student suggested that by using the same thermometer, quantities of **FA 5**, and water, a more accurate value for the temperature rise could be calculated.

Suggest how the student could obtain a more accurate measurement.

....

....

.... [1]

(ii) State the maximum error in a single thermometer reading in your experiment in **(a)**.

maximum error = ...

Hence calculate the maximum percentage error in the measurement of the temperature rise in **Experiment 2**.

% error = ...
[2]

[Total: 10]

G1 Gravimetric (thermal decomposition) experiments Chem 10 Q# 65/ ALvl

Chemistry/2022/s/TZ 1/Paper 3/Q# 2 :o) www.SmashingScience.org

2 In this experiment you will identify a magnesium compound by thermal decomposition. When heated this compound decomposes to give magnesium oxide.

FA 4 is the magnesium compound.

(a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the **FA 4** from the container into the crucible.
- Weigh the crucible, lid and **FA 4**. Record the mass.
- Calculate the mass of **FA 4**. Record the mass.
- Place the crucible and contents on a pipe-clay triangle.
- Heat the crucible gently, without the lid, for approximately 2 minutes.
- Heat strongly for a further 4 minutes.
- Place the lid on the crucible and leave it to cool for at least 5 minutes.

During the cooling period, you may wish to begin work on Question 3.

- When the crucible is cool, weigh the crucible with its lid and contents. Record the mass.
- Heat strongly, without the lid, for a further 2 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.
- When the crucible has cooled, reweigh the crucible with its lid and contents. Record the mass.
- Calculate the mass of residue obtained. Record the mass.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

(i) Calculate the amount, in mol, of magnesium oxide produced in your experiment.

amount of MgO = ... mol [1]

(ii) 1 mole of **FA 4** decomposes on heating to produce 1 mole of MgO and 1 mole of gas **X**.

Calculate the relative formula mass, M_r, of **X**.

M_r of **X** = ... [1]

(iii) **X** contains one or more oxygen atoms.

Suggest the identity of **X**.

X is .... [1]

(iv) Deduce the name of **FA 4**.

FA 4 is .... [1]

(c) A student suggests that this experiment will be more accurate if **FA 4** is heated throughout the experiment with a lid on the crucible.

State whether the student is correct. Explain your answer.

....

....

.... [1]

(d) State the uncertainty in a single reading of your balance.

uncertainty = ± .... g

Calculate the maximum percentage error in the mass of residue that you obtained.
Show your working.

maximum percentage error = ...%
[1]

[Total: 11]

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 You will investigate a compound of a Group 1 element to determine which element is present. Group 1 carbonates decompose to give carbon dioxide when heated to high temperatures.

$$X_2CO_3(s) \rightarrow X_2O(s) + CO_2(g)$$

FA 1 is the carbonate of the element, X_2CO_3.

(a) Method

- Weigh a crucible with its lid and record the mass.
- Add 1.40–1.60 g of **FA 1** to the crucible.
- Weigh the crucible and its lid with **FA 1** and record the mass.
- Place the crucible on the pipe-clay triangle. Heat the crucible, with its lid on, gently for approximately 1 minute. Then heat strongly for another minute.
- Carefully remove the lid. Heat the crucible strongly for 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

While the crucible is cooling you may wish to begin work on Question 2.

- Reweigh the crucible and contents with its lid. Record the mass.
- Remove the lid. Heat the crucible and contents strongly for a further 2 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes. Reweigh the crucible and residue with its lid. Record the mass.
- Calculate and record the mass of **FA 1** added to the crucible. Calculate the mass of residue obtained.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

(i) Calculate the mass of carbon dioxide produced when the sample of $\mathbf{X}_2CO_3$ was heated.

mass of CO_2 produced = ... g [1]

(ii) Calculate the number of moles of $\mathbf{X}_2CO_3$ needed to produce the mass of carbon dioxide calculated in **(b)(i)**.

moles of $\mathbf{X}_2CO_3$ needed = ... mol [1]

(iii) Use your answer to **(b)(ii)** and the information on page 2 to calculate the relative formula mass, M_r, of $\mathbf{X}_2CO_3$.

M_r of $\mathbf{X}_2CO_3$ = ... [1]

(iv) Use your answer to **(b)(iii)** to calculate the relative atomic mass, A_r, of **X**. Hence identify **X**. Explain how you reached your conclusion.

X is ....

....

.... [2]

(c) In this experiment you heated the sample of $\mathbf{X}_2CO_3$ for approximately 8 minutes.

Explain, using evidence from your results in **(a)**, whether your sample of $\mathbf{X}_2CO_3$ had decomposed completely.

....

.... [1]

[Total: 11]

Gravimetric (thermal decomposition) experiments **Chem 10 Q# 67/** ALvl Chemistry/2021/m/TZ 3/Paper 3/Q# 2 :o) www.SmashingScience.org

2 In this experiment you will determine the relative formula mass of the same metal hydrogencarbonate, $\mathbf{M}HCO_3$, by thermal decomposition. Then you will compare the result obtained with your answer from **1(c)(iv)**.

FA 4 is another sample of the metal hydrogencarbonate, $\mathbf{M}HCO_3$.

(a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the **FA 4** from the container into the crucible.
- Weigh the crucible, lid and **FA 4**. Record the mass.
- Calculate and record the mass of **FA 4** used.
- Place the crucible and contents on a pipe-clay triangle.
- Heat the crucible gently, with the lid on, for approximately one minute.
- Heat strongly, with the lid off, for a further four minutes.
- Replace the lid and leave the crucible to cool for at least five minutes.

During each cooling period, you may wish to work on Question 3.

- When the crucible has cooled, weigh the crucible with its lid and contents. Record the mass.
- Heat strongly, with the lid off, for a further two minutes.
- Replace the lid and leave the crucible to cool for at least five minutes.
- When the crucible has cooled, reweigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass of residue obtained.
- This residue is **FA 5**.

Keep FA 5 for use in 2(b)(i).

Results

I	
II	
III	
IV	
V	

[5]

(b) (i) Pour a 1 cm depth of dilute hydrochloric acid into a test-tube. Add a spatula measure of residue **FA 5** to the acid.

Record **all** your observations and identify any gas formed.

....

....

.... [2]

(ii) Use your observations in **(b)(i)** to identify the anion in **FA 5**. Assume all the **M**HCO_3 has decomposed.

Anion in **FA 5** is .... [1]

(iii) Steam is produced when the metal hydrogencarbonate, **FA 4**, is thermally decomposed.

Use your answer in **(b)(ii)** to complete the equation for the thermal decomposition of **M**HCO_3. Include state symbols.

.....**M**$HCO_3(s) \rightarrow$ .....$CO_2(g)$ + ... + ... [1]

(iv) The number of moles of carbon dioxide given off during the thermal decomposition is given by the formula below.

$$\text{moles of } CO_2 = \frac{\text{mass lost during heating}}{(M_r \text{ of } CO_2 + M_r \text{ of } H_2O)}$$

Calculate the number of moles of carbon dioxide given off.

moles CO_2 = ... mol [1]

(v) Calculate the relative formula mass, M_r, of **M**HCO_3.

Show how you obtained your answer using your data from **Question 2**.

M_r of **M**HCO_3 = ... [1]

(vi) You have obtained two values for the M_r of **M**HCO_3; one in **1(c)(iv)** and another in **2(b)(v)**.

State which value is likely to be more accurate. Explain your answer in terms of the practical procedures used.

The M_r obtained in Question .... is more accurate.

reason ....

....

.... [1]

[Total: 12]

2 In **Question 1** you measured the volume of carbon dioxide produced by a metal carbonate, **M**CO_3, in order to identify **M**. In **Question 2** you will identify another Group 2 metal, **Q**, by using a gravimetric method.

When Group 2 carbonates are heated they decompose.

$$\mathbf{Q}CO_3(s) \rightarrow \mathbf{Q}O(s) + CO_2(g)$$

FA 3 is the metal carbonate, **Q**CO_3.

(a) Method

- Weigh the crucible with its lid and record the mass.
- Add between 1.30 g and 1.50 g of **FA 3** into the crucible. Record the mass of crucible, lid and **FA 3**.
- Place the crucible on the pipe-clay triangle on the tripod. Put the lid on the crucible and heat gently for approximately 1 minute.
- Use tongs to remove the lid and heat the crucible strongly for approximately 5 minutes. Replace the lid and then leave to cool.
- While the crucible is cooling, begin work on **Question 3**.
- When cool, reweigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass of **FA 3** placed in the crucible.
- Calculate and record the mass of residue left after heating.

Keep the crucible and its contents for use in Question 3(b).

Results

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the number of moles of carbon dioxide produced during heating of **FA 3**.

moles CO_2 = ... mol [1]

(ii) Use the mass of **FA 3** in **(a)** and your answer to **(b)(i)** to calculate the relative atomic mass, A_r, of **Q** and hence identify **Q**. You should assume complete decomposition of **Q**CO_3.

A_r of **Q** is ....

Q is ....

[4]

(c) Explain why the lid was placed on the crucible when the residue was left to cool.

....

.... [1]

(d) In order to decompose Group 2 carbonates, the solid must be heated strongly. In this experiment **Q**CO_3 was heated for a few minutes.

(i) Suggest an improvement to the method used that would ensure that decomposition was complete.

....

.... [1]

(ii) Suggest a chemical test to determine whether the decomposition of **Q**CO_3 was complete. State the expected observation if the decomposition was incomplete.

Do not carry out this test.

....

.... [1]

(e) (i) In your calculation in **(b)** you used the mass of **Q**CO_3 and assumed that it was all decomposed during the heating.

Explain what effect incomplete decomposition would have on the calculated value of the A_r of **Q**.

....

....

.... [1]

(ii) A student suggested that you could use the mass of the residue, **Q**O, rather than the mass of **Q**CO_3 in a calculation to identify **Q**.

Explain why this method of calculating the A_r of **Q** is valid.

....

.... [1]

[Total: 14]

Gravimetric (thermal decomposition) experiments **Chem 10 Q# 69/** ALvl Chemistry/2019/m/TZ 3/Paper 3/Q# 2 :o) www.SmashingScience.org

2 It is possible that ores containing basic copper(II) carbonate also contain water of crystallisation. The formula of these ores would be written as $\mathbf{x}CuCO_3\cdot\mathbf{y}Cu(OH)_2\cdot\mathbf{z}H_2O$.

In this experiment you will heat a sample of a different basic copper(II) carbonate which will thermally decompose as shown.

$$\mathbf{x}CuCO_3\cdot\mathbf{y}Cu(OH)_2\cdot\mathbf{z}H_2O(s) \rightarrow (\mathbf{x}+\mathbf{y})CuO(s) + \mathbf{x}CO_2(g) + (\mathbf{y}+\mathbf{z})H_2O(g)$$

You will use your results to determine whether this sample of a different basic copper(II) carbonate contains water of crystallisation.

FA 3 is a sample of a different basic copper(II) carbonate.

(a) Method

- Weigh the empty crucible with its lid and record the mass.
- Add all the **FA 3** to the crucible.
- Reweigh the crucible, lid and **FA 3**. Record the mass.
- Support the crucible in the pipeclay triangle on top of the tripod.
- Remove the lid.
- Heat the crucible gently for about 1 minute and then strongly for about 4 minutes.
- Replace the lid and allow the crucible to cool.
- You may wish to start **Question 3** while the crucible is cooling.
- When the crucible has cooled, reweigh the crucible, lid and contents. Record the mass.
- Calculate and record the mass of **FA 3** used, the mass of residue and the loss of mass.

Results

I	
II	
III	
IV	
V	
VI	

[6]

(b) Calculations

(i) Assume the percentage by mass of copper(II) carbonate in **FA 3** is 60.0%.
Calculate the mass of copper(II) carbonate present in **FA 3**.

mass of $CuCO_3$ = ... g

Hence calculate the number of moles of copper(II) carbonate in **FA 3**.

moles of $CuCO_3$ = ... mol
[1]

(ii) Use your results from **(a)** to calculate the number of moles of copper(II) oxide formed on heating **FA 3**.

moles of CuO = ... mol [1]

(iii) Use your answers to **(i)** and **(ii)** and the equation on page 5 to calculate the number of moles of copper(II) hydroxide in **FA 3**.

moles of $Cu(OH)_2$ = ... mol [1]

(iv) Use your answer to **(i)** to calculate the mass of carbon dioxide produced by the **thermal decomposition** of the copper(II) carbonate in **FA 3**.

mass of CO_2 = ... g [1]

(v) Use your answer to **(iii)** to calculate the mass of water produced by the **thermal decomposition** of the copper(II) hydroxide in **FA 3**.

mass of H_2O = ... g [1]

(vi) Deduce whether water of crystallisation is present in basic copper(II) carbonate **FA 3**.

Justify your answer using your results from **(a)** and your answers to **(iv)** and **(v)**.

....
[1]

(c) (i) The lid was replaced before the crucible was cooled.

Explain how replacing the lid before the crucible was cooled may have increased the accuracy of your results.

....

.... [1]

(ii) Using the same apparatus, suggest an improvement to the method to increase the accuracy of your results.

....

.... [1]

(iii) A student carried out the method in **(a)** and obtained inaccurate results.
The student suggested that not all of the copper(II) carbonate in the sample of basic copper(II) carbonate **FA 3** had thermally decomposed.

Suggest a chemical test to determine whether the student was correct. Give the expected observations.

Do not carry out this test.

....

.... [1]

2 Zinc carbonate occurs in a basic form, which means that zinc hydroxide is also present. The chemical formula of basic zinc carbonate can be written as $ZnCO_3.\mathbf{y}Zn(OH)_2$, where **y** may not be an integer. In this experiment you will heat basic zinc carbonate to decompose it and use your results to determine the value of **y**.

When basic zinc carbonate is heated, it decomposes as shown.

$$ZnCO_3.\mathbf{y}Zn(OH)_2(s) \rightarrow (1 + \mathbf{y})ZnO(s) + CO_2(g) + \mathbf{y}H_2O(g)$$

FA 5 is basic zinc carbonate, $ZnCO_3.\mathbf{y}Zn(OH)_2$.

(a) Method

Read through the method before starting any practical work.
Prepare a table for all your results from Experiments 1 and 2 in the space on page 5.

Experiment 1

- Weigh a crucible with its lid and record the mass.
- Add 2.1–2.5 g of **FA 5** to the crucible. Weigh the crucible and lid with **FA 5** and record the mass.
- Place the crucible in the pipe-clay triangle on top of the tripod.
- Heat the crucible and contents gently for 1 minute with the lid on.
- Remove the lid. Heat the crucible and contents strongly, with the lid off, for approximately 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes, before re-weighing it with the lid on. Record the mass.
- **While the crucible is cooling, you may wish to begin work on Question 3.**
- Calculate, and record in your table, the mass of **FA 5** used and the mass of residue obtained.

(i) State the observation(s) you made while you were heating **FA 5**.

....

(ii) State the observation(s) you made once the residue had cooled down.

....

Experiment 2

- Repeat the procedure used in **Experiment 1**, using 1.5–1.9 g of **FA 5** and using the other crucible and lid.
- Record the three balance readings made during the experiment.
- Calculate and record the mass of **FA 5** used and the mass of residue obtained.

Results

I	
II	
III	
IV	
V	
VI	

[6]

(b) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the relative formula mass, M_r, of zinc hydroxide, $Zn(OH)_2$.

M_r of $Zn(OH)_2$ = ...

(ii) Using your answer to **(i)**, write down an expression, in terms of **y**, for the relative formula mass, M_r, of basic zinc carbonate, $ZnCO_3.\mathbf{y}Zn(OH)_2$.

M_r of $ZnCO_3.\mathbf{y}Zn(OH)_2$ = ...

(iii) Using the mass of $ZnCO_3.\mathbf{y}Zn(OH)_2$ from **Experiment 1** and your answer to **(ii)**, write down an expression, in terms of **y**, for the number of moles of $ZnCO_3.\mathbf{y}Zn(OH)_2$ that you heated in **Experiment 1**.

moles of $ZnCO_3.\mathbf{y}Zn(OH)_2$ = ... mol

(iv) Using your answer to **(iii)** and the equation below, write an expression, in terms of **y**, for the number of moles of zinc oxide produced in **Experiment 1**.

$$ZnCO_3.\mathbf{y}Zn(OH)_2(s) \rightarrow (1 + \mathbf{y})ZnO(s) + CO_2(g) + \mathbf{y}H_2O(g)$$

moles of ZnO produced = ... mol

(v) Use your results from **Experiment 1** to calculate the number of moles of zinc oxide, ZnO, obtained in the residue. You may assume complete decomposition has occurred.

moles of ZnO = ... mol

(vi) Using your answers to **(iv)** and **(v)**, calculate the value of **y** to one decimal place.

y = ...

[6]

(c) (i) Apart from altering the balance or the masses of **FA 5** used, state **one** improvement you could make to the experimental procedure to improve its accuracy.

....

....

....

(ii) Which experiment should be more accurate, **Experiment 1** or **Experiment 2**? Explain your answer.

....

....

....

[2]

[Total: 14]

2 Malachite is a basic form of copper carbonate in which copper hydroxide is also present. The accepted chemical formula of malachite is $CuCO_3.Cu(OH)_2.H_2O$.

When malachite is heated, it decomposes as shown.

$$CuCO_3.Cu(OH)_2.H_2O(s) \rightarrow 2CuO(s) + CO_2(g) + 2H_2O(g)$$

In this experiment, you will heat malachite to decompose it and use your results to obtain evidence about the accepted formula of malachite.

FA 5 is malachite, $CuCO_3.Cu(OH)_2.H_2O$.

(a) Method

Read through the method before starting any practical work.
In the space below prepare a **single** table for your results of **Experiments 1** and **2**.

Experiment 1

- Weigh a crucible with its lid and record the mass.
- Add between 2.5 g and 3.0 g of **FA 5** to the crucible. Weigh the crucible with **FA 5** and lid and record the mass.
- Place the crucible on the pipe-clay triangle.
- Heat the crucible and contents gently for about two minutes, with the lid on.
- Remove the lid and continue heating gently for about three minutes.
- Replace the lid and leave the crucible and residue to cool for at least five minutes. Then reweigh the crucible and contents with the lid on. Record the mass.
- **While the crucible is cooling, you may wish to begin work on Question 3.**
- Calculate and record the mass of **FA 5** used and the mass of residue obtained.
- State the observation(s) you made while the reaction was taking place.

....

....

Experiment 2

Repeat the method used in **Experiment 1**, using between 1.5 g and 2.0 g of **FA 5** in the second crucible.

Results

I	
II	
III	
IV	
V	
VI	

[6]

(b) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Use your results from **Experiment 1** to calculate the number of moles of copper oxide, CuO, obtained as residue.
Use the Periodic Table on page 12 for any data you may require.

moles of CuO obtained in **Experiment 1** = ... mol

(ii) Use your answer to **(i)**, the equation on page 4 and the mass of **FA 5** you used in **Experiment 1**, to calculate the relative formula mass, M_r, of malachite.

M_r of malachite (from **Experiment 1**) = ...

(iii) Use your results from **Experiment 2** to calculate another value for the relative formula mass, M_r, of malachite.

M_r of malachite (from **Experiment 2**) = ...

(iv) Use data from the Periodic Table to calculate the relative formula mass, M_r, of malachite from its accepted formula, $CuCO_3.Cu(OH)_2.H_2O$.

M_r of malachite (from formula) = ...

(v) If the relative formula mass of malachite obtained from **either** of your experiments is within 2.5% of the answer in **(iv)**, this is good evidence that the accepted formula, $CuCO_3.Cu(OH)_2.H_2O$, is correct.

Show by calculation whether either of your experiments supports the accepted formula.

[5]

(c) (i) State **one** way of improving the accuracy of the experimental method, using the same masses of **FA 5**.
Explain the benefit of your improvement.

....

....

....

....

(ii) Explain why you would expect **Experiment 1** to be more accurate than **Experiment 2**.

....

....

....

[3]

[Total: 14]

Gravimetric (thermal decomposition) experiments Chem 10 **Q# 72/** ALvl Chemistry/2010/w/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

For Examiner's Use

2 **FA 3** is powdered basic copper(II) carbonate, a hydrated mixture of copper(II) carbonate and copper(II) hydroxide.
The approximate formula for the basic carbonate is $CuCO_3.Cu(OH)_2.H_2O$.

When heated, basic copper(II) carbonate decomposes.

$$CuCO_3.Cu(OH)_2.H_2O(s) \rightarrow 2CuO(s) + CO_2(g) + 2H_2O(g)$$

You are to determine the change in mass as the solid is heated and decomposed.

(a) Method – Read through the instructions before starting any practical work.

- Record all weighings in an appropriate form in the space below.
- Weigh and record the mass of an empty boiling-tube.
- Tip the contents of the tube labelled **FA 3** into the weighed boiling-tube. Reweigh and record the total mass of the boiling-tube and **FA 3**.
- Heat **FA 3** in the boiling-tube **very gently** until the vigorous decomposition of the copper carbonate has stopped; then heat more strongly for 1 to 2 minutes. **Take care not to lose any solid from the tube during the initial heating.**
- Warm the upper parts of the boiling-tube to evaporate any water that may have condensed while heating the carbonate.
- Place the hot tube on a heat-proof mat and leave to cool.
- **You are advised to continue with part (d) of this question or to start another question while the tube cools.**
- When cool, reweigh the boiling-tube and the residual copper(II) oxide.
- Reheat, cool and reweigh the tube until you are satisfied decomposition is complete.

Results

In an appropriate form, in the space below, record all of your balance readings, the mass of basic copper(II) carbonate and the mass of residual copper oxide.

I	
II	
III	
IV	
V	
VI	

[6]

Calculations

(b) Calculate the loss in mass during the experiment as a percentage of the mass of solid heated.

[1]

(c) The theoretical loss in mass is 33.5%.

The proportions of $CuCO_3$ and $Cu(OH)_2$ in the basic carbonate can vary from the 1:1 ratio given in the formula.

Make use of the following information to account for the difference between the value you have calculated in **(b)** and the theoretical percentage loss in mass.

1 mol $CuCO_3(s) \rightarrow$ 1 mol $CO_2(g)$
1 mol $Cu(OH)_2(s) \rightarrow$ 1 mol $H_2O(g)$

Assume that 1 mol of any sample of the solid basic carbonate contains 1 mol H_2O.

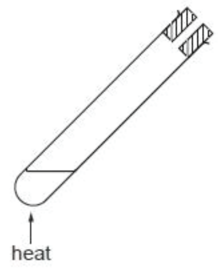
[M_r: CO_2, 44.0; H_2O, 18.0]

....

....

.... [1]

(d) Add to the diagram below additional standard laboratory apparatus that would enable you to collect and measure the volume of carbon dioxide evolved in the experiment. Ensure that your apparatus does not also collect and measure any of the water vapour evolved.



[2]

[Total: 10]

G2 Gravimetric (water of crystallisation) experiments Chem 2 Q# 73/ ALvl

Chemistry/2021/s/TZ 1/Paper 3/Q# 2 :o) www.SmashingScience.org

2 In **Question 1** you used a titration method to determine the value of *x* in a hydrated salt. In **Question 2** you will use a gravimetric method. In this method a sample of solid is heated to remove the water of crystallisation.

You will carry out this method on a different hydrated compound, **FA 4**, with formula $MZ \cdot yH_2O$. In **FA 4** the value of *y* is an integer.

$$MZ \cdot yH_2O(s) \rightarrow MZ(s) + yH_2O(g)$$

FA 4 is a hydrated compound, $MZ \cdot yH_2O$.

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Place between 2.40 g and 2.60 g of **FA 4** in the crucible and record its appearance below.
- Weigh the crucible, its lid and contents and record the mass.
- Without the lid, place the crucible on the pipe-clay triangle and heat gently for approximately one minute and record your observations.
- Then heat more strongly for approximately four minutes.
- Place the lid on the crucible and leave it to cool.

You may wish to start Question 3 while you are waiting for the crucible to cool.

- Weigh the crucible, its lid and contents and record the mass.
- Calculate and record the mass of **FA 4**, the mass of residue after heating and the mass of water lost.

Keep FA 4 for use in Question 3.

Results

appearance of **FA 4** ....

observations during heating for the first minute ....

....

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the number of moles of water lost when your sample of $MZ \bullet yH_2O$ was heated.

moles of water = ... mol

The relative formula mass of the anhydrous compound MZ is 120.4.

Calculate the number of moles of MZ present in the residue.

moles of MZ = ... mol
[1]

(ii) Use your answers from **(b)(i)** to calculate the value of *y* in **FA 4**, $MZ \bullet yH_2O$.
Show your working.

y = ... [1]

(iii) State an assumption you made when calculating the value of *y* in the hydrated compound.

.... [1]

(c) A student suggested that the experiment would be more accurate if the crucible had been heated with the lid on for the first minute.

State and explain whether you agree with the student.

....

.... [1]

[Total: 8]

Gravimetric (water of crystallisation) experiments Chem 2 **Q# 74/** ALvl Chemistry/2013/w/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

For Examiner's Use

2 In this experiment you are to determine the formula of hydrated barium chloride, **FA 5**, by heating to remove the water of crystallisation. You will heat **two** separate samples. The anhydrous barium chloride does not decompose when heated.

FA 5 is hydrated barium chloride, $BaCl_2.xH_2O$

(a) Method

Record **all** weighings, in an appropriate form, in the space below.

- Record the mass of the empty crucible **without** its lid.
- Add between 2.0 and 2.4 g of **FA 5** into the crucible. Record the mass of the crucible and its contents.
- Use a pipe-clay triangle to support the crucible and contents on a tripod.
- Heat the crucible and its contents gently for about **one** minute with the lid off. Then heat strongly for a further **four** minutes.
- Put the lid on the crucible and leave to cool for approximately 10 minutes.

While you are waiting for the crucible to cool, start work on Question 3.

- When the crucible is cool, **remove the lid**, and weigh the crucible with the residue.
- Record the mass of anhydrous barium chloride remaining in the crucible after heating and the mass of water lost.

- To prepare for the second experiment, use a spatula to remove the residue from the crucible into the beaker labelled **waste**.
- Reweigh the empty crucible **without** its lid.
- Carry out the experiment again. This time use between 1.5 and 1.9 g of **FA 5**.

I	
II	
III	
IV	
V	
VI	

[6]

(b) Calculation

Show your working in **each** step.

(i) Calculate the **mean** number of moles of water removed from the hydrated salt in the experiments.
(A_r: H, 1.0; O, 16.0)

moles of H_2O = ... mol

(ii) Calculate the **mean** number of moles of anhydrous barium chloride produced in the experiments.
(A_r: Ba, 137; Cl, 35.5)

moles of $BaCl_2$ = ... mol

(iii) Calculate the value of **x** in the formula of hydrated barium chloride, $BaCl_2.xH_2O$.

x = ...

[3]

(c) (i) Suggest how the experimental procedure could be modified to ensure that **all** of the water of crystallisation had been removed by heating hydrated **FA 5**.

....

....

....

(ii) Do you think that the results from your two experiments are consistent with each other?
Justify your answer by carrying out appropriate calculations.

[3]

[Total: 12]

1 In this experiment you will determine the identity of the Group 2 metal, **X**, in the carbonate, XCO_3. To do this you will react a known mass of XCO_3 with **excess** hydrochloric acid, HCl, and measure the mass of carbon dioxide that is given off.

FA 1 is XCO_3.
FA 2 is hydrochloric acid, HCl.

(a) Method

- Weigh the stoppered tube containing **FA 1** and record its mass.
- Use the measuring cylinder to transfer 25 cm^3 of **FA 2** into the 250 cm^3 beaker.
- Weigh the beaker containing the acid and record the mass.
- Carefully add all the sample of **FA 1** to the acid in the beaker.
- Stir the mixture until there is no further reaction.
- Reweigh the beaker and its contents and record the mass.

KEEP THE CONTENTS OF THE BEAKER FOR USE IN QUESTION 2.

- Reweigh the stoppered tube containing any residual **FA 1** and record its mass.
- Calculate the mass of **FA 1** added to the acid and record this value.
- Calculate the mass of carbon dioxide given off and record this value.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of carbon dioxide given off when XCO_3 reacted with the acid.
Use the data in the Periodic Table on page 16.

moles of CO_2 = ... mol

(ii) Write the equation for the reaction of **FA 1**, XCO_3, with hydrochloric acid, HCl. Include state symbols.

....

(iii) Use your answers to **(i)** and **(ii)** to calculate the number of moles of **X**CO_3 that were added to the acid.

moles of **X**CO_3 = ... mol

(iv) Use your answer to **(iii)** to calculate the relative atomic mass, A_r, of **X**.
Identify **X**.

I	
II	
III	
IV	
V	

A_r of **X** = ...

X is .... [5]

(c) One of the sources of error in this experiment is that it is very difficult to reduce acid spraying out of the beaker when the metal carbonate is added to the acid.

(i) Explain what effect this acid spray would have on the value you calculated for the relative atomic mass, A_r, of **X**.

....

....

....

(ii) Why is a small amount of acid spray not likely to cause an error in the identification of **X**?

....

....

(iii) How could you minimise acid spraying out of the beaker?

....

....

.... [3]

[Total: 15]

R1 Rate (thiosulfate and acid) experiments Chem 8 Q# 76/ ALvl Chemistry/2020/w/TZ 1/Paper 3/Q# 2 :o) www.SmashingScience.org

2 When a solution containing thiosulfate ions, $S_2O_3^{2-}$, is acidified the following reaction occurs.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(g) + H_2O(l)$$

The solid sulfur that is formed makes the mixture become cloudy. The rate of reaction can then be measured by timing how long it takes for the mixture to become too cloudy to see through.

You will investigate how changing the concentration of the thiosulfate ions affects the rate of reaction.

Throughout these experiments care must be taken to avoid inhaling the SO_2 that is produced. It is very important that as soon as each experiment is complete the contents of the beaker are emptied into the quenching bath.

FA 4 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.
FA 5 is a solution of sodium thiosulfate, $Na_2S_2O_3$.
distilled water

(a) Method

Experiment 1

- Use the 50 cm^3 measuring cylinder to transfer 40.0 cm^3 of **FA 5** into the 100 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to measure 20.0 cm^3 of **FA 4**.
- Add the 20.0 cm^3 of **FA 4** to **FA 5** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printed text on the insert from above through the mixture in the beaker.
- Note the time when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 2**.

Experiment 2

- Use the 50 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FA 5** into the 100 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 20.0 cm^3 of distilled water into the same beaker.
- Use the 25 cm^3 measuring cylinder to measure 20.0 cm^3 of **FA 4**.
- Add the 20.0 cm^3 of **FA 4** to **FA 5** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printed text on the insert from above through the mixture in the beaker.
- Note the time when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse the beaker thoroughly.

Keep FA 5 for use in Question 3.

Record all your results in a table. You should include the volume of **FA 5**, the volume of distilled water, the reaction time and the rate of reaction for both experiments.

The rate of reaction can be calculated using the following formula.

$$\text{rate of reaction} = \frac{1000}{\text{reaction time}}$$

I	
II	
III	
IV	

[4]

(b) A student suggested that the rate of the reaction is directly proportional to the concentration of the thiosulfate ions.

State whether your results support this suggestion.
Explain your answer.

....

....

.... [1]

(c) The student's suggestion in **(b)** could be made more reliable by carrying out further experiments.

Prepare a table to show three further experiments you could carry out. Show clearly the volumes of **FA 4**, **FA 5** and distilled water that you would use in each of these experiments. Do not suggest a volume of **FA 5** that is greater than $40.0\,cm^3$ or less than $20.0\,cm^3$.

DO <u>NOT</u> CARRY OUT THESE ADDITIONAL EXPERIMENTS.

[2]

[Total: 7]

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 You will investigate how increasing temperature affects the rate of a reaction.

Sodium thiosulfate reacts with acid to form a pale yellow precipitate of sulfur.
The ionic equation for the reaction is given.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(g) + H_2O(l)$$

You will measure the time it takes for the sulfur formed in the reaction to obscure the print on the Insert supplied.

Record your results in a table on page 4. Your table should include the rate of reaction for each experiment.

FA 1 is an $18.1\,g\,dm^{-3}$ solution of hydrated sodium thiosulfate, $Na_2S_2O_3.5H_2O$.
FA 2 is a $0.050\,mol\,dm^{-3}$ solution of a strong monoprotic acid, H**Z**.

(a) Method

- Approximately half fill the $250\,cm^3$ beaker with tap water and place it on the tripod and gauze over the Bunsen burner.
- Heat the water in the beaker to about 55 °C and then switch off the Bunsen burner. This will be your hot water bath.
- Use the $25\,cm^3$ measuring cylinder to transfer $10\,cm^3$ of **FA 1** into boiling tube **1**. Place boiling tube **1** into your hot water bath.
- Use the $50\,cm^3$ measuring cylinder to transfer $20\,cm^3$ of **FA 2** into boiling tube **2**. Place boiling tube **2** into your hot water bath.
- Leave boiling tubes **1** and **2** in the hot water bath to heat up for use in **Experiment 2**.
- Start **Experiment 1**.

Experiment 1

- Use the $50\,cm^3$ measuring cylinder to transfer $20\,cm^3$ of **FA 2** into the $100\,cm^3$ beaker.
- Measure and record the temperature of **FA 2**.
- Use the $25\,cm^3$ measuring cylinder to transfer $10\,cm^3$ of **FA 1** into the same beaker and start timing **immediately**.
- Swirl the beaker once to mix the solutions and place the beaker on the Insert.
- Look down through the beaker and contents onto the Insert.
- Stop timing as soon as the precipitate of sulfur obscures the print on the Insert.
- Record the reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 2**.

Experiment 2

- Measure and record the temperature of **FA 2** in boiling tube **2**.
- Carefully transfer the hot contents of boiling tube **2** into the 100 cm^3 beaker.
- Carefully transfer the hot contents of boiling tube **1** into the same beaker and start timing **immediately**.
- Swirl the beaker once to mix the solutions and place the beaker on the Insert.
- Look down through the beaker and contents onto the Insert.
- Stop timing as soon as the precipitate of sulfur obscures the print on the Insert.
- Record the reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 3**.

Experiment 3

- Use the 25 cm^3 measuring cylinder to transfer 10 cm^3 of **FA 1** into boiling tube **1**. Place boiling tube **1** into your hot water bath.
- Use the 50 cm^3 measuring cylinder to transfer 20 cm^3 of **FA 2** into boiling tube **2**. Place boiling tube **2** into your hot water bath.
- Place the thermometer in boiling tube **2**. When the temperature of **FA 2** is about 8 °C lower than that for **Experiment 2** record the temperature. Remove the thermometer and transfer the contents of boiling tube **2** into the 100 cm^3 beaker.
- Transfer the contents of boiling tube **1** into the same beaker and start timing **immediately**.
- Swirl the beaker once to mix the solutions and place the beaker on the Insert.
- Look down through the beaker and contents onto the Insert.
- Stop timing as soon as the precipitate of sulfur obscures the print on the Insert.
- Record the reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiments 4 and 5**.

Experiments 4 and 5

- Repeat the method for **Experiment 3** but at **two** different temperatures.
- Keep the temperature of **FA 2** between room temperature and 55 °C. Do **not** exceed 55 °C.

Record all your results in your table on page 4.

Results

The rate of reaction can be calculated as shown.

$$\text{rate} = \frac{1000}{\text{reaction time}}$$

Calculate the rate of reaction for each of your **five** experiments. Record these rates in your table.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) On the grid plot a graph of rate of reaction on the *y*-axis, starting at zero, against temperature on the *x*-axis. Select a scale for the *x*-axis which includes a temperature of 15.0 °C. Label your axes and any points you consider anomalous.

Draw a line of best fit and extrapolate it to 15.0 °C.

I	
II	
III	
IV	

[4]

(c) **Use your graph** to calculate the **time** to the nearest second that the reaction would have taken if you had carried it out at 17.5 °C. Show **on the grid** how you obtained your answer.

time = ... s [2]

(d) Explain, by referring to your graph or your table of results, how the rate of reaction is affected by increasing temperature.

....

....

.... [2]

(e) **Calculations**

(i) Calculate the concentration of hydrated sodium thiosulfate, $Na_2S_2O_3.5H_2O$, in **FA 1** in mol dm^{-3}.

concentration of $Na_2S_2O_3.5H_2O$ in **FA 1** = ... mol dm^{-3} [1]

(ii) Calculate the concentration of the strong monoprotic acid, H**Z**, in the solution immediately **after FA 1** was added to **FA 2** in the beaker.

concentration of H**Z** = ... mol dm^{-3} [1]

(iii) Use the equation on page 2 to determine which reagent, **FA 1** or **FA 2**, was in excess.

The reagent in excess was .... [2]

(f) (i) Calculate the maximum percentage error in measuring the reaction time you recorded for **Experiment 2**. Assume that the maximum error of the timer is ±0.5 s.

maximum percentage error in the reaction time = ... % [1]

(ii) A student suggested that the error in measuring the reaction time in **Experiment 1** was greater than for **Experiment 2**.

Give **one** reason why the student could be correct.

....

.... [1]

(g) Suggest **two** ways to improve the accuracy of the results of these experiments.

1 ....

....

2 ....

....

[2]

[Total: 24]

Rate (thiosulfate and acid) experiments Chem 8 **Q# 78/** ALvl Chemistry/2015/w/TZ 1/ Paper 3/Q# 2/ :o)
www.SmashingScience.org

2 In this experiment you will investigate how the rate of reaction between sodium thiosulfate and hydrochloric acid is affected by the concentration of the acid.

When aqueous thiosulfate ions react with hydrogen ions, H^+, in any acid, a pale yellow precipitate of sulfur is formed. The ionic equation for this reaction is given below.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(aq) + H_2O(l)$$

The rate of the reaction can be determined by measuring the time taken to produce a fixed quantity of sulfur.

FA 4 is 0.10 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 5 is 0.20 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

Record **all** your measurements, in an appropriate form, in the space below.

Experiment 1

- Use the larger measuring cylinder to transfer 40 cm^3 of **FA 4** into the 100 cm^3 beaker.
- Rinse the larger measuring cylinder thoroughly with water, then add 30 cm^3 of **FA 5** to the beaker and start timing **immediately**.
- Stir the mixture once and place the beaker on top of the printed insert page provided.
- Look down through the solution in the beaker at the print on the insert.
- Stop timing as soon as the precipitate of sulfur makes the print on the insert invisible.
- Record the reaction time to the **nearest second**.
- Empty and rinse the 100 cm^3 beaker.
- Dry the outside of the beaker ready for Experiment 2.

Experiment 2

- Rinse the larger measuring cylinder, then use it to transfer 40 cm^3 of **FA 4** into the 100 cm^3 beaker.
- Use the smaller measuring cylinder to add 10 cm^3 of distilled water to the beaker.
- Use the same measuring cylinder to add 20 cm^3 of **FA 5** to the mixture in the beaker and start timing **immediately**.
- Stir the mixture once and place the beaker on top of the printed insert page provided.
- Stop timing as soon as the print on the insert becomes invisible.
- Record the reaction time to the **nearest second**.
- Empty and rinse the 100 cm^3 beaker.
- Dry the outside of the beaker ready for Experiment 3.

Experiment 3

- Carry out the reaction using a mixture of 40 cm^3 of **FA 4**, 20 cm^3 of distilled water and 10 cm^3 of **FA 5**.
- Measure and record the reaction time to the **nearest second**.

I	
II	
III	
IV	

[4]

(b) (i) The 'rate of reaction' can be represented by the formula below.

$$\text{'rate of reaction'} = \frac{1000}{\text{reaction time}}$$

Use this formula to calculate the 'rate of reaction' for Experiments 1 and 3.
Give the unit.

'rate of reaction' for Experiment 1 .... unit ....

'rate of reaction' for Experiment 3 .... unit ....

(ii) Calculate the initial concentrations of hydrochloric acid in the reaction mixtures in Experiments 1 and 3.

initial concentration of HCl in Experiment 1 = ... mol dm^{-3}

initial concentration of HCl in Experiment 3 = ... mol dm^{-3}

(iii) How is the 'rate of reaction' affected by the concentration of hydrochloric acid in the mixture?

....

....

(iv) Predict how the reaction time measured in Experiment 1 would have been affected if the experiment had been carried out using 0.20 mol dm^{-3} sulfuric acid instead of 0.20 mol dm^{-3} hydrochloric acid.
Explain your answer.

....

....

....

(v) Predict how the reaction time measured in Experiment 3 would have been affected if the experiment had been carried out in a 250 cm^3 beaker instead of a 100 cm^3 beaker.
Explain your answer.

....

....

[5]

[Total: 9]

Rate (thiosulfate and acid) experiments Chem 8 **Q# 79/** ALvl Chemistry/2012/w/TZ 1/ Paper 3/Q# 1/ :o)
www.SmashingScience.org

1 You are to investigate how the rate of reaction between sodium thiosulfate and hydrochloric acid changes as the concentration of the sodium thiosulfate solution is varied.

When aqueous sodium thiosulfate reacts with aqueous hydrogen ions present in an acid, a fine suspension of solid sulfur is formed in the solution.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(g) + H_2O(l)$$

The rate of reaction can be determined by measuring the time taken to produce a fixed quantity of sulfur. The beaker containing a constant volume of reaction mixture is placed on the printed insert supplied. The time is recorded when the print is no longer visible through the suspension of sulfur.

FA 1 is 0.150 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 2 is 0.500 mol dm^{-3} hydrochloric acid, HC*l*.
distilled water

Read through the instructions carefully and prepare a table for your results on page 4 before starting any practical work.

In each of the following experiments you will use varying volumes of **FA 1** and distilled water and a fixed volume of **FA 2**. The **total** volume of solution used will be constant.

(a) Method

Experiment 1

- Use the measuring cylinder labelled **A** to transfer 50 cm^3 of **FA 1** into a 250 cm^3 beaker.
- Use the measuring cylinder labelled **B** to measure 20 cm^3 of **FA 2**.
- Tip the **FA 2** from measuring cylinder **B** into the beaker and **immediately** start timing.
- Stir the contents of the beaker once and place the beaker on the printed insert.
- View the print from directly above and through the solution in the beaker.
- Stop timing when the printed material on the insert is **just** no longer visible.
- Record the reaction time to the nearest second.
- Calculate and record the value of $\frac{(1000)}{(\text{reaction time})}$ to 3 significant figures.
- Empty, rinse and dry the beaker.

Experiment 2

- Use the measuring cylinder labelled **A** to transfer 40 cm^3 of **FA 1** into the rinsed and dried beaker.
- Use the same measuring cylinder labelled **A** to transfer 10 cm^3 of distilled water into the same beaker.
- Use the measuring cylinder labelled **B** to measure 20 cm^3 of **FA 2**.
- Tip the **FA 2** from measuring cylinder **B** into the beaker and **immediately** start timing.
- Stir the contents of the beaker once and place the beaker on the printed insert.
- View the print from directly above and through the solution in the beaker.
- Stop timing when the printed material on the insert is **just** no longer visible.
- Record the reaction time to the nearest second.
- Calculate and record the value of $\frac{(1000)}{(\text{reaction time})}$ to 3 significant figures.
- Empty, rinse and dry the beaker.

Experiments 3 – 5

- Repeat the experiment using the following volumes of **FA 1** and distilled water.

Experiment 3	30 cm^3 of **FA 1**	+	20 cm^3 of distilled water
Experiment 4	20 cm^3 of **FA 1**	+	30 cm^3 of distilled water
Experiment 5	10 cm^3 of **FA 1**	+	40 cm^3 of distilled water

Experiment 6

When you have completed experiments 1 – 5, carry out one further experiment using a different volume of both **FA 1** and distilled water.

When you have completed all of your experiments, empty and rinse the beaker.

Record the results for all six experiments in the space below.
Your table should include columns for the following.

- experiment number
- volume of **FA 1**
- volume of distilled water
- reaction time
- $\dfrac{(1000)}{(\text{reaction time})}$

For Examiner's Use

I	
II	
III	
IV	
V	
VI	
VII	
VIII	
IX	
X	
XI	

[11]

(b) The rate of reaction can be represented by the following formula.

$$\text{'rate'} = \frac{(1000)}{(\text{reaction time})}$$

On the next page plot a graph of **'rate'** against the **volume of FA 1**.

Start each of the axes at zero.

Draw the line of best fit.

For Examiner's Use

I	
II	
III	
IV	
V	

[5]

(c) A student carried out the experiments in a 100 cm^3 beaker instead of a 250 cm^3 beaker. State and explain what effect this would have on the times recorded.

....

.... [2]

(d) **FA 1** is 0.150 mol dm^{-3} $Na_2S_2O_3$.
Calculate the initial concentration of $Na_2S_2O_3$ in the reaction mixture in **Experiment 5**.
Show your working.

The initial concentration of $Na_2S_2O_3$ in **Experiment 5** = ... mol dm^{-3}
[2]

(e) In your experiments, the volume of **FA 1** represents the initial concentration of sodium thiosulfate in the reaction mixture.
A text book states that the rate of reaction between aqueous sodium thiosulfate and hydrochloric acid is directly proportional to the concentration of sodium thiosulfate.
Use your graph to decide whether the statement in the text book is correct or not.
Explain your answer.

....

....

....

.... [2]

(f) When viewing the insert through the solution it is difficult to judge the exact moment when the printed material just disappears.

This uncertainty is different for each experiment and is greater for longer reaction times when the printed material disappears slowly.

Complete the table below, assuming the uncertainties given.

	Experiment 1	**Experiment 5**
recorded reaction time / s		
uncertainty / s	±2	±8
percentage uncertainty	%	%

[1]

(g) Complete the headings in the table below to record the volume of **FA 1** (aqueous sodium thiosulfate), the volume of distilled water and the volume of **FA 2** (hydrochloric acid).

In the second row copy the volumes used in **Experiment 3** from your table of results on page 4.

In the following two rows suggest volumes of each of the reagents that could be used in two further experiments, **Experiment 7** and **Experiment 8**, to investigate how the rate of reaction varies with a change in the concentration of the acid.

Do not carry out these experiments.

Experiment			
3			
7			
8			

[2]

[Total: 25]

2 You are to investigate how the rate of formation of sulfur varies with the concentration of sodium thiosulfate, $Na_2S_2O_3$, in the reaction below.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow S(s) + 2NaCl(aq) + SO_2(g) + H_2O(l)$$

Care should be taken to avoid inhalation of SO_2(g) that is given off during this reaction.

You are provided with the following.

FA 1, 0.15 mol dm^{-3} $Na_2S_2O_3$	a measuring cylinder to measure 50 cm^3
FA 4, 2.0 mol dm^{-3} HCl	a measuring cylinder or marked tube to measure 5 cm^3
a printed insert	a stop clock or clock with seconds hand

For Examiner's Use

(a) Method – Read through the instructions before starting any practical work.

- Using the larger measuring cylinder transfer 50 cm^3 of **FA 1** into a 250 cm^3 beaker.
- Measure 5 cm^3 of **FA 4** in the smaller measuring cylinder (or marked tube).
- Tip the **FA 4** into the **FA 1** in the beaker and **immediately** start timing.
- Swirl the beaker to mix the solution and place it on top of the printed insert.
- View the printed insert from above so that it is seen through the solution.
- Note the time when the printing on the insert just disappears.

- Empty and rinse the beaker. Shake out as much of the rinse water as possible and dry the outside of the beaker.
- Repeat the experiment using 25 cm^3 of **FA 1** and 25 cm^3 of distilled water. Add 5 cm^3 of **FA 4** to start the reaction.

- Select suitable volumes of **FA 1** and distilled water for **one** further experiment to investigate the effect of sodium thiosulfate concentration on the rate of reaction. *Remember to use 5 cm^3 of* **FA 4** *and to keep the total volume of* **FA 1** *and distilled water constant.*

In an appropriate form record the following below:
- all measurements of volume and time (to the nearest second) for each experiment,
- calculated values of $^1/_{time}$ which are a measure of the rate of reaction.

Results

i	
ii	
iii	
iv	
v	
vi	
vii	
viii	
ix	

[9]

(b) The total volume in each experiment is constant. Using volumes from the first two experiments, show by simple calculation that the volume of **FA 1** used is a measure of its concentration in the reaction mixture.

[1]

(c) What is the relationship between the rate of reaction and the time taken?

....

....

.... [1]

(d) For **each** experiment calculate the numerical value of (volume of **FA 1** × time).

experiment	(volume of **FA 1** × time)/(cm^3 s)
1	
2	
3	

Use your results in **(a)** and these calculated values to deduce the relationship between the concentration of $Na_2S_2O_3$ and the rate of formation of sulfur.

....

....

.... [2]

(e) Outline briefly how you would modify the experimental method to investigate the effect of temperature change on the reaction rate.

....

....

.... [1]

[Total: 14]

R2 Rate (thiosulfate and iodine) experiments Chem 8 Q# 81/ ALvl Chemistry/2014/s/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

2 An acidified solution of hydrogen peroxide is able to oxidise iodide ions, $I^-(aq)$, to iodine, $I_2(aq)$.

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(l)$$

In this experiment, you will investigate how the rate of this reaction depends on the concentration of the hydrogen peroxide and on the concentration of the iodide ions.

The rate of this reaction can be measured by adding thiosulfate ions, $S_2O_3^{2-}$, and starch indicator to the mixture. As the iodine is produced, it reacts immediately with the thiosulfate ions and is reduced back to iodide ions.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

When all the thiosulfate has reacted, the iodine then turns the starch indicator blue-black. The rate of reaction may be determined by timing how long it takes the reaction mixture to turn blue-black.

FA 2 is aqueous hydrogen peroxide, H_2O_2.
FA 3 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.
FA 4 is 0.50 mol dm^{-3} potassium iodide, KI.
FA 5 is 0.025 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
starch indicator

Read through the instructions carefully and prepare a table for your results before starting any practical work.

(a) Method

Experiment 1
- Use the measuring cylinder to transfer the following volumes into the same 100 cm^3 beaker.
  - 10 cm^3 of **FA 3**
  - 20 cm^3 of **FA 4**
  - 10 cm^3 of **FA 5**
  - 10 cm^3 of distilled water
- Add 10 drops of starch indicator to the beaker.
- Rinse the measuring cylinder with water and shake dry.
- Use the measuring cylinder to measure 10 cm^3 of **FA 2**.
- Add the contents of the measuring cylinder to the beaker and start timing immediately.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second.
- Wash out the beaker and the measuring cylinder with water and shake dry.

Experiment 2
- Use the measuring cylinder to transfer the following volumes into the same 100 cm^3 beaker.
  - 10 cm^3 of **FA 3**
  - 20 cm^3 of **FA 4**
  - 10 cm^3 of **FA 5**
- Add 10 drops of starch indicator to the beaker.
- Rinse the measuring cylinder with water and shake dry.
- Use the measuring cylinder to measure 20 cm^3 of **FA 2**.

- Add the contents of the measuring cylinder to the beaker and start timing immediately.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second.
- Wash out the beaker and the measuring cylinder with water and shake dry.

Experiment 3
- Use the measuring cylinder to transfer the following volumes into the same 100 cm^3 beaker.
  - 10 cm^3 of **FA 3**
  - 10 cm^3 of **FA 4**
  - 10 cm^3 of **FA 5**
  - 10 cm^3 of distilled water
- Add 10 drops of starch indicator to the beaker.
- Rinse the measuring cylinder with water and shake dry.
- Use the measuring cylinder to measure 20 cm^3 of **FA 2**.
- Add the contents of the measuring cylinder to the beaker and start timing immediately.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second.

Record all your results in a single table. You should include the volume of hydrogen peroxide, the volume of potassium iodide, the volume of distilled water and the reaction time. You should also include the 'rate of reaction' which is given by the following expression.

$$\text{rate of reaction} = \frac{1}{\text{reaction time}}$$

I	
II	
III	
IV	
V	
VI	

[6]

(b) From your results, what can you conclude about how the 'rate of reaction' is affected by,

(i) the concentration of hydrogen peroxide,

....

(ii) the concentration of potassium iodide?

....

[1]

(c) It is not possible to draw a reliable conclusion about the effect of changing the concentration of a reagent on the 'rate of reaction' from only two experiments.

Suggest **three** experiments that could be carried out in addition to **Experiments 2** and **3** to investigate the effect of changing the concentration of **FA 4**, potassium iodide. In each case give the volumes of each solution/liquid that would be used.
Do not carry out these experiments.

[2]

(d) A student was unable to complete all three experiments on the same day but had to return to the investigation the following morning. The student noticed that the results were significantly different.

Give **two** possible reasons for these differences and explain how the student could have overcome these problems.

....

....

.... [2]

(e) There are many sources of error in these experiments. In the following, assume that the only error involves measuring the reaction time.

(i) If the error in each recorded time is ±1 s, calculate the percentage error in the time recorded in **Experiment 1**.

percentage error = ... %

(ii) Another student decided to repeat **Experiment 1** but used 0.050 mol dm^{-3} sodium thiosulfate in place of **FA 5**.

How would this change the percentage error in the recorded time? Explain your answer.

....

....

....

[2]

[Total: 13]

1 When iodide ions are mixed with peroxodisulfate ions, $S_2O_8^{2-}$, iodine is formed.

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

The rate of this reaction can be measured by adding thiosulfate ions, $S_2O_3^{2-}$, and some starch indicator to the mixture. As the iodine is produced, it reacts immediately with the thiosulfate ions and is reduced back to iodide ions.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

When all the thiosulfate ions have reacted, the iodine which continues to be produced then turns the starch indicator blue-black. The rate of reaction may be determined by timing how long it takes for the reaction mixture to turn blue-black.

You are to investigate how the rate of reaction is affected by changing the concentration of the peroxodisulfate ions.

FA 1 is 0.0200 mol dm^{-3} aqueous potassium peroxodisulfate, $K_2S_2O_8$.
FA 2 is 1.00 mol dm^{-3} aqueous potassium iodide, KI.
FA 3 is 0.00500 mol dm^{-3} aqueous sodium thiosulfate, $Na_2S_2O_3$.
starch indicator

Read through the instructions carefully and prepare a table for your results on page 3 before starting any practical work.

(a) Method

Experiment 1
- Fill the burette labelled **FA 1** with aqueous potassium peroxodisulfate, **FA 1**.
- Run 20.00 cm^3 of **FA 1** into a 100 cm^3 beaker.
- Using a 25 cm^3 measuring cylinder add the following to a second 100 cm^3 beaker:
  - 20 cm^3 of **FA 2**
  - 10 cm^3 of **FA 3**
- Add 10 drops of starch indicator to the second beaker.
- Add the contents of the first beaker to the second beaker and start timing immediately.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second in the table that you have prepared on page 3.
- Wash out both beakers.

Experiment 2
- Fill a second burette with distilled water.
- Run 10.00 cm^3 of **FA 1** into the first 100 cm^3 beaker.
- Run 10.00 cm^3 of distilled water into the beaker containing **FA 1**.
- Using a 25 cm^3 measuring cylinder add the following to the second 100 cm^3 beaker:
  - 20 cm^3 of **FA 2**
  - 10 cm^3 of **FA 3**
- Add 10 drops of starch indicator to the second beaker.
- Add the contents of the first beaker to the second beaker and start timing immediately.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second in the table that you have prepared on page 3.
- Wash out both beakers.

Experiments 3 – 5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of potassium peroxodisulfate.
  Remember that the combined volume of **FA 1** and distilled water must always be $20.00\,cm^3$.
  Do not use a volume of **FA 1** that is less than $6.00\,cm^3$.

Record all your results in a single table. You should include the volume of potassium peroxodisulfate, the volume of distilled water and the reaction time.

[9]

For Examiner's Use

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(b) In order to convert the times measured in the experiments into rates of reaction, it is necessary first to work out the concentration of $I_2(aq)$ that would have been produced in the reaction time if the thiosulfate had not been present. You must show your working.

(i) Calculate how many moles of thiosulfate ions, $S_2O_3^{2-}$, were added in each experiment.

moles of $S_2O_3^{2-}$ = ... mol

(ii) Calculate how many moles of iodine, I_2, must have been produced to react with this amount of thiosulfate ions.

moles of I_2 = ... mol

(iii) Calculate the concentration of iodine from **(ii)** in the total reaction volume.

concentration of I_2 = ... mol dm^{-3}
[3]

(c) The rate of the reaction can be represented by the following formula.

$$\text{'rate'} = \frac{\text{concentration of } I_2 \text{ from } \mathbf{(b)(iii)}}{\text{reaction time}} \times 10^6$$

Use your experimental results to complete the following table. Include the volume of **FA 1**, the reaction time and 'rate' with their units.

If you were unable to answer **(b)(iii)**, you may assume that the concentration of iodine is $4.25 \times 10^{-4}\,mol\,dm^{-3}$ (This is not the correct value).

[2]

(d) On the grid opposite, plot the 'rate' against the volume of **FA 1**. Draw a line of best fit.

[4]

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(e) In your experiments, the volume of **FA 1** represents the concentration of potassium peroxodisulfate. From your results, what conclusion can you draw about the relationship between the rate of reaction and the concentration of potassium peroxodisulfate?

....

....

....

.... [2]

(f) Assume that the error in the time measured for each reaction was ± 0.5 s.

(i) Calculate the maximum percentage error in the reaction time you recorded in **Experiment 1**.

maximum percentage error = ...%

(ii) Assuming this is the **only** source of error, calculate the minimum reaction rate for **Experiment 1**.

minimum reaction rate = ...

(iii) Suggest an additional source of error in these experiments and what improvement could be made to reduce this error.

....

....

....

....

[4]

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(g) (i) Carry out one additional experiment using the following volumes of each reagent. Use the same method as in **(a)**, mix **FA 2**, **FA 3**, the distilled water and the starch together and start the reaction by adding **FA 1** to this mixture.

- 10.00 cm^3 of **FA 1**
- 20 cm^3 of **FA 2**
- 20 cm^3 of **FA 3**
- 10 drops of starch

Record the time for the reaction to go blue-black.

(ii) Explain the relationship between this time and the one you recorded in **Experiment 2**.

....

....

.... [2]

[Total: 26]

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 You will determine the concentration of sulfuric acid by reaction with a known concentration of sodium hydroxide using a thermometric method. The equation for the reaction is shown.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

FA 1 is 1.90 mol dm^{-3} sodium hydroxide, NaOH.
FA 2 is dilute sulfuric acid, H_2SO_4.

(a) Method

- Place the cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 1** into the cup.
- Place the thermometer into the solution in the cup and record its temperature in the table of results.
- Fill a burette with **FA 2**.
- Run 5.00 cm^3 of **FA 2** into the solution in the cup.
- Stir the mixture and record the highest temperature reached.
- Repeat adding 5.00 cm^3 volumes of **FA 2** into the solution in the cup until 45.00 cm^3 has been added. Record the highest temperature reached after each addition.

Results

volume of **FA 2** added / cm^3	0.00	5.00	10.00	15.00	20.00
temperature of solution / °C					

volume of **FA 2** added / cm^3	25.00	30.00	35.00	40.00	45.00
temperature of solution / °C					

[3]

(b) (i) Plot a graph of temperature (*y*-axis) against volume of acid added (*x*-axis) on the grid provided. Select a scale on the *y*-axis to include a temperature 4.0 °C above the highest temperature you recorded.
Label any points you consider to be anomalous.

Draw two lines of best fit, one for the rise in temperature and one for after the maximum temperature has been reached.
Extrapolate the two lines so they intersect. [4]

(ii) Use your graph to determine the volume of sulfuric acid, **FA 2**, required to neutralise $25.0\,cm^3$ of sodium hydroxide, **FA 1**.

volume of H_2SO_4 = ... cm^3 [1]

(iii) Calculate the concentration of sulfuric acid in **FA 2**.

concentration of H_2SO_4 = ... $mol\,dm^{-3}$ [1]

(c) A student carrying out the same procedure used the results from their graph to determine the enthalpy of neutralisation for the reaction.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

(i) State how the student used their graph to determine the value of ΔT for use in the equation $q = mc\Delta T$.

....

.... [1]

(ii) The student correctly calculated the value of ΔH for the reaction as $\Delta H = -55.2\,kJ\,mol^{-1}$. The theoretical value for ΔH°_{neut} given in the student's textbook is $-57.6\,kJ\,mol^{-1}$.

Calculate the percentage error in the student's result compared with the theoretical value.

percentage error = ... % [1]

(iii) Suggest why the student's result was less negative than the theoretical value. Explain your answer.

....

.... [1]

[Total: 12]

1 The reaction between sulfuric acid and sodium hydroxide is exothermic.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

By measuring the temperature changes that occur when different volumes of the acid are added to a fixed volume of the alkali, it is possible to determine the neutralisation point. This is the point at which just enough acid has been added to react with all the alkali present. The aim of the investigation is to determine the concentration of the sulfuric acid.

FA 1 is 2.00 mol dm^{-3} sodium hydroxide, NaOH.
FA 2 is dilute sulfuric acid, H_2SO_4.

Read through the instructions carefully and prepare a table for your results before starting any practical work.

(a) Method

- Support a plastic cup in a 250 cm^3 beaker.
- Use a pipette to transfer 25.0 cm^3 of **FA 1** into the plastic cup.
- Record the temperature of **FA 1**, T_1, in the space below.

T_1 = ... °C

- Fill the burette labelled **FA 2** with **FA 2**.
- Add 5.00 cm^3 of **FA 2** from the burette to the plastic cup.
- Stir the mixture thoroughly and record the temperature of the solution.
- Add a further 5.00 cm^3 of **FA 2** to the plastic cup and again record the temperature.
- Repeat the addition of 5.00 cm^3 portions of **FA 2** until you have added a total of 50.00 cm^3 of **FA 2** to the plastic cup. Measure the temperature after each addition.
- Record in your table below the total volume of **FA 2** added and the temperature of the solution after each addition.

[5]

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(b) After each addition of acid, the temperature rise, ΔT, is given by,

ΔT = temperature recorded – T_1.

The total volume of solution in the plastic cup, V_T is given by,

V_T = volume of **FA 2** + volume of **FA 1**.

The heat given out by the reaction is proportional to the temperature rise, ΔT, multiplied by the total volume of solution in the plastic cup, V_T.

Use your experimental results to complete the following table.
You should include:

- the volume of **FA 2**
- the total volume in the plastic cup, V_T
- the temperature of the solution
- the temperature rise, ΔT
- the total volume × the temperature rise, ($V_T \times \Delta T$)

[1]

(c) (i) On the grid below, plot the values of $(V_T \times \Delta T)$ on the *y*-axis against the volume of **FA 2** on the *x*-axis.

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(ii) Draw a straight line of best fit through the points where the values of $(V_T \times \Delta T)$ are increasing. Draw a second straight line of best fit through the points where the values of $(V_T \times \Delta T)$ are decreasing.

(iii) From your graph, determine the volume of **FA 2** where the two lines of best fit intersect.

volume of **FA 2** = ... cm^3 [5]

(d) The value you recorded in **(c)(iii)** is the volume of **FA 2** which is needed to neutralise 25.0 cm^3 of **FA 1**. In the following calculations you will determine the concentration of **FA 2**.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate how many moles of sodium hydroxide are contained in 25.0 cm^3 of **FA 1**.

moles of NaOH = ... mol

(ii) Calculate how many moles of sulfuric acid would react with the number of moles of NaOH in **(i)**.

moles of H_2SO_4 = ... mol

(iii) Calculate the concentration of **FA 2**.

concentration of **FA 2** = ... $mol\,dm^{-3}$ [3]

(e) Other than heat losses from the plastic cup to the surroundings, suggest an additional source of error in this experiment and how this error could be reduced.

....

....

.... [1]

[Total: 15]

1 You are to determine the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide and also the concentration of the aqueous sodium hydroxide. These can be found by measuring the temperature change when solutions of the acid and alkali are mixed.

For Examiner's Use

FA 1 is aqueous sodium hydroxide, NaOH.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

(a) Method

- Fill a burette with **FA 1**. **[Care: FA 1 is corrosive]**
- Support the plastic cup in a 250 cm^3 beaker.
- Use a measuring cylinder to transfer 25 cm^3 of **FA 2** into a 100 cm^3 beaker.
- Use a measuring cylinder to add 35 cm^3 of distilled water to the acid in the beaker.
- Measure and record, in the table below, the initial temperature of the mixture in the beaker.
- Run 5.0 cm^3 of **FA 1** from the burette into the plastic cup.
- Add the mixture of acid and water from the 100 cm^3 beaker to the **FA 1** in the plastic cup.
- Stir carefully and measure the highest temperature obtained.
- Record this temperature in the table.
- Rinse the plastic cup with water.
- Repeat the experiment using 25 cm^3 of **FA 2**, 30 cm^3 of distilled water and 10.0 cm^3 of **FA 1** as shown for experiment **2** in the table.
- Carry out experiments **3** to **7** in the same way.
- Complete the table for each experiment.

Results

experiment number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
volume of **FA 2** / cm^3	25	25	25	25	25	25	25
volume of water / cm^3	35	30	25	20	15	10	5
volume of **FA 1** / cm^3	5.0	10.0	15.0	20.0	25.0	30.0	35.0
initial temperature of acid mixture / °C							
highest temperature / °C							
temperature change / °C							

[7]

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(b) On the grid below plot the temperature **change** (*y*-axis) against the volume of **FA 1** (*x*-axis). Using these points, draw two straight lines that intersect.

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(c) Reading from the intersection of the two lines on your graph,

the volume of **FA 1** is .... cm^3,

the temperature change is .... °C. [1]

The volume of **FA 1** at the intersection represents the volume of **FA 1** which neutralised 25.0 cm^3 of **FA 2**.

(d) The reaction between **FA 1** and **FA 2** is shown in the equation below.

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

This reaction is exothermic.

Use this information to explain the shape of the graph.

....

....

....

.... [2]

(e) Calculate the amount of heat energy produced in the reaction. Use the temperature change from **(c)** in calculating your answer.

[Assume that 4.3 J are required to raise the temperature of 1 cm^3 of any solution by 1 °C]

heat energy produced = ... J [2]

(f) Calculate how many moles of hydrochloric acid are present in 25 cm^3 of **FA 2**.

mol of hydrochloric acid = ... [1]

(g) Use your answers to **(e)** and **(f)** to calculate the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide.

Give your answer in kJ mol^{-1} and include the relevant sign.

enthalpy change of neutralisation = ... (*sign*) .... (*value*) kJ mol^{-1} [2]

(h) Explain why the **total** volume of solution used was kept constant in each of the experiments.

....

....

.... [1]

(i) Calculate the concentration, in mol dm^{-3}, of the aqueous sodium hydroxide, **FA 1**.

concentration of **FA 1** = ... mol dm^{-3} [2]

(j) A student thought that the experiment was not accurate because the temperature changes measured were small.

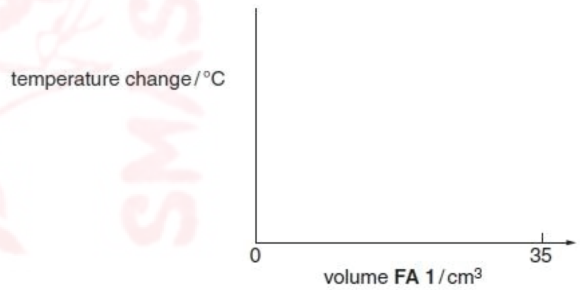
Suggest a modification to the experimental method used in order to give larger changes in temperature.

....

.... [1]

(k) Experiments **1** to **7** were repeated using 1.00 mol dm^{-3} sulfuric acid, H_2SO_4, instead of the 2.00 mol dm^{-3} hydrochloric acid, HCl.

On the axes below indicate an appropriate temperature scale and sketch the graph for the temperature changes you would expect.



[2]

[Total: 25]

1 Read through question 1 before starting any practical work.

You are provided with the following reagents.

FA 1, 2.0 mol dm^{-3} sulfuric acid, H_2SO_4
FA 2, aqueous sodium hydroxide, NaOH

The reaction of sulfuric acid with sodium hydroxide is exothermic.
In separate experiments you will add increasing volumes of **FA 2** to a fixed volume of **FA 1**. In each experiment you will measure the maximum temperature rise. As the volume of **FA 2** is increased, this maximum temperature rise will increase and then decrease.

By measuring the maximum temperature rise for different mixtures of the two reagents you are to determine the following.

- the concentration of sodium hydroxide, NaOH, in **FA 2**
- the enthalpy change when 1 mol of H_2SO_4 is neutralised by NaOH

(a) Method

- Fill the burette with **FA 1**.
- Support the plastic cup in the 250 cm^3 beaker.
- Run 10.00 cm^3 of **FA 1** from the burette into the plastic cup.
- Measure 10 cm^3 of **FA 2** in a measuring cylinder.
- Place the thermometer in the **FA 2** in the measuring cylinder and record the steady temperature of the solution.
- Tip the **FA 2** in the measuring cylinder into the plastic cup, stir and record the maximum temperature obtained in the reaction.
- Empty and rinse the plastic cup. Rinse the thermometer. Shake dry the plastic cup.
- Carry out the experiment four more times. Each time use 10.00 cm^3 of **FA 1**.
  Use 20 cm^3, 30 cm^3, 40 cm^3 and 50 cm^3 of **FA 2** in these different experiments.

Carry out **two further experiments**.
Choose volumes of **FA 2** which will allow you to investigate more precisely the volume of **FA 2** that produces the highest temperature rise when added to 10.00 cm^3 of **FA 1**.

Results
Record your results in an appropriate form showing, for each experiment, the volumes of solution used, temperature measurements and the temperature rise.

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[9]

(b) Use the grid below to plot a graph of temperature rise (*y-axis*) against the volume of **FA 2** added (*x-axis*).
Draw a line of best fit through the points where the temperature rise is increasing and another line through the points where the temperature rise is decreasing.
The intersection of these lines represents the temperature rise for the volume of **FA 2** that exactly neutralises the sulfuric acid present in 10.00 cm^3 of **FA 1**.

For Examiner's Use

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iii	
iv	

[4]

(c) Read from the graph the volume of **FA 2** that gives the maximum temperature rise.

The volume of **FA 2** giving the maximum temperature rise is ....cm^3. [1]

(d) Explain why the temperature rise is plotted on the *y-axis* rather than on the *x-axis*.

....

.... [1]

(e) Construct the balanced equation for the reaction of sulfuric acid with sodium hydroxide.

.... [1]

(f) **(i)** Calculate how many moles of sulfuric acid, H_2SO_4, are contained in 10.00 cm^3 of **FA 1**.

10.00 cm^3 of **FA 1** contain .... mol of H_2SO_4.

(ii) Calculate how many moles of NaOH are required to neutralise the amount of H_2SO_4 calculated in **(i)** above.

The sulfuric acid in 10.00 cm^3 of **FA 1** is neutralised by .... mol of NaOH. [2]

(g) Use the equation below to calculate the concentration of NaOH in **FA 2**.

$$\text{concentration of NaOH (mol dm}^{-3}\text{)} = \text{answer to (f)(ii)} \times \frac{1000}{\text{volume of FA 2 (cm}^3\text{) from (c)}}$$

The concentration of NaOH in **FA 2** = ...mol dm^{-3}. [1]

(h) Read the maximum temperature rise from the graph and use this to calculate the enthalpy change when 1 mol H_2SO_4 is neutralised by NaOH. Give your answer in kJ mol^{-1} and include the correct sign for the reaction.
[4.3 J are absorbed or released when the temperature of 1 cm^3 of solution changes by 1 °C. Remember that separate volumes of **FA 1** and **FA 2** were mixed together.]

ΔH = ... kJ mol^{-1}. [2]

(i) A student suggested that the accuracy of the experiment would be improved if the volume of **FA 2** had been measured using a burette rather than a measuring cylinder. Suggest an advantage **and** a disadvantage of using a burette in the procedure.

advantage ....

....

disadvantage ....

.... [2]

(j) Identify **two** further significant sources of error, other than the measurement of volume, in the experiments used for measuring temperature rise.

error 1 ....

....

error 2 ....

.... [1]

(k) Complete the sections below.

(i) The maximum error in taking a temperature reading on a thermometer with graduations at 1 °C is ....°C.

(ii) The temperature rise when 30 cm^3 of **FA 2** is added to 10.00 cm^3 of **FA 1** is ....°C.

(iii) Calculate the maximum percentage error due to the thermometer when measuring the temperature **rise** in **(ii)** above.

The maximum percentage error = ... %. [2]

[Total: 26]

GC1 Gas collection (carbonate reacting with acid) Chem 10 Q# 87/ ALvl Chemistry/2019/s/TZ 1/Paper 3/Q# 1 :o) www.SmashingScience.org

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 Metal carbonates react with acid to produce carbon dioxide. You will determine the identity of a Group 2 metal **M** in a carbonate of formula $\mathbf{M}CO_3$ by reacting the carbonate with excess dilute hydrochloric acid and measuring the volume of carbon dioxide produced.

$$\mathbf{M}CO_3(s) + 2HCl(aq) \rightarrow \mathbf{M}Cl_2(aq) + CO_2(g) + H_2O(l)$$

FA 1 is 50 cm^3 of 4.00 mol dm^{-3} hydrochloric acid, HCl.
FA 2 is the metal carbonate, $\mathbf{M}CO_3$.

(a) Method

- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Add all the **FA 1** into the flask labelled **X**.
- Check that the bung fits tightly into the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Weigh the container with **FA 2** and record the mass.
- Remove the bung from the neck of the flask. Tip the **FA 2**, from the container, into the acid in the flask and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp. Leave for several minutes, swirling the flask occasionally.

You may wish to start Question 2 while the gas is being evolved.

- When no more gas is collected, measure and record the final volume of gas in the measuring cylinder.
- Weigh the container, with any residual **FA 2**, and record the mass.
- Calculate and record the mass of **FA 2** added to flask **X**.

Results

[3]

(b) Calculations

(i) Calculate the number of moles of carbon dioxide collected in the measuring cylinder. [Assume that 1 mol of gas occupies 24.0 dm^3 under these conditions.]

moles of CO_2 = ... mol [1]

(ii) Use your answer to **(b)(i)** and the information on page 2 to calculate the relative atomic mass, A_r, of **M**.

A_r of **M** = ... [3]

(iii) Use your answer to **(b)(ii)** to identify **M**.

M is .... [1]

(c) (i) A student suggested that, using the same apparatus, the accuracy of the experiment would be increased if approximately 2 g of $\mathbf{M}CO_3$ were used to react with the excess hydrochloric acid.

State and explain whether the student was correct.

....

....

.... [1]

(ii) Another student suggested that the experiment would be more accurate if the carbon dioxide was collected in a gas syringe rather than over water.

State and explain whether the student was correct.

....

....

.... [1]

[Total: 10]

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 Several ores of copper contain both copper(II) carbonate and copper(II) hydroxide. This combination is called basic copper(II) carbonate. You will determine the composition of an ore of copper by reacting it with an **excess** of acid and collecting the gas evolved.

$$CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$$

FA 1 is a sample of basic copper(II) carbonate.
FA 2 is dilute sulfuric acid, H_2SO_4.

The formula of basic copper(II) carbonate, **FA 1**, can be written as $\mathbf{x}CuCO_3{\bullet}\mathbf{y}Cu(OH)_2$.
You will use your results to determine the ratio **x** : **y** in the formula.

(a) Method

- Fill the tub with water to a depth of about 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Use the 50 cm^3 measuring cylinder to transfer 50 cm^3 of **FA 2** into the conical flask.
- Fit the bung tightly in the neck of the flask, clamp the flask and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Weigh the container with **FA 1** and record the mass.
- Remove the bung from the neck of the flask. Tip **FA 1** into the flask and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents. Swirl the flask occasionally until no more gas is produced.
- Replace the flask in the clamp.
- Reweigh the container with any residual solid and record the mass.
- Calculate and record the mass of **FA 1** added to the flask.
- Measure and record the final volume of gas in the 250 cm^3 measuring cylinder.

Results

[2]

(b) Calculations

(i) Give your answers to **(ii)**, **(iii)**, **(iv)** and **(v)** to the appropriate number of significant figures. [1]

(ii) Calculate the number of moles of carbon dioxide collected in the measuring cylinder.
[Assume 1 mole of gas occupies 24.0 dm^3 under these conditions.]

moles of CO_2 = ... mol

Hence deduce the number of moles of copper(II) carbonate in **FA 1**.

moles of $CuCO_3$ = ... mol
[1]

(iii) Calculate the mass of copper(II) carbonate in **FA 1**.

mass of $CuCO_3$ = ... g [1]

(iv) Use your answer to **(iii)** and the mass of **FA 1** added to the flask in **(a)** to calculate the mass of copper(II) hydroxide in **FA 1**.

mass of $Cu(OH)_2$ = ... g [1]

(v) Hence calculate the mole ratio of the **two** components of basic copper(II) carbonate, **FA 1**. This is the ratio **x** : **y**.

$CuCO_3 : Cu(OH)_2$ = 1 : ....
x : **y**
[2]

(c) How would the value of **y** calculated in **(b)** change if the experiment was carried out at a much lower temperature?

Tick (✓) the correct box. Explain your answer.

y would decrease	
y would increase	
y would not change	

explanation ....

....

.... [1]

(d) Not all the carbon dioxide produced in the reaction is collected in the 250 cm^3 measuring cylinder. One reason for this is that some carbon dioxide is lost before the bung can be replaced in the flask.

Give **one** other reason why it is **not** possible to collect all of the carbon dioxide produced in **(a)**. Suggest an improvement to the method to address this.

reason ....

improvement ....

.... [1]

[Total: 10]

1 In **Questions 1** and **2** you will determine the percentage purity of industrial grade calcium carbonate, $CaCO_3$, by two different methods.

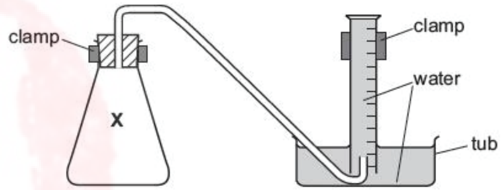
In the first method you will collect and measure the volume of gas given off in the reaction between a known mass of industrial grade calcium carbonate, in the form of small marble chips, and a known amount of dilute hydrochloric acid. The acid will be in excess. The impurities in the calcium carbonate will not react with the acid.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

FA 1 is industrial grade calcium carbonate, $CaCO_3$, in the form of small marble chips.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

Read through the whole method before starting any practical work.
The diagram below may help you in setting up your apparatus.



- Fill the tub with water to a depth of about 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Pipette 25.0 cm^3 of **FA 2** into the reaction flask labelled **X**.
- Check that the bung fits tightly in the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Weigh the container with **FA 1** and record the mass in the space on page 3.
- Remove the bung from the neck of the flask. Tip **FA 1** into the acid and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents. Swirl the flask occasionally until no more gas is evolved. Replace the flask in the clamp.
- Reweigh the container and any residue of **FA 1** and record the mass in the space on page 3.
- Calculate and record in the space on page 3 the mass of **FA 1** used.
- When no more gas is given off, measure and record the final volume of gas in the measuring cylinder in the space on page 3.

Keep the contents of flask X for use in Question 2.

Results

[2]

(b) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of carbon dioxide gas collected in the measuring cylinder. (Assume that 1 mole of gas occupies 24.0 dm^3 under these conditions.)

moles of CO_2 = ... mol

(ii) Use your answer to **(i)** and the Periodic Table on page 12 to calculate the mass of pure calcium carbonate in the sample of industrial grade calcium carbonate, **FA 1**.

mass of $CaCO_3$ = ... g

(iii) Use your answer to **(ii)** and the mass of marble chips used in **(a)** to calculate a value for the percentage purity of the sample of industrial grade calcium carbonate, **FA 1**.

percentage purity of **FA 1** = ... %

[4]

(c) Not all the carbon dioxide given off in the reaction is collected in the measuring cylinder.

Suggest a change to the method which would lead to an increase in the volume of carbon dioxide collected.

....

.... [1]

[Total: 7]

1 The concentration of hydrogen peroxide may be given in mol dm^{-3} or as 'volume strength'. You will determine the concentration of hydrogen peroxide in mol dm^{-3} and in 'volume strength' by a gas collection method.
Hydrogen peroxide decomposes to form water and oxygen. The reaction is much faster in the presence of a catalyst such as manganese(IV) oxide.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

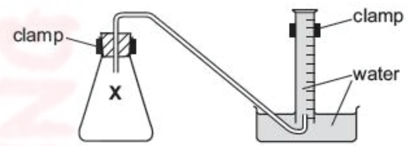
'Volume strength' is defined as the volume of oxygen in cm^3 produced from the decomposition of 1.0 cm^3 of hydrogen peroxide at room temperature and pressure. For example, 1.0 cm^3 of '100 volume' hydrogen peroxide will produce 100 cm^3 of oxygen.

FA 1 is a solution of hydrogen peroxide, H_2O_2.
FA 2 is manganese(IV) oxide, MnO_2.

(a) Method

Read the whole method before starting any practical work.

The diagram below may help you in setting up your apparatus.



- Fill the tub with water to a depth of about 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so that the open end is in the water just above the base of the tub.
- Rinse the 50 cm^3 measuring cylinder with a little **FA 1** then use it to transfer 150 cm^3 of **FA 1** into the reaction flask labelled **X**.
- Check that the bung fits tightly in the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Tip **FA 2** into the hydrogen peroxide and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents. Swirl the flask occasionally until no more gas is given off. Replace the flask in the clamp.
- Measure and record the final volume of gas in the measuring cylinder in the space below.

Keep FA 1 for use in Question 2.

Result

[2]

(b) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Use the information on page 2 to calculate the 'volume strength' of **FA 1**.

'volume strength' of **FA 1** = ...

(ii) Calculate the number of moles of oxygen collected in the measuring cylinder.
[Assume 1 mole of gas occupies 24.0 dm^3 under these conditions.]

moles of O_2 = ... mol

(iii) Using your answer to **(ii)** calculate the number of moles of hydrogen peroxide in the volume of **FA 1** added to flask **X**.

moles of H_2O_2 = ... mol

(iv) Calculate the concentration of hydrogen peroxide, **FA 1**, in mol dm^{-3}.

concentration of H_2O_2, **FA 1** = ... mol dm^{-3}
[4]

(c) (i) A source of error in this experiment is that some oxygen escapes before the bung can be inserted.

Suggest a change to the practical procedure given in **(a)** to reduce this source of error.
You may draw a diagram as part of your answer.

....

....

(ii) The error in reading a 50 cm^3 measuring cylinder is ±0.5 cm^3.

Calculate the maximum percentage error in the volume of hydrogen peroxide added to flask **X** in **(a)**.

maximum percentage error in volume of H_2O_2 = ... %

(iii) Explain why the presence of 20 cm^3 of air in the 250 cm^3 measuring cylinder before the start of the experiment would decrease the accuracy of the results obtained in **(a)**.

....

....

....
[4]

(d) If you repeated the method described using half the mass of **FA 2**, what volume of gas would you expect to collect? Explain your answer.

....

.... [1]

[Total: 11]

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 In this experiment you will determine the concentration of a sample of hydrochloric acid. You will do this by measuring the volume of hydrogen produced when an excess of magnesium reacts with the acid.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

FA 1 is magnesium powder, Mg.
FA 2 is hydrochloric acid, HC*l*.

(a) Method

- Weigh the container with **FA 1**. Record the mass.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder completely with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so that the open end is just above the base of the tub.
- Use the 25 cm^3 measuring cylinder to place 25.0 cm^3 of **FA 2** into the reaction flask, labelled **X**.
- Check that the bung fits tightly in the neck of flask **X**, clamp flask **X**, and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of flask **X**. Tip all of **FA 1** into flask **X** and replace the bung **immediately**. Remove the flask from the clamp and swirl to mix the contents.
- Swirl the flask occasionally until no more gas is evolved. Replace the flask in the clamp.
- Measure and record the final volume of gas in the measuring cylinder.
- Weigh and record the mass of the container with any residual solid.
- Calculate and record the mass of **FA 1** used.

Keep FA 2 for use in Question 2.

[2]

(b) Calculations

(i) Calculate the number of moles of hydrogen gas produced.
(Assume 1 mol of gas occupies 24.0 dm^3 at this temperature.)

moles of $H_2(g)$ = ... mol [1]

(ii) Calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HC*l* in **FA 2** = ... mol dm^{-3} [1]

(iii) In this experiment the magnesium powder was in excess.

Calculate the mass of magnesium powder needed for complete reaction with all the hydrochloric acid in 25.0 cm^3 of **FA 2**.

mass of Mg = ... g [1]

(c) A student suggested two modifications to the method in **(a)** to give a more accurate value for the concentration.

For each suggestion, state whether you agree with the student and explain your answer.

Suggestion 1: Use magnesium ribbon rather than powdered magnesium; keep the rest of the experiment the same.

....

....

Suggestion 2: Use twice the mass of magnesium powder; keep the rest of the experiment the same.

....

....

[2]

(d) Another student carried out the experiment in **(a)** but used less magnesium than that calculated in **(b)(iii)**.

State and explain the effect this would have on the calculated concentration of hydrochloric acid in **FA 2**.

....

....

.... [1]

[Total: 8]

Qo Qualitative tests to identify unknown organic compounds Chem 17 Q# 92/ ALvl Chemistry/2022/w/TZ 1/Paper 3/Q# 3 :o) www.SmashingScience.org

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

(b) Half fill the 250 cm^3 beaker with water and heat to approximately 80 °C. Turn off the Bunsen burner. This will be your hot water bath.

FA 7 is an organic compound with an M_r between 40–57.

(i) Carry out **Test 2** and **Test 3** on **FA 7** and record your observations. The result for **Test 1** is shown in the table.

test	*observations*
Test 1 Add a small piece of sodium.	no change
Test 2 To a 0.5 cm depth of aqueous iodine in a test-tube add aqueous sodium hydroxide dropwise until the yellow colour just disappears. Then add a few drops of **FA 7** and shake the test-tube. If no change is seen, warm the test-tube in your hot water bath.	
Test 3 To a 1 cm depth of **FA 7** in a test-tube add a few drops of acidified potassium manganate(VII). Warm the test-tube in your hot water bath.	

[2]

(ii) Using the observations in **(b)(i)** suggest what can be deduced from each test about the functional groups present in **FA 7**.

Test 1 ....

Test 2 ....

Test 3 ....

[2]

(iii) Use your deductions in **(b)(ii)** to suggest the identity of **FA 7**.

FA 7 is .... [1]

[Total: 15]

Qualitative tests to identify unknown organic compounds Chem 16 Q# 93/ ALvl Chemistry/2020/s/TZ 1/Paper 3/Q# 3 :o) www.SmashingScience.org

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

(b) **FA 7** and **FA 8** are aqueous solutions of covalently bonded compounds.

Half fill the beaker with water and place it on a tripod and gauze. Heat until the water begins to boil and then turn off the Bunsen burner. This will be used as a hot water bath.

(i) Complete the table by carrying out the tests described.
Use a 1 cm depth of **FA 7** or **FA 8** in a test-tube for each test.

test	*observation(s)*	
	FA 7	**FA 8**
Test 1 Add an equal volume of dilute sulfuric acid and a **few** drops of **FA 3**, aqueous acidified potassium manganate(VII), then		
place in the hot water bath for several minutes.		
Test 2 Add an equal volume of dilute sulfuric acid and an equal volume of aqueous potassium iodide, then		
add a few drops of aqueous starch.		
Test 3 Add an equal volume of aqueous iodine, then add aqueous sodium hydroxide until no further change occurs. Leave the tube to stand.		
Test 4 Add a few drops of **FA 4**, then		
add aqueous ammonia.		

[5]

(ii) **FA 8** contains an organic compound.

From your observation(s), suggest one **possible** identity for this compound.
Explain your answer.

name ....

reason ....

....

.... [2]

(iii) State the type of reagent **FA 7** acts as in its reaction with aqueous potassium iodide.
Explain your answer.

....

....

.... [1]

[Total: 18]

Qualitative tests to identify unknown organic compounds Chem 18 Q# 94/ ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# 3 :o) www.SmashingScience.org

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 **(a)** Half fill the 250 cm^3 beaker with water. Heat to approximately 70 °C, then turn off the Bunsen burner. This will be used as a water bath.

(i) **FA 5** is an aqueous solution of an organic compound. Carry out the following tests on **FA 5** and record your observations in the table.

test	*observations*
To a 1 cm depth of **FA 5** in a test-tube add a small spatula measure of sodium carbonate.	
To a 1 cm depth of **FA 5** in a test-tube add two drops of acidified potassium manganate(VII). Leave to stand in the water bath.	
To a 1 cm depth of **FA 5** in a test-tube add a few drops of aqueous silver nitrate.	
To a 1 cm depth of aqueous silver nitrate in a test-tube add a few drops of aqueous sodium hydroxide and then add aqueous ammonia slowly until the grey precipitate that forms **just** dissolves. This is Tollens' reagent. To this solution add a 1 cm depth of **FA 5** and leave to stand in the water bath. **Care: rinse the tube as soon as you have completed this test.**	

[4]

(ii) Suggest **two** functional groups that could be present in **FA 5**.

.... and .... [2]

Qualitative tests to identify unknown organic compounds Chem 17 Q# 95/ ALvl Chemistry/2016/s/TZ 1/Paper 3/Q# 3 :o) www.SmashingScience.org

3 **Qualitative Analysis**

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(d) **FA 6** and **FA 7** are different organic liquids. Their possible identities are listed below.

- 2-methylpropan-2-ol
- propanal
- propanone

Half fill the 250 cm^3 beaker with water and heat to about 50 °C. You will use this as a hot water bath.

Turn off the Bunsen burner.

Carry out the following tests and record your observations.

test	*observations*
To a 1 cm depth of **FA 6** in a test-tube, add a few drops of acidified potassium manganate(VII). If no reaction is seen, warm the solution in the hot water bath.	
To a 1 cm depth of **FA 7** in a test-tube, add a few drops of acidified potassium manganate(VII). If no reaction is seen, warm the solution in the hot water bath.	

Suggest the identity of **FA 6** and **FA 7** with an explanation.

FA 6 ....

FA 7 ....

[2]

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Read through the remainder of question 2 before starting further practical work.

Heat a half-full 250 cm^3 beaker of water for use as a hot water-bath.

(g) **FA 7**, **FA 8**, **FA 9** and **FA 10** are organic compounds. Each contains one of the following different functional groups.

- primary alcohol
- tertiary alcohol
- aldehyde
- ketone

You are to react some of these compounds with some of the following reagents.

- acidified aqueous potassium dichromate(VI)
- 2,4-dinitrophenylhydrazine (2,4-DNPH) reagent
- ammoniacal silver nitrate (Tollens' reagent)

You are provided with the first two reagents. You must prepare the last of these reagents, Tollens' reagent, immediately before use. Follow the instructions in the box below.

> To 2 cm depth of aqueous silver nitrate in a boiling-tube add ½ cm depth of aqueous sodium hydroxide. This will produce a brown precipitate of silver(I) oxide.
> Add aqueous ammonia a little at a time, with continuous shaking, until the brown precipitate **just** dissolves. **Do not add an excess of aqueous ammonia**.

In each of the following tests add a few drops of the reagent to 1 cm depth of **FA 7**, **FA 8**, **FA 9** and **FA 10** in separate test-tubes.

In the tests using acidified potassium dichromate(VI) and Tollens' reagent, if no initial reaction is seen, warm that tube and its contents in your hot water-bath. There is no need to heat any tube to which you have added 2,4-DNPH reagent.

Do **not** heat any tube with a naked flame.

Record your results in the table below.

Do **not** carry out tests for the shaded boxes.

reagent	*observations*			
	FA 7	**FA 8**	**FA 9**	**FA 10**
acidified potassium dichromate(VI)				
2,4-DNPH reagent				
Tollens' reagent				

[3]

(h) State which of the solutions contains a tertiary alcohol. Explain the observations leading to your conclusion.

FA .... contains the tertiary alcohol.

explanation ....

....

State which of the solutions contains the aldehyde. Explain the observations leading to your conclusion.

FA .... contains the aldehyde.

explanation ....

....

[2]

[Total: 14]

SECTION 2 **Unedited Mark Scheme** ordered by Experiment SubType

Q# 1/ Qualitative inorganic ions tests ALvl Chemistry/2022/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

FA 6 is aqueous $Zn(NO_3)_2$ and KI; FA 7 gives results for ethanal but is actually **butan-2-ol**

3(a)(i)	**observations** **Test 1** M1: NaOH: white ppt **and** soluble in excess M2: Heat: no change / no (visible) reaction / litmus stays red **Test 2** M3: *Al*: fizz **and** NH_3 / gas turns (damp red) litmus blue **Test 3** M4: H_2O_2: brown / (darker) yellow / yellow-brown / orange-brown / red-brown (solution)	4
3(a)(ii)	possible cations: aluminium / Al^{3+} and zinc / Zn^{2+}	1
3(a)(iii)	identifying the cation M1: cation test: add (aqueous) ammonia M2: white ppt soluble in excess $NH_3(aq)$ shows Zn^{2+}	2
3(a)(iv)	possible anions: any two from NO_3^-, NO_2^-, I^-	1
3(a)(v)	identifying the anion **if iodide in (iv)** M1: test: add (aqueous) silver nitrate / $AgNO_3$ M2: yellow ppt (insol in NH_3) shows I^- **if nitrite and nitrate (no iodide) in (iv)** M1: test: add (acidified aqueous) potassium manganate(VII) / $KMnO_4$ M2: purple / $KMnO_4$ solution turns (dark) yellow / yellow-brown / orange-brown / red-brown / brown / decolourised shows nitrite OR M1: add named (dilute) acid M2: no fizzing / no brown gas shows nitrate	2

Q# 2/ Qualitative inorganic ions tests ALvl Chemistry/2022/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

FA 5 is $NaNO_3$; FA 6 is $Al_2(SO_4)_3$; FA 7 is I_2 + KI

3(a)(i)	**M1**: 'table' (2 × 2 min) with headings: 'test / experiment / reagents' and 'observations' **AND** two (or more) reagents listed in the space **M2**: *(eliminating ammonium ion)* heat **FA 5** with (aqueous) NaOH **AND** no effervescence / (damp red) litmus stays red **M3**: *(identifying NO_2^- / NO_3^-)* add *Al* to warm NaOH and **FA 5** **AND** fizz / gas / NH_3 turns (damp red) litmus blue **M4**: *(eliminating NO_2^-)* anion is NO_3^- / nitrate / nitrate(V) **AND** Either add (a few drops of) (acidified) $KMnO_4$ / potassium manganate(VII) **AND** no change / no reaction / (solution) remains purple Or add (dilute) named mineral acid to (solid or aqueous) **FA 5 AND** no brown fumes / no blue solution / no reaction / no change produced	4

3(a)(ii)	• solid melts / solid dissolves / liquid forms • fizzing / bubbling / effervescence • (gas) re-lights glowing splint / spill • oxygen produced • (on cooling), (pale) yellow solid formed or residue is yellow *3 or more bullets = 2 marks* *2 bullets = 1 mark*	2
3(b)(i)	(see table below) 2 * = 1 mark (round down)	5

test	*FA 6*	*FA 7*
Test 1 NaOH	White ppt / solid (formed) * Soluble in excess *	Decolourises / **turns** (pale) yellow * (ppt is CON)
Test 2 Ba^{2+}	White ppt	No change / no reaction
+ HC*l*	AND ppt insoluble / remains / no change / no reaction *	**AND** no change / no reaction *
Test 3 starch		Dark blue / blue-black / black (colour formed) (ignore state)
+ thio		**AND** colourless solution (forms) ALLOW turns colourless / decolourises *
Test 4 Ag^+	No change / no reaction / no ppt	Yellow / brown ppt (forms) *
+ NaOH	**AND** ppt (forms) (ignore colour) *	Pale yellow ppt ALLOW ppt turns paler yellow * IGNORE use of excess NaOH
Test 5 + NH_3	White ppt **AND** ppt is insoluble in excess (NH_3) *	

3(b)(ii)	**FA 6** = $Al_2(SO_4)_3$ [1] **FA 7** = I_2 [1] **AND** KI [1]	3
3(b)(iii)	$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$ OR $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$ OR $I_2(aq) + 6OH^-(aq) \rightarrow I^-(aq) + IO_3^-(aq) + 3H_2O(l)$	1

Q# 3/ Qualitative inorganic ions tests ALvl Chemistry/2022/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

FA 7 is $Na_2S_2O_3$; **FA 8** is $AlNH_4(SO_4)_2(aq)$

3(a)(i)	(see table below) 2 x * = 1 mark	4

	FA 7	**FA 8**
Test 1 + H^+	(slow formation of) white / off-white / cream / pale yellow ppt *	no change / no (visible) reaction / no ppt*
+ Ba^{2+}	no change (provided ppt reported with H^+) / ppt remains / insoluble *	white ppt *
Test 2 + MnO_4^-	purple to colourless / $KMnO_4$ decolourises*	no change / no (visible) reaction / stays purple * *Not 'no ppt' alone*
Test 3 + $FeCl_3$	purple colour fades / turns colourless (on standing) *	no change / no (visible) reaction / solution stays yellow *

3(b)(iii)	One of: $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$ $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$ $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$ *Allow ecf from **(b)(ii)** on incorrect cations*	1

Q# 4/ Qualitative inorganic ions tests ALvl Chemistry/2021/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

FA 5 is $BaCl_2(aq)$; **FA 6** is $H_2SO_4(aq)$; **FA 7** is NaOH(aq); **FA 8** is HCOOH(aq)

3(b)(i)	M1: Test 1 purple / pink to colourless / (pale) yellow / pale brown OR $KMnO_4$ is decolourised M2: Test 2 effervescence / fizzing / bubbles **AND** gas/ H_2 pops with a lighted splint / burns with a pop	2
3(b)(ii)	M1: (**FA 8**) can be oxidised / is a reducing agent M2: (**FA 8**) is an acid	2

Q# 5/ Qualitative inorganic ions tests ALvl Chemistry/2021/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

FA 5 is $BaCl_2$(aq); **FA 6** is H_2SO_4(aq); **FA 7** is NaOH(aq); **FA 8** is HCOOH(aq)

3(a)(i) — 5 marks

	FA 5	FA 6	FA 7
H_2SO_4	white ppt / solid *	no (visible) reaction / no change / no ppt / solution remains colourless *	no (visible) reaction / no change / no ppt / solution remains colourless *
Na_2CO_3	white ppt / solid *	effervescence / fizzing / bubbles * gas / CO_2 turns limewater milky / cloudy white / forms white ppt *	no (visible) reaction / no change / no ppt / solution remains colourless *
$MgCl_2$	no (visible) reaction / no change / no ppt / solution remains colourless *	no (visible) reaction/ no change / no ppt / solution remains colourless *	white ppt / solid *

3(a)(ii)	M1: Cation in **FA 5** is Ba^{2+} or Ca^{2+} M2: Cation in **FA 6** is H^+ M3: Anion in **FA 7** is OH^-	3
3(a)(iii)	**Test for OH^-** Add specified (aqueous) metal compound gives appropriate (coloured) ppt OR Add a specified nitrate and *Al* and warm Positive test for ammonia OR Add a specified ammonium compound and warm Positive test for ammonia	1
3(a)(iv)	Yes, because the test gave a named ppt of specified hydroxide which is insoluble (in water). OR Yes, because it gave ammonia gas (on warming) which is alkaline.	1

Q# 6/ Qualitative inorganic ions tests ALvl Chemistry/2021/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

3(a)(i)	**Test 1** no change / (pale) orange / (pale) red / (pale) pink solution *Allow solution becomes colourless / paler*	1
	Test 2 (see table below) 2 asterisks = 1 mark (round down)	2
3(a)(ii)	Fe^{3+} is formed (in **Test 2**)	1
	oxidation of Fe^{2+} / redox	1
3(a)(iii)	NH_4SCN	1
3(a)(iv)	$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$	
	correct product formula	1
	balancing and state symbols	1

Test 2:

+ NaOH	green / dirty green / pale green / dark green ppt * ppt turns brown (at surface) *
+ H_2SO_4	ppt dissolves or yellow / yellow-brown / orange-brown solution formed *
+ SCN^-	(solution) turns dark(er) orange / blood-red / red / dark(er) red / deep red / red-brown * colour must be more intense than in **Test 1**

3(b)(i)	prepare solution of **FA 4**	1
	prepare a suitable table(s) minimum 2 tests and columns/ rows for tests and for observations	1
	2 asterisks = 1 mark (round down) (see table below) *Ignore additional reagents*	5
3(b)(ii)	cation: Mg^{2+} and anion: SO_4^{2-}	1

+NaOH *	white ppt * insoluble in excess *
+ NH_3 *	white ppt* insoluble in excess *
$BaCl_2$/$Ba(NO_3)_2$* HCl / HNO_3 *	white ppt * insoluble in excess suitable named acid *
OR dilute acid * + $KMnO_4$ *	no change / no reaction / solution remains purple **

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FA 6 is NH_4Cl; **FA 7** is NH_4I; **FA 8** is $BaCl_2$

3(a)(i)	1 mark for correct gas test: (gas / vapour / fumes) turn (moist red) litmus to blue *Reject if incorrect gas identified* 1 mark for any two bulleted observations correct: • solid sublimes / white solid forms near top of tube *(owtte; allow residue for solid)* *Reject 'solid evaporated'* *Allow 'white layer formed around glass tube' (bod)* • white and smoke / vapour / fumes produced *Reject 'effervescence'* *Reject 'gas'* • no residue (at bottom of tube) *Allow 'crystals disappear completely'* • after heating for some time, gas turns (moist blue) litmus to red	2
3(a)(ii)	ammonium / NH_4^+ *Reject if more than one ion identified*	1
3(b)(i)	14 observations. Two * = 1 mark (round down) *Reject 'no observation' (for 'no change') the first time seen, then allow*	6

test	reagent	FA 7	FA 8
1	$KMnO_4$	Solution / turns and yellow / red-brown / orange-brown / brown * *Reject any reference to purple colour at end* *Reject ppt*	*Ignore*
	starch	black / dark blue / blue-black / black-purple * *Reject purple on its own*	*Ignore*
2	$AgNO_3$	(pale) yellow precipitate (formed) * *Reject creamish-yellow*	white precipitate (formed) * *Reject off-white*
	NH_3	ppt does not dissolve / insoluble / no change *	ppt (mostly) dissolves or partially dissolves or (slightly) cloudy mixture forms or <u>some</u> white ppt remains * *Reject 'clear solution'*
3	NaOH (cold)	no reaction / no change / no precipitate * *Allow 'no visible observation'*	white precipitate **and** insoluble in excess * *Reject any variation on white, e.g. off-white*
	NaOH (hot)	<u>gas / NH_3</u> turns (red) litmus to blue *	*Ignore observations when heated* *(but reject litmus goes blue at any stage of this test)*
	Al	*Ignore observation(s) with Al*	fizzing / bubbling / effervescence or gas / H_2 pops with lighted spill *
4	H_2SO_4	no change / no reaction or solution <u>remains</u> colourless * *Reject 'no ppt'*	white precipitate (formed) *

3(b)(ii)	**FA 7** is NH_4I **FA 8** is $BaCl_2$ **ALLOW** $CaCl_2$ / $CaBr_2$ / $BaBr_2$ for **FA8** *If both are named correctly award one mark (out of 2).* *If both cations are correct, award one mark (out of 2).*	2
3(b)(iii)	$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ *State symbols are required. Allow ecf for Ca^{2+} or Mg^{2+} in (ii)*	1

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	FA 6 = $Na_2SO_3(s)$; FA 8 = $CuSO_4(aq)$	
3(a)(i)	+ $AgNO_3$ gives a white ppt	1
	soluble in **both** $NH_3(aq)$ and **FA 5** / thio	1
3(a)(ii)	Cl^- / chloride	1
3(a)(iii)	Selects $BaCl_2$ OR $Ba(NO_3)_2$ **and** HCl OR HNO_3 **OR** selects acidified (aqueous) $KMnO_4$ **OR** add named mineral acid and test for SO_2 (e.g. blue litmus turns red; acidified aqueous manganate(VII) paper turns colourless)	1
	Clear display of results to show: white ppt **and** (partially) soluble in acid OR $KMnO_4$ decolourises OR positive result for SO_2 **AND** **FA 6** = sodium sulfite	1
3(a)(iv)	$2Ag^+(aq) + SO_3^{2-}(aq) \rightarrow Ag_2SO_3(s)$ Allow sulfate if ppt seen in **(iii)**: $2Ag^+(aq) + SO_4^{2-}(aq) \rightarrow Ag_2SO_4(s)$(sic)	1
3(b)(i)	(Pale) blue ppt dissolves in excess to give a dark blue solution.	1
	+ H_2O_2 solution turns black / dark green **OR** black / dark green solid produced **AND** Effervescence / fizzing / bubbling	1
	gas / oxygen relights a glowing splint	1
3(b)(ii)	Cu^{2+} / copper(II)	1
3(b)(iii)	+ KI(aq) (turns) brown / yellow-brown / orange-brown / grey-brown Ignore state Allow mustard (brown) Reject red-brown	1
	+ **FA 5** then (brown solution becomes paler) ppt is off-white / white Allow cream / pale grey ppt. Ignore effect of excess thio / **FA 5**.	1
3(b)(iv)	Any 2 of: • (mixture) turns brown owing to the production of iodine • ppt formed is copper(I) iodide (allow copper(II) iodide) • I^- is oxidised (by Cu^{2+}) OR Cu^{2+} is reduced (by I^-) I_2 is reduced (by $S_2O_3^{2-}$) OR S is oxidised (by I_2) (ignore oxidation state of S)	2

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	FA 1/FA 6 is $(NH_4)_2Fe(SO_4)_2.6H_2O$; FA 7 is H_2O_2; FA 8 is ethanol	
3(a)(i)	Reagents used are NaOH **and** NH_3	1
	FA 6 dissolved in (distilled) water (before carrying out tests)	1
	Observations with both cold alkalis • With NaOH: green ppt, insoluble in excess • With NH_3: green ppt, insoluble in excess OR • If only one of NaOH or NH_3 was selected, award this mark if the observation is correct, but it must include 'ppt turns brown'.	1
	Observation when heated with NaOH Fizzing/bubbling **and** gas/NH_3 turns (moist red) litmus to blue	1

	Both ions correctly identified Iron(II) and ammonium (Fe^{2+} and NH_4^+)	1
3(a)(ii)	**Anion test and first observation** • Add barium nitrate/chloride • White precipitate	1
	Observation with acid and conclusion: • white ppt is insoluble in specified mineral acid (not H_2SO_4) • sulfate / SO_4^{2-} present	1
3(a)(iii)	**Ionic equation** *Any one of the following equations, provided that the appropriate test was carried out.* • $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ • $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l \text{ or } g)$ • $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$	1
3(a)(iv)	**Correct use of M_r to calculate no of moles water.** Mass of water = (392) - 55.8 -192.2 – 36	1
	• $n(H_2O) = {}^{392-284}/_{18}$ (expressed as integer)	1

Q# 10/ Qualitative inorganic ions tests ALvl Chemistry/2020/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

	FA 6 is $(NH_4)_2Fe(SO_4)_2(aq)$; FA 7 is KI(aq); FA 8 is HCl(aq)	
3(a)(i)	Green precipitate **and** insoluble / no change in excess (NaOH)	1
	(Green) precipitate darkens and / or goes brown	1
	(When mixture heated) gas / ammonia turns (red) litmus blue	1
	Both cations in **FA 6** identified • Fe^{2+} ions / iron(II) • Ammonium / NH_4^+	1
3(a)(ii)	Goes brown / rust / red-brown / orange-brown **AND** bubbles / fizzing / effervescence	1
3(a)(iii)	$Fe^{2+} \rightarrow Fe^{3+} + e^-$ / $Fe^{2+} - e^- \rightarrow Fe^{3+}$	1
3(b)(i)	Award one mark for every two correct observations (*) as shown in table below	5

test	*observations*	
	FA 7	**FA 8**
Test 1 + $Na_2CO_3(s)$	no (visible) reaction / no change / no precipitate / solid (carbonate) dissolves / no effervescence *	effervescence / fizzing / bubbles * gas / CO_2 gives a white ppt with limewater / turns limewater milky / cloudy white / chalky *
Test 2 + $H^+/KMnO_4(aq)$	solution turns yellow / brown / orange-brown / red-brown / yellow-brown *	no (visible) reaction / no change / $KMnO_4$ / solution stays purple / colourless solution turns purple / purple solution formed *
+ starch(aq)	(turns) dark blue / deep blue / blue-black / black *	*ignore*
Test 3 + $AgNO_3(aq)$	(pale) yellow ppt (formed) *	white ppt (formed) *
+ $NH_3(aq)$	(ppt) insoluble / does not dissolve / no change *	(ppt) dissolves / soluble / gives a colourless solution *

3(b)(ii)	Anion in **FA 7** is iodide (ion) / I^- must be concluded from a (pale) yellow precipitate	1
3(b)(iii)	**FA 8** is hydrochloric acid / HCl	1
3(b)(iv)	One suitable test for H^+ (reagent **and** observation) in any acid identified in **(b)(iii)** • named pH indicator **and** correct final colour OR • add magnesium **and** fizzes or gas / H_2 pops with a lighted splint	1

Q# 11/ Qualitative inorganic ions tests ALvl Chemistry/2019/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

	FA 5 is $AlNH_4(SO_4)_2.12H_2O$; FA 8 is KI and $FeSO_4$	
3(a)(i)	• melts / dissolves • condensation / moisture on the walls of the test-tube / steam produced • white smoke / fumes (NOT gas) • (gas) turns red litmus blue • gas turns blue litmus red • white residue Award 1 mark for two correct observations from the list, award 2 marks for three or more correct observations. If both gas observations are given they must be in the correct order for both to be credited.	2

3(a)(ii)	NH_3 White ppt and insoluble in excess	1
	NaOH White ppt and sol in excess **Allow** 1 mark for white ppt with both NH_3 and NaOH	1
	hot NaOH Gas / NH_3 (on warming) turns red litmus blue	1
	Ba^{2+} White ppt insoluble in acid / white ppt no reaction with acid **Reject** white ppt formed when acid added	1
3(a)(iii)	names or correct formulae	1
	NH_4^+ , Al^{3+} , SO_4^{2-} Award 1 mark for two ions, award 2 marks for three ions.	1

3(b)	Any formula (involving all three ions) in which the charges on the ions cancel (e.g. $K_3Cr(SO_4)_3$)	1
	$KCr(SO_4)_2.12H_2O$	1
3(c)(i)	Red-brown (allow yellow / yellow-brown / orange / orange-brown / brown) (solution) or $KMnO_4$ / purple decolourises **and** turns blue-black / **dark** blue / black (on adding starch)	1
	Green ppt **and** insoluble in excess / turns brown (on standing) Reject grey-green	1
3(c)(ii)	Fe^{2+} / iron(II) **and** I^- / iodide This mark is free-standing	1
3(c)(iii)	Uses silver nitrate **and** yellow ppt	1
	ppt insoluble in HNO_3 or ppt insoluble in NH_3 (nitric acid may be added initially)	1
3(c)(iv)	$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ ecf for Cr^{3+} / Cu^{2+} / Fe^{3+} or any other transition metal ion concluded in **(ii)**.	1

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3(a)(i) — 5 marks

	FA 4	FA 5
HCl	No (visible) reaction / no change * *Allow pale yellow solution / colourless solution*	**Pale** yellow / cream / white / off-white ppt *(ignore excess)
$CuSO_4$	Brown (ppt/ colour / soln) * *Do not allow orange/-brown or red-brown*	Green soln * allow blue-green / cyan / turquoise ppt is CON
$AgNO_3$	(pale) Yellow ppt *	Yellow ppt / black ppt / grey ppt / (allow solid/ particles for ppt) *
+ NH_3	Insol in NH_3 * *Allow no change*	ignore NH_3
Cl_2	Yellow or brown or red-brown / orange-brown / *yellow-brown soln* * *Do not allow orange.* *Ppt is CON*	No (visible) reaction / no change * *Allow colourless solution.*
+ FA 5	Decolourised * If Cl_2 reaction is incorrect then allow ecf e.g. colourless solution	

For every two correct observations (*) award 1 mark (round down)
Allow no observation for no (visible) change.

3(a)(ii)	**FA 4** contains iodide / I^- Or **FA 5** contains thiosulfate / $S_2O_3^{2-}$	1
3(a)(iii)	Reagent: starch Observation expected: dark blue or blue / black colour	1

3(b)(i)	(Red) litmus turns blue Gas turns litmus blue is CON	1
3(b)(ii)	$QO(s) + H_2O(l) \rightarrow Q(OH)_2(s) / (aq)$	1
3(c)(i)	hydrochloric / nitric acid allow sulfuric acid accept correct formula	1
3(c)(ii)	Clear layout to show tests, observations and conclusions.	1
	(Chooses) NH_3 Ignore NaOH / named sulfate / H_2SO_4 Any other reagent is CON	1
	FA 6: no ppt / no (visible) change / no reaction / colourless solution. (allow no observation)	1
	FA 7: white ppt insoluble in excess Ignore observations with other reagents	1
	M is calcium (or barium), **Q** is magnesium	1
3(c)(iii)	Conclusions to follow identification of **M** or **Q** in Questions **1** and **2** and conclusions of tests in **(b)(ii)**	1

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FA 4 is $Cu_2O(s)$; **FA 5** is $H_2SO_4(aq)$; **FA 6** is Cu powder

3(a)(i)	**FA 4** + **FA 5** observations may be in either order blue solution formed / colourless to blue / solution turns blue / blue filtrate	1
	pink / brown / red-brown **AND** residue / solid	1

3(a)(ii) — 5 marks

test	*observations*	*marks*
+ NH_3	((pale) blue ppt) forming deep / dark blue solution in excess	1
+ KI, then	turns brown / yellow-brown	1
+ $Na_2S_2O_3$	white ppt	1
+ HNO_3, then + $AgNO_3$	no (visible) reaction / no change / no ppt / remains a blue solution	1
+ HCl / HNO_3, then + $BaCl_2$ / $Ba(NO_3)_2$	white ppt	1

3(a)(iii)	**FA 6** + nitric acid: (pale) blue solution	1
	then + NaOH: (pale) blue ppt	1
3(b)(i)	metal ion: Cu^{2+} / copper(II) **AND** anion: SO_4^{2-} / sulfate	1
3(b)(ii)	$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ OR $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ OR $2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq) / (s)$	1
3(b)(iii)	redox (from some reaction in **(a)(iii)**) OR oxidation of metal / Cu OR reduction of nitrate	1
3(c)	Na_2CO_3 (or other named carbonate) / Mg / Al / Zn / Fe / sodium thiosulfate	1
	+ CO_3^{2-}: effervescence / gas turns limewater milky / chalky / cloudy white / white ppt + appropriate metal: effervescence / gas pops with lighted splint + thio: white / off-white / pale yellow ppt	1
	Student is correct / FA 5 is an acid from correct observation	1

Q# 14/ Qualitative inorganic ions tests ALvl Chemistry/2018/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

FA 4 is sodium chloride; **FA 6** is copper(II) carbonate; **FA 7** is a mixture of zinc sulfate and zinc nitrate

2(a)(i)	Make a solution of **FA 4** and add aqueous $AgNO_3$	1
	white ppt shows anion is Cl^-	1
2(a)(ii)	$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$	1
2(b)(i)	**Hydrochloric acid** Effervescence / bubbling and blue / green / cyan / turquoise solution formed	1

	gas / CO_2 turns limewater milky / cloudy white / chalky / forms a white ppt	1
	Ammonia (pale) blue ppt and dark blue solution with excess	1
	Heating (FA 6) turns black / black solid formed / it turns black	1
2(b)(ii)	2 * = 1 mark	5

NaOH	White ppt * sol in excess *
NH_3	White ppt * sol in excess *
$AgNO_3$	No reaction / no ppt *
$Ba(NO_3)_2$	White ppt *
HNO_3	Ppt remains / no change*
NaOH and warm	No gas / no reaction *
+ A*l*	Gas / NH_3 / effervescence / fizzing / bubbles* turns litmus blue *

2(b)(iii)	Cations: Cu^{2+} and Zn^{2+} / copper(II) and zinc	1
2(b)(iv)	Anions: any two of CO_3^{2-}, NO_3^-, NO_2^-, SO_4^{2-} / carbonate, nitrate, nitrite, sulfate	1
2(b)(v)	NO_3^-, NO_2^- / nitrate and nitrite / nitrate(V) and nitrate(III)	1

Q# 15/ Qualitative inorganic ions tests ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

FA 5 is HCOOH ; **FA 7** is $ZnCO_3$; **FA 8** is $Cu(NO_3)_2$

3(b)(i)	+ acid: fizz / effervescence / bubbling	1
	Gas / CO_2 / fizz turns limewater milky / cloudy white / forms white ppt	1
	+ NaOH: white ppt soluble in excess NaOH	1
3(b)(ii)	+ NaOH: (pale) blue ppt (reference to dark blue or dissolving is CON)	1
	Warming: goes black / brown / grey	1
	+ A*l* & NaOH: gas / ammonia turns litmus blue	1
3(b)(iii)	Cu^{2+} / copper(II) definitely present	1
	Zn^{2+} or Al^{3+} / aluminium or zinc could be present	1
	Add (aqueous) ammonia – give (white) ppt but **only** (that from) zinc dissolves in excess	1
3(b)(iv)	CO_3^{2-} / carbonate definitely present	1
	NO_3^- or NO_2^- / nitrate or nitrite could be present	1

Q# 16/ Qualitative inorganic ions tests ALvl Chemistry/2018/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

FA 3 = $HNO_3(aq)$; FA 4 = $BaCO_3(s)$; FA 5 = $MgSO_4(aq)$

2(a)	Test: selects $AgNO_3$ and NH_3 and test-tube or boiling tube used	1
	Observation: no reaction / no change / no ppt / (solution) remains colourless *This mark may be awarded without NH_3 being specified in test.*	1
	Test: selects NaOH + A*l* (and warm) and boiling tube used *Penalise lack of test-tube/boiling tube only once*	1
	Observation: effervescence / gas / NH_3 turns (damp) red litmus blue	1
	If the Devarda's test has been carried out first then allow Test: selects (aqueous acidified) $KMnO_4$ and test-tube or boiling tube used (1) Observation: stays purple / does not decolourise (1) *Allow the observation: no reaction / no ppt / no change if $BaCl_2$ or $Ba(NO_3)_2$ selected as a test.*	
2(b)	NO_3^- / nitrate (ion) from evidence of ammonia (*Allow NO_2^- / nitrite*)	1

2(c)	Gas / CO_2 / **effervescence** turns limewater milky / cloudy white / (forms) white ppt	1
	2* = 1 mark Do not penalise 'no observation', 'transparent', 'clear', '–' for 'no visible reaction' more than once.	
	FA 4 + FA 3 effervescence / fizzing / bubbling * colourless solution formed *	
	FA 5 + Na_2CO_3 white ppt * (soluble in excess is CON)	
	FA 5 + NaOH white ppt * insoluble in excess *	
	FA 5 + NH_3 white ppt * insoluble in excess *	
	FA 5 + Ag^+ no reaction / no ppt / no change *	
	FA 5 + Ba^{2+} white ppt * insoluble in acid * *(addition of H_2SO_4 shown in observation table negates second point)*	
	FA 6 + NaOH no change / no visible reaction / no ppt / faint / slight white ppt *	
	FA 6 + NH_3 no change / no visible reaction / no ppt / faint / slight white ppt *	
	FA 6 + H_2SO_4 white ppt * (soluble in excess is CON)	
	FA 6 + FA 5 white ppt * (soluble in excess is CON)	7
2(d)	Selects either HC*l* or HNO_3	1
2(e)	FA 4: Ba^{2+} / barium and CO_3^{2-} / carbonate *(allow Ca^{2+} if white ppt insoluble in excess formed with NaOH – see 8th observation box)*	1
	FA 5: Mg^{2+} / magnesium and SO_4^{2-} / sulfate *(allow Ca^{2+} if no ppt with NH_3 – see 4th observation box)* *(Do not allow Ca^{2+} for both. Anions are stand alone marks.)* 4 ions = 2 marks; 2 or 3 ions = 1 mark	1

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3(a)	**Tabulation of observations** Clear presentation of results to show **FA 6**, **FA 7** and **FA 8** with the reagents specified.	1
	(see table below) 2 correct boxes for each mark	3
3(b)	Add silver nitrate followed by ammonia **or** silver nitrate and nitric acid (and ammonia)	1
	FA 7 cream ppt **and FA 8** no reaction / no change / no ppt	1

	H_2SO_4	NaOH
FA 6	fizzing / bubbling or pale brown gas (formed) or yellow solution (formed) or goes yellow	no reaction / no change / no ppt
FA 7	no reaction / no change	on warming, gas / NH_3 turns litmus blue
FA 8	white precipitate	no reaction / no change / no ppt **or** (faint) white ppt **and** insoluble in excess NaOH

3(c)(i)	For **FA 6** and **FA 7** or **FA 8** not identified in **(b)** as a halide uses NaOH + Al **and** there is evidence of heating mixture	1
	Observations for **both** compounds tested gas / ammonia turns (red) litmus blue	1
3(c)(ii)	Uses the same unknowns as **(i)** and adds a named dilute acid or correct formula Allow if "acid" on reagent line and correct formula given in table, or adds (acidified) potassium manganate(VII)	1
	Observations: both must be correct for the reagent selected. **If HCl or HNO_3 used** • with **FA 6**, fizzing / bubbling or pale brown gas (formed) or yellow solution (formed) or goes yellow • with **FA 7**, no reaction • with **FA 8**, no reaction **If H_2SO_4 used** • with **FA 6**, fizzing / bubbling or pale brown gas (formed) or yellow solution (formed) or goes yellow • with **FA 7**, no reaction • with **FA 8**, white precipitate **If acidified $KMnO_4$ used** • with **FA 6**, decolourised / goes colourless / loses purple colour • with **FA 7**, no reaction / $KMnO_4$ not decolourised (or stays purple) • with **FA 8**, white / pink (allow "pale purple") precipitate formed	1
3(d)	**Correct formulae of unknowns** • **FA 6** is $NaNO_2$ • **FA 7** is NH_4Br • **FA 8** is $Ba(NO_3)_2$ / $Ca(NO_3)_2$ three formulae correct = 2 marks one formula correct = 1 mark	2

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FA 6 is $Cu(NO_3)_2$; FA 7 is $FeCl_3$		
3(a)(i)	• melts *or* dissolves *or* blue liquid / solution formed • condensation *or* steam / vapour produced • black residue / solid • brown gas / fumes • gas / oxygen relights a glowing spill *4 or 5 observations correct = 2 marks* *2 or 3 observations correct = 1 mark*	2
3(a)(ii)	FA 6 is $Cu(NO_3)_2$	1
3(b)(i)	• with KI, **FA 7** gives a brown / red-brown / red / orange solution • with starch, blue / blue-black / dark colour	1
	• with **FA 6**, blue precipitate (formed) • on heating, (blue precipitate) turns black • With **FA 7**, red-brown / brown / rust ppt. (formed)	1
	• With **FA 6**, no reaction / no change / no ppt. • With **FA 7**, white precipitate formed	1
	• With **FA 6**, (pale) blue precipitate, then • deep/dark blue (solution) with excess • With **FA 7**, red-brown / brown / rust precipitate (forms)	1
	Mg test **Both observations correct** With **FA 6**, brown / black precipitate / solid formed or blue colour fades / disappears With **FA 7**, fizzing / bubbling / effervescence	1
	Test for hydrogen: (gas) "pops" with lighted splint	1
3(b)(ii)	**FA 7** is acidic, because it fizzes / produces hydrogen with magnesium	1
3(b)(iii)	$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$	1
3(b)(iv)	Redox because iodine was produced (from iodide ions)	1
3(b)(v)	You can't be certain about the colour of the precipitate (with $AgNO_3$) due to the coloured solution / colour of **FA 7**. or You can't be sure whether the precipitate with $AgNO_3$ is white / AgCl or cream / AgBr	1
3(b)(vi)	Ammonia would react with the Fe^{3+} ions in **FA 7** (masking the effect of ammonia on AgCl) or The cation in **FA 7** gives a precipitate with ammonia (so the precipitate of AgCl would not appear to dissolve).	1
	Total:	14

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FA 5 is $C_6H_{12}O_6(aq)$; **FA 6** is $(NH_4)_2Fe(SO_4)_2(aq)$; **FA 7** is $NaNO_2(aq)$

3(a)(i)–(iv) see below — **11**

test	FA 5	FA 6	FA 7
(i) aqueous sodium hydroxide, then	no reaction / no ppt. **AND**	green ppt. **AND** insol in excess / turning brown 1	no reaction / no change / no ppt. **AND**
warm gently	solution turns yellow / yellow-brown / brown 1	gas / NH_3 turns (damp red) litmus (paper) blue 1	no reaction / solution remains colourless 1
aluminium foil and warm	effervescence with **FA 5 or FA 7**	**AND**	gas / NH_3 turns (damp red) litmus (paper) blue 1
(ii) acidified aqueous potassium manganate (VII)	no reaction **AND**	purple decolourises / solution turns yellow **AND**	purple decolourises / turns colourless 1
warm gently	purple decolourises / turns colourless 1		
(iii) hydrogen peroxide		solution turns yellow / effervescence **AND**	no reaction / no change 1
		gas relights glowing splint 1	
(iv) hydrochloric acid, then		no reaction / no change / no ppt.	brown gas / colourless bubbles / gas turning brown in air / blue solution
Ba^{2+} (aq)		**AND** white ppt. 1	**AND** no reaction 1

3(b)(i) — **3**

	cation(s)	anion(s)
FA 5	unknown	unknown
FA 6	Fe^{2+} / iron(II) and NH_4^+ / ammonium	SO_4^{2-} / sulfate
FA 7	unknown	NO_2^- / nitrite

3(b)(ii)	clearly shows the reagent and expected observation(s)	1
	add NH_3 **AND** green ppt. **AND** insoluble in an excess of ammonia / turning brown (on standing)	1
3(b)(iii)	$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ **OR** $[Fe(H_2O)_6]^{2+}(aq) + 2NH_3(aq) \rightarrow [Fe(OH)_2(H_2O)_4](s) + 2NH_4^+(aq)$	1

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FA 5 is $NaNO_3(s)$; **FA 6** is $CuCO_3(s)$; **FA 7** is $NaBr(aq)$

3(a)(i)

FA 5	FA 6	
(goes to) colourless or yellow liquid/ solution	(green) powder / solid (turns) black / black residue	1+1
gas relights glowing splint	or gas turns limewater milky / cloudy white / chalky / forms white ppt	1
gas (turns) brown / brown gas or solution turns blue	(pale) blue solution / liquid formed	1+1

3(a)(ii)–(iv)	<table><tr><th>FA 5</th><th>FA 6</th></tr><tr><td>(iii) solid dissolves / colourless solution allow no reaction / no change / no effervescence</td><td>effervescence / fizzing / bubbling and blue solution / liquid formed</td></tr><tr><td>(iv) no reaction / no change / no ppt / remains colourless</td><td>blue ppt and insoluble in excess</td></tr><tr><td>(v) no reaction / no change / no ppt / remains colourless</td><td>(pale) blue ppt and soluble in excess to give deep / dark blue (solution)</td></tr></table>	1 1 1	
3(a)(v)	FA 5: cation unknown; anion nitrate / NO_3^- FA 6: cation Cu^{2+} / copper(II); anion carbonate / CO_3^{2-} 4 correct = 3 marks 3 correct = 2 marks 2 correct = 1 mark	1 1 1	
3(a)(vi)	$CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$	1	12
3(b)(i)	Selects $AgNO_3$ and NH_3 Selects NaOH and Al and HCl / HNO_3 / H_2SO_4	1 1	
3(b)(ii)	Clearly defined test | observation | conclusion sections FA 7 + $AgNO_3$ cream ppt partially soluble in NH_3 FA 7 is bromide / Br^- from cream ppt	1 1 1	5
	Total		17

Q# 21/ Qualitative inorganic ions tests ALvl Chemistry/2016/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

	FA5 is $MnSO_4$ and NH_4Cl; **FA6** is propanone; **FA7** is propanal;		
3 (a) (i)	Red litmus turns blue (then red)	1	
	Condensation or sublimation / white smoke / white fumes	1	[2]
(a) (ii) and (b) (i)	NH_4^+ / ammonium in **3(a)(ii) and** Mn^{2+} / manganese(II) in **3(b)(i)**.	1	
(b) (i)	Selects NaOH and NH_3	1	
	Off-white / beige / light brown precipitate with both NaOH **and** NH_3	1	
	Both precipitates turns brown / darkens	1	
(ii)	white precipitate **and** insoluble in acid	1	
(iii)	Selects $AgNO_3$ / silver nitrate **and** NH_3 / ammonia	1	
	White precipitate **and** insoluble / partially soluble in ammonia	1	
	Cannot see if precipitate dissolves in ammonia / Mn^{2+} causes (off-white) precipitate (so cannot be used to distinguish between halides).	1	[8]
(c)	$MnCl_2$ **and** $(NH_4)_2SO_4$ **or** $MnSO_4$ **and** NH_4Cl	1	[1]

Q# 22/ Qualitative inorganic ions tests ALvl Chemistry/2015/w/TZ 1/ Paper 3/Q# 3/ :o)
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	FA 6 is Na_2SO_3; **FA 7** is $CaCl_2$; **FA 8** is $MgSO_4$; **FA 9** is $Al_2(SO_4)_3$; **FA 10** is $MnSO_4$		
3 (a) (i)	**Both observations required** • white precipitate with Ba^{2+} ion • Precipitate dissolves / partially dissolves in (excess) HCl	1	
(ii)	**Both observations required** • white precipitate with Ba^{2+} ion • precipitate insoluble / no change with HCl	1	
(iii)	When heated, gas produced decolourises $KMnO_4$ paper.	1	
(iv)	No change (when NaOH added) / no ppt / no reaction and green (solution) formed when $KMnO_4$ added	1	
	Colourless solution(with acid)	1	
(v)	Anion is sulfite **and** one piece of evidence • **FA 6** with acid – SO_2 / gas which decolourises $KMnO_4$ is formed **or** • **FA 6** with Ba^{2+} – white precipitate / $BaSO_3$ formed which dissolves in acid / partially soluble in acid	1	
(vi)	$Na_2SO_3 + H_2O_2 \rightarrow Na_2SO_4 + H_2O$	1	[7]
(b) (i)	<table><tr><th></th><th>FA 7</th><th>FA 8</th><th>FA 9</th><th>FA 10</th></tr><tr><td>NaOH</td><td>white ppt</td><td>white ppt</td><td>white ppt</td><td>off-white / buff / beige / light brown ppt</td></tr><tr><td>excess NaOH</td><td>no change **or** insoluble in excess</td><td>no change **or** insoluble in excess</td><td>(ppt) dissolves **or** soluble in excess</td><td>insoluble in excess **or** ppt darkens *(owtte)*</td></tr><tr><td>NH_3</td><td>no ppt **or** no reaction</td><td>white ppt</td><td>white ppt</td><td>off-white / buff / beige / light brown ppt</td></tr><tr><td>excess NH_3</td><td>*(ignore)*</td><td>no change **or** insoluble in excess</td><td>no change **or** insoluble in excess</td><td>insoluble in excess **or** ppt darkens *(owtte)*</td></tr></table>	5	
(ii)	Conclusions • **FA 7** – calcium / Ca^{2+} **or** barium / Ba^{2+} • **FA 8** – magnesium / Mg^{2+} • **FA 9** – aluminium / Al^{3+} • **FA 10** – manganese(II) / Mn^{2+} *Four correct = 2 marks* *Two or three correct = 1 mark*	2	
(iii)	$M^{2+} + 2OH^- \rightarrow M(OH)_2$ (for any divalent cation) **or** $M^{3+} + 3OH^- \rightarrow M(OH)_3$ (for any trivalent cation)	1	
(iv)	Use higher concentration	1	[9]
Qn 3			**[Total: 16]**

Q# 23/ Qualitative inorganic ions tests ALvl Chemistry/2015/s/TZ 1/ Paper 3/Q# 3/ :o)

	FA 5 is $(NH_4)_2Fe(SO_4)_2(aq)$; **FA 6** is $CuCO_3 + MgSO_4.7H_2O$		
3 (a)	Fizzing	1	
	Acid or any named acid	1	[2]
(b)(i)–(vi)	In **(i)** (solid goes from green) to black/grey	1	
	In **(i)** condensation/water/water vapour/steam/steamy fumes	1	
	In **(ii)** fizzing **and** forms a (light) blue solution .	1	
	Cloudy with limewater in **(i)** or **(ii)** or **(a)**	1	
	In **(ii)** blue ppt with sodium hydroxide and insoluble in excess.	1	
	Any **2** from: In **(iv)** white ppt insoluble in excess	1	
	In **(v)** white ppt insoluble in excess In **(vi)** white ppt	1	
(vii)	Cation: Cu^{2+}	1	
	Cation: Mg^{2+}	1	
	Anions: CO_3^{2-} **and** SO_4^{2-} **and** SO_3^{2-}	1	
(viii)	Selects acid/ named acid to add to test **(vi)** (**not** H_2SO_4) **or** Selects named acid to add to **FA 6 and** tests with $H^+/Cr_2O_7^{2-}$ or H^+/MnO_4^- **and** SO_4^{2-} insoluble and SO_3^{2-} soluble **or** SO_4^{2-} no change and SO_3^{2-} (orange) turns green or (purple) turns colourless	1	[11]
Qn 3	**Total**		**[13]**

Q# 24/ Qualitative inorganic ions tests ALvl Chemistry/2014/w/TZ 1/ Paper 3/Q# 2/ :o)
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	FA 6 is $NaNO_3(s)$; **FA 7** is $AgNO_3(aq)$; **FA 8** is $ZnCO_3(s)$		
2 (a) (i)	Chooses NaOH(aq) (+ heat) (to distinguish NH_4^+/ammonium) Chooses named (allow name from **(ii)**) dilute acid/(acidified) $KMnO_4$ (to distinguish between NO_2^-/nitrite and NO_3^-/nitrate) 2 ions chosen: NH_4^+ & NO_3^- : NaOH (and warm) NO_2^- & NO_3^- : named (dilute) acid NH_4^+ & NO_2^- : either of the above	1 1	
(ii)	Correct obs with relevant tests With NaOH **and** warming/heating: no ammonia/no change/no reaction With acid(aq): no brown fumes/no change/no reaction *'No observation' is not credited anywhere in the observations.*	1 1	
(iii)	**FA 6** contains NO_3^- (*with sufficient obs to eliminate other ion(s) given in* ***(i)***)	1	[5]

(b)	+ HC*l* (aq): white ppt	1	
	+ KI: yellow ppt + NH_3: no effect/ppt insol	1 1	
	+ glucose: silver mirror/black/(dark) grey ppt	1	[4]
(c) (i)	(Solid is) yellow when heated Goes white/paler on cooling	1 1	
(ii)	effervescence/fizzing/rapid bubbling **and** limewater turns milky	1	
(iii)	White ppt **and** soluble in excess NaOH	1	
(iv)	White ppt **and** soluble in excess NH_3	1	
(v)	Ions present: Zn^{2+} **and** CO_3^{2-} (from fizz **or** limewater test correct)	1	[6]
Qn 2		**Total**	**[15]**

Q# 25/ Qualitative inorganic ions tests ALvl Chemistry/2014/s/TZ 1/ Paper 3/Q# 3/ :o)

		FA 6 is $ZnSO_4(aq)$ and $NaBr(aq)$; **FA 7** is $FeSO_4(aq)$		
3 (a) (i)	MMO Decisions	**I** Selects NaOH(aq) and NH_3(aq), and uses each in excess	1	
	PDO Layout	**II** Unambiguous layout of all 4 observations (excess must be stated).	1	
	MMO Collection	**III** White ppt with NaOH and soluble in excess.	1	
		IV White ppt with NH_3 soluble in excess.	1	
	ACE Conclusion	**V** Zn^{2+}	1	
(ii)	MMO Collection	**VI** Cream ppt with $AgNO_3$ **and** partially sol / insol in NH_3	1	
		VII White ppt with $BaCl_2/Ba(NO_3)_2$ **and** insol in nitric acid.	1	
	ACE Conclusion	**VIII** Br^-	1	
		IX SO_4^{2-}	1	[9]
(b) (i)	MMO Collection	**I** Green ppt turning brown (in contact with air)	1	
(ii)		**II** No reaction/no change **or** yellow or green solution	1	
(iii)		**III** Red-brown/brown/green-brown ppt **and** effervescence	1	
		IV Gas relights a glowing splint	1	
(iv)	ACE Conclusion	**V** Redox	1	
(v)		**VI** Decomposition of hydrogen peroxide to give oxygen **or** ppt is $Fe(OH)_3$ / oxidation of Fe^{2+} to Fe^{3+}	1	[6]
Qn 3	**Total**			**[15]**

Q# 26/ Qualitative inorganic ions tests ALvl Chemistry/2013/w/TZ 1/ Paper 3/Q# 3/ :o)
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FA 6 is $(NH_4)_2Fe(SO_4)_2$(s); FA 7 is Na_2CO_3(aq); FA 8 is $Pb(NO_3)_2$(aq); FA 9 is K_2CrO_4(aq)				
3 (a) (i)	MMO Collection	Green precipitate **and** ppt insoluble in excess NaOH/ppt turning brown (in air / on standing).	1	
	MMO Decision	(When heated with NaOH) **gas** / NH_3 turns red litmus to blue.	1	
	MMO Collection	(With $BaCl_2$), white precipitate forms **and** insoluble in HC*l*.	1	
(ii)	ACE Conclusion	**FA 6** contains ammonium ions **and** sulfate ions. *(correct evidence needed for each ion in the observations table).*	1	
(iii)	ACE conclusion	$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$	1	
(iv)	MMO collection	**Any two** of • Solid goes paler / loses green colour (at first) **and then** becomes brown (on strong heating) • Condensation / water vapour / steam produced • (Gas/NH_3) turns red litmus blue.	1 1	[7]

Q# 27/ Qualitative inorganic ions tests ALvl Chemistry/2012/w/TZ 1/ Paper 3/Q# 2/ :o)
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FA 3 is $CuCl_2$(aq); FA 4 is $AlK(SO_4)_2$(aq) + KI(aq); FA 5 is $FeCl_3$(aq); FA 6 is $Pb(NO_3)_2$(aq)				
2 (a)	MMO Collection	Records a blue/greenish-blue ppt/solid with **FA 3** and Na_2CO_3. Records a brown/rust/orange-brown/red-brown ppt/solid with **FA 5** and Na_2CO_3. Records effervescence with **FA 5** (or **FA 3**).	1 1 1	
	MMO Decisions	Tests gas evolved with limewater. Allow from effervescence.	1	[4]
(b)	MMO Collection	Records a white precipitate with silver nitrate solution **and** soluble in aqueous ammonia.	1	[1]
(c)	MMO Collection	Records yellow-brown/orange-brown/brown/tan colour (solid/solution) (formed on mixing **FA 4** and **FA 3**). Allow dark brown for solution **only**. Allow (qualified) brown solution with white/off-white/grey ppt. Dark/deep blue/blue-black/black/purple colour on adding starch solution	1 1	[2]
(d)	MMO Collection	Mark the observations in the table horizontally or vertically to maximise marks available to the candidate.	4	[4]

Test	Observations			
	FA 3	FA 4	FA 5	FA 6
NaOH(aq)	blue ppt **not** dark/deep blue ppt	white ppt (which dissolves as more added/then dissolves)	red-brown/orange-brown/brown/rust ppt (**not** dark/deep brown)	white ppt
excess NaOH	ppt insoluble (no change no observation provided ppt above)	ppt soluble (if no ppt in 1st box allow no change)	ppt insoluble (no change no observation provided ppt above)	ppt soluble (not no change after 'no ppt')
NH_3(aq)	blue ppt **not** dark/deep blue ppt	white ppt	red-brown/orange-brown/brown/rust ppt (**not** dark/deep brown)	white ppt
excess ammonia	(ppt soluble) **deep blue soln**	ppt insoluble (no change no observation provided ppt above)	ppt insoluble (no change no observation provided ppt above)	ppt insoluble (no change no observation provided ppt above)

FA 3 is $CuCl_2$(aq); FA 4 is $AlK(SO_4)_2$(aq) + KI(aq); FA 5 is $FeCl_3$(aq); FA 6 is $Pb(NO_3)_2$(aq)					
(e)	ACE Conclusions	Con2 Con2	Give **one mark** for **FA 3** Cu^{2+}/copper/copper(II) **and FA 5** Fe^{3+}/iron(III). Give **one mark** for **FA 4 and FA 6** Al^{3+}/aluminium, Pb^{2+}/lead *Allow* **FA 4** $Al^{3+}(Pb^{2+})$ **and FA 6** Al^{3+}, Pb^{2+} *(There must be some correct evidence for Cu^{2+} and Fe^{3+} in* **(d)** *but does not have to be fully correct.)*	1 1	[2]
(f)	MMO Decisions	De7	Selects appropriate reagent to distinguish between Al^{3+} and Pb^{2+} e.g. KI, K_2CrO_4, H_2SO_4, HC*l* (***not*** $BaCl_2$).	1	[1]
(g)	ACE Conclusions	Con2	**No error carried forward in this section.** Award the mark for: **FA 3** chloride **FA 4** iodide **FA 5** insufficient tests	1	[1]
			Total	**15**	

Q# 28/ Qualitative inorganic ions tests ALvl Chemistry/2011/w/TZ 1/ Paper 3/Q# 2/ :o)
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FA 3 is $Na_2S_2O_5$(s); FA 4 is Na_2CO_3(s); FA 5 is Na_2SO_4(s); FA 6 is $Pb(NO_3)_2$(s) and (aq)				
2 (a)	MMO Decisions	(i) **I** Any named mineral acid or formula or (acidified) potassium dichromate Do **not** allow any reagent suitable for testing cations or more than one reagent.	1	
	PDO Recording	(ii) **II** Tabulates evidence of 3 tests carried out with no repeat headings. **Only** consider observations with acid or dichromate.	1	

	MMO Collection	**III** Bubbles/effervescence in **FA 4**.	1	
		IV Slower effervescence in **FA 3** than **FA 4** or **FA 3** turns green **and FA 5** stays orange if dichromate used.	1	
	MMO Decisions	**V** Appropriate test with positive result used to test for either gas.	1	
	ACE Conclusions	**VI** All three ions correct from suitable observations. **FA3** is a sulfite. **FA4** is a carbonate. **FA5** is a sulfate. (or correct formulae)	1	[6]

Q# 29/ Qualitative inorganic ions tests ALvl Chemistry/2011/s/TZ 1/ Paper 3/Q# 3/ :o)
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FA 7 is $Zn(NO_3)_2(s)$; **FA 8** is $CuSO_4(s)$				
3 (a) (i)	MMO Collection	No change (*or* no precipitate **or** no reaction) both with barium chloride and silver nitrate.	1	
	MMO Collection	**Gentle** heat: solid melts **or** dissolves **or** gives a colourless liquid	1	
(ii)		Brown fumes/gas produced (allow 'qualified' brown e.g. red/brown, do not allow orange).	1	
		(Gas produced) that relights a glowing splint **or** yellow solid, goes white on cooling. (Allow precipitate).	1	
(iii)	ACE Conclusions	**FA 7** is a nitrate/nitrite (from some evidence)	1	
(iv)	MMO Decisions	(Heat) **FA 7** with A*l* foil and NaOH/ecf from anion given.	1	
	MMO Collection	Gas/vapour/NH3 produced ***and*** it turns red litmus to blue ***and*** confirms that **FA 7** contains nitrate/nitrite ions.	1	
(v)	MMO Decisions	Adds ammonia. *(This mark is **not** awarded if a second test is also used)*	1	
	ACE Conclusions	Zinc ions are present. (No ecf) *(Deduction **must** be consistent with observations recorded – white ppt soluble in excess).*	1	[9]

(b) (i)	MMO Collection	With KI, goes yellow/orange/brown ***and*** gives a blue (blue-black ***or*** purple ***or*** black) colour with starch. *No reference to the state is required, just the colours.*	1	
		Brown/yellow/white/off- white precipitate forms.	1	
(ii)	ACE Conclusions	KI is the reducing agent (**or** it is oxidised) as iodine is formed **or** $2I^- - 2e^- \rightarrow I_2$ **or** $2Cu^{2+} + 2I^- \rightarrow I_2 + 2Cu^+$ *Ignore state symbols.*	1	
(iii)	MMO Collection	Blue (do not allow dark blue) precipitate obtained, which does not dissolve in excess NaOH	1	
	ACE Conclusions	$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$	1	[5]
				[Total: 14]

Q# 30/ Qualitative inorganic ions tests ALvl Chemistry/2010/s/TZ 1/ Paper 3/Q# 2/ :o)
Question 2

Question	Sections	Indicative material	Mark	
FA 3 is $BaCl_2(aq)$; **FA 4** is $MgBr_2(aq)$ *[$MgCl_2$ + NaBr]*; **FA 5** is $CaI_2(aq)$ *[$CaCl_2$ + NaI]*; **FA 6** is $K_2CrO_4(aq)$				
2 (a)	MMO Decisions	Chooses silver nitrate/$Ag^+(aq)$/solution containing Ag^+ ions followed by (aqueous) ammonia.	1	[1]
(b)	PDO Recording	Results for three solutions and the two reagents from **(a)** (or three reagents if **(a)**: '$Ag^+ + NH_3$', Pb^{2+}) if recorded in a single table *(no repetition of solutions or reagents)*	1	
	MMO Collection	Give one mark for correct observations with **FA 3**, **FA 4** and **FA 5**. **FA 3** – white ppt with Ag^+, soluble in NH3(aq) **FA 4** – cream ppt with Ag^+, partially soluble or insoluble in $NH_3(aq)$ (allow "creamy" not "creamy white") **FA 5** – yellow ppt with Ag^+, insoluble in $NH_3(aq)$ If Ag^+ and Pb^{2+} in **(a)**, all observations must be correct (ignore any 'extra' NH_3 if not in **(a)**) (Pb^{2+}: white, white, yellow ppts respectively)	1	[2]
(c)	ACE Conclusion	Mark consequentially on observations in **(b)** Expected conclusion Identifies **FA 3** as solution containing Cl^- from "white ppt with Ag^+ (soluble in $NH_3(aq)$) given as evidence. *Mark consequentially – ecf allowed here. (No retrospective to observations)*	1	[1]
(d)	MMO Collection	Mark each of the boxes and see whether correct columns or rows give the better mark. Award the better mark. See table below for the expected observations	1 1 1	[3]

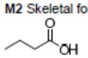
	FA 3	FA 4	FA 5
+ NaOH(aq)	**ignore**	white ppt	white ppt **or** "cloudiness"
+ NH_3(aq)	no ppt *(allow reference to "cloudiness"/"slight white ppt")*	white ppt	no ppt/no change/ no reaction

Q# 31/ Qualitative inorganic ions tests ALvl Chemistry/2009/s/TZ 1/ Paper 3/Q# 3/ :o) www.SmashingScience.org

Question	Sections	Indicative material	Mark	
		FA 5 is K_2CrO_4(aq); FA 6 is $NaNO_2$(aq); FA 7 is $Pb(NO_3)_2$(aq), FA 8 is $MgSO_4$(aq)		
3 (a)	MMO Collection	**(i)** Records no reaction, no change or no precipitate on adding NaOH and NH_3(aq) to **FA 5** and **FA 6**.	1	
		(ii) Records white ppt soluble (in excess NaOH) and white ppt insoluble (in excess NH_3) with **FA 7**	1	
		(iii) Records white ppt insoluble (in excess for both NaOH and NH_3) with **FA 8**	1	
	ACE Conclusion	**(iv)** Conclusion is marked **consequentially** from the observations for a single cation and a pair of cations. *Mg^{2+}/magnesium from white ppt insoluble in an excess of NaOH(aq) and in an excess of NH_3(aq)* *Ca^{2+}/calcium from white ppt insoluble in an excess of NaOH(aq) no ppt in NH_3(aq)* *Pb^{2+}/Al^{3+} from white ppt soluble in an excess of NaOH(aq) and insoluble in an excess of NH_3(aq)* *Ba^{2+}/NH_4^+ from no ppt with NaOH(aq) or NH_3(aq)* **FA 6 only**	1	[4]
(b)	MMO Decisions	(Warms) with NaOH and Al(s) and records appropriate test for ammonia. <u>**Gas**</u> must be tested in at least one test. *This is a mark for the method not the observation.*	1	
	ACE Conclusion	Must have indication that the test has been performed with **FA 6**, **FA 7** and **FA 8**. In awarding the conclusion mark, assume, **in this section only**, that a blank box indicates no reaction (no ammonia detected). Award this mark for any of the following: (i) a conclusion, from correct observations, that **FA 6** and **FA 7** contain nitrate or nitrite (ii) correct observations for NH_3 – only with **FA 6** and **FA 7**, but no conclusion given (iii) a statement that NH_3 is evolved – only with **FA 6** and **FA 7** (iv) observation that red litmus turns blue (gas not needed) – only with **FA 6** and **FA 7**	1	[2]
(c)	MMO Collection	**(i)** Observes a change in colour (from yellow) to yellow/orange or orange (solution), **no ppt**, with **FA 5** **and** a white ppt with **FA 7**.	1	
		(ii) Observes a brown gas formed with only **FA 6**.	1	
	ACE Conclusions	**Mark (iii) and (iv) consequentially to observations** **(iii)** Give this mark for **one** conclusion providing it is supported by an acceptable explanation. **(iv)** Give this mark for **two** further conclusions supported by acceptable explanations. Minimum acceptable supporting evidence: CrO_4^{2-} from yellow soln **or** soln turning orange in acid NO_2^- from brown gas **or** from effervescence/fizzing/bubbling with acid, **if** named soln has yielded ammonia or an alkaline gas in **(b)** NO_3^- no brown gas etc with acid, but ammonia evolved in **(b)** Pb^{2+} white ppt with HC*l* if Pb^{2+} in **(a) (iv)** Al^{3+} no white ppt with HC*l* if Al^{3+} in **(a) (iv)**	2	[4]
(d)	MMO Collection	Mixes **FA 5** and **FA 7** and observes a yellow ppt. If this section has not been attempted, the correct <u>observation</u> on mixing **FA 5** and **FA 7** can be carried forward from the conclusions in **(c)**.	1	
	ACE Conclusions	Concludes that **FA 5** contains CrO_4^{2-} and **FA 7** contains Pb^{2+} providing the ions have been previously mentioned in **(a)** or **(c)**.	1	[2]
				[Total: 12]

Q# 32/ Acid/base titrations ALvl Chemistry/2022/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

1(a)	**I**	All the following data are recorded: • two burette readings and titre for the rough titration • initial and final burette readings for two (or more) accurate titrations	1
	II	Appropriate headings and units in the accurate titration table and titre values recorded for accurate titrations • initial / start and (burette) reading / volume • final / end and (burette) reading / volume • titre or volume used / added / or FA 2 added • unit: / cm^3 or (cm^3) or in cm^3 (for each heading) or cm^3 unit given for each volume recorded	1
	III	All accurate burette readings are recorded to the nearest 0.05 cm^3	1
	IV	The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre	1
		For assessment of accuracy marks, round all burette readings to the nearest 0.05 cm^3. Check and correct subtractions where necessary. Then select the 'best' titres using the hierarchy: • two (or more) accurate identical titres (ignoring any that are labelled 'rough'), *then* • two (or more) accurate titres within 0.05 cm^3, *then* • two (or more) accurate titres within 0.10 cm^3, *etc.* These best titres should be used to calculate the mean titre, expressed to nearest 0.01 cm^3. Write the Supervisor's [corrected] mean titre in a ring on each candidate script. Calculate the difference (δ) between the candidate's mean titre and the Supervisor's. Write the value of δ on each script. Award the accuracy marks as shown below.	
		Award **V** if $\delta \leqslant 0.50$ (cm^3) Award **VI** if $\delta \leqslant 0.30$ Award **VII** if $\delta \leqslant 0.20$	3

1(b)	Candidate must average two (or more) titres that are within a total spread of not more than 0.20 cm^3 **AND** working / explanation must be shown or ticks must be put next to the two (or more) accurate titres selected **AND** mean quoted to 2 decimal places	1
1(c)(i)	Correctly calculates moles of NaOH used = 0.110 × **(b)** / 1000 **AND** answer to 3 or 4 sig fig	1
1(c)(ii)	Correctly uses **(c)(i)** to calculate M_r = $^{10.5}/_{(c)(i) \times 40}$	1
1(c)(iii)	**M1** Identity of carboxylic acid [must be consistent with the M_r in **(c)(ii)**] **M2** Skeletal formula (must correspond to candidate's name of acid) 	2
1(d)(i)	Correct equation with state symbols $NH_2CH_2COOH(aq)$ + $NaOH(aq)$ → $NH_2CH_2COONa(aq)$ + $H_2O(l)$	1
1(d)(ii)	Student's titre would be larger **AND** M_r of amino acid is 75 / is lower than M_r of **FA 1** so more moles of amino acid are present ORA	1

Q# 33/ ACID/BASE TITRATIONS ALvl Chemistry/2021/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** The following data must be shown • burette readings **and** titre for rough titration • 2 × 2 'box' showing both accurate burette readings *'Correct' headings and units are not required for this mark*	1
	II Headings and units correct for accurate titration table and headings match readings. • initial / start **and** (burette) reading / volume + unit • final / end **and** (burette) reading / volume + unit • titre or volume / **FA 3 and** used / added + unit *Units: (cm^3) or / cm^3 or in cm^3 or cm^3 by every entry*	1
	III All accurate burette readings to 0.05 cm^3	1
	IV The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre. *Do **not** award the mark if any 'accurate' burette readings (apart from initial 0) are given to **zero** dp.*	1
	Award **V** if δ ⩽ 0.50 cm^3 Award **VI** if δ ⩽ 0.30 cm^3 Award **VII** if δ ⩽ 0.20 cm^3	3
2(b)	Candidate must average two (or more) titres that are **all** within 0.20 cm^3 and quoted to 2 dp. Working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
2(c)(i)	Answers for **(c)(ii)**, **(c)(iii)**, **(c)(iv)** to 3–4 sf	1
2(c)(ii)	Correctly calculates $n(H_2SO_4)$ = 0.050 × **(b)** / 1000	1
2(c)(iii)	Correctly uses **[FA 4]** = **(c)(ii)** × 2 × 40 mol dm^{-3}	1
2(c)(iv)	Correctly calculates **[FA 2]** = **(c)(iii)** × 10 mol dm^{-3}	1
2(c)(v)	Correctly uses M1: $M_r = \dfrac{26.3}{\textbf{(c)(iv)}}$ = Answer M2: Use of Answer – 17 and identify **Z** < Li ⩽ 14.9 15.0 ⩽ Na ⩽ 31.1 31.2 ⩽ K ⩽ 62.3 62.3 ⩽ Rb ⩽ 109.2 109.2 ⩽ Cs ⩽ 250	2
2(d)	Correctly uses | A_r from **(c)(v)** – A_r from periodic table | × 100 / A_r from periodic table Answer from default = 18.16 or 18.2 or 18 %	1

Q# 34/ ACID/BASE TITRATIONS ALvl Chemistry/2021/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

1(a)	**I** Headings and data are recorded in the space provided • (mass of) container with **FA 2** • (mass of empty) container • (mass of) **FA 2** (used) Subtraction for the mass of **FA 2** used must be correct *Headings must be unambiguous and include either 'mass' or g for each piece of datum. Reject 'weight'.*	1
	II The following data must be shown: • two burette readings **and** titre for the rough titration • initial and final burette readings for **two** (or more) accurate titrations	1
	III Titre values recorded for accurate titrations, **and** correct headings and units in the **accurate** titration table • initial/start **and** (burette) reading / volume • final/end **and** (burette) reading / volume • titre or volume / **FA 1 and** used / added *reject 'difference' or 'total' or 'amount' or 'V' but allow 'vol'* • unit: / cm^3 or (cm^3) or in cm^3 for each heading **or** cm^3 unit given for each volume recorded	1
	IV All accurate burette readings are recorded to the nearest 0.05 cm^3, including 0.00. *Reject 50(.00) as an initial burette reading* *Reject if more than one final burette reading is 50.(00)* *Reject any burette reading is greater than 50.(00)*	1
	V: The **final** accurate titre recorded is within 0.10 cm^3 of any other accurate titre *Ignore any titre labelled 'rough'* *Reject if any 'accurate' burette reading is recorded as an integer (apart from an initial 0 cm^3)*	1
	Check and correct titre and mass subtractions where necessary. *Examiner selects the best mean titre.* *Apply hierarchy: 2 identical, titres within 0.05 cm^3, titres within 0.10 cm^3, etc. Examiner calculates supervisor's corrected average titre / supervisor's mass of **FA 2** to 2 dp.* *Examiner calculates candidate's corrected average titre / candidate's mass of **FA 2** to 2 dp.* *Subtract the candidate value from that of the supervisor: δ*	

1(a)	Award **VI** if 0.40 < δ ⩽ 0.60 cm^3 g^{-1}	1
	Award **VI** and **VII** if 0.20 < δ ⩽ 0.40 cm^3 g^{-1}	1
	Award **VI**, **VII** and **VIII** if δ ⩽ 0.20 cm^3 g^{-1}	1
	If there is only one accurate titration award accuracy marks based on that titration without further penalty. If **only** a rough titration is shown award accuracy marks based on this value but cancel one accuracy mark. Apply spread penalty as follows: if titres selected (by examiner) differ ⩾ 1.00 cm^3 then cancel one accuracy mark. *If Supervisor's value ⩽ 10.00 cm^3 then halve tolerances*	
1(b)	Candidate calculates the mean correctly: • Candidate must take the average of two (or more) accurate titres that are within a total spread of not more than 0.20 cm^3 • Working/explanation must be shown *or* ticks must be put next to the two (or more) accurate readings selected • The mean should be quoted to **2 dp**, and be rounded to nearest 0.01 cm^3	1
1(c)(i)	All answers given to **(c)(ii)** – **(c)(v)** must be to 3 or 4 sig fig *(Minimum 3 answers required to award the mark)*	1
1(c)(ii)	Correctly calculates: no of moles of H_2SO_4 used = 0.0550 × $^{\text{mean titre}}/_{1000}$ *The candidate's mean titre must be used.*	1
1(c)(iii)	Correct equation and correctly uses **(ii)** • $2MHCO_3 + H_2SO_4 \rightarrow M_2SO_4 + 2CO_2 + 2H_2O$ *Allow multiples and ignore state symbols.* **AND** • no of moles of $MHCO_3$ = 2 × answer **(ii)**	1
1(c)(iv)	Correctly uses **(iii)** M_r = $^{\text{mass of FA 2 used}}/_{10 \times \text{answer (iii)}}$	1

1(c)(v)	Correct use of M_r and appropriate identity of M • A_r = answer **(iv)** – 61 **AND** • M identified as Group 1 metal with closest A_r *Li 0–14.9; Na 15.0–31.0; K 31.1–62.2; Rb 62.3–109.1; Cs 109.2–250* *Reject if the A_r calculated is > 250 or if A_r < 0*	1
1(d)(i)	Correct expression % error = $^{0.06}/_{25}$ × 100 (= 0.24 %) *No answer needed but reject incorrect answer.* *No mark for just 0.24 without some working.*	1

1(d)(ii)	Student is incorrect **AND** error in burette reading = 2 × 0.05 > 0.06 *(or candidate **compares** the % errors, 0.40 % and 0.24 %)* *Reject suggestion that error in 1 burette reading is 0.1*	1

Q# 35/ ACID/BASE TITRATIONS ALvl Chemistry/2019/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** Uses a volume between 40.00 and 45.00 cm^3 **and** answer to at least 1 dp	1
	II The following data must be shown • burette readings *and* titre for rough titration • 2 × 2 'box' showing both accurate burette readings	1
	III Headings and units correct for accurate titration table and headings match readings. • Initial / start (burette) and reading / volume + unit • Final / end (burette) and reading / volume + unit • titre or volume / **FA 4** and used / added (*not 'difference' amount or 'total'*) + unit	1
	IV All accurate burette readings to 0.05 cm^3	1
	V The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre.	1
	Award **VI** if $20 < \delta \leqslant 30$ cm^3	1
	Award **VII** if $10 < \delta \leqslant 20$ cm^3	1
	Award **VIII** if $\delta \leqslant 10$ cm^3	1
2(b)	Candidate must average two (or more) titres that are **all** within 0.20 cm^3. Working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
2(c)(i)	Answers for **(ii)**, **(iii)** and **(iv)** given to 3–4 sf. Minimum three answers displayed.	1
2(c)(ii)	Correctly calculates 2.50×10^{-3}	1
2(c)(iii)	Correct use of ans **(c)(ii)** × 1000 / ans **(b)**	1
2(c)(iv)	Correct expression: ans **(c)(iii)** × 250 / vol used from **(a)**	1
2(d)	Correctly calculates 0.10 / vol used in **(a)** × 100.	1

2(e)	**Question 1** • measuring cylinder **greater** error than **burette** / **pipette** • molar gas volume of 24 dm^3 may not be valid / temperature of the lab may not be known • too much gas for the measuring cylinder (check that vol > 250 cm^3) • use gas syringe (if volume < 100 cm^3)	1
	Question 2 • dilution introduces extra stage / greater cumulative error • methyl orange **end-point** can be difficult to see / **colour change** gradual / difficult to see	1

Q# 36/ ACID/BASE TITRATIONS ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** Initial and final readings and titre recorded for a minimum of two **accurate** titre details tabulated *(minimum 2 × 3 'boxes')*	1
All burette readings should be rounded to the nearest 0.05 cm^3. Subtractions should be checked. The 'best' titres should be selected using the hierarchy: two (or more) identical; then 2 (or more) within 0.05 cm^3; then two (or more) within 0.1 cm^3, etc the mean titre calculated and this then compared with the supervisor's value.		
	II and III Award **II and III** for $\delta \leqslant 0.20$ cm^3 Award **II** for $0.20 < \delta \leqslant 0.40$ cm^3	2
2(b)(i)	Correctly calculates moles $HCl = \dfrac{\text{vol of FA 2 from (a)} \times 0.100}{1000}$ **and** moles NaOH are the same	1
2(b)(ii)	Correctly calculates moles NaOH added to **W** = 0.40 × 250 ÷ 1000 = 0.10 **and** moles NaOH remaining = answer to **(b)(i)** × 10	1
2(b)(iii)	Correctly uses moles NaOH reacting with **W** = 1st answer in **(b)(ii)** – 2nd answer in **(b)(ii)** (0.10 – 2nd answer in **(b)(ii)**) **and** moles **W** = answer ÷ 2	1
2(b)(iv)	Correctly uses M_r of **W** = 4 ÷ answer to **(b)(iii)**	1
2(b)(v)	Expression to show 59 + A_r of X = M_r from **(b)(iv)**	1
	Identification of X as halogen with nearest A_r to that calculated	1

2(c)	Error: Mass was given correct to 1 sig fig / nearest g Modification: Use a more accurate balance **or** Error: Hydrolysis of halogeno group may be incomplete Modification: Use more concentrated NaOH / heat for longer	1

2(d)	If F chosen then 87 If Cl chosen then 86 or 117 If Br chosen then 116 or 163 If I chosen then 162	1

Q# 37/ ACID/BASE TITRATIONS ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

1(a)	**I** Initial and final readings and titre recorded for rough titre **and** accurate titre details tabulated *(minimum 2 × 2 'boxes')*	1
	II All **three** headings and units correct for accurate titrations Headings: initial / final (burette) **and** reading / volume / vol **or** reading / volume / vol at start / finish (but not V) **and** volume / **FA 2 and** added/used **or** titre **and** Units: (cm^3) **or** / cm^3 **or** in cm^3 [or cm^3 by every entry]	1
	III All accurate burette readings are recorded to the nearest 0.05 cm^3 Do **not** award this mark if: • 50(.00) is used as an initial burette reading; • more than one final burette reading is 50(.00); • any burette reading is greater than 50(.00)	1
	IV The **final** accurate titre recorded is within 0.1 cm^3 of any other accurate titre.	1
All burette readings should be rounded to the nearest 0.05 cm^3. Subtractions should be checked. The 'best' titres should be selected using the hierarchy: two (or more) identical; then 2 (or more) within 0.05 cm^3; then two (or more) within 0.1 cm^3, etc, the mean titre calculated and this then compared with the supervisor mean titre.		
	V, VI and VII Award **V, VI and VII** for a difference from supervisor within 0.20 cm^3 Award **V and VI** for $0.20 < \delta \leqslant 0.40$ cm^3 Award **V** for $0.40 < \delta \leqslant 0.60$ cm^3	3

1(b)	Candidate must average two (or more) titres for which the total spread is not greater than 0.2 cm^3. Working must be shown or ticks must be put next to the two (or more) accurate readings selected. *The mean should normally be quoted to 2 dp rounded to the nearest 0.01. Example: 26.667 must be rounded to 26.67.* *Two special cases where the mean may not be to 2 dp:* *allow mean to 3 dp only for 0.025 or 0.075 e.g. 26.325;* *allow mean to 1 dp if all accurate burette readings were given to 1 dp and the mean is exactly correct e.g. 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.* *Do not award this mark if:* *any selected titre is not within 0.20 cm^3 of any other selected titre;* *the rough titre was used to calculate the mean;* *the candidate carried out only 1 accurate titration;* *burette readings were incorrectly subtracted to obtain any of the accurate titre values.* *All burette readings, excluding initial 0, (resulting in titre values used in calculation of mean) are integers.* *Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the examiner for the purpose of assessing accuracy.*	1
1(c)(i)	All answers to **(c)** correct to 3 or 4 sig figs.	1
1(c)(ii)	Correctly calculates moles Na_2CO_3 in 25.0 cm^3 **FB 1** = $\dfrac{1.30}{106 \times 10}$	1
1(c)(iii)	Correctly calculates answer to **(c)(ii)** × 2	1
1(c)(iv)	Correctly uses $\dfrac{\text{answer to (iii)} \times 1000}{\text{Volume from (b)}}$	1

2(a)	**I** Initial and final burette readings and volume added recorded for rough titre **and** accurate titre details tabulated. [minimum 2 × 2 'boxes' with relevant information]	1	
	II Initial and final burette readings recorded and volume of **FA 3** added recorded for each accurate titration. Headings and units correct for accurate titrations Headings: initial / final (burette) reading / volume or reading / volume at start / finish **and** volume / **FA 3** added / used or titre **[not difference/total]** allow vol but not V **and** Units: (cm^3) or / cm^3 or in cm^3 [or cm^3 by every entry]	1	
	III All accurate burette readings are recorded to the nearest 0.05 cm^3 Do **not** award this mark if: 50(.00) is used as an initial burette reading; more than one final burette reading is 50(.00); any burette reading is greater than 50(.0)	1	
	IV Final uncorrected titre is within 0.10 cm^3 of any previous uncorrected accurate titre. *Do not include a reading if it is labelled rough.* *Do not award the mark if any accurate burette readings (apart from the initial zero) are given as integers.*	1	

2(b)	Check mean titre is correctly calculated from clearly selected values (ticks or working). • Candidate must average two (or more) titres where the **total** spread is ⩽ 0.20 cm^3. • Working must be shown or ticks must be put next to the two (or more) accurate readings selected. • The mean should normally be quoted to 2 dp rounded to the nearest 0.01. [e.g. *26.667 must be rounded to 26.67*] Two special cases where the mean may not be to 2 dp: allow mean to 3 dp only for 0.025 or 0.075, e.g. 26.325; allow mean to 1 dp if **all** accurate burette readings were given to 1 dp and the mean is exactly correct. [e.g. *26.0 and 26.2 = 26.1 is correct* *but 26.0 and 26.1 = 26.1 is incorrect.*] Do **not** award this mark if: • the rough titre was used to calculate the mean; • candidate carried out only 1 accurate titration; • burette readings were incorrectly subtracted to obtain any of the accurate titre values; • **all** burette readings (resulting in titre values used in calculation of mean) are integers. *Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the examiner for the purpose of assessing accuracy.*	1	1
2(c)(i) and (ii)	Correctly calculates $\frac{0.140 \times (b)}{1000}$ **and** same answer in **(ii)** **and** both answers to 3 or 4 sf	1	
2(c)(iii) and 2(c)(iv)	Correctly uses **(ii)** × 10 **and** Answer = 5.(00) × 10^{-2}	1	
2(c)(v)	Correctly calculates **(iv) – (iii)**	1	
2(c)(vi)	Correctly uses [(v) × 100.1]/2	1	
2(c)(vii)	Correctly uses [(vi) × 100]/(mass in (a)] to a minimum of 2 sf	1	5
2(d)	Question 1: % purity lower as loss of gas means fewer moles / less mass $CaCO_3$ Question 2: no change / % same as same amount of acid reacts / (amount) acid left is same	1 1 1 1	4 max 3
	Total		16

2 (a)	**I** Initial and final readings and titre value for rough titre **and** initial and final reading for **two** (or more) accurate titrations	1	
	II Titre values recorded for accurate titrations **and** Appropriate headings for the **accurate** titration table **and** cm^3 units. • initial / start burette reading / volume / value • final / end burette and reading / volume / value • titre **or** volume / **FA4 and** used / added • unit: / cm^3 **or** (cm^3) **or** in cm^3 **or** cm^3 (for each heading)	1	
	III All **accurate** burette readings are recorded to nearest 0.05 cm^3 *Do **not** award this mark if:* • *50.(00) is used as an initial burette reading* • *more than one final burette reading is 50.(00);* • *any burette reading is greater than 50.(00)* • *there is only one accurate titration*	1	
	IV There are two uncorrected, **accurate** titres within 0.10 cm^3 • *Do **not** award this mark if, having performed two titres within 0.1 cm^3, a further titration is performed which is more than 0.10 cm^3 from the closer of the two initial titres, **unless** a further titration, within 0.10 cm^3 of any other, has also been carried out.* • *Do **not** award the mark if any "accurate" burette readings (apart from initial 0 cm^3) are given to **zero** dp*	1	[4]
(b)	Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm^3. Working must be shown **or** ticks must be put next to the two (or more) accurate readings selected. The mean should be quoted to **2 dp**, rounded to the nearest 0.01. Two special cases where the mean may not be to 2 dp: • Allow mean expressed to 3 dp **only** for 0.025 or 0.075 (e.g. 26.325) • Allow mean if expressed to 1 dp if **all** accurate burette readings were given to 1 dp **and** the mean is **exactly** correct. *(e.g. 26.0 and 26.2 = 26.1 is allowed)* *(e.g. 26.0 and 26.1 = 26.1 is incorrect – should be 26.05.)* ***Note**: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the examiner for the purpose of assessing accuracy.*	1	[1]
(c) (i)	**I** Correctly calculates n(NaOH) = 0.001	1	
(ii)	**II** Shows use of $\frac{250(\mathbf{c})(\mathbf{i})}{(\mathbf{b})}$	1	
(iii)	**III** Correctly calculates 2 × **1(b)(i)**	1	

(iv)	**IV** Shows use of **2(c)(ii)** + **2(c)(iii)** either as expression **or** correct calculation	1	
	V Shows use of /0.025(0) **or** × 40 **or** × 1000/25	1	[5]
(d) (i)	States that the measuring cylinder/volume of **FA2** has the greatest error **and** should be replaced by burette or pipette	1	
(ii)	Student is correct/greater volume HC*l* used **and** greater mass would react with more HC*l*/would leave less HC*l* unreacted	1	[2]
Question 2			**[12]**

Q# 40/ ACID/BASE TITRATIONS ALvl Chemistry/2013/s/TZ 1/ Paper 3/Q# 2/ :o)

2 (a)	MMO collection	**I** Initial and final volumes recorded for rough AND initial, final and volume added recorded for accurate titre.	1	
	PDO recording	**II** All accurate readings recorded to 0.05 cm^3. *Do not award if 50(.00) is used as an initial burette reading; more than one final burette reading is 50.(00); any burette reading is greater than 50.(0).*	1	
	MMO decision	**III** Two uncorrected accurate titres within 0.1 cm^3. *Do not award if, having performed 2 titres within 0.1 cm^3, a further titration is performed that is >0.1 cm^3 from the closer of the original 2 titres unless a further titration has been carried out which is within 0.1 cm^3 of any other.*	1	
	MMO quality	**IV + V** Award 2 marks if difference from Supervisor within 0.20 cm^3. Award 1 mark if difference from Supervisor within 0.50 cm^3. Examiner compares candidate mean titre with Supervisor mean titre. If best titres are ≥ 0.5 cm^3, cancel one of the Q marks.	2	[5]
(b)	ACE interpretation	Calculates the mean to appropriate decimal places. *The mean should normally be quoted to 2 dp rounded to the nearest 0.01. Example: 26.667 must be rounded to 26.67.* *Two special cases where the mean may not be to 2 dp: allow mean to 3 dp only for 0.025 or 0.075 e.g. 26.325; allow mean to 1 dp if **all** accurate burette readings were given to 1 dp and the mean is exactly correct. eg 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.* *Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the Examiner for the purpose of assessing accuracy.*	1	[1]

(c)	ACE interpretation	All answers correct. **(i)** 0.15 × **(b)** /1000 **(ii)** (i)/2 **(iii) (ii)** × 400	1	
	PDO display	Working shown in **(i)** and **(iii)**	1	
	PDO display	All answers given to 3 or 4 sig figs (minimum 2).	1	[3]
(d)	ACE interpretation	Correctly works out % difference to min 2 sig figs.	1	[1]
				[Total: 10]

Q# 41/ ACID/BASE TITRATIONS ALvl Chemistry/2011/s/TZ 1/ Paper 3/Q# 1/ :o)
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1 (a)	PDO Layout	**I** Volume given for rough titre **and** accurate titre details tabulated. *Minimum of 2 × 2 boxes.*	1	
	MMO Collection	**II** Initial and final burette readings recorded for rough titre **and** initial and final burette readings and volume of **FA 2** added recorded for each accurate titre. *Headings should match readings. Do **not** award this mark if: 50(.00) is used as an initial burette reading; more than one final burette reading is 50.(00); any burette reading is greater than 50.(00)*	1	
	PDO Recording	**III** All accurate burette readings (initial and final) recorded to nearest 0.05 (cm^3) *Assessed on burette readings only.*	1	
		IV Has two uncorrected, accurate titres within 0.1 cm^3 *Do **not** award this mark if having performed two titres within 0.1 cm^3 a further titration is performed which is more than 0.10 cm^3 from the closer of the initial **two** titres, unless a fourth titration, within 0.1 cm^3 of any of the previous titres has also been carried out.*	1	
Round any burette readings to the nearest 0.05 cm^3. Check and correct subtractions in the titre table. Examiner then selects the "best" titre using the hierarchy: two identical; titres within 0.05 cm^3; titres within 0.1 cm^3; etc				
	MMO Quality	**V, VI** and **VII** Award **V, VI** and **VII** for a difference from Supervisor within 0.20 cm^3 Award **V** and **VI** for a difference of > 0.20 – ≤ 0.40 cm^3 Award **V** for a difference of > 0.40 – ≤ 0.60 cm^3 *If the "best" titres are ≥ 0.60 cm^3 apart cancel one of the Q marks.*	3	[7]

(b)	ACE Interpretation	Calculates the mean, correct to 2 decimal places from any accurate titres within 0.20 cm^3. *The third decimal place may be rounded to the nearest 0.05 cm^3.* *A mean of exactly .x25 or .x75 is allowed but the candidate may round up or down to the nearest 0.05 cm^3.* *If **ALL** burette readings are given to 1 decimal place then the mean can be given to 1 decimal place* if numerically correct without rounding. *Mean of 24.3 and 24.4 = 24.35 (✓)* *Mean of 24.3 and 24.4 = 24.4 (✗)* ***Titres to be used in calculating the mean must be clearly shown – in an expression or ticked in the titration table.***	1	[1]
(c)	ACE Interpretation	**I** Expression needed in step **(i)** (= mean titre $^{\times 0.15}/_{1000}$ mol) **and** step **(ii)** (= answer to step **(i)** / 2) *No irrelevant or incorrect working should be included.*	1	
		II Correctly evaluates step **(iii)** (= answer to step **(ii)** × 10) **and** step **(iv)** (= answer to step **(iii)** × 40)	1	
	PDO Display	**III** Some **relevant working** shown in a minimum of **three** parts in the calculation. (In **(ii)** could be × 2 or ÷ 2, in **(iii)** could × 10 or ÷ 10).	1	
		IV All answers given are quoted to 3 or 4 sig figs (must be a **minimum** of three steps)	1	[4]
				[Total: 12]

Q# 42/ Redox titrations with $KMNO_4$ ALvl Chemistry/2022/w/TZ 1/Paper 3/Q# :o)

1(a)	I all the following data recorded • two burette readings and titre for rough titration • initial and final burette readings for two (or more) accurate titrations	7
	II titre values shown for accurate titrations **and** appropriate headings and units in the accurate titration table • initial / start **and** (burette) reading / volume • final / end **and** (burette) reading / volume • titre or volume / **FA 2 and** used / added • unit: /cm^3 or (cm^3) or in cm^3 (for each heading) or cm^3 unit given for each volume recorded	
	III all accurate burette readings are to nearest 0.05 cm^3	
	IV the final accurate titre recorded is within 0.10 cm^3 of any other accurate titre	
	V, VI, VII award **V** if $\delta \leqslant 0.60$ (cm^3) award **VI** if $\delta \leqslant 0.40$ (cm^3) award **VII** if $\delta \leqslant 0.20$ (cm^3) where δ is the difference between the supervisor's and candidate's mean titre	
1(b)	**candidate calculates mean correctly to 2 decimal places** (dp) • candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm^3 • working / explanation must be shown or ticks must be put next to the two (or more) accurate readings selected • the mean should be quoted to **2 dp** and be rounded to the nearest 0.01 cm^3	1
1(c)(i)	**significant figures** (sf) all quoted answers in **(c)(ii)** – **(c)(iv)** are expressed to 3 or 4 sf	1
1(c)(ii)	**correctly calculates amount of MnO_4^- used** amount of MnO_4^- = $\frac{0.02 \times \text{vol in (b)}}{1000}$ (mol)	1

1(c)(iii)	**correctly uses equation and converts volume** amount of $(COO^-)_2$ that reacted = **(c)(ii)** × $^5/_2$ (mol) **and** concentration of $(COO^-)_2$ in **FA 1** = amount of $(COO^-)_2$ × $^{1000}/_{25}$ (mol dm^{-3})	1
1(c)(iv)	**correctly uses M_r = $^{mass}/_{moles}$** M_r = $^{10.14}/_{\text{concentration from (c)(iii)}}$	1
1(c)(v)	**identity of M** M1: A_r of **M** = $\frac{M_r \text{ from (c)(iv)} - 124}{2}$ M2: identifies **M** as being the Group 1 element with the nearest A_r (Li ⩽ 14.9; 15.0 ⩽ Na ⩽ 31.0; 31.1 ⩽ K ⩽ 62.3; 62.3 ⩽ Rb ⩽ 111.4; 111.4 ⩽ Cs ⩽ 250)	2
1(d)	**explanation for use of acid** to provide H^+ **and** for the reaction (to proceed) / as given in the equation / to acidify the $KMnO_4$	1

Q# 43/ REDOX TITRATIONS WITH $KMNO_4$ ALvl Chemistry/2021/s/TZ 1/Paper 3/Q# :o)
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1(a)	**I** The following data must be shown • burette readings ***and*** titre for rough titration • 2 × 2 'box' showing both accurate burette readings *'Correct' headings and units are not required for this mark*	1
	II Headings and units correct for accurate titration table and headings match readings. • initial/start **and** (burette) reading / volume + unit (*allow vol but not V*) • final/end **and** (burette) reading / volume + unit (*allow value for reading*) • titre or volume/**FA 2 and** used/added (*not 'difference' or 'total' or 'amount'*) + unit *Units: (cm^3) or / cm^3 or in cm^3 or cm^3 by every entry*	1
	III All accurate burette readings to 0.05 cm^3 *Do **not** award this mark if:* *50(.00) is used as an initial burette reading;* *More than one final burette reading is 50(.00);* *Any burette reading is greater than 50(.00).*	1
	IV The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre. *Do **not** award the mark if any 'accurate' burette readings (apart from initial 0) are given to **zero** dp.*	1
	For assessment of accuracy (Q) marks, the Examiner should round any burette readings to the nearest 0.05 cm^3. Check and correct subtractions. Then select the 'best' titres using the hierarchy: • two (or more) accurate identical titres (ignoring any that are labelled 'rough'), *then* • two (or more) accurate titres within 0.05 cm^3, *then* • two (or more) accurate titres within 0.10 cm^3, *etc.* These best titres should be used to calculate the mean titre, expressed to nearest 0.01 cm^3. Calculate the difference (**δ**) between the candidate's titre and the supervisor's titre. Award the accuracy (Q) marks as shown below.	1
	Award **V** if δ ⩽ 0.50 cm^3	1
	Award **VI** if δ ⩽ 0.30 cm^3	1
	Award **VII** if δ ⩽ 0.20 cm^3	
1(b)	Candidate must average two (or more) titres that are **all** within 0.20 cm^3. Working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
1(c)(i)	Answers for **(c)(ii)**, **(c)(iii)**, **(c)(iv)** to 3–4 sf	1
1(c)(ii)	Correctly calculates $n(MnO_4^-)$ = 0.02 × **(b)** / 1000	1
1(c)(iii)	Correctly uses $n(FeSO_4)$ in 25 cm^3 = **(c)(ii)** × 5 × 40	1
1(c)(iv)	Correctly uses mass($FeSO_4$) in 1 dm^3 = **(c)(iii)** × 151.9	1
1(c)(v)	Correctly uses $n(H_2O)$ = [26.52 – **(c)(iv)**] / 18	1
	ratio $n(H_2O)$: $n(FeSO_4)$ **AND** *x* given as integer **OR** M1: M_r hydrated salt = 26.52 / **(c)(iii)** M2: (26.52 / **(c)(iii)** – 151.9) / 18 **and** answer as integer	1

1(d)	(as) mole / amount / volume MnO_4^- smaller or (as) mass / moles / amount Fe^{2+} smaller	1
	mass/moles/amount water larger so (mole) ratio larger so *x* increases *Allow difference in titre/moles of MnO_4^- / Fe^{2+} will be too small to change the (integer) value of x for 1 mark.* *Allow for 1 mark: less MnO_4^- / Fe^{2+} **and** x increases*	1

Q# 44/ REDOX TITRATIONS WITH $KMNO_4$ ALvl Chemistry/2020/s/TZ 1/Paper 3/Q# :o)
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1(a)	I The following headings and data are recorded in the space provided • mass of container with **FA 1** • mass of (empty) container • mass of **FA 1** used, correctly subtracted • consistent decimal places for weighings (at least one d.p.)	1
	II All the following data is recorded • two burette readings **and** titre for the rough titration • initial and final burette readings for two (or more) accurate titrations	1
	III Titre values recorded for accurate titrations, **and Appropriate headings** and units in the accurate titration table • initial / start (burette) reading / volume • final / end (burette) reading / volume • titre or volume used / added / or FA 1 added *(not 'difference' or 'total' or 'amount')* • unit: / cm^3 or (cm^3) or in cm^3 (for each heading) or cm^3 unit given for each volume recorded	1
	IV All accurate burette readings are recorded to the nearest 0.05 cm^3.	1
	V The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre	1
	Award VI, VII and VIII if $\delta \leqslant 0.020$ ($cm^3\ g^{-1}$) Award VI and VII if $0.020 < \delta \leqslant 0.040$ Award VI, only if $0.040 < \delta \leqslant 0.060$	3
1(b)	**Candidate calculates the mean correctly.** • Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm^3. • Working/explanation must be shown **or** ticks must be put next to the two (or more) accurate readings selected. • The mean should be quoted to **2 dp** and be rounded to nearest 0.01 cm^3.	1
1(c)(i)	**Correct calculation** (expressed to 3 or 4 sf) No of moles of $KMnO_4$ used = $0.0200 \times {}^{\text{mean titre}}/_{1000}$ *The candidate's mean titre must be used in the calculation*	1
1(c)(ii)	**Correct use of (i) to calculate concentration of FA 4** Concentration of **FA 4** = ans **(i)** $\times 5 \times {}^{1000}/_{25}$	1
1(c)(iii)	**Correct expression for M_r** $M_r = {}^{\text{mass of FA 1 used} \times 4}/_{\text{answer (ii)}}$ alternatively: M_r = ans (i) / 4	1

Q# 45/ REDOX TITRATIONS WITH KMNO4 ALvl Chemistry/2020/m/TZ 3/Paper 3/Q# :o)
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1(a)	I Titration data shown • two burette readings for the rough titration • titre for rough titration • initial **and** final burette readings for two (or more) accurate titrations	1
	II Titre values for accurate titrations recorded **and** appropriate headings and units in accurate titration table • initial / start **and** (burette) reading / volume • final / end **and** (burette) reading / volume • titre or volume / FA 1 and used / added • unit: / cm^3 or (cm^3) or in cm^3 (for each heading) or cm^3 unit given for each volume recorded	1
	III All accurate burette readings are recorded to the nearest 0.05 cm^3.	1
	IV The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre.	1
	Award V, VI and VII if $\delta \leqslant 0.20$ (cm^3) Award V and VI if $0.20 < \delta \leqslant 0.40$ Award V only if $0.40 < \delta \leqslant 0.60$	3
1(b)	Correctly calculates mean titre from two (or more) accurate titres where the **total** spread is $\leqslant 0.20\ cm^3$ **AND** Answer is given to 2 dp **AND** Working must be shown or ticks must be put next to the two (or more) accurate titres selected	1

1(c)(i)	All final answers in **1(c)** are quoted to 3 or 4 significant figures Minimum of four answers attempted	1
1(c)(ii)	Correctly calculates number of moles of $KMnO_4$ used = $0.03(00) \times \frac{\text{mean titre}}{1000}$	1
1(c)(iii)	Two correct multiplying factors shown • answer **(ii)** × 2.5 • (subsequent answer) (mol of H_2O_2) × 40 ($\times \frac{1000}{25}$)	1
1(c)(iv)	Correctly calculates concentration of H_2O_2 = final answer in **(iii)** × 10	1
1(c)(v)	Correctly uses (iv) to find moles of O_2 = answer **(iv)** × 0.5	1
	Correctly uses (iv) to find 'volume strength' = moles of O_2 × 24 Answer for default value = 12.24 vol	1
1(d)	% error pipette = 0.24 **and** % error burette = 0.4(0) OR 2 × 0.05 (cm^3) is greater (than 0.06 / pipette error) Working must be shown	1

Q# 46/ REDOX TITRATIONS WITH $KMNO_4$ ALvl Chemistry/2017/m/TZ 3/Paper 3/Q# :o)
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2(a)	**I** initial and final burette readings and volume added recorded for rough titre **AND** accurate titre details tabulated	1
	II initial and final burette readings recorded and volume of **FA 3** added recorded for each accurate titration • all headings and units correct for accurate titrations – initial / final (burette) reading / volume **OR** reading / volume at start / finish – titre **OR** volume **FA 3** added / used – (cm^3) **OR** / cm^3 **OR** in cm^3 by every entry	1
	III all accurate burette readings are recorded to the nearest 0.05 cm^3	1
	IV final titre within 0.10 cm^3 of any previous accurate titre	1
	V, VI and **VII** award **V**, **VI** and **VII** for $\delta \leqslant 0.20\ cm^3$ award **V** and **VI** for $0.20\ cm^3 < \delta \leqslant 0.30\ cm^3$ award **V** for $0.30\ cm^3 < \delta \leqslant 0.50\ cm^3$	3
2(b)	mean titre correctly calculated from clearly selected values: • candidate must average two (or more) titres where the **total** spread is $\leqslant 0.20\ cm^3$ • working must be shown or ticks must be put next to the two (or more) accurate readings selected • the mean should normally be quoted to 2 d.p. rounded to the nearest 0.01 *Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the examiner for the purpose of assessing accuracy.*	1
2(c)	**M1** correctly calculates $\frac{0.030 \times (b)}{1000}$	1
	M2 correctly uses **(i)** × 5/2	1
	M3 correctly uses **(ii)** × 1000/25	1
	M4 all final answers to 3 or 4 sig. fig. (minimum two parts attempted)	1

Q# 47/ REDOX TITRATIONS WITH $KMNO_4$ ALvl Chemistry/2015/w/TZ 1/ Paper 3/Q# 1/ :o)
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1	(a)	**I** Initial and final readings and titre value given for rough titre **and** initial and final readings for two (or more) accurate titrations *(minimum of 2 × 2 box)*	1
		II Titre values recorded for accurate titrations **and** Appropriate headings for the **accurate** titration table **and** cm^3 units. • initial / start burette reading / volume / value • final / end burette reading / volume / value *(not amount)* • titre **or** volume / **FA 4 and** used / added • unit: / cm^3 **or** (cm^3) **or** in cm^3 (for each heading)	1

	III All **accurate** burette readings are to the nearest 0.05 cm^3. *Do **not** award this mark if:* • *50(.00) is used as an initial burette reading* • *more than one final burette reading is 50.(00)* • *any burette reading is greater than 50.(00)* • *there is only one accurate titration.*	1	
	IV There are two uncorrected **accurate** titres within 0.10 cm^3 • *Do **not** award this mark if, having performed two titres within 0.10 cm^3, a further titration is performed which is more than 0.10 cm^3 from the closer of the initial two titres, **unless** a further titration, within 0.10 cm^3 of any other, has also been carried out.* • *Do **not** award the mark if any "accurate" burette readings (apart from initial 0 cm^3) are given to **zero** dp*	1	
	Examiner rounds any burette readings to the nearest 0.05 cm^3, checks subtractions and then selects the **"best" titres** using the hierarchy: • two (or more) accurate identical titres, *then* • two (or more) accurate titres within 0.05 cm^3, *then* • two (or more) accurate titres within 0.10 cm^3, *etc* These best titres are used to calculate the mean titre, expressed to nearest 0.01 cm^3. Examiner calculates the difference (δ) between the mean titres obtained by the candidate and the Supervisor. Accuracy marks are awarded as shown. Award **V**, **VI** and **VII** if $\delta \leqslant$ **0.20** (cm^3) Award **V** and **VI** if **0.20** < $\delta \leqslant$ **0.30** Award **V**, only, if **0.30** < $\delta \leqslant$ **0.50** ***Spread penalty**: if the two "best" (corrected) titres used by the Examiner were $\geqslant$ 0.50 cm^3 apart, cancel **one** accuracy mark.*	3	[7]

(b)	Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm^3. Working/explanation must be shown **or** ticks must be put next to the two (or more) accurate readings selected. The mean should be quoted to **2 dp**, and be rounded to nearest 0.01 cm^3. Two special cases, where the mean need not be to 2 dp: • Allow mean expressed to 3 dp **only** for 0.025 or 0.075 *(e.g. 26.325 cm^3)* • Allow mean if expressed to 1 dp, if **all** accurate burette readings were given to 1 dp **and** the mean is **exactly** correct. *(e.g. 26.0 and 26.2 = 26.1 is allowed)* *(e.g. 26.0 and 26.1 = 26.1 is wrong – should be 26.05)* ***Note**: the candidate's mean will sometimes be marked correct even if it was different from the mean calculated by the Examiner for the purpose of assessing accuracy.*	1	[1]
(c)(i)(ii)	Correctly calculates • n(thio) = $0.10 \times {}^{(b)}/_{1000}$ • $n(I_2) = 0.5 \times$ **(i)** *Both answers must be given to 3 or 4 significant figures*	1	
(iii)	Correctly calculates $n(KMnO_4) = 0.025 \times 0.018 = 0.00045$ or 0.000450 or 0.0004500	1	

(iv)	Correct expression, with answer given to 2, 3 or 4 sig fig $n(I_2) = {}^{(ii)}/_{(iii)} \times 2$ *Theoretical answer = 5.0 (for 2.0 mol $KMnO_4$)*	1	
(v)	Correct equation ticked, corresponding to **(iv)**	1	
(vi)	Allow any **one** of the following answers: • **An** iodide ion loses **one** electron • $2I^- - 2e^- \rightarrow I_2$ *(ionic equation must be correctly balanced)* • Oxidation number of iodine **increases** from –1/ 1– (in iodide ion) to 0 (in iodine)	1	[5]
(d) (i)	% error = ${}^{0.06}/_{25} \times 100 = 0.24$ %	1	
(ii)	The student is wrong, since KI / **FA 3** is in **excess.**	1	[2]
Qn 1			**[Total: 15]**

Q# 48/ REDOX TITRATIONS WITH $KMNO_4$ ALvl Chemistry/2015/s/TZ 1/ Paper 3/Q# 1/ :o)
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1 (a)	**I** Initial and final burette readings and titre unambiguously recorded in rough and accurate titrations. *Minimum of 2 × 2 boxes for accurate.*	1	
	II Headings and units correct for accurate titration and headings match readings. *Headings: initial / final (burette) reading / volume or Reading / volume / vol / value at start / finish **and** Volume / vol / **FA 1** added / used or titre [not "difference or "total"]* ***and** Units: (cm^3) or / cm^3 or in cm^3 or cm^3 by every entry*	1	
	III All accurate burette readings (initial and final) recorded to nearest 0.05 cm^3 *Do **not** award this mark if:* *50(.00) is used as an initial burette reading;* *more than one final burette reading is 50.(00);* *any burette reading is greater than 50.(00)*	1	
	IV Has two uncorrected, accurate titres within 0.1 cm^3 *Do **not** award this mark if, having performed two titres within 0.1 cm^3, a further titration is performed that is more than 0.1 cm^3 from the closer of the two initial titres unless further titrations within 0.1 cm^3 of any other has also been carried out.* *Do **not** award the mark if any 'accurate' burette readings (apart from initial 0) are given to **zero** dp.*	1	

Examiner rounds all all burette readings to the nearest 0.05 cm^3 and checks subtractions. Examiner selects the 'best' titres using the hierarchy:
two (or more) identical,
then two (or more) within 0.05 cm^3 ,
then two (or more) within 0.1 cm^3, etc.

	Award **V**, **VI** and **VII** if $\delta \leqslant 0.20$ cm^3 Award **V** and **VI** if $0.20 \leqslant \delta \leqslant 0.40$ cm^3 Award **V** if $0.40 \leqslant \delta \leqslant 0.60$ cm^3 *Spread penalty: if the two 'best' titres used by the examiner are more than 0.50 cm^3 apart cancel one of the Q marks.*	1 1 1	[7]

(b)	Calculation of mean Candidate must average two (or more) titres that are **all** within $0.20 cm^3$. Working must be shown or ticks must be put next to the two (or more) accurate readings selected. *The mean should normally be quoted to 2 dp rounded to the nearest 0.01. Example: 26.667 must be rounded to 26.67.* *Two special cases where the mean may not be to 2 dp:* *allow mean to 3 dp only for 0.025 or 0.075, e.g. 26.325;* *allow mean to 1 dp if **all** accurate burette readings were given to 1 dp and the mean is exactly correct, e.g. 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.*	1	[1]
(c)(i)(ii)	**I** Correctly calculates $\frac{0.0200 \times (b)}{1000}$ in step **(i)** **and** $\times$ 5 in **(ii)**	1	
(iii)	**II** Expression **(ii)**/0.025	1	
(iv)	**III** Expression **(iii)** $\times$ 392.0 (or addition of A_rs shown)	1	
	IV Answers to **(i)** to **(iv)** given to 3 or 4 sf (min 3 answers needed)	1	[4]
Qn 1	**Total**		**[12]**

Q# 49/ REDOX TITRATIONS WITH $KMNO_4$ ALvl Chemistry/2014/s/TZ 1/ Paper 3/Q# 1/ :o)

1 (a)	PDO Layout	**I** Initial and final readings and titre value given for rough titre **and** initial and final readings for two (or more) accurate titrations (*minimum of 2 $\times$ 2 box*)	1	
	PDO Recording	**II** Appropriate headings and units for all accurate data. **and** volume **FA 1** added recorded for each accurate titre. *Headings should match readings.* • initial/start (burette) reading/volume • final/end (burette) reading/volume • titre **or** volume/**FA 1** used/added (***not*** *"difference"*) unit: $/cm^3$ **or** (cm^3) **or** in cm^3 **or** cm^3 for **each** entry	1	
		III All accurate burette readings recorded to $0.05 cm^3$. *The need to record to 0.05 applies only to the burette readings and **not** to the recorded titres.* *Do **not** award this mark if:* • *50(.00) is used as an initial burette reading* • *more than one final burette reading is 50.(00)* • *any burette reading is greater than 50.(00).*	1	
	MMO Decisions	**IV** Has two uncorrected, accurate titres within $0.1 cm^3$ *Do not include a reading labelled 'rough'.* *Do **not** award this mark if, having performed two titres within $0.1 cm^3$, a further titration is performed that is more than $0.1 cm^3$ from the closer of the two initial titres unless further titrations within $0.1 cm^3$ of any other have also been carried out.* *Do **not** award the mark if any 'accurate' burette readings (apart from initial 0) are given to **zero** dp.*	1	

Examiner rounds burette readings to the nearest $0.05 cm^3$, checks subtractions and then selects the 'best' titres using the hierarchy: two (or more) identical, then two (or more) within $0.05 cm^3$, then two (or more) within $0.1 cm^3$, etc. Examiner compares candidate mean titre with Supervisor mean titre.				
(a)	MMO Quality	Award **V** and **VI** for difference from Supervisor, $\delta \le 0.20 cm^3$ Award **V** only for $0.20 < \delta \le 0.40 cm^3$ *Spread penalty: if the two 'best' titres are $\ge 0.50 cm^3$ apart cancel one of the Q marks.*	2	[6]

(b)	ACE Interpretation	Candidate must average two (or more) titres that are within $0.20 cm^3$. Working must be shown or ticks must be put next to the two (or more) accurate readings selected. *The mean should normally be quoted to 2 dp rounded to the nearest 0.01.* *Two special cases where the mean may not be to 2 dp:* *allow mean to 3 dp only for 0.025 or 0.075 e.g. 26.325;* *allow mean to 1 dp if **all** accurate burette readings were given to 1 dp and the mean is exactly correct. e.g. 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.* *Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the Examiner for the purpose of assessing accuracy.*	1	[1]
(c)	ACE Interpretation	**I** Correctly evaluates $\frac{0.0200 \times \textbf{(b)}}{1000}$ in **(i)**	1	
		II Correctly evaluates $\frac{\textbf{(i)} \times 5/2}{25}$ in **(iii)**	1	
	PDO Display	**III** Correct balanced equation in **(iv)**	1	
	ACE Interpretation	**IV** Correctly evaluates ans **(iii)** $\times$ ½ $\times$ 24.0 in **(v)** (Allow ecf from incorrect equation)	1	
	PDO Display	**V** All answers given to 3 or 4 sf (minimum of 3 answers attempted)	1	[5]
Qn 1	**Total**			**[12]**

Q# 50/ REDOX TITRATIONS WITH $KMNO_4$ ALvl Chemistry/2013/w/TZ 1/ Paper 3/Q# 1/ :o)
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1 (a)	PDO Layout	**I** The following data must be given • mass of solid used (**or** both weighings) • volume for rough titre (**or** both readings) • initial **and** final readings for two (or more) accurate titrations.	1	

	PDO Recording	**II** Appropriate headings for **all** data given in weighing **and** accurate titration tables **and** g and cm^3 units. • mass/weight (of) beaker (empty) • mass/weight (of) beaker + **FA 1**/solid • initial/start (burette) reading/volume • final/end (burette) reading/volume • titre **or** volume/**FA 2** used/added • unit: /cm^3 **or** (cm^3) **or** in cm^3 **or** cm^3 for **each** volume *If g and/or cm^3 units are not given in the heading, every entry in the table must have the correct unit.*	1	
	PDO Recording	**III** All **accurate** burette readings (including 0.00) are to the nearest 0.05 cm^3. *The need to record to 0.05 applies only to the burette readings and* ***not*** *to the recorded titres.* *Do* ***not*** *award this mark if:* • *50(.00) is used as an initial burette reading* ***or*** • *more than one final burette reading is 50.(00)* ***or*** • *any burette reading is greater than 50.(00).*	1	
	MMO Decision	**IV** There are two uncorrected **accurate** titres within 0.10 cm^3. *Do* ***not*** *include a reading if it is labelled "rough".* *Do* ***not*** *award this mark if, having performed two titres within 0.1 cm^3, a further titration is performed which is more than 0.10 cm^3 from the closer of the initial* ***two*** *titres,* ***unless*** *a further titration, within 0.1 cm^3 of any other, has also been carried out.* *Do* ***not*** *award the mark if any 'accurate' burette readings (apart from initial 0) are given to* ***zero*** *dp.*	1	

(a) (cont)	MMO Quality	Award **V**, **VI** and **VII** if **$\delta \le 0.03$** ($cm^3\,g^{-1}$) *i.e. three Q marks.* Award **V** and **VI** if **$0.03 < \delta \le 0.06$** *i.e. two Q marks.* Award **V**, only, if **$0.06 < \delta \le 0.10$** *i.e. one Q mark.* ***Spread penalty****: if the two "best" (corrected) titres used by the Examiner were ≥ 0.50 cm^3 apart, cancel* ***one*** *Q mark.*	1 1 1	[7]

(b)	MMO Decision	Check mean titre is correctly calculated from clearly selected values (ticks or working). • Candidate must average two (or more) titres where the **total** spread is ≤ 0.20 cm^3. • Working must be shown or ticks must be put next to the two (or more) accurate readings selected. • The mean should normally be quoted to 2 dp rounded to the nearest 0.01. *[e.g. 26.667 must be rounded to 26.67]* Two special cases where the mean may not be to 2 dp: allow mean to 3 dp only for 0.025 or 0.075 e.g. 26.325; allow mean to 1 dp if **all** accurate burette readings were given to 1 dp (*ignoring initial given as 0*) and the mean is exactly correct. *[e.g. 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.]* Do **not** award this mark if: • the rough titre was used to calculate the mean; • candidate carried out only 1 accurate titration; • burette readings were incorrectly subtracted to obtain any of the accurate titre values; • **all** burette readings (resulting in titre values used in calculation of mean) are integers.	1	[1]
(c) (i)	ACE Interpretation	**I** Correctly calculates No. of moles of $KMnO_4 = 0.0200 \times {}^{(b)}/_{1000}$	1	
(ii)	ACE Conclusion	**II** $Fe^{2+} \rightarrow Fe^{3+} + e^-$ / $5Fe^{2+} \rightarrow 5Fe^{3+} + 5e^-$	1	
(iii) + (iv)	PDO Display	**III** Correct working shown in **(iii)** and **(iv)**. *The answer to* ***(i)*** *should be multiplied by 5 to give* ***(iii)****.* *The answer to* ***(iii)*** *should be multiplied by 10 to give* ***(iv)****.*	1	
(v)	ACE Interpretation	**IV** Correct calculation of relative formula mass. $M_r = {}^{\text{correct mass of FA 1 used}}/_{\text{answer to (iv)}}$	1	

(v) (cont)	PDO Display	**V** All answers are quoted to 3 or 4 significant figures. A minimum of three answers is needed to qualify.	1	[5]
(d) (i)	ACE Interpretation	% error for pipette = ${}^{0.06}/_{25} \times 100 = 0.24\%$ (or 0.240%)	1	
(ii) + (iii)	ACE Interpretation	*If balance displays to 1 decimal place:* *error in balance reading is ±0.05g or ±0.1(0)g.* *If balance displays to 2 decimal places:* *error in balance reading is ±0.005g or ±0.01g.* *If balance displays to 3 decimal places:* *error in balance reading is ±0.0005g or ±0.001g.* % error = $2 \times {}^{\text{balance error (above)}}/_{\text{mass of FA 1 used}} \times 100$ *Correct answer is* ***not*** *required, but if the "× 100" factor was omitted, a correctly calculated % error answer scores the mark.*	1	[2]

Q# 51/ Titrations with thiosulfate and iodine ALvl Chemistry/2022/m/TZ 3/Paper 3/Q# :o)

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2(a)	**I** The following data must be shown: • burette readings **and** titre for rough titration • 2 × 2 'box' showing both accurate burette readings.	1
	II Headings and units correct for accurate titration table and headings match readings. • initial / start **AND** (burette) reading / volume + unit • final / end **AND** (burette) reading / volume + unit • titre OR volume / **FA 4 AND** used / added + unit	1
	III All accurate burette readings given to the nearest 0.05	1
	IV The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre.	1
	Accuracy marks *Check and correct titre subtractions where necessary. Exclude any titre from the calculation for the mean where final burette reading is greater than 50(.00). Examiner selects the best titres for calculating the mean, using the hierarchy:* *2 identical titres, titres within 0.05 cm^3, titres within 0.10 cm^3 etc.* *Examiner subtracts (corrected) candidate's titre from Supervisor's titre.* *Write and ring Supervisor's value next to the accurate titration table of each candidate, also candidate mean value (calculated by examiner) and δ.*	
	Award **V** if $\delta \leqslant 0.50$ cm^3 Award **VI** if $\delta \leqslant 0.30$ cm^3 Award **VII** if $\delta \leqslant 0.20$ cm^3	3
2(b)	Candidate must average two (or more) titres that are **all** within 0.20 cm^3 **AND** give the answer to 2 dp. **AND** working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
2(c)(i)	All final answers for **(c)(ii)**, **(c)(iii)**, **(c)(iv)** are to 3–4 sf	1

2(c)(ii)	Correctly calculates amount of (n) $Na_2S_2O_3 = 0.1 \times$ **(b)** / 1000 mol **AND** $n(I_2)$ = ans / 2	1
2(c)(iii)	Correctly calculates initial amount of (n) $I_2 = 2.5(0) \times 10^{-3}$ mol **AND** $n(I_2)$ that reacted $= 2.5(0) \times 10^{-3}$ – final answer to **(ii)**	1
2(c)(iv)	Correctly uses amount of (n) Na_2SO_3 = final answer to **(iii)** × 100 mol	1
2(c)(v)	**M1** Correctly uses M_r $Na_2SO_3{\cdot}xH_2O = {}^{31.5(0)}/_{(c)(iv)}$ **AND** M_r Na_2SO_3 = 126.1	1
	M2 $n(H_2O)$ = (answer above – 126.1)/18 **AND** answer is a (correctly rounded) integer OR **M1** mass(Na_2SO_3) = **(c)(iv)** × 126.1 **AND** mass(H_2O) = 31.5(0) – answer above **M2** $n(H_2O)$ = mass above / 18 **AND** $x = n(H_2O) / n(Na_2SO_3)$ **AND** answer is a (correctly rounded) integer	1

2(d)	agree: Na_2CO_3 would neutralise acid (formed in reaction between sulfite and iodine which would react with the thiosulfate) / some thio would (otherwise) react with the acid (formed) **OR** disagree: (no advantage) as the reaction of thio with acid is slow **OR** disagree: (no advantage) as Na_2CO_3 will react with iodine (so less to react with thio)	1

Q# 52/ TITRATIONS WITH THIOSULFATE AND IODINE ALvl Chemistry/2020/w/TZ 1/Paper 3/Q# :o)

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1(a)	**I** Clearly shows initial and final mass **and** both recorded to the same precision **and** with correct units. Units: (g) or / g or in g or g by every entry (including mass used if given) Reject weight	1
	II The following data must be shown • burette readings *and* titre for rough titration • 2 × 2 'box' showing both accurate burette readings	1
	III Headings and units correct for accurate titration table **and** headings match readings. • initial / start **and** (burette) reading / volume • final / end **and** (burette) reading / volume • titre or volume / **FA 2 and** used / added Units: (cm^3) or / cm^3 or in cm^3 or cm^3 by every entry Allow vol for volume, value for reading Allow change in volume Reject difference, total or amount	1
	IV All accurate burette readings are recorded to 0.05 cm^3 (including 0.00) Reject if 50(.00) is used as an initial burette reading; Reject if more than one final burette reading is 50(.00) Reject if any burette reading is > 50(.00)	1
	V The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre. Ignore any titre labelled 'rough' Reject if any 'accurate' burette reading (apart from an initial 0 cm^3) is given to zero dp.	1
	Check and correct titre and mass subtractions where necessary. *Examiner selects the best mean titre.* *Apply hierarchy: 2 identical, titres within 0.05 cm^3, titres within 0.10 cm^3, etc.Examiner calculates supervisor's corrected average titre × supervisor's corrected mass to 1 dp.* *Examiner calculates candidate's corrected average titre × candidate's corrected mass to 1 dp.* *Subtract the candidate product value from that of the supervisor: δ*	

1(a)	Award **VI** if $4.0 < \delta \leqslant 6.0$ g cm^3	1
	Award **VI** and **VII** if $2.0 < \delta \leqslant 4.0$ g cm^3	1
	Award **VI**, **VII** and **VIII** if $\delta \leqslant 2.0$ g cm^3	1
	If there is only one accurate titration award accuracy marks based on that titration without further penalty. If only a rough titration is shown award accuracy marks based on this value but cancel one accuracy mark. Apply spread penalty as follows:if titres selected (by examiner) differ $\geqslant$ 1.00 cm^3 then cancel one accuracy mark. *If Supervisor's value $\leqslant$ 10.00 cm^3 then halve tolerances* *(3 marks: $\delta \leqslant 1.0$; 2 marks: $\delta \leqslant 2$.; 1 mark: $\delta \leqslant 3.0$ g cm^3)*	
1(b)	Candidate must average two (or more) titres that are **all** within 0.20 cm^3. Working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
1(c)(i)	Answers for (ii) and both parts of (iii) are quoted to 3–4 sf.	1
1(c)(ii)	Correctly calculates 1.25×10^{-3}	1
1(c)(iii)	Correctly uses 2.50×10^{-3} **AND** $2.50 \times 10^{-3} \times \frac{250}{(b)} \left(= \frac{0.625}{(b)} \right)$	1
1(c)(iv)	Correctly uses correctly calculated mass from $\frac{(a)}{ans(iii)}$	1
	Display of $\frac{(ANS - 158.2)}{18}$	1
1(c)(iv)	Uses values to calculate x to the nearest integer	1

1(d)(i)	Uncertainty in a single reading: *for 1 dp balance allow the uncertainty given to be ± 0.1 or 0.05* *for 2 dp balance allow the uncertainty given to be ± 0.01 or 0.005, etc.* **AND** Display of $\left(\frac{2 \times \text{uncertainty given}}{\text{candidate mass}} \right) \times 100$	1

1(d)(ii)	Correctly uses $\left(\frac{(100-(\text{d})(\text{i}))}{100}\right) \times$ candidate's M_r **OR** $\frac{(\text{mass}(\text{a}) - 2\times(\text{single})\,\text{uncertainty})}{ans(\text{c})(\text{iii})}$ Allow numerator as (mass **(a)** – single uncertainty) if lack of doubling already penalised in **(d)(i)**.	1
1(e)	Titre value is less because concentration of thiosulfate is greater	1
1(f)	The indicator colour change is easier to see blue-black to colourless. **OR** The dark colour of the aqueous iodine makes the burette harder to read.	1

Q# 53/ TITRATIONS WITH THIOSULFATE AND IODINE ALvl Chemistry/2017/w/TZ 1/Paper 3/Q# :o)
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1(a)	**I** All the following data is recorded • both burette readings **and** the titre for the rough titration • initial and final burette readings for **two** (or more) accurate titrations *Headings and units are **not** required for this mark*	1
	II Titre values recorded for accurate titrations, **and** appropriate headings and units in the accurate titration table • initial / start (burette) reading / volume / value • final / end (burette) reading / volume / value • titre **or** volume / **FA 4 and** used / added • unit: / cm^3 **or** (cm^3) **or** in cm^3 (for each heading) **or** cm^3 unit given for each volume recorded	1
	III All accurate burette readings are to the nearest 0.05 cm^3. *The requirement to record to 0.05 applies to burette readings, including 0.00 cm^3 (if this was the initial reading), but it does **not** apply to the titre.* *Do **not** award this mark if:* • *50(.00) is used as an initial burette reading* • *more than one final burette reading is 50.(00)* • *any burette reading is greater than 50.(00)*	1
	IV The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre.	1
	Examiner rounds any accurate burette readings to the nearest 0.05 cm^3, checks subtractions and then selects the "best" titres using the hierarchy: • identical titres *then* • accurate titres within 0.05 cm^3, *then* • accurate titres within 0.10 cm^3, *etc.* These best titres should be used to calculate the mean titre, expressed to nearest 0.01 cm^3. Examiner compares candidate's mean titre value with that of the Supervisor.	
	Award **V**, **VI** and **VII** if $\delta \leqslant 0.20$ (cm^3)	1
	Award **V** and **VI** if $0.20 < \delta \leqslant 0.40$	1
	Award **V**, only, if $0.40 < \delta \leqslant 0.60$	1

1(b)	Candidate must take the average of **two** (or more) titres that are within a total spread of not more than 0.20 cm^3. • Working / explanation must be shown *or* ticks must be put next to the two (or more) accurate readings selected. • The mean should be quoted to **2 dp**, and be rounded to nearest 0.01 cm^3. *(e.g. 26.666 cm^3 must be rounded to 26.67 cm^3)* Two special cases, where the mean need not be to 2 dp: • Allow mean expressed to 3 dp **only** for 0.025 or 0.075 *(e.g. 26.325 cm^3)* • Allow mean if expressed to 1 dp, if **all** accurate burette readings were given to 1 dp **and** the mean is **exactly** correct. *(e.g. 26.0 and 26.2 = 26.1 is allowed)* *(e.g. 26.0 and 26.1 = 26.1 is wrong – should be 26.05)* *Do **not** award this mark if:* • *The rough titre was used to calculate the mean.* • *The candidate did only one accurate titration.* • *Burette readings were incorrectly subtracted to obtain **any** of the accurate titre values.* • *All burette readings used to calculate the mean were recorded as integers*	1
1(c)(i)	**Correctly calculates** No of moles of thiosulfate used $= 0.105 \times \frac{\text{mean titre}}{1000}$ to 3 or 4 sf	1
1(c)(ii) and (iii)	**Correct use of data in both parts** **(ii)** moles I_2 = 0.5 × ans **(i)** **and** **(iii)** moles **FA1** = 0.025 × 0.0197 (= 0.000493, 0.0004925)	1

1(c)(iv)	**Correctly calculates answer, expressed as integer** No of moles = $\frac{(ii)}{(iii)}$	1
1(c)(v)	**Correct balancing and value of x** **First** mark: integer in answer **(iv)** shown in front of I_2 **and** correct number of moles of I^- entered in equation	1
	Second mark: any equation fully balanced $IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$	1
1(c)(vi)	Oxidation state = 2**x** – 1.	1

Q# 54/ TITRATIONS WITH THIOSULFATE AND IODINE ALvl Chemistry/2017/s/TZ 1/Paper 3/Q# :o)
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1(a)	**I:** All the following data is recorded • rough titration: both burette readings **and** the titre • initial and final burette readings for two (or more) accurate titrations *Headings and units are not required for this mark*	1
	II: Titre values recorded for accurate titrations, **and** **Appropriate** headings and units in the **accurate** titration table • initial / start (burette) reading / volume • final / end (burette) reading / volume • titre or volume used / added *(not "difference")* • unit: / cm^3 or (cm^3) or in cm^3 (for each heading) or cm^3 unit given for each volume recorded	1
	III: All accurate burette readings are recorded to the nearest 0.05 cm^3. *The requirement to record to 0.05 applies to burette readings, including 0.00 cm^3 (if this was the initial reading), but it does not apply to the titre.* *Do not award this mark if:* • *50(.00) is used as an initial burette reading* • *more than one final burette reading is 50.(00)* • *any burette reading is greater than 50.(00)*	1
	IV: Final uncorrected titre is within 0.10 cm^3 of any previous uncorrected accurate titre.	1
Examiner rounds any accurate burette readings to the nearest 0.05 cm^3, check subtractions and then select the "best" titres using the hierarchy: • identical titres *then* • accurate titres within 0.05 cm^3, *then* • accurate titres within 0.10 cm^3, *etc.* These best titres should be used to calculate the mean titre, expressed to nearest 0.01 cm^3. Examiner compares candidate's tire value with that of the Supervisor.		
	Award V, VI and VII if $\delta \leqslant 0.30$ (cm^3)	1
	Award V and VI if $0.30 < \delta \leqslant 0.50$	1
	Award V, only, if $0.50 < \delta \leqslant 0.80$	1
1(b)	**Candidate calculates the mean correctly.** • Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm^3. • Working / explanation must be shown *or* ticks must be put next to the two (or more) accurate readings selected. • The mean should be quoted to **2 dp**, and be rounded to nearest 0.01 cm^3. • *(e.g. 26.667 cm^3 must be rounded to 26.67 cm^3)*	1

1(b)	Two special cases, where the mean need not be to 2 dp: • Allow mean expressed to 3 dp **only** for 0.025 or 0.075 *(e.g. 26.325 cm^3)* • Allow mean if expressed to 1 dp, if **all** accurate burette readings were given to 1 dp **and** the mean is **exactly** correct. • *(e.g. 26.0 and 26.2 = 26.1 is allowed)* • *(e.g. 26.0 and 26.1 = 26.1 is wrong – should be 26.05)* *Do not award this mark if:* • *The rough titre was used to calculate the mean.* • *The candidate did only one accurate titration.* • *Burette readings were incorrectly subtracted to obtain **any** of the accurate titre values.* • *All burette readings used to calculate the mean were recorded as integers* ***Note**: the candidate's mean will sometimes be marked correct even if it was different from the mean calculated by the Examiner for the purpose of assessing accuracy.*	
1(c)(i)	No of moles of thiosulfate used = 0.110 × $^{\text{mean titre}}/_{1000}$ (expressed to 3 or 4 sig fig)	1
1(c)(ii) + (iii)	Equation balanced $I_2 + 2Na_2S_2O_3 \rightarrow Na_2S_4O_6 + 2NaI$ **and** no of moles of I_2 = 0.5 × ans. in (i)	1

1(c)(iv)	**Correct answer,** No of moles of copper(II) ions = 2 × answer (iii) (expressed to 3 or 4 sig fig)	1
1(c)(v)	$M_r = {}^{26.0}/_{\text{ans (iv)}} \times {}^{25}/_{1000}$	1
	Total:	12

Q# 55/ TITRATIONS WITH THIOSULFATE AND IODINE ALvl Chemistry/2010/w/TZ 1/ Paper 3/Q# 1/ :o)
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1 (a)	PDO layout	**I**	Volume given for Rough titre **and** accurate titre details tabulated.	1	
	MMO Collection	**II**	In the correct spaces, records Initial and final burette readings for Rough titre **and**; Initial and final burette readings **and**, volume of **FB 2** added recorded for each accurate titre *Headings should match readings.* *Do **not** award this mark if:* *50(.00) is used as an initial burette reading;* *More than one final burette reading is 50.(00);* *Any burette reading is greater than 50.(00)*	1	
	MMO Decisions	**III**	Has two uncorrected, accurate titres within 0.1 cm^3 *Do **not** award this mark if having performed two titres within 0.1 cm^3 a further titration is performed which is more than 0.10 cm^3 from the closer of the initial **two** titres, unless a fourth titration, within 0.1 cm^3 of the third titration or of the first two titres has also been carried out.*	1	
	PDO Recording	**IV**	All accurate burette readings (initial and final) recorded to nearest 0.05 cm^3. *Assessed on burette readings only.*	1	
	MMO Quality	**V, VI and VII**	Round any burette readings to the nearest 0.05 cm^3 Check and correct subtractions in the titre table. **Select the "best"titre using the hierarchy**: two identical; titres within 0.05 cm^3, titres within 0.10 cm^3 etc. Award V, VI and VII for a difference to Supervisor within 0.20 cm^3 Award V and VI only for a difference of 0.20+ cm^3 – 0.40 cm^3 Award V only for a difference of 0.40+ cm^3 - 0.80 cm^3 *If the selected "best" titres are > 0.50 cm^3 apart, cancel one of the Q marks awarded.*	3	[7]

(b)	ACE Interpretation	Calculates the mean, correct to 2 decimal places (third decimal place maybe rounded to the nearest 0.05 cm^3) from any accurate titres within 0.20 cm^3. *A mean of exactly .x25 or .x75 is allowed but the candidate may round up or down to the nearest 0.05 cm^3.* *If **ALL** burette readings are given to 1 decimal place then the mean can be given to 1 decimal place if numerically correct without rounding.* *Mean of 24.3 and 24.4 = 24.35 (✓)* *Mean of 24.3 and 24.4 = 24.4 (✗)* *Mean of 24.3 and 24.5 = 24.4 (✓)* ***Titres to be used in calculating the mean must be clearly shown – in an expression or ticked in the titration table.***	1	[1]
(c)		**No additional factor/expression is allowed in any step** *If an answer, with no working, is given in any section allow if correct.*	1	
	ACE Interpretation	**I** Uses ${}^{15.0}/_{248.2}$ only in step **(i)** *If no working shown accept only the following evaluated answers:* *(0.060, 0.0604 or 0.06044)*		
		II Uses **answer (i)** × ${}^{\text{cand average titre}}/_{1000}$ in step **(ii)**	1	
		and **answer (iv)** × ${}^{1000}/_{25}$ in step **(v)**	1	
		III Uses **answer (ii)** × ½ in step **(iii)**, and **answer (iii)** × 2 in step **(iv)**	1	
	PDO Display	**IV** Appropriate working shown in a minimum of **three** sections. To include equations as steps for the working mark; *In **(iii)** must see **x2** or **x0.5**.* *In **(iv)** must see **multiplication or division** by **6**, **1.2** or **2**.* *1:6 for $IO_3^-/6H^+$,* *1:1.2 for $5I^-/6H^+$,* *1:2 for $6H^+/3I_2$*	1	
		V 3 to 5 significant figures in final answers to all sections attempted – *minimum of **three** final answers required to qualify for the award of this mark.*	1	[5]
(d)	ACE Interpretation	Gives 0.1(0) cm^3 as the maximum error in **(i)**. *Ignore any sign* **and** the expression ${}^{0.1}/_{\text{cand titre in (b)}} \times 100$ in **(ii)**	1	
		Evaluates ${}^{0.06}/_{25.0} \times 100$ in step **(iii)** *Accept only 0.240 or 0.24,* ***or*** *rounded to 0.2 **provided** 0.24 has been seen in the working.*	1	[2]
				[Total: 15]

Q# 56/ TITRATIONS WITH THIOSULFATE AND IODINE ALvl Chemistry/2009/s/TZ 1/ Paper 3/Q# 1/ :o) www.SmashingScience.org

Supervisor's Report

Calculate, correct to 2 dp, the titre if the Supervisor had diluted 47.25 cm^3 of **FA 2**.

This is given by the expression $\dfrac{\mathbf{47.25}}{\textbf{volume diluted}}$ **x Examiner selected titre**

Candidate scripts

Calculate the scaled titre for 47.25 cm^3 of **FA 2**.
Record the value against the titration table and calculate the difference to Supervisor.

Question	Sections	Indicative material	Mark	
1 (a)	PDO Layout	(i) Tabulates initial and final burette readings and volume added in each of the tables. *Do **not** award this mark if any final and initial burette readings are inverted or 50 is used as the initial burette reading.*	1	
	PDO Recording	(ii) Both burette readings in the dilution table and <u>final and initial</u> burette readings for all accurate titres in the titration table recorded to the nearest 0.05 cm^3.	1	
	MMO Collection	(iii) Follows instructions: dilutes 47.00 cm^3 to 47.50 cm^3 **and** has any two titres within 0.20 cm^3	1	
	MMO Decisions	(iv) Has at least two uncorrected "accurate" titres within 0.1 cm^3 *Do **not** include any titre labelled "rough"/"trial" **unless** the candidate has ticked that value or used it in an expression when calculating the average in **(b)**.*	1	
	MMO Quality	**Accuracy (v) and (vi)** Give **(v) and (vi)** if difference to Supervisor is **0.3** or less. Give **(vi) only** for a difference of **0.3+ to 0.5**. Give **neither mark** for a difference greater than **0.5**.	2	[6]
(b)	ACE Interpretation	Candidate selects/calculates appropriate "average" from any uncorrected titre values within 0.20 cm^3. *Candidate is permitted to use a titre labelled "rough" or "trial". Titres to be used **must be shown**.* Where **all** titres are given to 1 decimal place the average should be calculated correct to 1 or 2 decimal places. Where any titre is recorded to 2 decimal places, the average should be calculated to 2 decimal places or rounded to the nearest 0.05 cm^3.	1	[1]
(c)	ACE Interpretation	**(i), (ii) and (iii)** Award three marks if all steps are chemically correct. Withhold 1 mark for each chemical error – no negative marks. Count non-completed steps as chemical errors. step 1 $\dfrac{\textbf{titre}}{\mathbf{1000}} \times \mathbf{0.15}$ step 2 $\times \dfrac{\mathbf{1}}{\mathbf{2}}$ step 3 $\times \mathbf{2}$ step 4 $\times \dfrac{\mathbf{1000}}{\mathbf{25}}$ step 5 $\times \dfrac{\mathbf{250}}{\textbf{volume diluted}}$ step 6 $\times \mathbf{249.6}$	3	
	PDO Display	**(iv)** Working shown in at least three of the 5 steps	1	
		(v) Answers to 3 or 4 significant figures in final answer to each step attempted **(minimum of three steps required)**	1	[5]
(d)	ACE Interpretation	Explains that the maximum error is given by + 0.05 cm^3 on one burette reading and –0.05 cm^3 on the other burette reading, **or** Individual errors are in opposite directions.	1	[1]
(e)	ACE Interpretation	Calculates $\dfrac{\mathbf{0.1}}{\textbf{titre}}$ **× 100 %** Answer must be correct to 2 or 3 decimal places.	1	[1]
				[Total: 14]

Q# 57/ Thermometric (metal displacement) enthalpy experiments ALvl Chemistry/2015/s/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

2 (a)	**I** Table with unambiguous headings and correct units. All readings must be included.	1	
	II All temperatures recorded to .0 or .5 °C. Must include at least one ending in .0 and one ending in .5.	1	
Examiner calculates candidate's ΔT max from table.			
	III Award if the difference between candidate and Supervisor is within 4.0 °C	1	
	IV Award if the difference between candidate and Supervisor is within 2.0 °C	1	[4]

(b) (i)	Axes labelled temperature or *T* or °C or temperature and time or minutes or min or t. Linear scales chosen to use more than half of each axis and to include 5 °C more than the maximum temp.	1	
	All points recorded (minimum of 10). Correct plotting – each point accurately plotted (within ½ small square and in the correct square).	1	
(ii)	All three straight lines drawn	1	
	Lines of best fit and extrapolated	1	
(iii)	Correct ΔT from graph to within .2 °C of examiner value using the candidate's lines.	1	[5]

Question	Indicative material	Mark	Total
(c) (i)	Correct answer to $4.2 \times 40 \times$ ans**(b)(iii)**. Allow answers to 2 –4 sf	1	
(ii)	Correct answer to **(i)**/219000 Allow answers to 2–4 sf	1	
(iii)	Expression **(ii)**/0.040 Allow answers to 2–4 sf	1	[3]
(d) (i)	Correct answer correct to number of sf shown (min 2 sf): 0.5/highest temp × 100	1	
(ii)	Do not agree as the zinc is in excess	1	
(iii)	Incorrect as temperature rise is the same **or** Incorrect as (a smaller volume) has a greater % error ORA	1	[3]
Qn 2	**Total**		**[15]**

Q# 58/ THERMOMETRIC (METAL DISPLACEMENT) ENTHALPY EXPERIMENT ALvl Chemistry/2014/w/TZ 1/ Paper 3/Q# 1/ :o) www.SmashingScience.org

1 (a)	**I** Two balance readings and correct mass of magnesium recorded. Table to show temperature and time. Headings and units – must be temperature /°C, (°C), in °C and time/s, (s), or time in seconds or /min, /minutes, ... and /g, (g), ...	1	
	II Thermometer readings to ±0.5 °C (at least 1 ending in .5 or .0) (*Minimum 8 readings*)	1	
	III All specified readings taken **and** balance readings to the same number of dp	1	
	Difference between temperature at 2 minutes and highest temperature (in table) calculated and compared with ΔT of Supervisor.		

	IV, V and **VI** ΔT within 10% of Supervisor **IV**and **V** ΔT within 15% of Supervisor **IV** only ΔT within 20% of Supervisor	3	[6]
(b) (i)	**I** Axes labelled, linear scales chosen so that more than half the available space is used on both axes for plotted points.	1	
	II Plotted points should be drawn clearly with a sharp pencil. Points should be plotted to within half a small square and in the correct square for *y*-axis and on line for *x*-axis.	1	
(ii)	**III** Correctly extrapolated best fit straight lines drawn up to time 2½ minutes and after 2½ minutes.	1	
(iii)	**IV** Examiner calculates ΔT from graph and checks answer is within 0.25 °C of candidate's stated answer	1	[4]
(c) (i)	**All** the magnesium/solid dissolved/disappeared **or all** solid/Mg has gone/been used up **or no** solid/Mg left	1	
(ii)	Correctly calculates $25 \times 4.2 \times \Delta T$	1	
(iii)	Correctly calculates **(ii)** ÷ number of moles of magnesium **and** converts to kJ ($\frac{\textbf{(ii)} \times 24.3}{1000 \times \text{mass Mg}}$) **and** final answer to 2–4 sf	1	
	Sign is negative in **(c)(iii) and (e)(iv)**	1	[4]
(d)	8 readings (in space below printed area) • 4 × balance readings • 2 × initial temp • 2 × highest/max temp with unambiguous headings	1	
	Correctly calculates both masses of Mg and both ΔTs.	1	[2]

(e) (i) & (ii)	Correctly calculates • mean ΔT • mean mass	1	
(iii)	Moles $CuSO_4 = \frac{25 \times 1}{1000} = 0.025$	1	
	Moles Mg $= \frac{\textbf{(ii)} \text{ or max mass Mg}}{24.3}$ so $CuSO_4$ in excess **or** <0.025	1	
(iv)	**Working** to calculate ΔH using mean values of mass Mg and ΔT $\left(\frac{\Delta T\textbf{(i)} \times 25 \times 4.2 \times 24.3}{\textbf{(ii)} \times 1000}\right)$ **or** $\left(\frac{\Delta T\textbf{(i)} \times 25 \times 4.2}{\text{mol Mg from } \textbf{(iii)} \times 1000}\right)$	1	[4]
(f)	Attempt at use of Hess' law either by cycle or reverse reaction 2	1	
	Correctly calculates ΔH reaction 3 = ΔH reaction 1 – ΔH reaction 2	1	[2]

(g) (i)	**Any 2 of** Lower ΔH and so higher % error No correction made for loss of heat on cooling Some bubbles/gas/H_2 in reaction 2 so wrong reaction taking place Not all Mg reacts/reaction does not go to completion in 2 (so not all energy released) Reaction 2 slower so more heat loss	1 1	
(ii)	No, since (larger volume of solution means) smaller ΔT OR Yes, since there would be a smaller T rise so less heat would be lost.	1	[3]
Qn 1		**Total**	**[25]**

Q# 59/ THERMOMETRIC (METAL DISPLACEMENT) ENTHALPY EXPERIMENT ALvl Chemistry/2011/s/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

2 (a)	MMO Collection	**I** Two pairs of temperature values recorded as instructed in **(a)**, with units for all readings in **(a)** and **(b)** – minimum of 3 readings. *Acceptable units are /°C, (°C), temperature in degrees Celsius, temperature in °C.*	1	
	PDO Recording	**II** **All** thermometer readings recorded to 0.0 °C or 0.5 °C. (check readings in sections **2(a)** ***and*** **2(b)** – minimum of 4 readings).	1	
	ACE Interpretation	**III** Correct subtractions to give temperature rises **and** the correct mean value in **2(a)**. *Mean value may be rounded to 0.5 °C* ***or*** *to one d.p* ***or*** *to 0.05 °C and from 0.025 and 0.075 or these may be rounded up or down to nearest 0.1.*	1	
Supervisor script: check subtractions and calculate mean ΔT *Marks are awarded for comparing the "true" means: check working of candidate and Supervisor.* *Show Supervisor's mean (corrected* ***if*** *necessary) on the script in a ring.*				
	MMO Quality	Award **IV** and **V** if candidate's mean temp rise is within 2.0 °C of Supervisor's (incl) Award **IV** if the difference is between 2.0 °C and 3.0 °C.	1 1	[5]
	PDO Display	Heat produced (J) = 25 × 4.3 × temp rise *(method mark).* *Unit is needed in the quoted answer (kJ if divided by 1000).* Correctly evaluates enthalpy change = $^{\text{heat produced}}/_{0.016}$. *Division by 1000 is not required if candidate did this in the previous step.* *Answer must be negative and to 3 sig figs.*	1 1	[2]

Examiner to calculate 20% and 40% of supervisor's ΔT and convert to nearest 0.5°C.				
(b)	ACE Interpretation MMO Quality	**I** Both temperature measurements clearly shown. Award **II** and **III** if candidate's temp rise is within 20% of Supervisor's. Award **II** if candidate's temp rise is within 40% of Supervisor's.	1 1 1	[3]
	ACE Interpretation PDO Display	**IV** Calculates 0.032 for moles in **(ii)** or 0.016 for moles in **(a)(ii)**. **V** Enthalpy change correctly calculated $(= -\,^{\text{heat change}}/_{0.032})$. *Answer* ***must*** *show negative sign (unless already penalised) and be given to 3 sig figs. (unless already penalised).*	1 1	
	ACE Conclusions	**VI** Correct calculation of enthalpy change $\Delta H_1 = \Delta H_2 - \Delta H_3 - 286$	1	[3]
(c)	ACE Improvements	Extra/thicker lagging ***or*** use a lid ***or*** use a vacuum flask	1	[1]
				[Total: 14]

Q# 60/ THERMOMETRIC (METAL DISPLACEMENT) ENTHALPY EXPERIMENT ALvl Chemistry/2009/w/TZ 1/ Paper 3/Q# 1/ :o) www.SmashingScience.org

1 (a)	PDO layout	Two balance readings and mass of **FA 1** clearly recorded for each experiment. (Data for 2nd experiment could be on page 4) *Examiner to check subtraction for each experiment – no penalty in this section but see section* **(e)**	1	[1]
(b) If the candidate performs one experiment only, the following marks may **not** be awarded: **(i)** **(iv)** **(viii) & (ix)** **(xi)**	PDO Recording MMO Collection	***If the candidate has only performed one experiment the following points*** ***<u>only</u>*** ***can be awarded: (ii), (iii), (vi), (vii) and (x).*** **(i)** Single table recording observations for both experiments. Times at ½ minute intervals. **(ii)** Appropriate headings and units *Allow times in minutes (min) or seconds* **(iii)** All temps recorded to nearest 0.5 °C (Must be more than one at .5 as well as .0) **(iv)** Some temps recorded before mixing and some after mixing for **<u>each</u>** expt. **or** Candidate records initial temperature and at least three temperatures after mixing for each experiment **(v)** First temperature after mixing is clearly taken 1 minute after adding the zinc powder *(Examiner judgement re temperatures recorded before mixing / temperatures only recorded after mixing)* **and** cooling for at least 5 minutes after recorded maximum temperature.	 1 1 1 1 1	
	For Supervisor -	calculate mean maximum ΔT to nearest 0.5 °C; calculate mean of time taken (to nearest ½ min) to reach max temperature after mixing.		

	MMO Quality	**(vi) & (vii)** 1st expt. Compare ΔT with Supervisor. award **(vi)** and **(vii)** if within 2 °C award **(vii) only** if >2 °C and ≤5°C **(viii) & (ix)** 2nd expt. Compare ΔT with Supervisor. award **(viii)** and **(ix)** if within 2 °C award **(ix) only** if >2 °C and ≤5°C **(x)** (1st expt) **& (xi)** (2nd expt). Compare time after mixing at which max temp is obtained with same time for Supervisor, for each expt. If Supervisor ≤3 min; 1 mark for Δ time ≤1 min. If Supervisor >3 min; 1 mark for Δ time ≤1½ min.	2 2 1 1	[11]
(c)	PDO Layout	Plots temperature on *y*-axis and time on *x*-axis and has at least one temperature and one time label (*ignore absent or incorrect units*) Scales used are linear and easy for the examiner to use, *(3 or 4 min. per large square are acceptable)* Scales should enable the temperature when zinc is added and all points after the addition of zinc to be plotted. *Points should be within a minimum of 5 large squares on temperature axis* If the candidate has recorded temperatures and times before zinc is added: Correctly plots on each graph: the last temperature/time, from results **before** zinc is added **or** the temperature **and** maximum temperature *(associated time not required* If the candidate has only recorded the initial temperature of the solution: Correctly plots on each graph: the temperature when zinc is added **and** maximum temperature *(associated time not required* Draws a cooling curve or straight line and projects the curve / line back to the time of mixing	1 1 1 1	[4]
(d)	ACE Interpretation	**For experiment 1:** Correctly reads the temperature rise from the graph to within 1 °C of the value obtained from the graph by the examiner. If the value is incorrect for experiment 1, check value for experiment 2. Award mark if either value is correct.	1	[1]
(e)–(h)	PDO Display	Shows working in all sections attempted – *minimum of three sections required.* Significant figures in final answers. 2 or 3 sf in 1(e), 2 to 4 sf in 1(g), 3 sf **only** in 1(h) *minimum of three sections required.*	1 1	[2]

A completely horizontal line, drawn at the initial temperature can be accepted as equivalent to plotting of initial temperature.

If only one graph has been drawn, the 1st and 2nd marks may be awarded and one further mark if the initial and maximum temperatures are correctly plotted **and** there is an appropriate extrapolation.

(e)	ACE Interpretation	Correctly calculates 2.0 x 10^{-2} mol of $CuSO_4$, and ($^{\text{mass zinc}}/_{65.4}$) for each experiment. *Answers correctly rounded for the number of significant figures displayed.* ***Do not award this mark if there is an error in subtraction or there are missing balance readings in section (a).***	1	[1]
(f)	ACE Conclusions	To gain this mark the candidate must refer to: **(i)** the 1:1 mole ratio from the equation **and** **(ii)** the relative moles of Cu^{2+} and Zn(s) used, as calculated in **(e)** *If candidate states that "more moles of zinc were present" and this fits the calculated values in* **(e)** *– accept as the relative statement.*	1	[1]
(g)	ACE Interpretation	Shows (25 × 4.3 × candidate mean ΔT) with appropriate unit, J or kJ, on final answer. (Allow use of 4.2 or 4.18 without penalty) *Award this mark for the correct expression and unit* ***OR*** *where the expression is not shown, a correct evaluation of that expression and unit*	1	[1]
(h)	ACE Interpretation	**No mark is awarded in this section if there is no division by (moles of zinc) or by (moles of Cu^{2+}).** Calculates $\dfrac{\textbf{answer to (g)}}{\textbf{moles of reagent not stated as being in excess in (f)}}$ *If (moles of zinc) is used in this expression, candidate may use either value from* **(e)** *or the mean of the (moles of zinc).* Examiner evaluates the candidate expression which should be: **(i)** correctly rounded for sig fig displayed, (allow variation of ±1 on 3rd significant figure) **(ii)** have a -ve sign on the final answer; **(iii)** be correctly converted to kJ	 1 1	[2]
(i)	ACE Interpretation	Candidate identifies one source of error in the experiment. This must be related to: Apparatus used or method described – no human error allowed. *Heat loss is most likely error to be seen* *Accept reference to the graduation (precision) of the thermometer.*	1	[1]
(j)	ACE Improvement	**Answer must follow on from (i)** Suggests a way in which method could be improved *e.g. Use of a lid or increased insulation to minimise heat loss.*	1	[1]
Qn 1	**Total**			**[26]**

Where candidate has given a maximum temperature in **(g)**, allow use here (ecf). Also allow use of ΔT calculated in this section.

Q# 61/ Thermometric (carbonate and acid) enthalpy experiment ALvl Chemistry/2018/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

1(a)	I Table drawn with suitable headings and units; Temperature / T and time / t / °C, (s) or / minutes or mins or min	1
	II Table completed with all temperature readings from 0 to 9 minutes at half minute intervals **and** 2 balance readings shown to the same number of decimal places	1
	III All recorded thermometer readings to .5 °C with at least one ending in .0 °C and at least one ending in .5 °C.	1
	Calculate ΔT from T at 2 minutes to T_{max} from table. Compare with supervisor ΔT. Award IV if ΔT within 1 °C of supervisor. Award IV and V if ΔT within 0.5 °C of supervisor.	2
1(b)(i)	Axes unambiguously labelled. Scale chosen so that plotted points (and 2 °C extra on y-axis) occupy more than half the available space in both directions.	1
	All recorded points plotted. Points plotted to within half a small square. Points that should be on lines must be on the line and points that should not be on lines must not be on lines. Do not award if crosses / blobs are > half square thick.	1
	Two straight lines of best fit drawn (with a ruler) – one up 2 minutes and the other after the maximum temperature.	1
	Both lines extrapolated to 2½ minutes.	1
1(b)(ii)	Candidate ΔT to at least 1 decimal place is within half a small square or 1 decimal place (whichever is more appropriate) of examiner's calculated ΔT.	1
1(c)(i)	Correctly calculates energy evolved = 25 × 4.2 × ΔT; ΔT from **(b)(ii)** or table and answer to 2–4 sf	1
1(c)(ii)	Correct use of moles Na_2CO_3 = **(c)(i)** / 27000	1
	Correct use of % mass Na_2CO_3 = moles × 106 / sum of A_r and answer to 2–4 sf	1
1(c)(iii)	Correct use of % Na_2CO_3 = **(c)(ii)** / mass **FA1** used and answer to 2–4 sf.	1
1(d)	Assumption: the impurity does not react with hydrochloric acid or **FA 2** or impurities are not alkaline	1
1(e)	Data with unambiguous headings (not weight). **and** Correct subtraction of mass and ΔT.	1
	Examiner calculates expression: mass **FA 1** × ΔT in **(e)** / mass **FA 3** × ΔT in **(a)** to 2 decimal place. Award mark if this value lies in range 0.80 to 1.25	1
1(f)	All 4 stages in **method** (same as **(c)(i) – (iii)**) scores 2 marks; 2 or 3 stages shown clearly scores 1	2
1(g)	First box ticked (If there is a temperature fall after the max in Method 1 then this is more accurate) **because** as heat lost is compensated for / cooling curve plotted **OR** Third box ticked (special case if no temp fall in **(a)**) If there is no temperature fall after the maximum in Method 2 then both seem to be equally accurate **because** the temperature rise is potentially the same for both methods.	1
1(h)	(The student used) fewer moles / less amount of carbonate	1
	(The temperature increase is less and hence calculated) enthalpy change would be less exothermic / ΔH is less negative.	1
1(i)	**Correctly calculates** Moles Na_2CO_3 = (3 / 106) × 0.8 = 0.0226 / 0.02264	1
	Ratio 1: 2 moles HCl = 0.0452 / 0.0453	1
	Vol HCl = 0.0452 / 0.002 = 22.6(0) / 22.7(0) cm^3 and answer to 3 or 4 significant figures (or nearest 0.05 cm^3)	1

Q# 62/ Thermometric (decomposition of H_2O_2) enthalpy experiment ALvl Chemistry/2020/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** Table (or two lists) showing unambiguous headings and data for both experiments in the space provided: • two initial thermometer readings + values • two final / highest thermometer readings + values • two temperature rises / changes + values	1
	II Recording of data • correct units 'covering' all thermometer readings • **all four readings** recorded to .0 or .5 °C • both rises in temperature correctly calculated	1
	III Award this mark based on the table below	1
	IV Award this mark based on the table below	1
	V Award mark if both the candidate's corrected temperature rises are within 1.0 °C of each other	1
2(b)(i)	Correctly calculates heat produced = 30 × 4.2 × temp rise for expt **1** **AND** answer given to 2–4 sf	1
2(b)(ii)	Correctly uses number of moles H_2O_2 = 0.03 × answer to **1(c)(iv)** **AND** answer given to 2–4 sf; Answer for default value = 0.0306 / 0.031 mol	1
2(b)(iii)	Correct expression for enthalpy change • Enthalpy change = $-\frac{\text{ans (i)}}{\text{ans (ii)}} \times \frac{1}{1000}$ • Negative sign must be shown • Answer is shown to 2–4 sf	1
2(c)(i)	(**FA 5** / MnO_2 is a) catalyst	1
	(Student is wrong:) the mass of MnO_2 used does not alter the heat produced / enthalpy change / temperature change (for decomposition of H_2O_2)	1
2(c)(ii)	Student is correct: energy / heat released is greater because more / greater (moles / molecules of) hydrogen peroxide / **FA 3** is used in Experiment 2 **AND** more moles / molecules / greater amount of water / solution / **FA 3** / hydrogen peroxide heated is greater (in the same proportion)	1

Table for III and IV:

ΔT_{sup} (°C)	$\Delta T \geqslant 15.0$	$15 > \Delta T \geqslant 10.0$	$10 > \Delta T \geqslant 5.0$	$\Delta T < 5.0$
δ	2.0	1.5	1.0	0.5

Q# 63/ Thermometric (enthalpies of solution) experiments ALvl Chemistry/2022/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**M1: table of readings** with unambiguous headings **and** correctly displayed units for all entries in the space for **Results** • (mass of) container + **FA 4** • (mass of) container (+ residue) • first / start / initial temperature / temperature of water • lowest / final temperature M2: readings in **2(a)** • both thermometer readings shown to 0.0 °C or 0.5 °C • balance readings shown consistently to either 2 dp or to 3 dp • mass and temperature rise in (a) subtracted correctly and shown in the space for results	2
2(b)(i)	**correctly calculates energy change** energy change = 25 × 4.18 × T fall (J) **and** answer to 2–4 sf	1
2(b)(ii)	**correctly calculates amount of FA 4** amount = mass **FA 4** / 249.6 (mol) **and** answer to 2–4 sf	1
2(b)(iii)	**correctly uses** **(b)(i)** / **(b)(ii)**; enthalpy change = $\frac{\textbf{(b)(i)}}{\textbf{(b)(ii)} \times 1000}$ (kJ mol^{-1}) **and + sign** **and answer to 2–4 sf**	1
2(c)	**readings** mass of **FA 5** and temperature rise are correctly calculated; two thermometer readings are both above 10 °C; temperature rise is greater than T fall in **(a)**	1

2(d)(i)	**correct expressions shown for enthalpy change** • energy change = 25 × 4.18 × T change (J) • amount used = mass of **FA 5** used / 159.6 (mol) • ΔH = energy change / number of moles × 1000 (kJ mol^{-1}) • negative sign in answer	2
2(d)(ii)	**Hess's cycle calculation** correct calculation of ΔH = **(b)(iii)** – **(d)(i)** (kJ mol^{-1}) **and** some working shown e.g., equation as shown and 2 downward arrows with labelling / correct values from **(b)(iii)** and **(d)(i)** with correct signs	1
2(e)	**explanation for answer selected** box 1 ticked: ΔT is larger for **(b)(iii)** (ora) box 2 ticked: ΔT is the same for both experiments box 3 ticked: ΔT is larger for **(d)(i)** (ora)	1

Q# 64/ Thermometric (enthalpies of solution) experiments ALvl Chemistry/2020/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I Unambiguous table of data** • Mass of cup • Mass of cup + **FA 5** • Mass of **FA 5** used • Initial temperature or temperature of water / °C • Final / maximum temperature / °C • Temperature rise / °C • Both experiments must be attempted	1
	II Readings recorded appropriately • All four thermometer readings recorded to .0 or .5. • All four subtractions correct (two masses and two temp rises). • No thermometer reading is less than 10 °C • Mass of FA 5 used for first experiment is 4.0–4.2 g • Mass of FA 5 used for second experiment is 5.0–5.2 g	1
	III + IV Accuracy marks Check and correct temp subtractions for candidate and supervisor. Round each measured temperature to 0.5 °C if necessary Compare the temperature rises for the two experiments.	
	Award **III** if candidate's rise is within 1.0 °C of supervisor in **Expt 1**.	1
	Award **IV** if candidate's rise within 1.0 °C of supervisor in **Expt 2**.	1
2(b)(i)	**Correct calculation of energy change (2, 3 or 4 sf)** Energy change = 30 × 4.2 × temp rise (J)	1
2(b)(ii)	**Correct calculation of no of moles of Na_2CO_3 used (2–4 sf)** n = mass claimed / 106	1
2(b)(iii)	**Correct use of (i) and (ii) to calculate enthalpy change (2–4 sf)** Enthalpy change = – energy / 1000 × moles	1
2(c)(i)	**Accuracy improvement** Plot graph to obtain better (estimate of) temp rise or plot a cooling curve	1
2(c)(ii)	Error = 0.5	1
	Correct calculation of % error to 2 or more sig fig % error = 2 × 0.5 / temp rise (expt 2) × 100	1

Q# 65/ Gravimetric (thermal decomposition) experiment ALvl Chemistry/2022/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** Unambiguous headings and units for four weighings: • (mass of) crucible, lid (empty) • (mass of) crucible, lid and **FA 4** (or 'contents before heating') • (mass of) crucible, lid and MgO / residue after first heating • (mass of) crucible, lid and MgO / residue after second heating	1
	II Readings are appropriately recorded: • all weighings recorded to same decimal places (two or more) • mass of **FA 4** is within range 0.80 g–1.80 g (from weighings) • fourth weighing within +0.02 and –0.05 g of third weighing	1
	III Correct subtractions to give masses of **FA 4** and MgO / residue	1

	IV and V: Accuracy marks Calculate supervisor's mass ratio (to 2 d.p.) = mass FA 4 / mass of residue Calculate the candidate's mass ratio (to 2 d.p.) = mass FA 4 / mass of residue Calculate 20% of this ratio and calculate ratio ± this ratio Award **IV** if δ is within the range 0.00–0.25 Award **V** if δ is within the range 0.00–0.10	2
2(b)(i)	Correctly calculates moles of MgO = mass of residue / 40.3 **AND** answer to 2–4 sig fig	1
2(b)(ii)	Correctly uses **(b)(i)** to calculate M_r of **X** = mass lost / moles of MgO OR M_r of **X** = (mass FA 4 / moles of MgO) – 40.3 **AND** answer to 2–4 sf	1
2(b)(iii)	**X** is water / steam / H_2O / CO_2	1
2(b)(iv)	**FA 4** is magnesium hydroxide	1
2(c)	Student is not correct because there is no spitting / frothing during heating OR student is correct because there was spitting / frothing during heating	1
2(d)	*2 d.p. balance uncertainty = 0.01 g or 0.005 g* *3 d.p. balance uncertainty = 0.001 g or 0.0005 g* Correct expression for % error = (2 × balance uncertainty / mass of residue) × 100	1

Q# 66/ GRAVIMETRIC (THERMAL DECOMPOSITION) EXPERIMENT ALvl Chemistry/2021/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

1(a)	**I** Unambiguous headings and correct units • (Mass of) crucible and lid • (Mass of) crucible, lid and **FA 1** (or 'contents before heating') • (Mass of) crucible, lid and residue / oxide / contents after first heating / contents after cooling • (Mass of) crucible, lid and residue / oxide / contents after second heating / contents after cooling • (Mass of) **FA 1** used	1
	II Weighings recorded appropriately • Four weighings recorded in the space provided • All weighings recorded to same number of decimal places (one or more) • Mass used between 1.40 and 1.60 g	1
	III Mass after second heating within 0.05 g of mass after first heating for 2 or 3 dp balance. Mass **FA 1** and residue calculated correctly.	1
	IV and V Award **IV** if mass ratio within 0.30 of supervisor Award **V** if mass ratio within 0.15 of supervisor	2
1(b)(i)	Correctly calculates Mass CO_2 = mass **FA 1** – mass X_2O OR total mass before heating – total mass after 2nd heating	1
1(b)(ii)	Correctly calculates moles X_2CO_3 = moles of CO_2 = **(b)(i)** / 44 correctly calculated **AND** to 2–4 sf	1
1(b)(iii)	**Correctly uses:** M_r of $X_2CO_3 = \frac{\text{mass FA 1 used}}{\text{ans (b)(ii)}}$ **AND** Ans to 2–4 sf	1
1(b)(iv)	**Correctly shows and uses:** M1: $A_r = \frac{\text{(b)(iii)} - 60}{2}$ M2: Chooses Group 1 nearest A_r using value from M1 **and** explains reason that it is closer to the A_r value. $0.1 < Li \leqslant 14.9$ $15.0 \leqslant Na \leqslant 31.1$ $31.2 \leqslant K \leqslant 62.3$ $62.3 \leqslant Rb \leqslant 109.2$ $109.2 \leqslant Cs \leqslant 250$	2
1(c)	If no change in mass between first and second heating decomposition was complete OR Not complete if further loss of mass	1

Q# 67/ GRAVIMETRIC (THERMAL DECOMPOSITION) EXPERIMENT ALvl Chemistry/2021/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

2(a)	Award **IV** only if 0.05 < δ ⩽ 0.10	1
	Award **IV** and **V** if δ ⩽ 0.05	1
2(b)(i)	*2 or 3 bullets = 1 mark* *4 bullets = 2 marks* • fizzing / bubbling / effervescence • gas turns lime water milky / white ppt / cloudy white *Reject 'cloudy' alone* • gas is identified as carbon dioxide *Reject if an incorrect positive gas test is observed* • reaction is rapid / vigorous or colourless solution forms / (all) solid dissolves	2
2(b)(ii)	CO_3^{2-} / carbonate	1
2(b)(iii)	**$2MHCO_3(s) \rightarrow CO_2(g) + H_2O(g$ or $l) + M_2CO_3(s)$** *Allow use of the symbol of Group 1 metal identified in question 1*	1
2(b)(iv)	**Correctly calculates no of moles of CO_2** $n(CO_2) = {}^{\text{mass loss during heating}}/_{62}$ *Answer must be given correct to 2–4 sig figs* *Allow ecf from (incorrect) subtraction mass shown in list (FA 4 – residue / FA 5)*	1
2(b)(v)	**Correct use of (iv) to calculate M_r** $M_r = {}^{\text{mass of FA 4 used}}/_{2 \times \text{answer (iv)}}$ *Answer to 2 – 4 sf but do not penalise sf more than once in Q2.* *Ecf on incorrect mole ratio in equation*	1
2(b)(vi)	**Any one answer from the following:** • **2** is more accurate since fewer readings required. • **2** is more accurate since there is less cumulative error / fewer processes involved *Reject less total error* • **1** is more accurate because **2** was not heated to constant mass. *Candidate must refer to their results* *Reject if mass readings after heating are within 0.02 of each other* • **1** is more accurate since titres were consistent / concordant. *Ignore comments about burettes/pipettes being more accurate*	1

Q# 68/ GRAVIMETRIC (THERMAL DECOMPOSITION) EXPERIMENT ALvl Chemistry/2019/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** Correct headings and units shown. Mass of crucible (+ lid) (Use of lid must be consistent) Mass of crucible (+ lid) + FA 3 Mass of crucible (+ lid) + residue / contents after heating Mass of FA 3 (used) Mass of residue	1
	II All balance readings to same dp **and** recorded mass QCO_3 between 1.30 g and 1.50 g AND Mass QCO_3 and residue correctly calculated	1
	Award **III** and **IV** if δ ⩽ 0.10	1
	Award **IV** if δ ⩽ 0.20 Do not allow any Q marks if mass of residue ⩾ mass of FA 3.	1
2(b)(i)	Correctly calculates moles = candidate's mass lost / 44 **and** answer to 2 – 4 sf	1
2(b)(ii)	Correct use of $M_r = \dfrac{\textit{candidate's mass of } QCO_3}{\textbf{(b)(i)}}$	1
	Use of 60	1
	Use of 3 – 4 sf for *Mr* and correct A_r If no subtraction at step 2 then step 3 cannot be awarded. Identification of Q as Group 2 metal with nearest A_r Do not allow ecf if no evidence to support conclusion.	1
	Be ⩽ 16.65; 16.65 ⩽ Mg ⩽ 32.10; 32.10 ⩽ Ca ⩽ 63.85; 63.85 ⩽ Sr ⩽ 112.45; 112.45 ⩽ Ba	1
2(c)	So that water vapour / carbon dioxide (from air) not absorbed.	1

2(d)(i)	Heat to constant mass.	1
2(d)(ii)	Add an acid **and** it will fizz / bubble / effervesce **or** Add named acid **and** pass gas through limewater which turns milky / cloudy white / chalky / forms white ppt	1
2(e)(i)	(Mass lost too low →) **moles CO_2 too low** (→ moles QCO_3 (or residue) too low → **M_r** too high →) **A_r too high**	1
2(e)(ii)	Method is valid since 1 mol QCO_3 gives 1 mol QO. **OR** moles QO : CO_2 = 1 : 1	1

Q# 69/ GRAVIMETRIC (THERMAL DECOMPOSITION) EXPERIMENT ALvl Chemistry/2019/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** Tabulates / clearly lays out all data	1
	II Appropriate headings and units for all items listed in the table • mass (empty) crucible (+ lid) • mass crucible (+ lid) + **FA 3** / contents before heating • mass crucible (+ lid) + contents after heating / residue • mass **FA 3** • mass of residue • mass loss Units: / g, (g), in grams. *Use of lid must be consistent.*	1
	III All recorded weighings to the same number of dp and all subtractions listed are correct (minimum 1)	1
	Examiner checks subtractions then calculates and records the difference between the supervisor's and candidate's mass ratio: mass **FA 3** ÷ mass loss (all to 2 dp)	
	IV Award **IV** if δ ⩽ ±0.80	1
	V Award **V** if δ ⩽ ±0.60	1
	VI Award **VI** if δ ⩽ ±0.40 *(Supervisor > 10.00, tolerances are 1.20, 0.90, 0.60; Supervisor > 20.00, tolerances are 2.00, 1.50, 1.00)*	1
2(b)(i)	Correctly calculates: mass $CuCO_3$ from mass of **FA 3** in **(a)** $= \dfrac{60.0 \times \text{mass FA3}}{100}$ **AND** Correctly uses moles $CuCO_3$ = answer/123.5	1
2(b)(ii)	Correctly calculates: $\dfrac{\text{mass residue}}{79.5}$ from mass of residue in **(a)**	1
2(b)(iii)	Correctly uses: **(iii)** = **(ii)** – **(i)**	1
2(b)(iv)	Correctly uses: mass CO_2 = n($CuCO_3$) × 44	1
2(b)(v)	Correctly uses: mass H_2O = **(iii)** × 18	1
2(b)(vi)	mass loss in **(a)** – **[(iv) + (v)]** / comparison of values **AND** appropriate comment on presence / absence of water	1
2(c)(i)	prevents absorption of water (vapour) from atmosphere	1
2(c)(ii)	heat to constant mass / heat for longer to ensure all CO_2 and H_2O driven off OR increase the mass (of **FA 3**) (to reduce % error)	1
2(c)(iii)	add (named) acid **AND** fizz / effervescence / bubbling / gas gives white ppt with limewater (means student correct) OR no fizz indicates all $CuCO_3$ decomposed OR reheat residue **AND** pass any gas through limewater which turns milky (means student correct) OR limewater does not turn milky indicates all $CuCO_3$ decomposed	1

Q# 70/ GRAVIMETRIC (THERMAL DECOMPOSITION) EXPERIMENT ALvl Chemistry/2017/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I** **(i)** (Goes) yellow **(ii)** (On cooling, becomes) white solid / residue / powder	1

	II:Table of data Appropriate headings: Mass of crucible and lid Mass of crucible, lid and **FA 5** (or "contents before heating") Mass of crucible, lid and residue / ZnO / contents after heating Mass of **FA 5** used Mass of residue	1
	III: Weighings shown in list / table Six weighings all recorded in the space provided All weighings recorded to same number of decimal places (one or more)	1
	IV: Both masses of FA 5 and residue, correctly subtracted • Masses of **FA 5** used recorded on pages 4 and 5, correctly subtracted • Masses of **FA 5** used were between 2.1 – 2.5 and 1.5 – 1.9 g • Masses of residue recorded on page 5, correctly subtracted	1
	Examiners check and correct (if necessary) the masses of **FA 5** used and masses of ZnO obtained by the supervisor and by the candidate for both experiments. Examiners calculate the ratio $\frac{\text{mass of FA 5}}{\text{mass of ZnO}}$ for the supervisor and candidate for each experiment to 2 dp and take the average of the two to 2 dp. Examiner calculates δ the difference between these two ratios. **Award V** if δ for Expt 1 $\leqslant$ 0.10 **Award VI** if δ for Expt 2 $\leqslant$ 0.10	2
2(b)(i)	$M_r = 99.4$	1
2(b)(ii)	$M_r = 125.4 + 99.4y$	1
2(b)(iii)	No of moles $= \frac{\text{mass of FA 5 (expt 1)}}{\text{ans (ii)}}$	1
2(b)(iv)	No of moles ZnO = (1 + y) × answer **(iii)**	1
2(b)(v)	**Correctly calculates moles of ZnO** • No of moles ZnO $= \frac{\text{mass of residue}}{81.4}$ • Answer must be expressed to 2 or more significant figures	1
2(b)(vi)	Use of **(iv)** = **(v)** with working shown **and** an answer to 1 dp	1
2(c)(i)	Heat (crucible and residue) to constant mass **or cool** in a desiccator	1
2(c)(ii)	Experiment 1 because (larger masses) have lower percentage error (in weighing).	1

Q# 71/ GRAVIMETRIC (THERMAL DECOMPOSITION) EXPERIMENT ALvl Chemistry/2017/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I: Table of data**, to include: • Unit "covering" all weighings, or given for each weighing • No repeat headings *(i.e. not two lists of weighings)* • Appropriate headings for the three weighings: Mass of crucible and lid Mass of crucible, lid and **FA 5** (or "contents before heating") Mass of crucible, lid and residue / CuO / contents after heating	1
	II: Weighings recorded • Six weighings recorded in the space provided. • All weighings recorded to same number of decimal places (one or more) • Label/heading to indicate which is Expt 1 and Expt 2	1
	III: Both masses of FA 5 and residue, correctly subtracted • Masses of **FA 5** used recorded on page 4, correctly subtracted • Masses of **FA 5** used were between 2.5 – 3.0 g and 1.5 – 2.0 g • Masses of residue recorded on page 4, correctly subtracted	1
	For assessment of accuracy, examiner must check and correct (if necessary) the masses of **FA 5** used and of CuO obtained by the supervisor and by the candidate for Experiment 1. • Examiner works out the ratio $^{\text{mass of FA5}}/_{\text{mass of CuO}}$ for the supervisor (2 dp) • Examiner works out the ratio (mass **FA** 5: mass CuO) for the candidate (2 dp) • Examiner calculates δ the difference between these two ratios. **Award IV and V if δ $\leqslant$ 0.08** **Award IV if 0.08 < δ $\leqslant$ 0.15**	2
	VI: Observations made during heating Solid goes black / black residue (formed) or reference to blue/green flame	1
2(b)(i)	• No of moles CuO = $^{\text{mass of residue}}/_{79.5}$ • Answer must be correct and expressed to 3 or 4 sig fig	1

2(b)(ii)	• No of moles of FA 5 = $^{\text{answer (i)}}/_2$ • $M_r = {}^{\text{mass of FA 5 used}}/_{\text{no of moles of FA 5}}$	1
2(b)(iii)	$M_r = {}^{\text{mass of FA5 used in Expt 2} \times 79.5 \times 2}/_{\text{mass of residue (CuO)}}$	1
2(b)(iv)	M_r of FA 5 calculated from A_r values = 239	1
2(b)(v)	Candidate should • correctly calculate the 2.5% of M_r in (iv) = 5.98 / 6.0, **and** • make a correct statement about the accuracy of the accepted formula, based on their result(s). or correctly calculate % difference for their result(s) from M_r in **(iv)** and correct comment	1
2(c)(i)	• heat (crucible and residue) to constant mass • heat more gently for longer period • cool in a desiccator	1
	• to ensure that decomposition (of FA 5) is complete or to ensure that <u>all</u> the residue is CuO • to prevent escape of dust / smoke / solid (during heating)	1
2(c)(ii)	Larger masses have lower <u>percentage</u> error in weighing	1
	Total:	**14**

Q# 72/ GRAVIMETRIC (THERMAL DECOMPOSITION) EXPERIMENT ALvl Chemistry/2010/w/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

2 (a)	PDO Layout	I	Records at least **four** different balance readings and at least one mass of solid/gas *Accept 0.0(0X) g as the mass of the empty tube or a statement that the tube is tared.*	1
	PDO Recording	II	Gives all appropriate headings and units when recording results. *Do **not** accept mass of empty tube as 0.0(00)g here unless tube is described as tared.* *(minimum of three pieces of information)*	1
		III	All recorded balance readings consistent to at least 1 decimal place. *(minimum of **three** balance readings)*	1
	MMO Decisions	IV	Evidence of reheating to "constant" mass. For balances reading to 1 d.p. two masses must be identical For 2 or 3 d.p.balances, two masses must be within 0.05 g	1
	MMO Quality	V and VI	Check and correct all subtractions in the results table. Calculate $^{\text{mass heated}}/_{\text{mass of residue}}$ to 3 significant figures. Compare to **Supervisor standard or standard value of 1.45**. Award <u>**V and VI**</u> for a difference up to 0.15 Award <u>**V only**</u> for a difference of 0.15+ to 0.30 *Where a candidate repeats the experiment use cumulative masses of **FA 3** and residue.* *Where masses of **FA 3** and residue cannot be checked, accept candidate values to calculate the ratio.*	2
				[6]

(b)	ACE Interpretation	Evaluates cand mass loss from (a) / cand mass of **FA 3** correct to 2–4 significant figures. *Where mass loss or mass of* **FA 3** *is not given in* **(a)**, *check, from balance readings, the values.* *A candidate who incorrectly describes the mass of the residue as the mass loss in tabulated results in* **(a)** *may "correct" the error and use the correct mass loss here.*	1	[1]
(c)	ACE Conclusions	Uses M_r (values) of CO_2 or H_2O to justify how the ratio of $CuCO_3$ to $Cu(OH)_2$ affects the mass loss. If % loss is too high – more $CuCO_3$ If % loss is too low – more $Cu(OH)_2$	1	[1]
(d)	ACE Improvements	Draws apparatus showing the collection of carbon dioxide in a syringe or in a burette or measuring cylinder inverted over water. *Allow use of an inverted tube if graduations are shown or it is suitably labelled.* *All apparatus should be recognisable from the drawing or appropriately labelled.*	1	
		Shows, in the diagram, an effective method of removing water vapour. *Named reagent; e.g. (concentrated H_2SO_4, $CaCl_2$, silica gel, (CaO), anhydrous $CuSO_4$.* **or** *stated purpose of an un-named reagent given.* *Allow also a suitable reflux arrangement, returning water to the heated tube.* ***or*** *a* ***statement*** *that water vapour condenses in a water bath. Do* ***not*** *accept a diagram showing the gas bubbling through water without some written indication that the water is a condenser.*	1	[2]
				[Total: 10]

Q# 73/ Gravimetric (water of crystallisation) experiment ALvl Chemistry/2021/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	**I Appearance** **FA 4**: white / colourless and crystals /solid **AND** obs during heating: swelling / steam / (some) solid melts / dissolves / white powder forms around the edges *Allow evaporation of water* *Allow bubbling / bubbles of water* *Ignore fizzing / effervescence*	1
	II Unambiguous headings and units in list / table of data: • (Mass of) crucible and lid *(not 'weight' in any reading)* • (Mass of) crucible, lid and **FA 4** (or 'contents before heating') • (Mass of) crucible, lid and residue / contents after heating • (Mass of) **FA 4** (used) • (Mass of) residue • (Mass of) water (lost) *Ignore mention of 1st heating if reheated* *Do not allow 'mass of* ***FA 4*** *after heating' in third weighing.* *Use of lid must be consistent.* *Unit must be given correctly in each case.*	1
	III Three weighings recorded and all listed subtractions (minimum one) correct • All weighings to the same number of dp • Mass of **FA 4** used between 2.40 and 2.60 g *If 4 weighings shown then all must be to the same number of dp*	1
	IV Accuracy mark Award if ratio between 1.80–2.10	1

2(b)(i)	**Correctly calculates** $n(H_2O)$ = mass loss in (a) / 18 and answer to 2 or more sf **AND** n(MZ) = mass of residue in (a) / 120.4 and answer to 2 or more sf *If masses are not shown in* ***(a)*** *then values used must be correct*	1
2(b)(ii)	**Shows use of** ratio n(MZ) : $n(H_2O)$ **AND** *y* is an integer *Other correct methods are available.*	1
2(b)(iii)	**One of the following** • All water (of crystallisation) was lost / dehydration was complete • No MZ decomposed on heating	1
2(c)	**One of the following** • student incorrect and because there was no spitting (and therefore lid not required) • student correct and to catch any spitting (check observations for spitting or swelling) • student incorrect and because putting the lid on makes no difference to water (vapour) escaping	1

Q# 74/ GRAVIMETRIC (WATER OF CRYSTALISATION) EXPERIMENT ALvl Chemistry/2013/w/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

2 (a)	MMO Collection	I	The masses of **FA 5** used by the candidate were between 2.0–2.4 g (expt 1) and 1.5–1.9 g (expt 2).	1	
	PDO Display	II	Suitable headings for a table or list, shown completely for at least one experiment carried out. If 2 experiments, all headings must be correct. • (mass of) empty crucible • (mass of) crucible + **FA 5** • (mass of) crucible + residue / **FA 5** after heating • (mass of) residue *(owtte)* • mass lost **or** (mass of) water lost. **and** unit was given "covering" every weighing; *Unit: /g* ***or*** *(g)* ***or*** *in grams* ***or*** *g following* ***each*** *weighing*	1	
	PDO Recording	III	Records **all** weighings **consistently** to at least 1 dp. *A minimum of* ***three*** *weighings are needed.*	1	
	Accuracy (Q) marks for gravimetric experiment – 3 marks available Examiner checks working for mass of residue **and** mass of water and expresses the ratio $^{\text{mass of hydrated solid}}/_{\text{mass of water}}$ to 2 dp for **each** experiment. The expected ratio = $^{244}/_{36}$ = 6.78.				

(a) (cont)	MMO Quality	Award **IV** if the ratio in expt **1** is between 6.30 and 7.25. Award **V** If the ratio in expt **2** is between 6.30 and 7.25. Award **VI** If the ratio in **both** of experiments **1** and **2** is between 5.90 and 7.65, inclusive.	1 1 1	[6]
(b) (i)	MMO Display	Correct expression for the number of moles of water lost (from mass as recorded) **or** correct answer.	1	

(ii)	ACE Interpretation	Correct expression for the number of moles of residue with **correct** masses of anhydrous salt **and** 208 **and** answer expressed to 2–4 sf **or** correct answer **and** 2–4 sf If only **one** expt carried out then **correct calculation** for number of moles of residue expressed to 2–4 sig fig.	1	
(iii)	ACE Interpretation	Correct calculation of **(i)** ÷ **(ii)** to give answer as an integer. (should be **x** = 2)	1	[3]
(c) (i)	ACE Improvements	Heat to constant **mass** (owtte)	1	
(ii)	ACE Interpretation	An **attempt** to "**scale**" mass loss to the mass of **FA 5** used **or** to calculate **x** separately for the two experiments.	1	
	ACE Conclusion	Uses calculated values to comment sensibly on the consistency the results.	1	[3]
				[Total: 12]

Q# 75/ Gravimetric (mass of gas lost) experiment ALvl Chemistry/2016/s/TZ 1/Paper 3/Q# :o)
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1 (a)	**I** Six identifiable masses recorded	1	
	II All recorded masses have unambiguous headings **and** unit: /g **or** (g) **or** g (for each heading) by each entry.	1	
	III Four measured masses all recorded to the same number of decimal places *minimum 1 decimal place*	1	
	IV Correctly calculates mass of **FA1** added **and** mass of CO_2 evolved.	1	
	V, VI and **VII** Examiner compares corrected mass of **FA1**/corrected mass of CO_2 with supervisor value. Accuracy marks are awarded as shown. Award **V**, **VI** and **VII** if $\delta \leqslant 0.10$ Award **V** and **VI** if $0.10 < \delta \leqslant 0.20$ Award **V** if $0.20 < \delta \leqslant 0.40$	3	[7]
(b) (i)	**I** Correctly calculates n(CO_2) (mass CO_2/44)	1	
(ii)	**II** Correct equation **and** all state symbols $XCO_3(s) + 2HCl(aq) \rightarrow XCl_2(aq) + H_2O(l) + CO_2(g)$	1	
(iii) (iv)	**III** **(iii)** = **(i)** **and** Expression mass of **FA1**/**(iii)** shown in **(iv)**	1	

(iv)	**IV** Correctly uses 60 and the M_r to calculate A_r of **X** (mass of **FA1**/**(iii)** – 60)	1	
	V Identifies **X** as Group 2 metal or ion with nearest A_r value (must have some working for A_r used). Be 9.0, Mg 24.3, Ca 40.1, Sr 87.6, Ba 137.3	1	[5]
(c) (i)	Apparently more moles of CO_2 (lost) so A_r of **X** is smaller. **or** Apparently more moles of XCO_3 (used) so A_r of **X** is smaller.	1	
(ii)	Any 2 from: • Small loss in mass • not much difference to A_r so does not cause confusion in identity/still closest to identity of **X**	1	
(iii)	Any 1 from • Add slowly/add a little at a time • Use a taller beaker (accept larger beaker)/use a conical flask • Use less solid • Use less concentrated acid • Use lumps of solid • Use cotton wool plug • Use a lower temperature	1	[3]
Question 1			**[15]**

Q# 76/ Rate (thiosulfate and acid) experiment ALvl Chemistry/2020/w/TZ 1/Paper 3/Q# :o)
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2(a)	I Appropriate headings and units for data given. • volume of FA 5 • volume of water • time • rate Volumes in cm^3 or / cm^3 or (cm^3). Time in seconds or / s or (s), rate in s^{-1} or (s^{-1}). Ignore 1000. Allow ecf for display of units if penalised in **1(a)**.	1
	II Both times recorded to the nearest second.	1
	Examiner corrects times to the nearest second. Examiner calculates ratio: $\frac{\text{time for experiment 2}}{\text{time for experiment 1}}$ to 1 dp.	
	III Award if this ratio is between 1.9 and 2.1.	1
	IV Both rates correctly calculated using $\frac{1000}{\text{time}}$ and recorded to a minimum of 2 sf.	1
2(b)	Agree because ratio is almost 2. OR Disagree because ratio is not 2. Allow answers in terms of time	1
2(c)	Records volumes of **FA 4**, **FA 5** and water. 3 additional volumes of **FA 5** chosen with intervals not less than 4.0 cm^3 **and** all volumes of **FA 5** $\geqslant$ 24.0 cm^3 and $\leqslant$ 36.0 cm^3	1
	In all 3 additional experiments water is added to make a total volume of **FA 5** + water = 40.0 cm^3 Allow for intervals of less than 4.0 cm^3 for **FA 5**. Allow if **FA 4** omitted. Reject if **FA 4** ≠ 20(.0) cm^3	1

Q# 77/ RATE (THIOSULFATE AND ACID) EXPERIMENT ALvl Chemistry/2018/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

1(a)	I Single table to show temperature of FA 2/reactant(s), time and rate for 5 experiments. (*not all experiments need have been done – minimum 2*)	1
	II Headings unambiguous and units correct – displays: (°C), / s, in s^{-1} (*ignore factor of 1000 in rate unit*)	1
	III All temperatures recorded to .0 or .5, all times as integers. (*minimum 4 experiments carried out*)	1
	IV Selects temperatures in experiments 4 and 5 that are ⩾ 4 °C apart from all others and none above 60 °C. (*Paper states 55 °C but T for Expt 2 may be slightly higher.*)	1
	V Rates correctly calculated to 2–4 sf (*minimum 3 results*)	1
	Award VI if candidate for expt 1 is within 10% of supervisor (*If expts have been renumbered by candidate then compare time for the expt carried out at the lowest temperature.*)	1
	Award VII if **all** times decrease with increasing temperature.	1
	Award VIII if all results give an increasing gradient graph (*Allow if 4 out of the 5 points show an increasing gradient line.*) (*Do not award if no graph drawn or fewer than 5 points plotted.*)	1
1(b)	I Axes labelled (*name or unit*) and linear scales chosen so graph occupies more than half the available length for both axes including 15 °C on *x*-axis and 0 on *y*-axis.	1
	II **All** points recorded (*minimum 4 recorded*) accurately plotted *Any point which should be on a line must be on that line.* *Any point not on a line must be in the correct part of the small square.* *If blobs shown then they must be correctly centred and be less than ½ a small square across.*	1
	III Line of best fit drawn (*smooth curve expected but allow suitable straight line*) *Ignore any obviously anomalous points.*	1
	IV Anomalous points indicated and line extrapolated to 15 °C If no points anomalous then smooth line very close to all points	1
1(c)	Both construction lines at 17.5 °C shown *Allow other clear indication linking 17.5 °C with rate*	1
	Correctly calculates time from rate reading (*ignore sf*) Rate must be correctly read from the graph (to within 0.5 s^{-1} of examiner value) If no construction lines are drawn examiner infers rate and checks rate and time given by candidate. *If construction lines / 'point' drawn in wrong place then allow as ecf (i.e. wrong temp selected)*	1
1(d)	Rate of reaction increases with / is proportional to increase in temperature because it / **graph line** curves upwards / has a positive gradient or **figures** from table. Directly proportional is CON	1
	Rate of rate of reaction increases because gradient increases with temperature / rate of reaction increases more / at a greater rate than increase in temperature as gradient increases (or from relevant figures from graph or results table)	1
1(e)(i)	Correctly calculates initial concentration of thio to 2–4 sf. (*Penalise incorrect sf only once in this section.*) $^{18.1}/_{248.2}$ = 0.073 / 0.0729 / 0.07293 mol dm^{-3}	1
1(e)(ii)	Correctly calculates concentration of acid in the mixture to 2–4 sf 0.05 □ $^{2}/_{3}$ = 0.033(3) mol dm^{-3}	1
1(e)(iii)	Shows working to compare concentration of thio in mixture with **(ii)** or moles of thio and of acid in mixture [conc of thio in mixture = 0.073 □ $^{1}/_{3}$ = 0.024(31) mol dm^{-3}] or [moles of thio (in 10 cm^3) = (7.3 / 7.29 / 7.293) □ 10^{-4} mol and moles of acid (in 20 cm^3) = 1(.000) □ 10^{-3} mol]	1
	Comparison using equation moles thio : acid = 1 : 2 ($^{thio}/_{acid}$ = 0.5) and thio / FA 1 in excess [concentration of $^{thio}/_{acid}$ in mixture = $^{0.024}/_{0.033}$ > 0.5 This may be shown as thio : acid = 0.0243 > 0.0167 or 0.0486 > 0.033] or [moles of $^{thio}/_{acid}$ in mixture = $^{0.00073}/_{0.001}$ > 0.5 This may be shown as thio : acid = 0.00146 > 0.001] *Allow ecf from* ***(ii)*** (7.29 □ 10^{-2} □ $^{2}/_{3}$ > 3.33 □ 10^{-2} and FA 1 / thio in excess gains both marks)	1
1(f)(i)	Correct working shown or correct answer to minimum 2 sf ($^{0.5}/_{\text{time for expt 2}}$) □ 100 *If '□ 100' not in working allow if answer shows its use.* (*t_2 must match the time recorded for the expt labelled 2 in the results table*)	1
1(f)(ii)	It is more difficult to distinguish exactly when the printing disappears at the lower temperature (in expt 1) *ora*	1

1(g)	One of Take the temperature on initial mixing and the temperature as soon as the printed sheet is obscured (and calculate a mean T). Take the temperature of FA 1 / both solutions (and calculate (weighted) mean) Use a thermostatically controlled water bath (to prevent temperature fluctuations)	1
	One of Use (graduated) pipette / burette / measuring cylinders calibrated to greater precision / smaller percentage error to measure volumes. Use (graduated) pipette / burette to measure FA 1 / thio and FA 2 / acid / (volumes of) solutions / reactants (instead of the measuring cylinders) Use light sensor/colorimeter (to avoid subjective judgement of turbidity) (*Do not allow use a more accurate thermometer*)	1

Q# 78/ RATE (THIOSULFATE AND ACID) EXPERIMENT ALvl Chemistry/2015/w/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

2 (a)	**I** Table for readings, headings **and** correct units: Headings: • volume of **FA 5** / acid • (volume of water – *if included must be correct*) • Time *Units allow Vol or / cm^3 etc.*	1	
	II Three reaction times all recorded to **nearest second**	1	

	III and **IV**
	Examiner to calculate the time differences between Expt 1 and Expt 2 ($t_2 - t_1$).
	Then calculate 10% of the time for Expt 1 to 1dp (*x*).
	If ($t_2 - t_1$).> x award **III**.
	Examiner to calculate the time differences between Expt 2 and Expt 3 ($t_3 - t_2$).
	Then calculate 20% of the time for Expt 2 to 1dp (*y*).
	If ($t_3 - t_2$).> y award **IV**.
		2	[4]

(b) (i)	• Rates correctly calculated • All answers expressed to same sig fig (but not 1 sf) • Unit given.... / s^{-1} or (s^{-1})	1	
(ii)	Correctly calculates • Expt 1, conc = 0.08571 (or 0.0857 or 0.086) mol dm^{-3} **and** • Expt 3, conc = 0.02857 (or 0.0286 or 0.029) mol dm^{-3} *Both answers must be given to 2, 3 or 4 sig figs*	1	
(iii)	Rate increases with (increase of) concentration	1	
(iv)	• Time is shorter for sulfuric acid • Sulfuric acid has a greater / doubled **concentration** of H^+ ions.	1	
(v)	• time (for reaction) will be greater • less depth (of solution) in the 250 cm^3	1	[5]
Qn 2			**[Total: 9]**

1	(a)	PDO Recording	**I** All columns correctly headed and correct units given for all columns except for rate/(1000/time) e.g. /s, (s), time in s, time in seconds.	1	
			II Records **all** times to the nearest second. Allow for only 5 expts carried out.	1	
		MMO Decisions	**III** Additional experiment (experiment 6) uses volume of **FA 1** $\geqslant$ 3 cm^3 of any other, and adds water to make 50 cm^3. Other volumes are those specified.	1	
		PDO Display	**IV** Candidate gives **all** values of (1000/time) to 3 sig fig – ignore calculation or rounding errors (minimum of 4 expts carried out).	1	
		ACE Interpretation	**V** **All** values of (1000/time) **correctly** calculated to sig fig shown by candidate (minimum of 4 expts carried out).	1	
		MMO Quality	**VI** and **VII** Experiments 2 and 4: calculate $100(2t_2 - t_4)/t_4 \leqslant 20\%$ for 1 mark; $\leqslant$ 10% for 2 marks. **VIII** and **IX** Experiments 3 and 5: calculate $100(3t_3 - t_5)/t_5 \leqslant 30\%$ for 1 mark; $\leqslant$ 10% for 2 marks. **X** and **XI** Experiments 4 and 5: calculate $100(2t_4 - t_5)/t_5 \leqslant 30\%$ for 1 mark; $\leqslant$ 10% for 2 marks. If the candidate has not completed the 5th experiment, marks **VI** and **VII** are available. Also check Experiments 1 and 2: t_2 should equal to $t_1 \times 5/4$. Use the 10% and 20% boundaries. If only the first three experiments are completed, award Q marks based on Experiments 1 and 2 (as above). *(If 50, 45, 40, 35, marks **X** and **XI** not available. Use 40 and 20 if there + 'rescue' pair as above.)* The Examiner is to round all reaction times to the nearest second before awarding accuracy marks. (*Volumes **FA 1**/expt no as specified in Qn)*	6	[11]

(b)	PDO Layout	**I** Plots rate or (1000/time) on *y*-axis and volume of **FA 1**/**FA 1** cm^3 on *x*-axis. Axes correctly labelled.	1	
		II Uniform scales selected. Each scale starts at zero and highest point plotted on each axis has used more than half of the available grid.	1	
		III and **IV** Examiner to check all plotted points. Points must be correct to ½ small square and in correct small square.		
		Award <u>III and IV</u> for correct points for all experiments carried out (minimum 5). Award <u>III only</u> if one mistake made. (If only four expts carried out then all 4 correct.)	2	
		V Draws a "best-fit" straight line – one that passes close to the majority of points and points are balanced. The line does not have to pass through the origin. (Allow curve if appropriate.)	1	[5]
(c)	ACE Conclusions	Depth (of solution) is greater,	1	
		... so time is shorter/less//<u>time</u> is faster//fewer seconds (*time is conditional on depth*)	1	
		or solution/liquid depth unchanged so reaction time unchanged for 1 mark.		[2]
(d)	ACE Interpretation	Give **one mark** for a concentration of 0.021/0.0214/0.02143 mol dm^{-3} for expt 5.	1	
	PDO Display	Working shown must include correct use of 70.	1	[2]
(e)	ACE Interpretation	Two pieces of evidence with no conclusion **or** one piece and conclusion.	1	
		2nd piece of evidence **and** conclusion.	1	
		Evidence for 'correct' **(i)** a straight line/(line with) constant gradient **(ii)** straight line passes through origin (if appropriate from results) is 2 pieces of evidence **(iii)** line passes through origin = 1 **if** line drawn is straight **Evidence for 'incorrect'** **(i)** a curve has been drawn/no straight line/not constant gradient **(ii)** straight line does not pass through the origin **(iii)** points too scattered/not on best fit line **(iv)** a curve drawn but expect straight line = 2 *A straight line, not passing through the origin could score both marks depending on explanation given (proportional but not directly proportional).* *If two points are compared they must be on or very close to the graph line.*		[2]

(f)	ACE Interpretation	Candidate correctly evaluates each % uncertainty.	1	[1]
(g)	ACE Improvement/s	Constant volume of **FA 1**. Varies volume of **FA 2** and water correspondingly (Volume **FA 2** + H_2O same).	1 1	[2]
		Total	**25**	

Q# 80/ RATE (THIOSULFATE AND ACID) EXPERIMENT ALvl Chemistry/2009/s/TZ 1/ Paper 3/Q# 2/ :o)

Supervisor's Report

From the Supervisor's experimental results **round times to the nearest second** and calculate the average of (volume of sodium thiosulfate x time) for 50 cm^3 and for 25 cm^3 of sodium thiosulfate.

Candidate's scripts

From the candidate's experimental results **round times to the nearest second** and calculate (volume of sodium thiosulfate x time) as above.

Record values of (V x t) on script and use in assessing accuracy marks.

Question	Sections	Indicative material	Mark	
2 (a)	PDO Layout	**(i)** Tabulates all experimental readings: volumes of sodium thiosulfate and water, time and rate ($^1/_t$)	1	
	PDO Recording	**(ii)** Single table covering all three experiments *A single table has no repetition of column headings.*	1	
		(iii) Table has correct labels and units: e.g. /cm^3, /cubic centimetres, **or** (cm^3), (cubic centimetres) **or** volume in cubic centimetres; **Similarly** for time (s or seconds but **not** sec) **and** rate (s^{-1}, rate (in) per second; $^1/_s$ etc.) **At least two different units are required.** *Where units have not been included in the column or row header there should be the appropriate unit for <u>each entry</u> in the table.*	1	
	MMO Collection	**(iv)** All times of reaction are recorded to the nearest second (**no** decimal places).	1	
	MMO Quality	**(v) and (vi)** Give **(v) and (vi)** if difference between candidate's (V x t) values (**50 & 25 cm^3 FA 1**), is within 5% of the larger value. *Give **(vi) only** if the difference is > 5% but ≤10% of the larger value.*	2	
		(vii) and (viii) Compare the closer of the candidate's (V x t) values with the Supervisor's average Vt. Give **(vii) and (viii)** if difference is within 10% of the <u>Supervisor's value</u>. *Give **(viii) only** if the difference is > 10% but ≤20% of the <u>Supervisor's value</u>.*	2	
	MMO Decisions	**(ix)** Selects (10–15) **or** (35–40) cm^3 sodium thiosulfate and an appropriate volume of water to give a total volume of 50 cm^3 (or 55 cm^3 if the volume of acid is tabulated).	1	[9]

(b)	ACE Interpretation	Candidate shows by calculation or by mathematical expression that $[Na_2S_2O_3] \propto$ volume of $Na_2S_2O_3(aq)$ in 50/55 cm^3 of solution. *Reference to ($^{50}/_{50}$ or $^{50}/_{55}$) and ($^{25}/_{50}$ or $^{25}/_{55}$)*	1	[1]
(c)	ACE Conclusions	Explains that rate is given by the inverse of time **or** is inversely proportional to time; **or** Rate $\propto$ $^1/_{time}$ *Allow Rate = $^1/_{time}$*	1	[1]
(d)	ACE Interpretation	(i) **Correctly** evaluates all Vt values (using times given by candidate, including decimal places where appropriate – *or* (ii) gives an appropriate qualitative statement relating (rate or time) and concentration. *Award this mark if **either** is correct.*	1	
	ACE Conclusions	Gives a quantitative description of relationship. *Vt values are required but do not have to be correctly evaluated.* *Where no pattern is obvious accept an appropriate statement to that effect.*	1	[2]
(e)	ACE Improvements	Explains that volumes of reactants or concentration (of thiosulfate and acid) must be kept constant **and** describes <u>how</u> the temperature will be varied.	1	[1]
				[Total: 14]

Q# 81/ Rate (thiosulfate and iodine) experiment ALvl Chemistry/2014/s/TZ 1/ Paper 3/Q# 2/ :o)

2 (a)	PDO Recording	**I** Table to include • volume of hydrogen peroxide/**FA 2**, • volume of potassium iodide/**FA 4**, • volume of distilled water, • reaction time. volume/V in cm^3//cm^3/ (cm^3), time/t in seconds//s/(s). (Minimum 2 expts recorded)	1	
		II All times recorded to the nearest second. (Minimum 2 expts)	1	
	ACE Interpretation	**III** Correctly calculates all three rates (allow to 2 or 3 sf) Compare times for Expts 1 and 3 with those of the Supervisor.	1	
	MMO Quality	Award **IV**, **V** and **VI** for both times within 3 s Award **IV** and **V** for one within 3 s and one within 6 s Award **IV** only for either within 6 s (If only 2 expts carried out **IV** is available – from either expt performed)	3	[6]
(b)	ACE Conclusion	Rate increases with increasing concentration of hydrogen peroxide and potassium iodide (ora). Allow ecf from candidate's results.	1	[1]
(c)	MMO Decisions	Selects different volumes of **FA 4** (less than 20 cm^3, not 10 cm^3 and not closer than 2 cm^3 to suggested volumes or to 20 cm^3 or to 10 cm^3) Volumes of distilled water selected so that vol of water + vol of **FA 4** = 20 cm^3 **and FA 2** = 20 cm^3 If **FA 3** and **FA 5** are shown then the volumes must be constant.	1 1	[2]

2 (a)	PDO Recording	**I** Table to include • volume of hydrogen peroxide/**FA 2**, • volume of potassium iodide/**FA 4**, • volume of distilled water, • reaction time. volume/V in cm^3//cm^3/ (cm^3), time/t in seconds//s/(s). (Minimum 2 expts recorded)	1	
		II All times recorded to the nearest second. (Minimum 2 expts)	1	
	ACE Interpretation	**III** Correctly calculates all three rates (allow to 2 or 3 sf)	1	
		Compare times for Expts 1 and 3 with those of the Supervisor.		
	MMO Quality	Award **IV**, **V** and **VI** for both times within 3 s Award **IV** and **V** for one within 3 s and one within 6 s Award **IV** only for either within 6 s (If only 2 expts carried out **IV** is available – from either expt performed)	3	[6]
(b)	ACE Conclusion	Rate increases with increasing concentration of hydrogen peroxide and potassium iodide (ora). Allow ecf from candidate's results.	1	[1]
(c)	MMO Decisions	Selects different volumes of **FA 4** (less than $20\,cm^3$, not $10\,cm^3$ and not closer than $2\,cm^3$ to suggested volumes or to $20\,cm^3$ or to $10\,cm^3$)	1	
		Volumes of distilled water selected so that vol of water + vol of **FA 4** = $20\,cm^3$ **and FA 2** = $20\,cm^3$ If **FA 3** and **FA 5** are shown then the volumes must be constant.	1	[2]
(d)	ACE Improvements	Reason: change of temperature Use water bath to maintain constant temperature	1	
		Reason: decomposition of hydrogen peroxide Store $H_2O_2(aq)$ in the fridge, make up fresh $H_2O_2(aq)$, check conc. of $H_2O_2(aq)$, keep $H_2O_2(aq)$ in dark/dim light.	1	[2]
(e) (i)	ACE Interpretation	Expression $\frac{1}{\text{time from Expt 1}} \times 100$ **or** correct value.	1	
(ii)		(Higher conc. of thiosulfate means) greater reaction time (allow reaction will be slower) **and** so a smaller percentage error.	1	[2]
Qn 2	**Total**		**[13]**	

Q# 82/ RATE (THIOSULFATE AND IODINE) EXPERIMENT ALvl Chemistry/2012/s/TZ 1/ Paper 3/Q# 1/

1 (a)	PDO layout	**I** Constructs a table for results	1	
	PDO recording	**II** Appropriate headings and units for data given. Volume / V in cm^3, / cm^3 or (cm^3) Time/t in seconds, /s or (s)	1	
	PDO recording	**III** All times recorded to the nearest second.	1	
	MMO decision	**IV** 3 additional volumes chosen with intervals not less than $2.00\,cm^3$ and all volumes of **FA 1** greater or equal to $6.00\,cm^3$	1	
	MMO collection	**V** In all 3 additional experiments water is added to make a total of $20.00\,cm^3$	1	
	MMO quality	Round times to nearest second. **VI + VII** Compare time for $20.00\,cm^3$ of **FA 1** with that of supervisor.	2	
		VIII + IX Compare time for $10.00\,cm^3$ of **FA 1** with that of supervisor. The range for award of 1 or 2 depends on the supervisor value. Supervisor value: < or = 15 δ for 2 is 2 and for 1 is 4 16 to 30 δ for 2 is 3 and for 1 is 6 31 to 45 δ for 2 is 4 and for 1 is 8 46 το 60 δ for 2 is 5 and for 1 is 10 > 60 δ for 2 is 6 and for 1 is 12	2	[9]
(b)	PDO display	(i) Working to show ans = 5×10^{-5} mol	1	
	ACE interpretation	(ii) 0.5 x ans to **(b)(i)** = 2.5×10^{-5} mol	1	
	PDO display	(iii) Working to show that: $(2.5 \times 10^{-5}) / 0.050 =$ $(5 \times 10^{-4}\ mol\ dm^{-3})$	1	[3]
(c)	ACE interpretation	Rate correctly calculated using ans **(b)(iii)** / time (or 4.25×10^{-4}). Min 2 s.f. rounded correctly and minimum 4 results.	1	
	PDO recording	Unit for rate given as mol $dm^{-3}s^{-1}$.	1	[2]
(d)	PDO layout	**I** Rate on *y*-axis and volume on *x*-axis. Axes clearly labelled (ignore units)	1	
		II Linear scale chosen to use at least half of each axis (need not include 0, 0) If no point at 0, 0 cannot count for > half.	1	
		III Plotting of points. Minimum of 3 readings.	1	
		IV Draws a line of best fit. Minimum 4 readings including 0, 0 (if plotted).	1	[4]

(e)	ACE conclusion	Rate is proportional to peroxodisulfate **concentration** Rate increases as concentration (volume) increases would score one	2 [2]
(f)	ACE interpretation	(i) correctly calculates (0.5 / time from Expt 1) × 100. Minimum of 2 s.f.	1
		(ii) $\frac{\text{ans (b)(iii)}}{\text{Expt 1 time} + 0.5} \times 10^6$ mol dm^{-3} s^{-1} **or** Rate– (% from **(i)** × rate)	1
		(iii) Any reasonable suggestion e.g. difficult to judge colour change / measurement of volumes / variation in T	1
	ACE improvement	use of colorimeter / burettes for all volumes / (thermostatic) waterbath. Not air conditioning.	1 [4]
(g)	ACE conclusion	(ii) Thiosulfate concentration / number moles / volume is doubled (1) Time is longer/ reaction is slower with more thiosulfate (1)	2 [2]
			[Total: 26]

Q# 83/ Thermometric titration experiments ALvl Chemistry/2022/m/TZ 3/Paper 3/Q# :o)

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1(a)	10 thermometer readings recorded, all to .0 or .5 °C **AND** at least one reading at .0 and one at .5	1
	Examiner calculates supervisor's greatest ΔT (= $T_{max} - T_{initial}$) and writes it ringed on each candidate script. Examiner calculates candidate's ΔT at the same volume then calculates the difference, δ, from the supervisor value.	2
	Award 2 marks if $\delta \leqslant 1.5$ °C for ΔT 10.5–15.0 **Award 1** mark if 1.5 °C < $\delta \leqslant$ 2.0 °C ΔT 10.5–15.0	
1(b)(i)	Temperature on *y*-axis and volume of **FA 2** on the *x*-axis **AND** some numbers for scales **AND** with unambiguous names or units	1
	Linear scales chosen so that the graph occupies more than half the available length for both axes	1
	All points recorded accurately plotted	1
	Two lines of best fit drawn and extrapolated **AND** Lines must give a sharp intersection at a temperature equal to or higher than the highest recorded temperature	1
1(b)(ii)	Correct volume from intersection to 1 or 2 dp	1
1(b)(iii)	Correct expression with answer to 2 – 4 sf Concentration = $\boxed{\frac{25 \times 1.9}{2 \times \textbf{(b)(ii)}}}$	1
1(c)(i)	ΔT = T at intercept – initial T from table OR ΔT = T at intercept – T at intersect on *y*-axis	1
1(c)(ii)	Correctly calculates % error = 4.167, 4.17 or 4.2%	1
1(c)(iii)	One of: • temperature started dropping between additions (of acid)/ heat loss so ΔT low(er) (than it should be) • maximum temperature at intersection is lower (than it should be) as insufficient readings near end point • alkali volume less than 25 cm^3 as measuring cylinder used.	1

2(a)	**I** The following data must be shown: • burette readings and titre for rough titration • 2 × 2 'box' showing both accurate burette readings.	1
	II Headings and units correct for accurate titration table and headings match readings. • initial / start **AND** (burette) reading / volume + unit • final / end **AND** (burette) reading / volume + unit • titre OR volume / **FA 4 AND** used / added + unit	1
	III All accurate burette readings given to the nearest 0.05	1
	IV The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre.	1
	Accuracy marks *Check and correct titre subtractions where necessary. Exclude any titre from the calculation for the mean where final burette reading is greater than 50(.00). Examiner selects the best titres for calculating the mean, using the hierarchy:* *2 identical titres, titres within 0.05 cm^3, titres within 0.10 cm^3 etc.* *Examiner subtracts (corrected) candidate's titre from Supervisor's titre.* *Write and ring Supervisor's value next to the accurate titration table of each candidate, also candidate mean value (calculated by examiner) and δ.*	
	Award **V** if $\delta \leqslant 0.50$ cm^3 Award **VI** if $\delta \leqslant 0.30$ cm^3 Award **VII** if $\delta \leqslant 0.20$ cm^3	3
2(b)	Candidate must average two (or more) titres that are **all** within 0.20 cm^3 **AND** give the answer to 2 dp. **AND** working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
2(c)(i)	All final answers for (c)(ii), (c)(iii), (c)(iv) are to 3–4 sf	1

Q# 84/ Thermometric titration experiments ALvl Chemistry/2013/s/TZ 1/ Paper 3/Q# 1/ :o)
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1 (a)	PDO layout	**I** Constructs a table for results with space for 10 volumes.	1	
	PDO recording	**II** Appropriate headings and units for data given. Volumes in cm^3 or /cm^3 or (cm^3), temperature in °C or /°C or (°C) in table. All volumes to same dp.	1	
	PDO recording	**III** All temperatures recorded to the nearest 0.5 °C both in the table and for T_1. At least one ending in .0 and one in .5.	1	
	MMO quality	**IV + V** Compare temp rise for addition of 25 cm^3 of **FA 2** with the Supervisor value. Award 2 marks for ΔT within ± 1 °C. Award 1 mark for ΔT within ± 2 °C.	2	[5]
(b)	ACE interpretation	Correctly calculates ΔT, V_T and $\Delta T \times V_T$ (assume correct data from **(a)**) (min 8 results)	1	[1]
(c) (i)	PDO layout	**I** $\Delta T \times V_T$ on *y-axis* and volume of **FA 2** on *x-axis*. Axes clearly labelled (ignore units).	1	
		II Uniform scales chosen to use more than half of each axis. Only include 0 if point plotted. Points plotted use 5 large squares vertically and 4 horizontally.	1	
		III All points plotted. Examiner to check points at V = 5, 10, 15, 20 and 25. The points should be within ½ small square and in correct small square. Min 8	1	

(c) (ii)		**IV** Draws both straight lines of best fit.	1	
(c) (iii)	ACE interpretation	Reads correctly the value of **FA 2** from the intercept of the two lines. Answer within 0.5 cm^3. Ignore sf.	1	[5]
(d) (i)		0.0500 mol (Allow 0.050)	1	
(d) (ii)		0.0250 mol (allow 0.025) Allow ecf from **(i)**/2	1	
(d) (iii)		1000 × **(d)(ii)** / **(c)(iii)** (2–4 sf) Allow ecf from **(ii)**. Penalise sf once only.	1	[3]

(e)	ACE improvements	Accuracy of temperature measurement – use a 0 to 50 °C thermometer or a thermometer with smaller scale divisions (not just more accurate/ electronic thermometer/parallax). Uncertainty about where the lines cross – sample more values of **FA 2** in the region of the intersection. Repeat/ extra readings on LHS of intersection/ near maximum. Initial temperatures of acid and alkali not same – measure both. Other answers acceptable if **specific**.	1	[1]
				[Total: 15]

Q# 85/ Thermometric titration experiments ALvl Chemistry/2011/w/TZ 1/ Paper 3/Q# 1/ :o)
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1 (a)	PDO Recording ACE Interpretation MMO Quality	**I** Thermometer readings for all experiments recorded to 0.0 or 0.5°C. (At least one recorded to 0.5°C.) **II** Calculation of all temperature changes correct. Award **III** for a temperature rise followed by constant temperature (within 0.5°C). Award **IV** and **V** for a **maximum** rise within 0.5°C of supervisor. Award **IV** for a **maximum** rise within 1.0°C of supervisor. Award **VI** and **VII** for the experiment **3** temperature rise within 0.5°C of supervisor. Award **VI** for the experiment **3** temperature rise within 1.0°C of supervisor.	1 1 1 1 1 1 1	[7]

(b)	PDO Layout	**I** Axes correct and labelled: temperature change/ T change/ΔT and volume/vol/V (of) sodium hydroxide/NaOH/**FA 1** **and** correct units /°C or (°C) or 'in °C'; /cm^3 or (cm^3) (allow NaOH in cm^3) **II** Scales chosen so that graph occupies at least half the available length for *x*- and *y*-axes. **III** Plotting – all points accurate to within half a small square and in the correct square. **IV** Draws two straight lines of best fit which intersect.	1 1 1 1	[4]
(c)	ACE Interpretation	Reads to nearest ½ square to 1 or 2 dp volume of **FA 1** and temperature rise from intercept. Do **not** award if ΔT at intercept (or point) **<** max ΔT from table unless candidate has clearly indicated the max ΔT is anomalous.	1	[1]

(d)	ACE Conclusions	**I** The temperature/temperature change increases as **more** reaction/more hydrochloric acid/sodium hydroxide reacts/as more water formed. **II** The temperature/temperature change stays constant/decreases when all acid/limiting reagent has reacted/excess NaOH is added.	1 1	[2]
(e)	ACE Interpretation	**I** Volume used in calculation is 65 cm^3 **II** Heat energy change calculated using candidate's value for ΔT correct to 3 or 4 sf	1 1	[2]
(f)	ACE Interpretation	$\frac{25 \times 2}{1000}$ = **0.05**	1	[1]
(g)	ACE Interpretation PDO Display	**I** $\frac{\text{Candidate's answer to (e)}}{\text{Candidate's answer to (f)}}$ **II** Correct calculation, conversion J to kJ and negative sign to 3 or 4 sf	1 1	[2]
(h)	ACE Conclusions	So that rise in temperature is proportional to increase in energy produced/change in volume gives different change in temperature for same energy produced/ increase in volume requires increase in energy for same temperature rise.	1	[1]
(i)	PDO Display ACE Interpretation	**I** Number moles NaOH = number moles HC*l* (stated or clearly shown) **II** Calculates or expression for Concentration = $\frac{\text{0.05 (ecf from (f))}}{\text{answer to (c)/1000}}$ If answer only, award mark if correct to 3 or 4 sf	1 1	[2]
(j)	ACE Improvements	Use more **concentrated** solutions. (allow use **≤ 5** cm^3 water each time) Ignore all references to heat energy losses.	1	[1]
(k)	ACE Conclusions	**I** Two straight intersecting lines (positive followed by zero gradient). **II** Same ΔT and V shown as in **(b)**.	1 1	[2]
				[Total: 25]

Question 1 Round all thermometer readings to the nearest 0.5°C.

Question	Sections	Indicative material	Mark	
1 (a)	PDO Recording	**(i)** Presents data in single table of results – *to include volume of **FA 2**, initial and final temperatures and temperature change.*	1	
		(ii) All columns correctly labelled with appropriate unit shown. *Must use solidus, brackets or describe unit fully in words. If units not included in column headings every entry must have the correct unit shown.*	1	
	MMO Collection	**(iii)** All thermometer readings recorded to 0.5°C	1	
		(iv) Follows instructions – uses 10, 20, 30, 40, 50 cm^3 of **FA 2** + two additional volumes	1	
	MMO Decisions	**(v)** One extra volume of **FA 2** on either side of the maximum for the first five expts. **or** Two extra volumes between identical values for the first five expts. **or** Two extra volumes the same side as the next highest reading.	1	
	MMO Quality	**(vi)** and **(vii)** Check and correct ΔT where necessary. *(If multiple readings for max. T then apply hierarchy: take value of consistent readings; take average and correct to nearest 0.5°C)* Compare temp rise with that obtained by the Supervisor *(Expected value is 14.0°C)* For 30 cm^3 **FA 2**: Award **(vi)** and **(vii)** for a temp rise of 0.0°, 0.5°, 1.0°C *Award (vi) **only** for a difference of 1.5°C*	2	
	MMO Quality	**(viii)** and **(ix)** Check and correct ΔT where necessary. Compare temp rise with that obtained by the Supervisor *(Expected value is 13.5°C)* For 40 cm^3 **FA 2**: Award **(viii)** and **(ix)** for a temp rise of 0.0°, 0.5°, 1.0°C *Award (viii) **only** for a difference of 1.5°C*	2	[9]

Question	Sections	Indicative material	Mark	
(b)	PDO Layout	**(i)** Temperature (rise) plotted on *y-axis* against volume (of **FA 2**) **or FA 2** added /cm^3 on *x-axis*. Clearly labelled axes (ignore units unless T, ΔT or V used as labels)	1	
		(ii) Uniform and sensible scales that allow points to be plotted in at least half of the squares on each axis. (6 × 4 big squares). (0,0) may be considered – as an additional point or with a line going through it	1	
		(iii) Visual check the "sweep" of **all** points, for all experiments recorded. Check the plotting of points for 10, 30 and 50 cm^3 of **FA 2** (and any other "suspect" point) If any point is missing **and** that experiment was not carried out, check adjacent point *Points should be within ½ of a small square, in the correct square* **Do not award if T plotted instead of ΔT**	1	
		(iv) Appropriate lines drawn through the ascending and descending points. *(Ignore any deviation through rounding at the maximum temperature rise)* **Do not award** if both straight lines and curves drawn **or** there is any forced change in gradient.	1	[4]
(c)	ACE Interpretation	Reads from the graph *(to within ½ small square)* the volume of **FA 2** at the **intersection** of two lines. Allow rounding to the closest cm^3 ***Do not award this mark if the lines/curves have been rounded at the maximum ΔT.***	1	[1]
(d)	PDO Layout	Explains that the **temperature rise** is the dependent variable **or** **Volume of FA 2** is the independent variable/one that is controlled/one that you vary *(or words to that effect)*	1	[1]
(e)	ACE Conclusion	Gives correct equation for the reaction *(ignore state symbols)* $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$ **or** $NaOH + H_2SO_4 \rightarrow NaHSO_4 + H_2O$	1	[1]
(f)	PDO Display	Working is shown in **(f)(i)** (involves volumes and concentration, 2.0 mol dm^{-3}) **and** **(f)(ii)** *(any clear mole ratio)*	1	
	ACE Interpretation	Has correct expression for $\frac{10.00}{1000} \times 2.0$ **or** an answer of **0.02(00)** in **(f)(i)** **and 0.04(00)** in **(f)(ii)** *There is no ecf within (f)*	1	[2]
(g)	PDO Display	Expression given in the question paper is **correctly** evaluated to 2 or 3 significant figures. *Allow a volume, read from rounded curves to be used in this expression. Normal rounding rules apply to the sig fig.*	1	[1]
(h)	ACE Interpretation	Uses the expression: (answer from **(c)** + 10) × 4.3 × ΔT read from graph	1	
		Divides the answer above by answer to **(f)(i) and** gives answer in kJ mol^{-1} with –ve sign *Do not award this second mark unless candidate has calculated (a volume of soln × 4.3 × ΔT)*	1	[2]
(i)	ACE Improvements	Advantage of burette: Lower % error **or** more accurately calibrated *(must refer to or infer scale/graduations/markings/divisions)*	1	
		Disadvantage of burette: Takes longer to add the **FA 2**	1	[2]

(j)	ACE Interpretation	Candidate gives **two** of the following as significant sources of error. Heat loss (to the surroundings) Thermometer graduated at 1°C intervals Drying of cup/thermometer Initial temps of both solutions should be taken *Other acceptable sources of error may be seen.*	1	[1]
(k)	ACE Interpretation	(i) Maximum error in reading a 1°C graduated thermometer is given as 0.5°C (iii) Calculates answer in $\frac{\text{answer in } \mathbf{(k)(i)} \times 2}{\text{answer in } \mathbf{(k)(ii)}} \times 100\%$	1 1	[2]
	Total			**[26]**

Q# 87/ Gas collection (carbonate reacting with acid) ALvl Chemistry/2019/s/TZ 1/Paper 3/Q# :o)

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1(a)	Unambiguous recording of volume of gas, 2 balance readings to same dp and correct mass of **FA 2** used. Units as /cm³ or (cm³) and / g or (g).	1
	Volume of gas within range 0.9 – 1.1 × supervisor volume	1
	Volume of gas within range 0.8 – 1.2 × supervisor volume	1
1(b)(i)	Correctly calculates moles = vol of gas / 24 000 AND answer given to 2 – 4 sf	1
1(b)(ii)	Correct use of $M_r = \frac{\textit{mass from (a)}}{\textit{(b)(i)}}$	1
	Use of 60	1
	Correct (from candidate's value of M_r) A_r and correct to 2 to 4 sf Be ⩽ 16.65; 16.65 ⩽ Mg ⩽ 32.10; 32.10 ⩽ Ca ⩽ 63.85; 63.85 ⩽ Sr ⩽ 112.45; 112.45 ⩽ Ba	1
1(b)(iii)	Identification of **M** as Group 2 metal with nearest A_r	1
1(c)(i)	Student not correct as too much gas for measuring cylinder OR Student not correct as the acid is not in excess.	1
1(c)(ii)	Student correct because CO_2 soluble in water / reacts with water.	1

2(a)	I Correct headings and units shown. Mass of crucible (+ lid) (Use of lid must be consistent) Mass of crucible (+ lid) + FA 3 Mass of crucible (+ lid) + residue / contents after heating Mass of FA 3 (used) Mass of residue	1
	II All balance readings to same dp **and** recorded mass QCO_3 between 1.30 g and 1.50 g AND Mass QCO_3 and residue correctly calculated	1
	Award **III** and **IV** if δ ⩽ 0.10	1
	Award IV if δ ⩽ 0.20 Do not allow any Q marks if mass of residue ⩾ mass of FA 3.	1
2(b)(i)	Correctly calculates moles = candidate's mass lost / 44 and answer to 2 – 4 sf	1

Q# 88/ Gas collection (carbonate reacting with acid) ALvl Chemistry/2019/m/TZ 3/Paper 3/Q# :o)

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1(a)	I Clear layout for 4 data items with unambiguous headings and units covering all entries (2 weighings, 1 mass, 1 gas volume)	1
	II Recording of volume of CO_2 (collected) **AND** both weighings **AND** mass of **FA 1** correctly calculated	1
1(b)(i)	All answers to parts (ii) to (v) are given to 2–4 sf	1
1(b)(ii)	Correctly calculates: $\frac{V(a)}{24.0 \times 1000}$ **AND** (ii) = (i)	1
1(b)(iii)	Correctly uses: (iii) = (ii) × 123.5	1
1(b)(iv)	Correctly uses: candidate's mass **FA 1** – (iii)	1
1(b)(v)	Correctly uses: moles $Cu(OH)_2$ = (iv) / 97.5	1
	Correctly uses: ratio (ii) : n($Cu(OH)_2$) = 1 : .... *Allow correctly rounded to nearest integer.*	1
1(c)	Ticks 2nd box (y would increase): lower *T* => smaller volume (of CO_2) => smaller mass / moles / amount of $CuCO_3$ OR lower *T* => more CO_2 dissolves (=> less collected) => smaller mass / moles / amount $CuCO_3$ Ticks 3rd box (y unchanged): lower *T* => molar gas volume will be smaller (compensates for smaller volume)	1
1(d)	some CO_2 dissolves (in water) so: hot water in tub / saturate water with CO_2 initially / collect gas (directly) in gas syringe / use oil / non-polar solvent (in place of water)	1

Q# 89/ Gas collection (carbonate reacting with acid) ALvl Chemistry/2016/w/TZ 1/Paper 3/Q# :o)

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1(a)	I Correct headings and units for mass of **FA 1 and** volume of CO_2 • Mass of container + **FA 1** • Mass of container (+ residue) • Mass of **FA 1** • Volume of gas Allow vol for volume but not V Units needed for **all** readings **II** Both weighings to the same number of dp **and** correct mass of **FA 1** calculated (If initial and final volumes recorded then subtraction for volume collected must be correct.)	1 1	2
1(b)(i) 1(b)(ii) 1(b)(iii)	Correctly calculates $\frac{V(a)}{24.0 \times 1000}$ Correct expression (i) × 100.1 **or** (i) × (40.1 + 12 + (3)16) Must show working Correctly uses $\frac{(ii) \times 100}{\text{mass in (a)}}$ All three answers to 2 to 4 sf	1 1 1 1	4
1(c)	Any of: warm water in tub / saturate water with CO_2 / a specific method of separation of $CaCO_3$ and acid so only mixed after bung inserted / gas syringe	1	1
	Total		7

Q# 90/ Gas collection (Decomposition of H_2O_2) ALvl Chemistry/2017/m/TZ 3/Paper 3/Q# :o)

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1(a)	**M1** unambiguous recording of volume of oxygen gas with unit	1
	M2 volume of gas within 10% of the supervisor's value	1
1(b)(i)	correctly calculates **V(a)** ÷ 150 to 2–4 sig. fig.	1
1(b)(ii)	correctly calculates $\frac{V(a)}{24.0 \times 1000}$ to 2–4 sig. fig.	1
1(b)(iii)	correctly uses **(ii)** × 2 **AND** answer to 2–4 sig. fig.	1
1(b)(iv)	shows working $\frac{(iii) \times 1000}{150}$ **AND** answer to 2–4 sig. fig.	1
1(c)(i)	MnO_2 in (ignition) tube / floating in weighing boat **OR** use a dropping funnel / syringe for H_2O_2 **AND** subtract the liquid volume	1
1(c)(ii)	**M1** $\frac{0.5 \times 100}{50} = 1.0\%$	1
	M2 × 3 = 3.0% (3.0 with no working shown scores [2].)	1
1(c)(iii)	(agree as) two readings to find volume of gas evolved are needed so there is twice the percentage error in the gas volume reading	1
1(d)	no change because MnO_2 / **FA 2** / solid is a catalyst	1

Q# 91/ Gas collection (metal and acid) ALvl Chemistry/2019/w/TZ 1/Paper 3/Q# :o)

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1(a)	3 masses recorded with unambiguous headings in the space provided, with correct units mass used correctly calculated volume of gas collected or final volume recorded with correct units	1
	Award this mark if volume recorded by candidate lies within ± 10% of supervisor value.	1
1(b)(i)	Correctly calculates volume of gas in cm^3 / 24 000 answer to 2–4 sf	1
1(b)(ii)	Correct use of: 2 × **AND** ans **(b)(i)** / 0.025 (answer to 2–4 sf)	1
1(b)(iii)	Correctly uses ans **(b)(i)** × 24.3 **and** answer to 2–4 sf	1
1(c)	Student correct as reaction now **slower** so **less gas lost** (while bung is being fitted).	1
	Student incorrect as Mg is in excess. or Student incorrect as reaction is **faster** so **more gas lost**	1
1(d)	gas volume / amount / moles lower so concentration is lower	1

2(a)	**I** Uses a volume between 40.00 and 45.00 cm^3 **and** answer to at least 1 dp	1
	II The following data must be shown • burette readings *and* titre for rough titration • 2 × 2 'box' showing both accurate burette readings	1
	III Headings and units correct for accurate titration table and headings match readings. • Initial / start (burette) and reading / volume + unit • Final / end (burette) and reading / volume + unit • titre or volume / **FA 4** and used / added (*not 'difference' amount or 'total'*) + unit	1
	IV All accurate burette readings to 0.05 cm^3	1
	V The final accurate titre recorded is within 0.10 cm^3 of any other accurate titre.	1
	Award **VI** if $20 < \delta \leqslant 30$ cm^3	1
	Award **VII** if $10 < \delta \leqslant 20$ cm^3	1
	Award **VIII** if $\delta \leqslant 10$ cm^3	1
2(b)	Candidate must average two (or more) titres that are **all** within 0.20 cm^3. Working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
2(c)(i)	Answers for **(ii)**, **(iii)** and **(iv)** given to 3–4 sf. Minimum three answers displayed.	1
2(c)(ii)	Correctly calculates 2.50×10^{-3}	1
2(c)(iii)	Correct use of ans **(c)(ii)** × 1000 / ans **(b)**	1
2(c)(iv)	Correct expression: ans **(c)(iii)** × 250 / vol used from **(a)**	1
2(d)	Correctly calculates 0.10 / vol used in **(a)** × 100.	1

Q# 92/ Qualitative tests to identify unknown organic compounds ALvl Chemistry/2022/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

	FA 6 is aqueous $Zn(NO_3)_2$ and KI; **FA 7** gives results for ethanal but is actually **butan-2-ol**	
3(b)(i)	M1: **Test 2** (triiodomethane test) (Pale) yellow ppt M2: **Test 3** add (acidified aqueous) potassium manganate(VII) purple / $KMnO_4$ decolourised	2
3(b)(ii)	any 2 of the following tests correct **Test 1:** does not contain –OH / not an alcohol / not a carboxylic acid / not hydroxyl group **Test 2:** contains $-CH_3C{=}O$ (or $-CH(OH)CH_3$) group **Test 3:** is an aldehyde (or a 1° or 2° alcohol)	2
3(b)(iii)	**FA 7** is ethanal / CH_3CHO	1

Q# 93/ Qualitative tests to identify unknown organic compounds ALvl Chemistry/2020/s/TZ 1/Paper 3/Q# :o)

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	FA 1/FA 6 is $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$; **FA 7** is H_2O_2; **FA 8** is ethanol	
3(a)(i)	Reagents used are NaOH **and** NH_3	1
	FA 6 dissolved in (distilled) water (before carrying out tests)	1
	Observations with both cold alkalis • With NaOH: green ppt, insoluble in excess • With NH_3: green ppt, insoluble in excess OR • If only one of NaOH or NH_3 was selected, award this mark if the observation is correct, but it must include 'ppt turns brown'.	1
	Observation when heated with NaOH Fizzing/bubbling **and** gas/NH_3 turns (moist red) litmus to blue	1
	Both ions correctly identified Iron(II) and ammonium (Fe^{2+} and NH_4^+)	1

3(a)(ii)	**Anion test and first observation** • Add barium nitrate/chloride • White precipitate	1
	Observation with acid and conclusion: • white ppt is insoluble in specified mineral acid (not H_2SO_4) • sulfate / SO_4^{2-} present	1
3(a)(iii)	**Ionic equation** *Any one of the following equations, provided that the appropriate test was carried out.* • $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ • $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l \text{ or } g)$ • $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$	1
3(a)(iv)	**Correct use of M_r to calculate no of moles water.** Mass of water = (392) - 55.8 -192.2 – 36	1
	• $n(H_2O) = {}^{392-284}/_{18}$ (expressed as integer)	1

3(b)(i)	Award one mark for every two correct observations (*) as shown in table below	5

test	observation(s)	
	FA 5	FA 6
Test 1	$KMnO_4$ decolorised*. fizzing/bubbling/effervescence or gas relights glowing spill* No (further) change	no reaction $KMnO_4$ not decolorised and $KMnO_4$ goes from purple to colourless (solution)*
Test 2	Red-brown/ brown solution formed* Mixture goes to (dark) blue / blue-black*	No change and No change*
Test 3	Yellow or colourless solution formed*	(On standing) off-white / pale yellow <u>precipitate</u> formed*.
Test 4	No change / pale yellow (solution) formed* Red-brown / brown / rust <u>precipitate</u> (formed)* *Ignore fizzing*	

3(b)(ii)	FA 8 is ethanol or propan-2-ol or butan-2-ol *(or any secondary 2-ol)* Correct reference to the <u>CHI_3</u> test or to $CH_3CH(OH)$- or CH_3CO group	1
	Correct reference to the redox reaction with $KMnO_4$ (provided that FA 8 was identified as an alcohol/aldehyde).	1
3(b)(iii)	FA 7 is an <u>oxidising agent</u> because <u>iodine</u> is formed.	1

Q# 94/ Qualitative tests to identify unknown organic compounds ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

FA 5 is HCOOH ; **FA 7** is $ZnCO_3$; **FA 8** is $Cu(NO_3)_2$		
3(a)(i)	+ Na_2CO_3: fizz / effervescence / bubbling	1
	+ $KMnO_4$: purple (allow pink) to colourless (allow pale yellow)	1
	+ $AgNO_3$: no (visible) reaction / no change / no ppt / solution remains colourless	1
	+ Tollens': silver mirror / black ppt / grey ppt	1
3(a)(ii)	(Carboxylic) acid	1
	Aldehyde / primary alcohol / secondary alcohol / alkene	1

Q# 95/ Qualitative tests to identify unknown organic compounds ALvl Chemistry/2016/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

FA5 is $MnSO_4$ and NH_4Cl; **FA6** is propanone; **FA7** is propanal;

(d)	**Both observations required** **FA6** no reaction / solution turns pink **and** **FA7** turns colourless / decolourises the $KMnO_4$	1	
	FA6 is either 2-methylpropan-2-ol **or** propanone as they cannot be oxidised (only 1 needed) **and** **FA7** is propanal as it can be oxidised.	1	[2]
Question 3			**[13]**

Q# 96/ Qualitative tests to identify unknown organic compounds ALvl Chemistry/2010/s/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

FA 7 is a tertiary alcohol; **FA 8** is an aldehyde; **FA 9** is a ketone; **FA 10** is a primary alcohol

(g)	MMO Collection	One mark for two correct observations with **FA 7**	1	
		One mark for correct observations with **FA 8** and **FA 9**	1	
		One mark for two correct observations with **FA 10** See table below for expected observations	1	[3]

reagent	observations			
	FA 7	**FA 8**	**FA 9**	**FA 10**
acidified dichromate	no reaction		no reaction	(colour change to) green/blue-green/ cyan/turquoise (solution **not** ppt)
2,4-DNPH	~~no reaction~~	~~yellow ppt~~	~~yellow ppt~~	
Tollens' reagent	no reaction	silver mirror **or** black/grey solution or ppt		no reaction

(h)	ACE Conclusions	**No ecf from (g)** **FA 7** contains the tertiary alcohol from <u>no reaction with all three reagents</u> **or** <u>no reaction</u> with dichromate **and** 2,4-DNPH **provided** there is no CON in the observation with Tollens' **FA 8** contains the aldehyde from the silver (mirror), black or grey precipitate or solution with ammoniacal silver nitrate Allow from brown ppt if it is the only positive result with Tollens'.	1 1	[2]
	Total			**[14]**

Qualitative Analysis Notes, Constants and Periodic Table

9701/31/O/N/23

Qualitative analysis notes

1 Reactions of cations

cation	reaction with	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on warming	–
barium, Ba^{2+}(aq)	faint white ppt. is observed unless [Ba^{2+}(aq)] is very low	no ppt.
calcium, Ca^{2+}(aq)	white ppt. unless [Ca^{2+}(aq)] is very low	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives cream / off-white ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives pale yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; decolourises acidified aqueous $KMnO_4$
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca^{2+}(aq)]
sulfite, SO_3^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids); decolourises acidified aqueous $KMnO_4$
thiosulfate, $S_2O_3^{2-}$(aq)	gives off-white / pale yellow ppt. slowly with H^+

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^4\,C\,mol^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$
molar volume of gas	$V_m = 22.4\,dm^3\,mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,dm^3\,mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ (4.18 $J\,g^{-1}\,K^{-1}$)

The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
				Key			1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0			atomic number atomic symbol name relative atomic mass								5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –