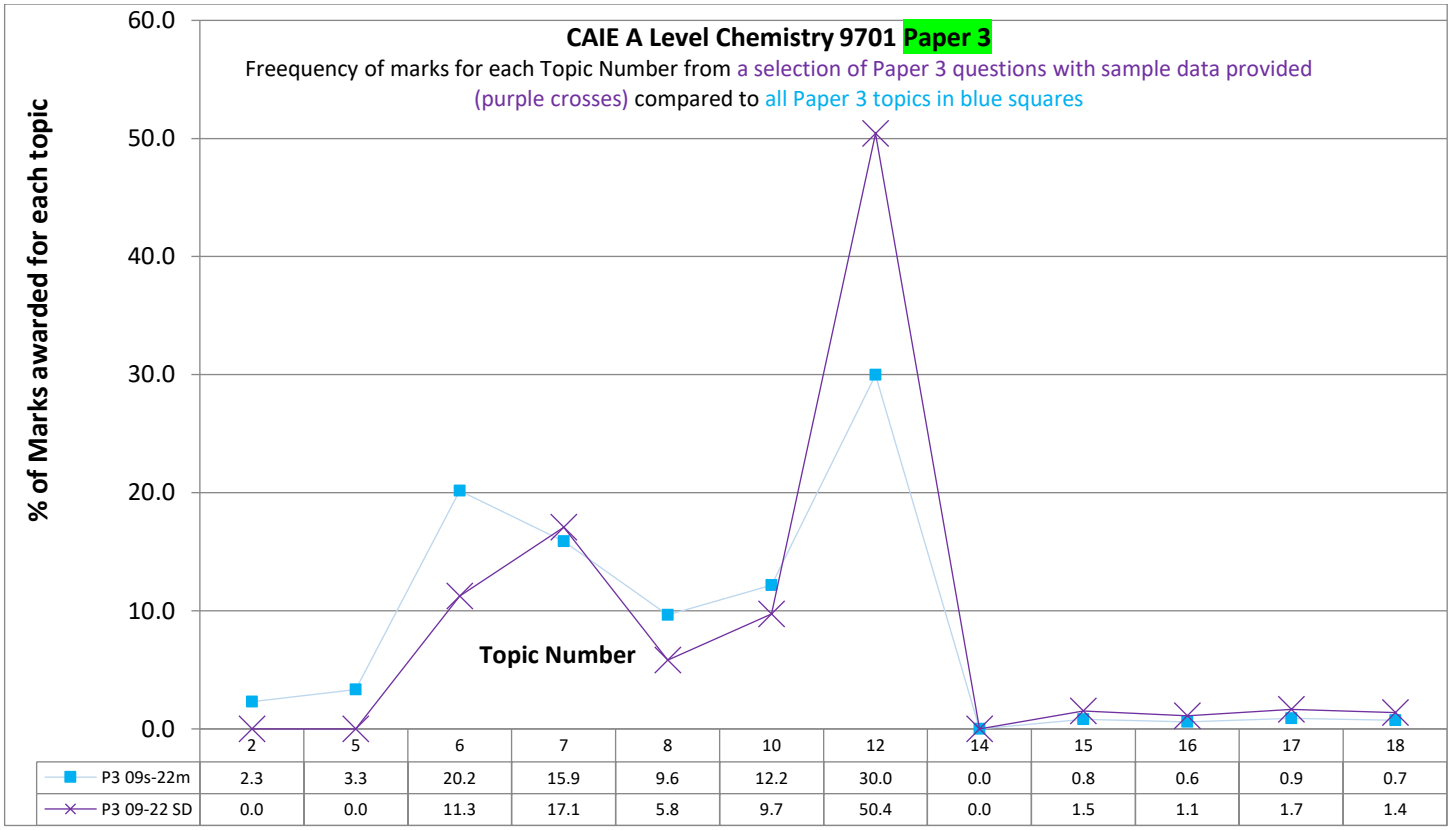
Name: Class: Date:

ALvl Chem 7 EQ P3 22w to 09s Paper 3 SAMPLE DATA Equilibria 123marks

- This **booklet cannot replace lab experience** as the best way to prepare for Paper 3, but it can help with understanding some of the theory aspects.
- This booklet contains 399marks worth of Paper 3 questions with SAMPLE DATA provided which allows you to work on the theory parts of the questions outside of a chemistry lab.
- Not all types of experiment are included (as of May 2024), so **this is only partially complete**. This can be seen best in the graphs comparing experiment types rather than topic numbers.
- It is usually better to revise Paper 3 by looking at specific experiment types, rather than by topic. But these booklets may be helpful when learning each topic for the first time.
- 75 seconds have been budgeted for these theory-based questions (same as Paper 2 questions), which roughly privileges the time allocation to the marks derived directly from practical work. The mean average time per mark is 180 seconds in Paper 3, but there are a lot of different ways that this time allocation could be more carefully worked out.

As you start and work through this worksheet you can tick off your progress to show yourself how much you have done, and what you need to do next. The first task is just to read the first question and should take you less than one minutes to complete.

Paper3 Topic 7 Checklist Tick each task off as you go along	RANK:	P1 Noob 1 Q started	P1 Novice 1 Q done	P1 Bronze 10% of marks	P1 Silver 25% of marks	P1 Gold 40% of marks	P1[1] Winner 50% of marks	P1 Hero 75% of marks	P1 Legend 100% of marks
Topic (marks)	123		14	12	31	49	62	92	123
Time @**75s**/mark (minutes)	154		17	15	38	62	77	115	154

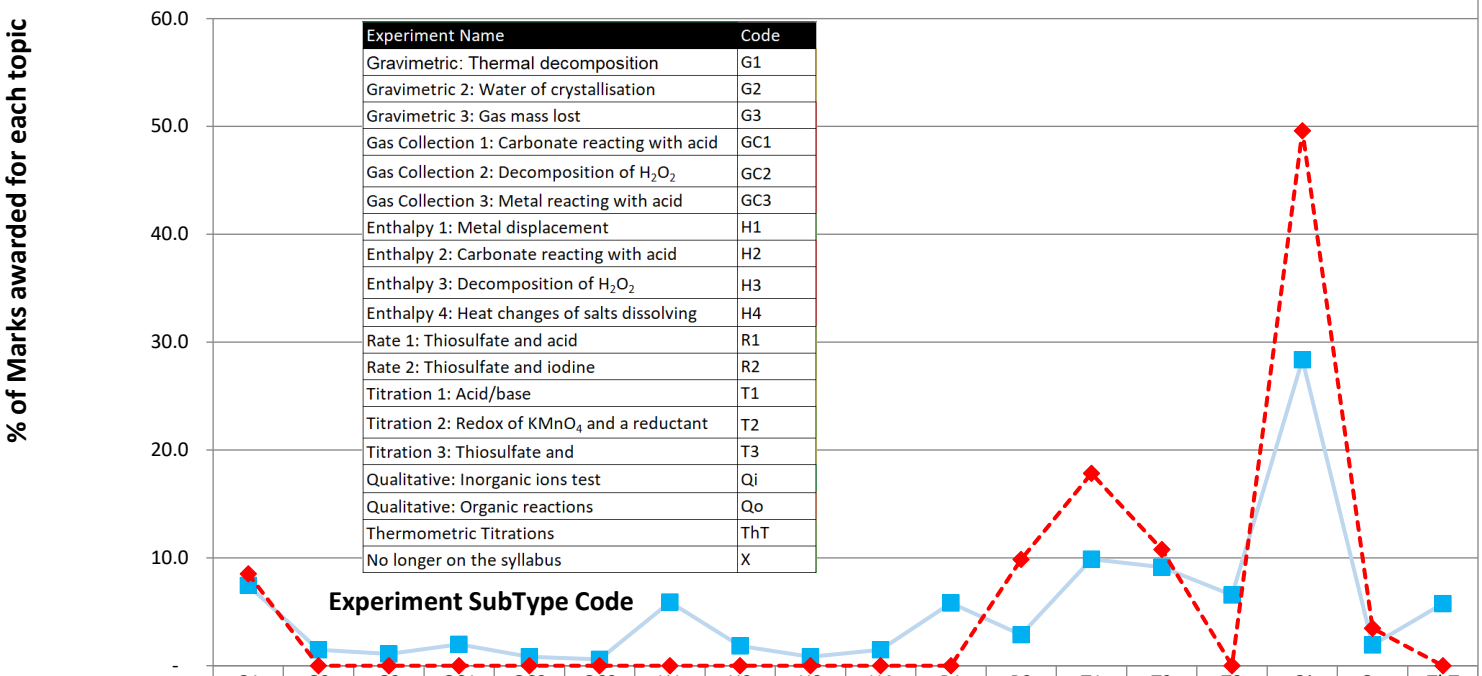


	2	5	6	7	8	10	12	14	15	16	17	18
P3 09s-22m	2.3	3.3	20.2	15.9	9.6	12.2	30.0	0.0	0.8	0.6	0.9	0.7
P3 09-22 SD	0.0	0.0	11.3	17.1	5.8	9.7	50.4	0.0	1.5	1.1	1.7	1.4

[1] **DO NOT** work on these higher levels of completion in your AS year unless you have also achieved at least a "**Gold**" (40%) in the same topic in both **Paper 1** and **Paper 2**, which is **MOST (77%)** of your **AS grade**

CAIE A Level Chemistry 9701 Paper 3

Freequency of marks for each Experiment SubType from m2022 to m2016 blue squares, compared to SAMPLE DATA Section 1 of this workbook in the red diamonds



Experiment Name	Code
Gravimetric: Thermal decomposition	G1
Gravimetric 2: Water of crystallisation	G2
Gravimetric 3: Gas mass lost	G3
Gas Collection 1: Carbonate reacting with acid	GC1
Gas Collection 2: Decomposition of H_2O_2	GC2
Gas Collection 3: Metal reacting with acid	GC3
Enthalpy 1: Metal displacement	H1
Enthalpy 2: Carbonate reacting with acid	H2
Enthalpy 3: Decomposition of H_2O_2	H3
Enthalpy 4: Heat changes of salts dissolving	H4
Rate 1: Thiosulfate and acid	R1
Rate 2: Thiosulfate and iodine	R2
Titration 1: Acid/base	T1
Titration 2: Redox of $KMnO_4$ and a reductant	T2
Titration 3: Thiosulfate and	T3
Qualitative: Inorganic ions test	Qi
Qualitative: Organic reactions	Qo
Thermometric Titrations	ThT
No longer on the syllabus	X

	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

What the most thoughtful students will get out of their extensive studying will be a capacity to do meaningful brain-based work even under stressful conditions, which is a part of the self-mastery skillset that will continue to deliver value for the whole of their lives. Outstanding grades will also happen, but the most important goal from skillful action in study is being better at any important task, even if circumstances do not feel ideal.

As you are moving through your studies you can learn more about yourself by trying out new ways to manage yourself, and analysing how effective those new techniques were. In this reflective process not only will you get better at working positively and productively to deliver ambitious and successful outcomes, but you will be working towards one aspect of life's highest pursuit, summarised and inscribed on the Temple of Apollo at Delphi: "know thyself".

1. To complete these questions, as important as your answer, is checking your answer against the mark scheme.
2. For each page or group of 10-20 marks, convert your mark score into a percentage. This will allow you to see (and feel) your progress as you get more experience and understanding with each topic.
3. Multiple choice questions, done carefully where you explain and show yourself your thinking using written notes as you move through each question, can be more useful than just Paper 2 for students aiming for a C or B grade. Paper 2 should be the larger focus for students aiming for A and A* grades, however.
4. If you find you get a higher percentage answering short answer questions than multiple choice questions that often means you are NOT using the marking scheme correctly; your correct answer might not be fully complete for all the marks you are awarding. The marks easiest to miss rely on providing the largest amount of detail.

SAMPLE DATA Burette readings: 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	
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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]

SAMPLE DATA Burette readings: 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**.

$$2\mathbf{Z}OH(aq) + H_2SO_4(aq) \rightarrow \mathbf{Z}_2SO_4(aq) + 2H_2O(l)$$

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	
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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]

SAMPLE DATA Burette readings: 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	
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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 → .....$\mathbf{M}_2SO_4$ + ... + ...

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 Burette readings: 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, HC*l*.
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	
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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 HC*l* = ... mol
[1]

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

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

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

concentration of HC*l* 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 **Q# 11/** ALvl Chemistry/2018/s/TZ 1/Paper 3/Q# 1 :o) www.SmashingScience.org

SAMPLE DATA Burette readings: 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 HC*l* in **FA 2** = ... mol dm^{-3} [1]

T1 Acid Base Titration **Q# 12/** ALvl Chemistry/2016/w/TZ 1/Paper 3/Q# 2 :o) www.SmashingScience.org

SAMPLE DATA Burette readings: 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 Burette readings: 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 Burette readings: 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.

[5]

I	
II	
III	
IV	
V	

(b) From your 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 **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**.

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]

[Total: 10]

SAMPLE DATA Burette readings: 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).

For Examiner's Use

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.

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]

(c) Calculations

For Examiner's Use

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

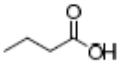
(iv) Calculate the concentration, in mol dm^{-3}, of H_2SO_4 in **FA 1**.

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

[Total: 12]

I	
II	
III	
IV	

Q# 7/ 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 = $0.110 \times {}^{(b)} / {}_{1000}$ **AND** answer to 3 or 4 sig fig	1
1(c)(ii)	Correctly uses **(c)(i)** to calculate $M_r = {}^{10.5} / {}_{\text{(c)(i)} \times 40}$	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 $NH_2CH_2COOH(aq) + NaOH(aq) \rightarrow NH_2CH_2COONa(aq) + H_2O(l)$	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# 8/ 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 $n(H_2SO_4) = 0.050 \times$ **(b)** / 1000	1
2(c)(iii)	Correctly uses **[FA 4] = (c)(ii)** $\times 2 \times 40$ mol dm^{-3}	1
2(c)(iv)	Correctly calculates **[FA 2] = (c)(iii)** $\times$ 10 mol dm^{-3}	1
2(c)(v)	Correctly uses M1: $M_r = \frac{26.3}{\text{(c)(iv)}}$ = 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 $\lvert A_r$ from **(c)(v)** $- A_r$ from periodic table $\rvert \times 100 / A_r$ from periodic table Answer from default = 18.16 or 18.2 or 18 %	1

Q# 9/ 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 ⩾ 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 = $0.0550 \times {}^{\text{mean titre}}/_{1000}$ *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# 10/ 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# 11/ 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# 12/ 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]	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

Q# 13/ 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]**

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]

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 (✗)* ***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 $\times \frac{0.15}{1000}$ 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]