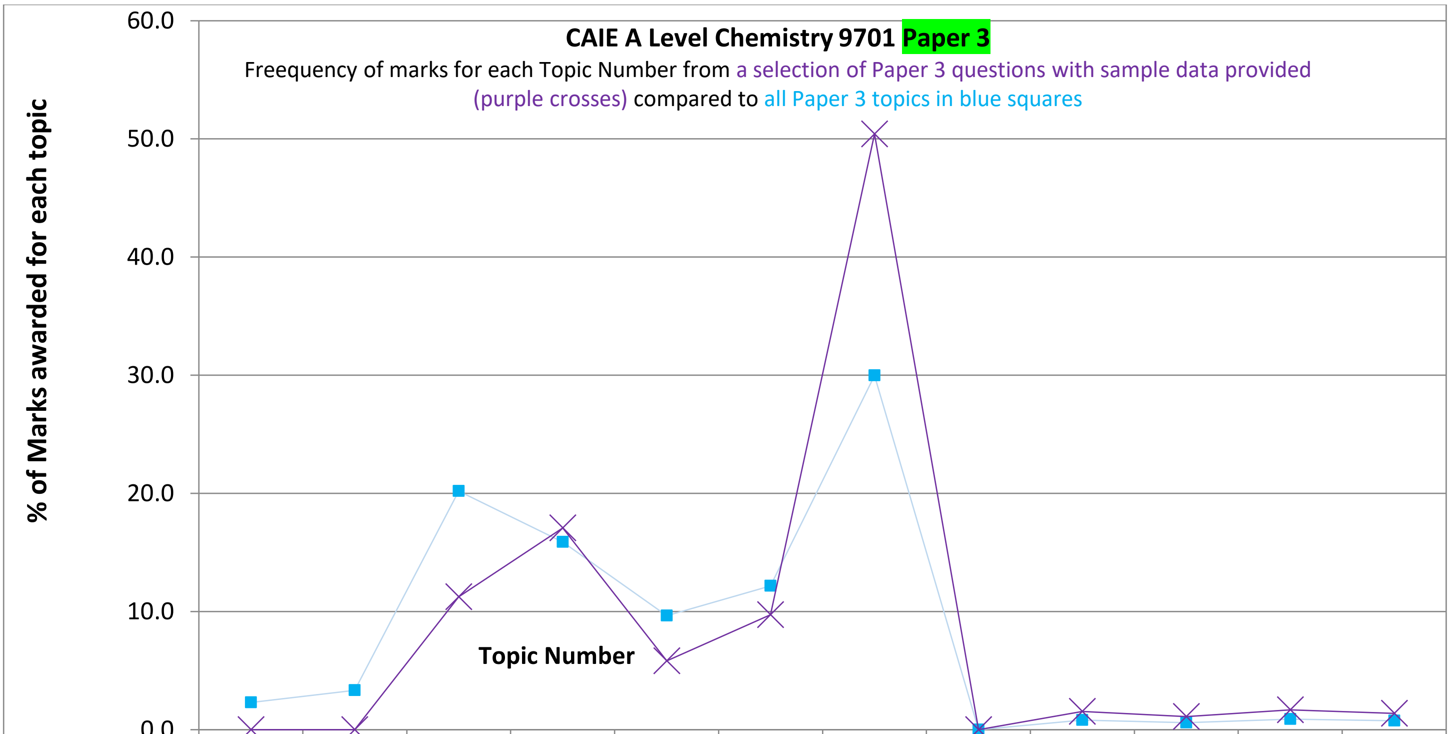
Name: Class: Date:

ALvl Chem 7 EQ P3 22w to 09s Paper 3 Equilibria 214marks

- 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 does not include sample data, though such booklets do exist for most experiment types on www.SmashingScience.org
- 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.
- Successful work on these questions without doing the experiments is much harder to do, but you can use them to investigate the kinds of experiments that each topic has, and as a starting point to learn about that experiment in a way that would allow you to understand the question and deliver correct answers.
- The average time in Paper 3 for each mark is 180 seconds, or 3minutes. The marks that result from a successful experiment relate to work that will require more time than this average. Most, if not all, of the theory marks will require a good student far less time than 180 seconds of work to achieve. The biggest challenge in Paper 3 tends to be effective time management, so thinking carefully and analytically about the time required for the different parts of the exam is a critical Paper 3 skill.

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	P1 Novice	P1 Bronze	P1 Silver	P1 Gold	P1[1] Winner	P1 Hero	P1 Legend
		1 Q started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topic (marks)	214		15	21	54	86	107	161	214
Time @180/mark (minutes)	642		46	64	161	257	321	482	642

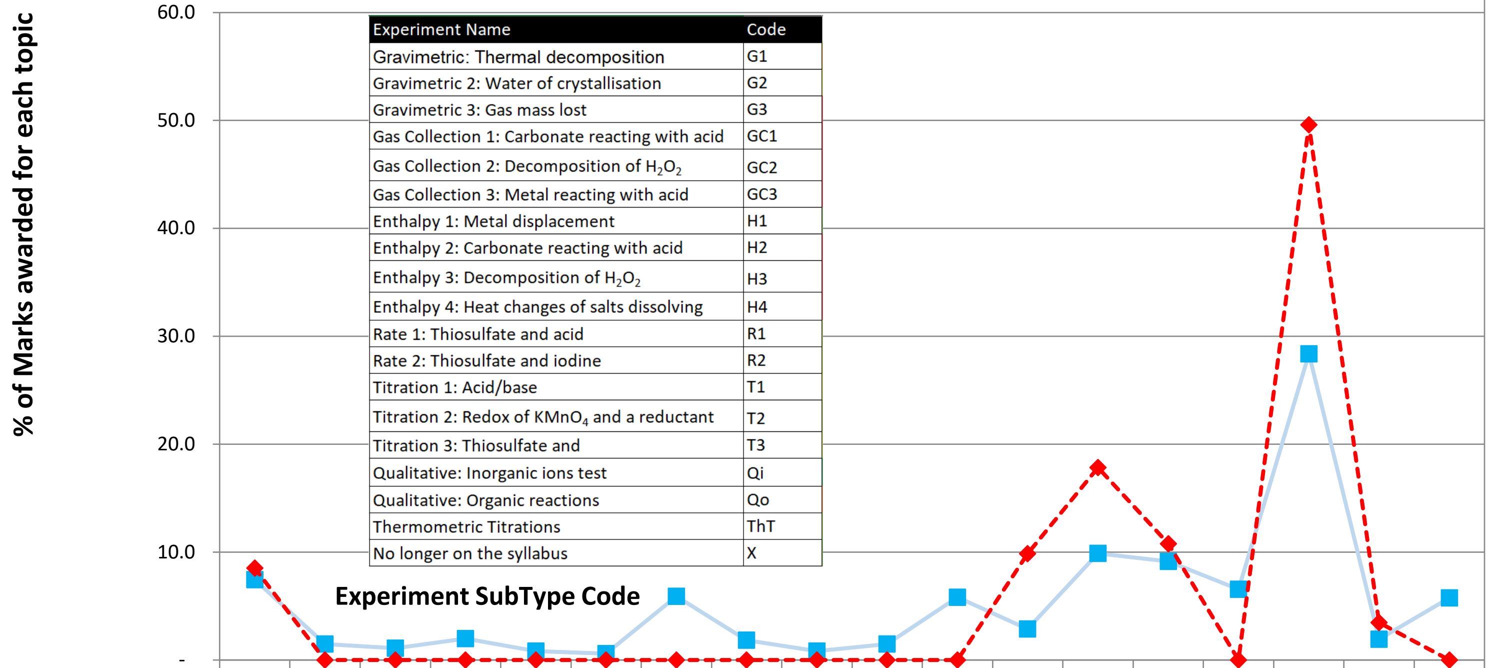


	2	5	6	7	8	10	12	14	15	16	17	18
P3 09s-22m	2.3	3.3	20.2	15.9	9.6	12.2	30.0	0.0	0.8	0.6	0.9	0.7
P3 09-22 SD	0.0	0.0	11.3	17.1	5.8	9.7	50.4	0.0	1.5	1.1	1.7	1.4

[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. Paper 3 can sometimes cause a good student at a higher-grade boundary to gain or lose that higher grade, but generally tends to have less impact than the 2 theory papers. However, success in Paper 3 is unusually strongly linked to good preparation.
5. 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.

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.

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[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 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.

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[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 $Na_2SO_3{\bullet}xH_2O$.

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]

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]

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.

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[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.

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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 → .....**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.

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[8]

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(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]

Gas collection (carbonate reacting with acid) **Q# 32/** ALvl Chemistry/2019/m/TZ 3/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 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 cm³ 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 cm³ measuring cylinder to transfer 50 cm³ 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 cm³ 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 cm³ 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]

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]

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]

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, HCl, present in 250 cm^3 of **FA 4**.

moles of HCl 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 HCl that reacted with **FA 1** in the experiment you carried out in **Question 1**.

moles of HCl 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]

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]

SMASHING!!!

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**.

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]

For Examiner's Use

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.

I	
II	
III	
IV	
V	

[5]

(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.

For Examiner's Use

I	
II	
III	
IV	

(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]

For Examiner's Use

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.

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]

I	
II	
III	
IV	
V	
VI	
VII	

(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.

For Examiner's Use

I	
II	
III	
IV	

[4]

(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.

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

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 = ... $kJ\,mol^{-1}$

sign *value* [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.

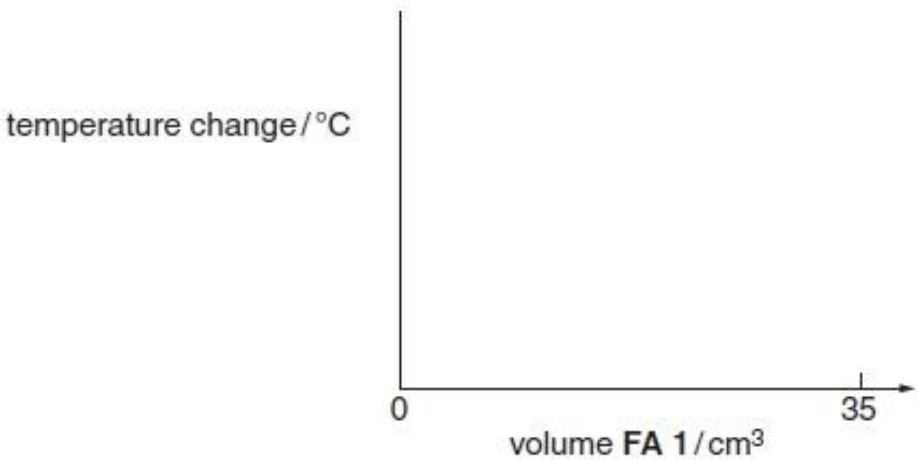
Suggest a modification to the experimental method used in order to give larger changes in temperature.

....

.... [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, HC*l*.

On the axes below indicate an appropriate temperature scale and sketch the graph for the temperature changes you would expect.



[2]

[Total: 25]

For Examiner's Use

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.

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

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]

1 Read through question 1 before starting any practical work.

For Examiner's Use

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.

i	
ii	
iii	
iv	
v	
vi	
vii	
viii	
ix	

[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**.

[4]

For Examiner's Use

i	
ii	
iii	
iv	

(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**.

$$\text{concentration of NaOH (mol dm}^{-3}) = \text{answer to } \mathbf{(f)(ii)} \times \frac{1000}{\text{volume of } \mathbf{FA\,2}\ (cm^3) \text{ from (c)}}$$

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.

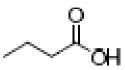
(iii) Calculate the maximum percentage error due to the thermometer when measuring the temperature **rise** in **(ii)** above.

The maximum percentage error = ... %. [2]

[Total: 26]

Q# 26/ 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 $M_r = {}^{10.5}/_{(c)(i) \times 40}$	**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**

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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 × **(b)** / 1000 mol **AND** n(I_2) = ans / 2	1
2(c)(iii)	Correctly calculates initial amount of (n) I_2 = 2.5(0) × 10^{-3} mol **AND** n(I_2) that reacted = 2.5(0) × 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•$x$$H_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

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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 = $\frac{25 \times 1.9}{2 \times \textbf{(b)(ii)}}$	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 cm³ 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 cm³ 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 cm³, titres within 0.10 cm³ 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 δ ⩽ 0.50 cm³ Award **VI** if δ ⩽ 0.30 cm³ Award **VII** if δ ⩽ 0.20 cm³	3
2(b)	Candidate must average two (or more) titres that are **all** within 0.20 cm³ **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

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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 *'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: (cm³) or / cm³ or in cm³ or cm³ by every entry*	1
	III All accurate burette readings to 0.05 cm³	1
	IV The final accurate titre recorded is within 0.10 cm³ 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 cm³ Award **VI** if δ ⩽ 0.30 cm³ Award **VII** if δ ⩽ 0.20 cm³	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) × 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: $M_r = \frac{26.3}{(c)(iv)}$ = 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 $\lvert A_r$ from (c)(v) – A_r from periodic table$\rvert$ × 100 / A_r from periodic table Answer from default = 18.16 or 18.2 or 18 %	1

Q# 30/ 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 $\leqslant$ 0.60 $cm^3\,g^{-1}$	1
	Award VI and VII if 0.20 $<$ δ $\leqslant$ 0.40 $cm^3\,g^{-1}$	1
	Award VI, VII and VIII if δ $\leqslant$ 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# 31/ 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# 32/ ALvl Chemistry/2019/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

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

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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 < δ ⩽ 0.40 cm^3 Award **V** for 0.40 < δ ⩽ 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# 34/ 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 = $5.(00) \times 10^{-2}$	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**

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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 HCl used **and** greater mass would react with more HCl / would leave less HCl unreacted	1	[2]
Question 2			**[12]**

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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]

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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]

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1 (a)	PDO Recording	**I** Thermometer readings for all experiments recorded to 0.0 or 0.5°C. (At least one recorded to 0.5°C.)	1	
	ACE Interpretation	**II** Calculation of all temperature changes correct.	1	
	MMO Quality	Award **III** for a temperature rise followed by constant temperature (within 0.5°C).	1	
		Award **IV** and **V** for a **maximum** rise within 0.5°C of supervisor.	1	

		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	[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	$\frac{25 \times 2}{1000} = \mathbf{0.05}$	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]

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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]

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(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]

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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]
(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 <u>points</u>. *(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 ACE Interpretation	Working is shown in **(f)(i)** (involves volumes and concentration, 2.0 mol dm^{-3}) **and** **(f)(ii)** *(any clear mole ratio)* 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 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 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 1	[2]
(i)	ACE Improvements	Advantage of burette: Lower % error **or** more accurately calibrated *(must refer to or infer scale/graduations/markings/divisions)* Disadvantage of burette: Takes longer to add the **FA 2**	1 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]**