

ALyl Chem 6 EQ P3 22w to 09s Paper 3 Electrochemistry 272marks

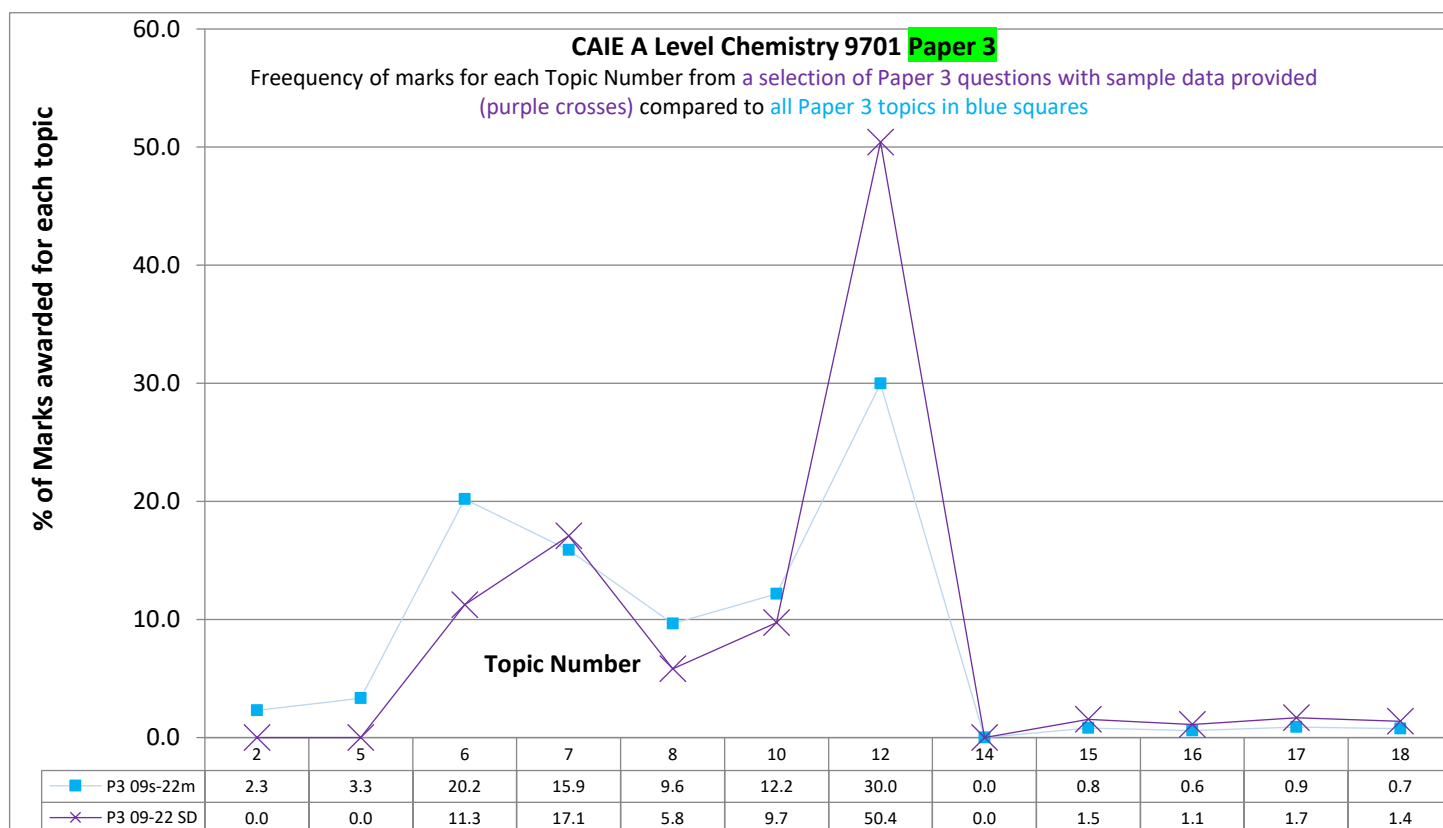
- This **booklet cannot replace lab experience** as the best way to prepare for Paper 3, but it can help with understanding some of the theory aspects.
- This booklet does not include sample data, though such booklets do exist for most experiment types on www.SmashingScience.org
- It is usually better 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 3 minutes. 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 6

Checklist Tick each task off as you go along

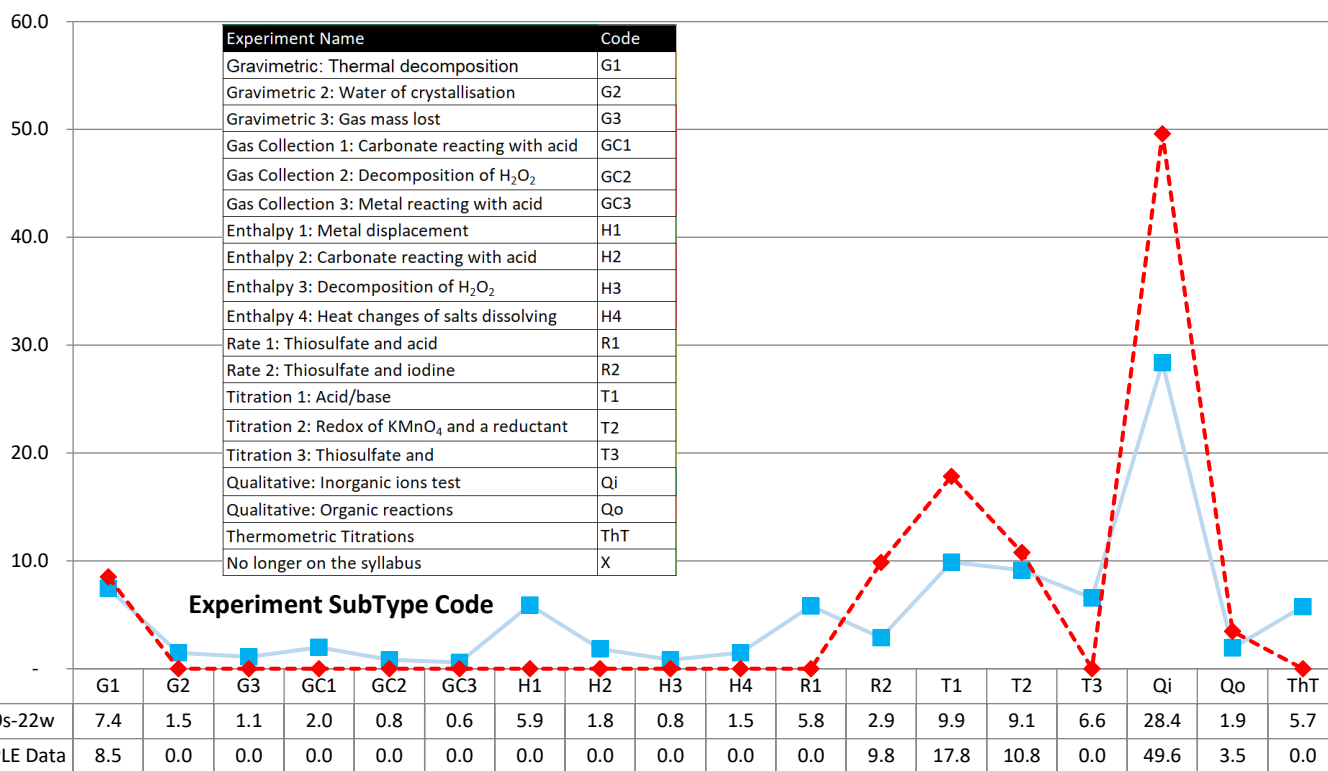
RANK:		P1 Noob	P1 Novice	P1 Bronze	P1 Silver	P1 Gold	P1 ¹ Winner	P1 Hero	P1 Legend
		1 Q started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topic (marks)	272		15	27	68	109	136	204	272
Time @180/mark (minutes)	816		45	82	204	326	408	612	816



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**

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

% of Marks awarded for each topic



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

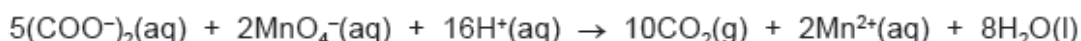
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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 Group 1 elements form salts with ethanedioic acid. These salts are ethanedioates and have the formula $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$, where **M** is the Group 1 metal.

Ethanedioate ions react with manganate(VII) ions as shown.



You will determine which metal is present in $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$ by titrating a solution of this salt with manganate(VII) ions.

FA 1 is 10.14 g dm^{-3} aqueous hydrated ethanedioate of metal **M**, $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$.

FA 2 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 3 is 1 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately 20 cm^3 of **FA 3** into the conical flask.
- Place the conical flask on a tripod and gauze and heat carefully until the temperature of the solution is approximately 70°C .
- Remove the flame.
- **Carefully** lift the hot conical flask and place it on the white tile under the burette.
- During titrations, add **FA 2**, **slowly at first**, until a permanent pale pink colour is formed. The pink colour on initial addition may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70°C . If the brown colour disappears, continue with the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- Perform a rough titration with **FA 2**. Record your burette readings in the space below.

The rough titre is cm^3 .

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

I	
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[7]

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

25.0 cm³ of **FA 1** required cm³ of **FA 2**. [1]

(c) Calculations

- (i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the appropriate number of significant figures. [1]
- (ii) Calculate the amount, in mol, of manganate(VII) ions, MnO_4^- , in the volume of **FA 2** calculated in **(b)**.

amount of MnO_4^- = mol [1]

- (iii) Calculate the amount, in mol, of ethanedioate ions that reacted with the manganate(VII) ions in **(c)(ii)**.

amount of $(\text{COO}^-)_2$ = mol

Hence calculate the concentration, in mol dm^{-3} , of ethanedioate ions in **FA 1**.

concentration of $(\text{COO}^-)_2$ = mol dm^{-3} [1]

- (iv) Calculate the relative formula mass, M_r , of the hydrated ethanedioate, $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$.

M_r = [1]

- (v) Identify **M**. Show your working.

M is [2]

- (d) Explain why it is necessary to add **FA 3** in each titration.

.....
..... [1]

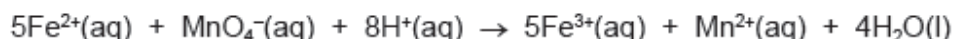
[Total: 15]

Quantitative analysis

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

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

- 1 Iron(II) sulfate crystals, $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$, contain water of crystallisation. You will carry out a titration to determine the value of x in the formula, where x is an integer. A solution containing a known mass of the crystals will be titrated with acidified aqueous potassium manganate(VII) of known concentration.



FA 1 contains 26.52 g dm^{-3} of hydrated iron(II) sulfate, $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$.

FA 2 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 3 is dilute sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the 25 cm^3 measuring cylinder to transfer 25 cm^3 of **FA 3** into the same conical flask.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

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

Keep FA 1 for use in Question 3.

I	
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[7]



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

25.0 cm³ of **FA 1** required cm³ of **FA 2**. [1]

(c) Calculations

- (i) Give your answers to (c)(ii), (c)(iii) and (c)(iv) to an appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 2** calculated in (b).

moles of KMnO_4 = mol [1]

- (iii) Calculate the number of moles of iron(II) sulfate present in 1.00 dm³ of **FA 1**.

moles of FeSO_4 = mol [1]

- (iv) Calculate the mass of iron(II) sulfate present in 1.00 dm³ of **FA 1**.

mass of FeSO_4 = g [1]

- (v) Calculate the value of x in $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$.

x = [2]

(d) Iron(II) sulfate in solution is readily oxidised by air to form iron(III) sulfate.

State the effect, on the value of x calculated in (c)(v), if some of your sample of **FA 1** had oxidised before you carried out the titration.
Explain your answer.

[2]

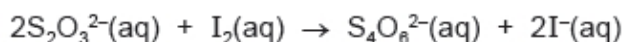
Titrations with thiosulfate and iodine **Q# 10/** ALvl Chemistry/2020/w/TZ 1/Paper 3/Q# 1 :o) www.SmashingScience.org

Quantitative Analysis

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

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

- 1 In this experiment you will determine the value of x in the formula of hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$, where x is an integer. You will first prepare a solution of the salt and then use this solution in a titration with aqueous iodine. The thiosulfate ions react with iodine as shown.



FA 1 is hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$.

FA 3 is $0.0500 \text{ mol dm}^{-3}$ iodine, I_2 .
starch indicator

(a) Method

Preparation of salt solution

- Weigh the container containing **FA 1**.
- Tip the contents of the container into the 250 cm³ beaker.
- Weigh the container with any residue.
- Record all your readings in the space below.

- Add approximately 200 cm³ of distilled water to the salt in the beaker and stir until the salt has dissolved.
- Pour the contents carefully into the 250 cm³ volumetric flask.
- Rinse the beaker with a little distilled water and add these washings to the flask.
- Fill the flask to the mark with distilled water and shake to ensure thorough mixing.
- Label this solution **FA 2**.



Titration

- Fill a burette with **FA 2**.
- Pipette 25.0 cm³ of **FA 3** into the conical flask.
- Add **FA 2** from the burette until the solution in the flask turns yellow.
- Add 10 drops of starch indicator to the conical flask. The solution will turn blue-black.
- Continue to add more **FA 2** from the burette until the blue-black colour just disappears. This is the end-point of the titration.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is cm³.

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

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[8]

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

25.0 cm³ of **FA 3** required cm³ of **FA 2**. [1]

(c) Calculations

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

(ii) Calculate the number of moles of iodine in 25.0 cm³ of **FA 3**.

moles of I₂ = mol [1]

(iii) Calculate the number of moles of thiosulfate ions in the volume recorded in **(b)**.

moles of S₂O₃²⁻ = mol

Hence calculate the number of moles of hydrated sodium thiosulfate in the mass weighed in **(a)**.

moles of Na₂S₂O₃•xH₂O = mol [1]

(iv) Calculate the value for x in the formula of hydrated sodium thiosulfate, Na₂S₂O₃•xH₂O. Show your working.

x = [3]

- (d) (i) State the maximum error in a single reading on the balance used in (a).

maximum error = $\pm$ g

Calculate the maximum percentage error in the mass of **FA 1** used in (a).
Show your working.

maximum percentage error = $\pm$ %
[1]

- (ii) Assume that the uncertainty in the mass of **FA 1** is the only source of error in your experiment.

Calculate the minimum value for the relative formula mass of **FA 1**.
Show your working.

minimum value for the relative formula mass of **FA 1** = [1]

- (e) A student prepares **FA 2** using anhydrous sodium thiosulfate salt and the same mass of salt that you used in (a).

State how the student's titre would compare with the average titre value you obtained in (b).
Explain your answer.

.....
.....
.....
..... [1]

- (f) In many titrations it is usual to fill the burette with the solution of known concentration.

Suggest why this was not done in (a).

.....
..... [1]

[Total: 19]

Quantitative Analysis

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

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

- 1 In this experiment you will carry out a titration to determine the relative formula mass of a hydrated salt, **FA 1**.

FA 1 is a hydrated salt.

FA 2 is dilute sulfuric acid.

FA 3 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII).

(a) Method

Preparing a solution of **FA 1**

- Weigh the stoppered container of **FA 1**. Record the mass in the space below.
- Tip all the **FA 1** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FA 1** used.
- Add approximately 100 cm^3 of **FA 2** to the **FA 1** in the beaker.
- Stir the mixture until all the **FA 1** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Rinse the beaker and glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of the hydrated salt is **FA 4**. Label the flask **FA 4**.

Titration

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Use the 25.0 cm^3 measuring cylinder to add 10 cm^3 of **FA 2** to the **FA 4** in the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

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VIII	

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

Keep FA 3 and FA 4 for use in Question 3.

[8]

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

25.0 cm³ of **FA 4** required cm³ of **FA 3**. [1]

(c) Calculations

- (i) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 3** calculated in (b).

moles of KMnO₄ = mol [1]

- (ii) 1 mol of KMnO₄ reacts with 5 mol of the hydrated salt, **FA 1**.

Calculate the concentration of the hydrated salt, in mol dm⁻³, in **FA 4**.

concentration of **FA 4** = mol dm⁻³ [1]

- (iii) Use your answer to (c)(ii), and your data on page 2, to calculate an experimentally determined value for the relative formula mass of the hydrated salt, **FA 1**.
Show your working.

M_r of **FA 1** = [1]

[Total: 12]

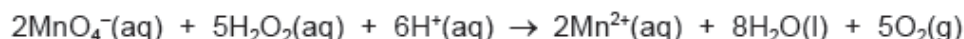


Quantitative analysis

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

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

- 1 The concentrations of solutions of hydrogen peroxide are often represented in terms of 'volume strength'. In this experiment you will determine the 'volume strength' of a solution of hydrogen peroxide by titration with acidified potassium manganate(VII).



FA 1 is $0.0300 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 2 is dilute sulfuric acid, H_2SO_4 .

FA 3 is aqueous hydrogen peroxide, H_2O_2 .

(a) Method**Dilution of FA 3**

- Pipette 25.0 cm^3 of **FA 3** into the 250 cm^3 volumetric flask.
- Make the solution up to the mark using distilled water.
- Shake the flask thoroughly.
- Label this diluted solution of hydrogen peroxide **FA 4**.

Titration

- Fill the burette with **FA 1**.
- Rinse the pipette thoroughly with distilled water and then with a little **FA 4**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 20 cm^3 of **FA 2** into the same conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

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

Keep FA 1, FA 2 and FA 3 for use in Questions 2 and 3.

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VII	

[7]



- (b) From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.

Show clearly how you obtained this value.

25.0 cm³ of **FA 4** required cm³ of **FA 1**. [1]

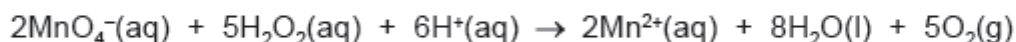
(c) Calculations

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

- (ii) Calculate the number of moles of potassium manganate(VII) present in the volume calculated in (b).

moles of KMnO₄ = mol [1]

- (iii) The equation for the reaction of potassium manganate(VII) with hydrogen peroxide is shown.



Use your answer to (c)(ii) to calculate the number of moles of hydrogen peroxide used in each titration.

moles of H₂O₂ = mol

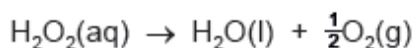
Hence calculate the concentration of H₂O₂ in **FA 4**, in mol dm⁻³.

concentration of H₂O₂ in **FA 4** = mol dm⁻³ [1]

(iv) Calculate the concentration of H_2O_2 in **FA 3**, in mol dm^{-3} .

concentration of H_2O_2 in **FA 3** = mol dm^{-3} [1]

(v) When hydrogen peroxide decomposes in the presence of a catalyst, oxygen is produced.



The 'volume strength' of hydrogen peroxide is equal to the volume of oxygen, in dm^3 , produced under room conditions, when 1.00 dm^3 of the solution decomposes.

Use your answer to (c)(iv) and the equation above to calculate the volume, in dm^3 , of oxygen produced when 1.00 dm^3 of **FA 3** decomposes. This is the 'volume strength', in vol, of **FA 3**.

(Under room conditions 1.00 mol of gas occupies a volume of 24.0 dm^3 .)

If you were unable to calculate the concentration of H_2O_2 in **FA 3**, assume that it is 1.02 mol dm^{-3} . This may **not** be the correct value.)

'volume strength' of **FA 3** = vol [2]

(d) The maximum error in reading a 25.0 cm^3 pipette is $\pm 0.06 \text{ cm}^3$.

Show by calculation that the pipette is more accurate than a burette for measuring 25.0 cm^3 of solution.

.....
..... [1]

[Total: 15]

Quantitative Analysis

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

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

- 1 In this experiment you will determine the concentration of a sample of hydrochloric acid. You will do this by measuring the volume of hydrogen produced when an excess of magnesium reacts with the acid.



FA 1 is magnesium powder, Mg.

FA 2 is hydrochloric acid, HCl.

(a) Method

- Weigh the container with **FA 1**. Record the mass.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 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 that the open end is just above the base of the tub.
- Use the 25 cm³ measuring cylinder to place 25.0 cm³ of **FA 2** into the reaction flask, labelled **X**.
- Check that the bung fits tightly in the neck of flask **X**, clamp flask **X**, and place the end of the delivery tube into the inverted 250 cm³ measuring cylinder.
- Remove the bung from the neck of flask **X**. Tip all of **FA 1** into flask **X** and replace the bung **immediately**. Remove the flask from the clamp and swirl to mix the contents.
- Swirl the flask occasionally until no more gas is evolved. Replace the flask in the clamp.
- Measure and record the final volume of gas in the measuring cylinder.
- Weigh and record the mass of the container with any residual solid.
- Calculate and record the mass of **FA 1** used.

Keep FA 2 for use in Question 2.

[2]



(b) Calculations

- (i) Calculate the number of moles of hydrogen gas produced.
(Assume 1 mol of gas occupies 24.0 dm³ at this temperature.)

moles of H₂(g) = mol
[1]

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

concentration of HCl in **FA 2** = mol dm⁻³
[1]

- (iii) In this experiment the magnesium powder was in excess.

Calculate the mass of magnesium powder needed for complete reaction with all the hydrochloric acid in 25.0 cm³ of **FA 2**.

mass of Mg = g
[1]

- (c) A student suggested two modifications to the method in (a) to give a more accurate value for the concentration.

For each suggestion, state whether you agree with the student and explain your answer.

Suggestion 1: Use magnesium ribbon rather than powdered magnesium; keep the rest of the experiment the same.

.....
.....

Suggestion 2: Use twice the mass of magnesium powder; keep the rest of the experiment the same.

.....
.....

[2]

(d) Another student carried out the experiment in **(a)** but used less magnesium than that calculated in **(b)(iii)**.

State and explain the effect this would have on the calculated concentration of hydrochloric acid in **FA 2**.

.....

.....

..... [1]

[Total: 8]

- 1 In this experiment you will determine the oxidation number of iodine in one of its compounds by titration.

FA 1 is a $0.0197 \text{ mol dm}^{-3}$ solution of the iodine-containing compound.

FA 2 is dilute sulfuric acid, H_2SO_4 .

FA 3 is aqueous potassium iodide, KI .

FA 4 is $0.105 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

starch indicator

FA 1 reacts with excess acidified potassium iodide to produce iodine, I_2 . This iodine is then titrated with aqueous sodium thiosulfate using starch indicator.

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Using the measuring cylinder, add 10 cm^3 of **FA 2** to the same conical flask.
- Using the same measuring cylinder, add 20 cm^3 of **FA 3** to the mixture in the conical flask. The mixture will now be a red-brown colour, due to iodine produced.
- Carry out a rough titration by adding **FA 4** from the burette until the mixture becomes light brown.
- Then add 10 drops of starch indicator. The mixture will change to a dark blue colour.
- Continue titrating until the mixture becomes colourless. This is the end-point.

The rough titre is cm^3 .

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

I	
II	
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[7]

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

The iodine produced required cm^3 of **FA 4**. [1]

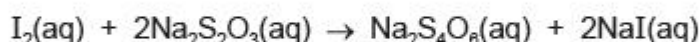
(c) Calculations

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

- (i) Calculate the number of moles of sodium thiosulfate in the volume of **FA 4** calculated in (b).

moles of $\text{Na}_2\text{S}_2\text{O}_3 = \dots\dots\dots \text{mol}$

- (ii) The equation for the reaction of iodine with sodium thiosulfate is shown.



Calculate the number of moles of iodine that reacted with the sodium thiosulfate calculated in (i).

moles of $\text{I}_2 = \dots\dots\dots \text{mol}$

- (iii) Use the information on page 2 to calculate the number of moles of iodine-containing compound in the 25 cm^3 of **FA 1** used in each titration.

moles of iodine-containing compound in 25 cm^3 **FA 1** = $\dots\dots\dots \text{mol}$

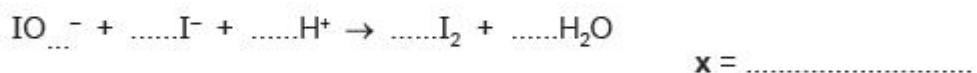
- (iv) Use your answers to (ii) and (iii) to calculate the number of moles of iodine produced when 1 mole of the iodine-containing compound in **FA 1** reacts with excess **FA 3**. Give your answer as an integer.

moles of $\text{I}_2 = \dots\dots\dots \text{mol}$

- (v) The anion in **FA 1** is IO_x^- where x is the number of oxygen atoms present in the formula.

Use your answer to (iv) to balance the ionic equation for the reaction between **FA 1** and **FA 3** under acidic conditions.

Hence deduce the value of x in the formula IO_x^- .



- (vi) Calculate the oxidation state of iodine in **FA 1**.
(If you were unable to calculate x in part (v), assume that $x = 4$.)

oxidation state of iodine = $\dots\dots\dots$
[6]

[Total: 14]

- 1** In this experiment you will determine the relative formula mass of a copper salt by titration.

A solution of the copper salt reacts with excess acidified potassium iodide, producing iodine. This iodine is then titrated with aqueous sodium thiosulfate, using starch indicator.

FA 1 is an aqueous solution of the copper salt prepared by dissolving 26.0g of the salt to make 1.00 dm³ of solution.

FA 2 is dilute sulfuric acid, H₂SO₄.

FA 3 is aqueous potassium iodide, KI.

FA 4 is 0.110 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.
starch indicator

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm³ of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately 10 cm³ of **FA 2** to the same conical flask.
- Use the measuring cylinder to add approximately 20 cm³ of **FA 3** to the mixture in the conical flask. The mixture will now be a brown colour, due to iodine produced in the reaction.
- Begin your rough titration by adding **FA 4** from the burette until the mixture becomes light brown.
- Add 10 drops of starch indicator. The mixture will become darker.
- Continue titrating until the mixture becomes an off-white colour. This is the end-point.
- Add **one** drop of starch indicator to check that no traces of dark colour are produced. If the mixture stays off-white, the titration is finished. If some dark colour is produced, because iodine is still present, continue the titration.
- Record your burette readings and the rough titre in the space below.

The rough titre is cm³.

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

I	
II	
III	
IV	
V	
VI	
VII	

Keep FA 3 and starch indicator for use in Question 3.

[7]

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

The iodine produced required cm³ of **FA 4**. [1]

(c) Calculations

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

- (i) Calculate the number of moles of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, in the volume of **FA 4** calculated in (b).

moles of $\text{Na}_2\text{S}_2\text{O}_3$ = mol

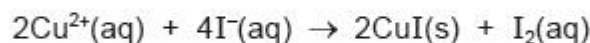
- (ii) Balance the equation for the reaction of iodine with sodium thiosulfate. State symbols are not required.



- (iii) Using your answer to (ii), calculate the number of moles of iodine that reacted with the number of moles of $\text{Na}_2\text{S}_2\text{O}_3$ calculated in (i).

moles of I_2 = mol

- (iv) Iodine, I_2 , is produced in the reaction between **FA 1** and **FA 3**. **FA 3** is in excess.



Using your answer to (iii), calculate the number of moles of copper(II) ions in 25.0 cm^3 of **FA 1**.

moles of Cu^{2+} ions = mol

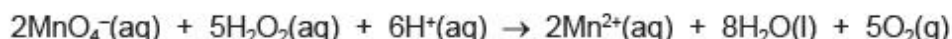
- (v) Using your answer to (iv) and the information on page 2, calculate the relative formula mass of the copper compound in **FA 1**.

M_r of copper compound =

[4]

[Total: 12]

- 2 You will carry out a second experiment to determine the concentration of hydrogen peroxide, **FA 1**, in mol dm^{-3} , by titration with acidified aqueous potassium manganate(VII). The equation for the reaction is given below.



FA 1 is a solution of hydrogen peroxide, H_2O_2 .

FA 3 is $0.0300 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 4 is dilute sulfuric acid.

(a) Method

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add approximately 20 cm^3 of **FA 4** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

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

I	
II	
III	
IV	
V	
VI	
VII	

[7]

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

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

(c) Calculations

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

- (i) Calculate the number of moles of manganate(VII) ions present in the volume of **FA 3** calculated in **(b)**.

moles of MnO_4^- = mol

- (ii) Calculate the number of moles of hydrogen peroxide present in 25.0 cm^3 of **FA 1**.

moles of H_2O_2 = mol

- (iii) Using your answer to **(ii)** calculate the concentration, in mol dm^{-3} , of hydrogen peroxide in **FA 1**.

concentration of H_2O_2 in **FA 1** = mol dm^{-3}
[4]

[Total: 12]

- 1 In this experiment you will determine the ionic equation for the reaction of acidified potassium manganate(VII) with potassium iodide. Excess potassium iodide is used and the reaction produces iodine. The amount of iodine produced is measured by titration with sodium thiosulfate.

FA 1 is $0.0180 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 2 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4 .

FA 3 is $0.500 \text{ mol dm}^{-3}$ potassium iodide, KI .

FA 4 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

starch indicator

(a) Method

- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the measuring cylinder to add 25 cm^3 of **FA 2** to the conical flask.
- Use the measuring cylinder to add 20 cm^3 of **FA 3** to the conical flask.
- Fill the burette with **FA 4**.
- Carry out a rough titration. When the colour of the mixture becomes yellow/orange, add a few drops of starch indicator. Then titrate until the mixture goes colourless.
- Record all your burette readings in the space below.

The rough titre is cm^3 .

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

Keep **FA 1** and **FA 2** for use in Question 3 and **FA 4** for use in Question 2.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

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

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

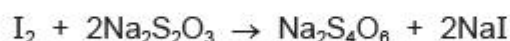
(c) Calculations

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

- (i) Calculate the number of moles of sodium thiosulfate in the volume of **FA 4** calculated in (b).

moles of $\text{Na}_2\text{S}_2\text{O}_3 = \dots\dots\dots$ mol

- (ii) Use the equation below to calculate the number of moles of iodine that reacted with the sodium thiosulfate in the titration.



moles of $\text{I}_2 = \dots\dots\dots$ mol

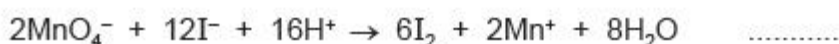
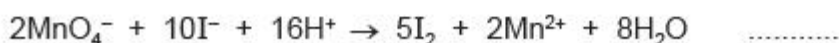
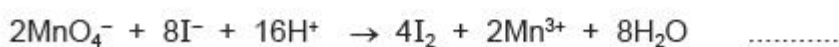
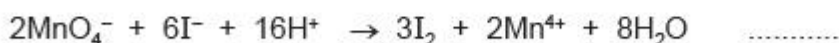
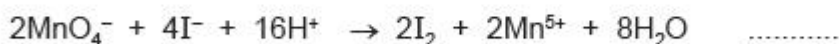
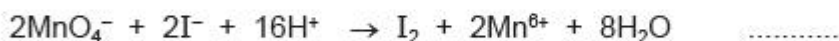
- (iii) Use information on page 2 to calculate the number of moles of potassium manganate(VII) in **FA 1** used in the titration.

moles of $\text{KMnO}_4 = \dots\dots\dots$ mol

- (iv) From your answers to (ii) and (iii), calculate the number of moles of iodine produced by the reaction of **2.00** moles of potassium manganate(VII) with excess potassium iodide.

moles $\text{I}_2 = \dots\dots\dots$ mol

- (v) Using your answer to (iv), put a tick next to the ionic equation that represents the reaction between **FA 1** and **FA 3**.



(vi) Prove that the iodide ion has been oxidised in the equation that you selected in (v).

.....

.....

.....

[5]

(d) (i) The error in calibration of the pipette you used is $\pm 0.06 \text{ cm}^3$.
Calculate the percentage error when measuring **FA 1**, using the pipette.

percentage error = %

(ii) A student suggested that the experiment would be more accurate if a pipette was used to measure solution **FA 3**.
State and explain whether you agree with the student.

.....

.....

.....

[2]

[Total: 15]

- 2 In this experiment you will measure the heat given out by the reaction of excess zinc with copper(II) sulfate solution and use this to estimate the concentration of the copper(II) sulfate.



FA 4 is zinc powder.

FA 5 is aqueous copper(II) sulfate, CuSO_4 .

(a) Method

Read through the instructions carefully and prepare a table below for your results before starting any practical work.

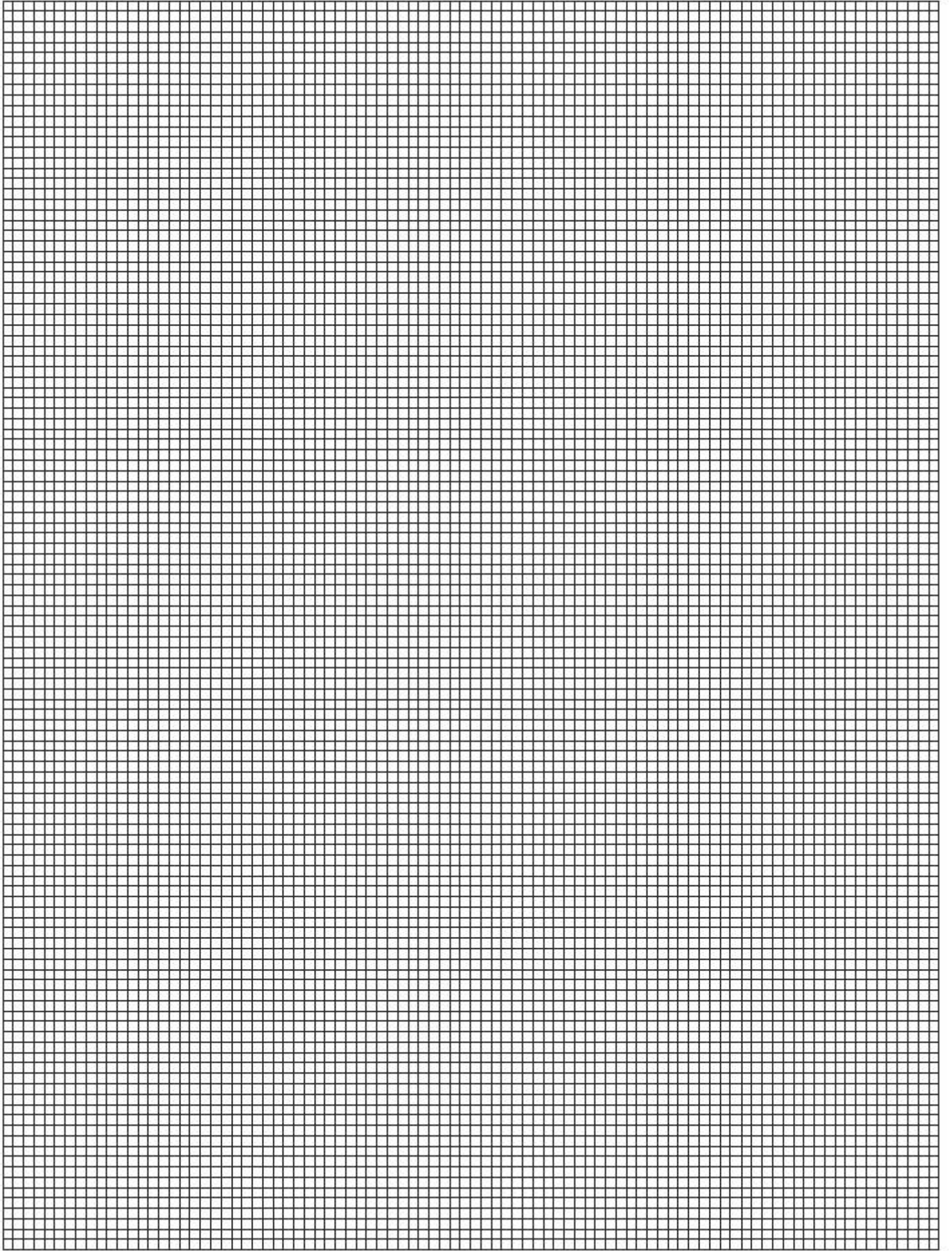
- Support the plastic cup in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 40 cm^3 of **FA 5** into the plastic cup.
- Measure and record the initial temperature of the solution in the plastic cup.
- Start the stopwatch. Measure and record the temperature of the solution every 30 seconds up to and including the temperature at 2 minutes. Stir the solution frequently.
- At time $t = 2\frac{1}{2}$ minutes, add **all** the powdered zinc to the solution in the plastic cup and stir the mixture.
- Record the temperature every 30 seconds from $t = 3$ minutes up to and including $t = 9$ minutes. Stir the solution constantly.

I	
II	
III	
IV	

[4]

- (b) (i) On the grid opposite, plot the temperature (y-axis) against the time (x-axis). The scale for the temperature axis must allow you to plot a point with a temperature 5°C greater than the maximum temperature you recorded.
- (ii) Draw the following best-fit **straight** lines on the graph.
- a line through the points between time $t = 0$ minutes and time $t = 2$ minutes
 - a line through the points between time $t = 5$ minutes and time $t = 9$ minutes
 - a vertical line at time $t = 2\frac{1}{2}$ minutes
- (iii) Extrapolate the first two straight lines so that they intersect the vertical line at time $t = 2\frac{1}{2}$ minutes.
Use these extrapolated lines to determine the theoretical temperature **change** at time $t = 2\frac{1}{2}$ minutes.

change in temperature = $^\circ\text{C}$
[5]



(c) Calculations

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

- (i) Use your answer to **(b)(iii)** to calculate the heat energy produced in the reaction.
(Assume that **4.2 J** are required to increase the temperature of 1 cm³ of solution by 1 °C.)

heat energy produced = J

- (ii) The molar enthalpy change, ΔH , for the reaction shown below is -219 kJ mol^{-1} .



Use this value and your answer to **(i)** to calculate the number of moles of copper(II) sulfate in your reaction.

moles of CuSO_4 = mol

- (iii) Use your answer to **(ii)**, to calculate the concentration of copper(II) sulfate, in mol dm^{-3} , in **FA 5**.

concentration of CuSO_4 = mol dm^{-3}
[3]

- (d) (i) Calculate the maximum percentage error in the highest temperature that you recorded in your results table.

maximum percentage error = %

- (ii) A student suggested that the concentration of the copper(II) sulfate could be determined more accurately if a greater mass of zinc had been used.
Explain whether you agree with this student.

.....

.....

.....

- (iii) A second student suggested that the concentration of the copper(II) sulfate could be determined more accurately if a smaller volume of copper(II) sulfate was used.
Explain whether you agree with this student.

.....

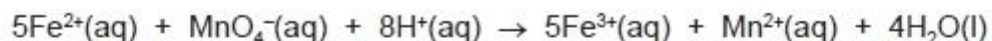
.....

.....

[3]

[Total: 15]

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



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

FA 1 contains $0.0200 \text{ mol dm}^{-3}$ manganate(VII) ions, MnO_4^- .

FA 2 is a solution containing iron(II) ions, Fe^{2+} .

FA 3 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

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

The rough titre is cm^3 .

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

Keep FA 2 to use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

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

25.0 cm³ of **FA 2** required cm³ of **FA 1**. [1]

(c) Calculations

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

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

moles of MnO_4^- = mol

- (ii) Calculate the number of moles of iron(II) ions present in 25.0 cm³ of **FA 2**.

moles of Fe^{2+} = mol

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

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

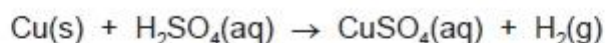
- (iv) **FA 2** was prepared by dissolving hydrated ammonium iron(II) sulfate, $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ in distilled water. Calculate the mass of salt that would have to be dissolved in 1.00 dm³ of water to prepare **FA 2**.
(A_r : H, 1.0; N, 14.0; O, 16.0; S, 32.1; Fe, 55.8)

I	
II	
III	
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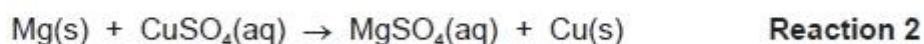
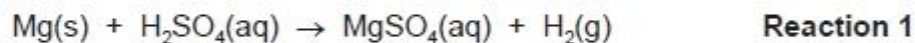
mass of $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ = g
[4]

[Total: 12]

- 1** You are to determine the enthalpy change of reaction, ΔH , for the reaction shown below.



Since copper is an unreactive metal it does not react directly with dilute acids. You will therefore need to find the enthalpy change of reaction for two reactions that do occur. The equations for these two reactions are below.



You will carry out experiments to find the enthalpy changes for each of **Reaction 1** and **Reaction 2** and use these values to calculate the enthalpy change for the reaction of copper with sulfuric acid.

TURN OVER FOR EXPERIMENTAL METHOD

Determining the enthalpy change for Reaction 1



Reaction 1

(a) Method

FA 1 is 1.00 mol dm⁻³ sulfuric acid, H₂SO₄.

FA 2 is magnesium powder, Mg.

Read through the method before you start any practical work and prepare a suitable table for your results.

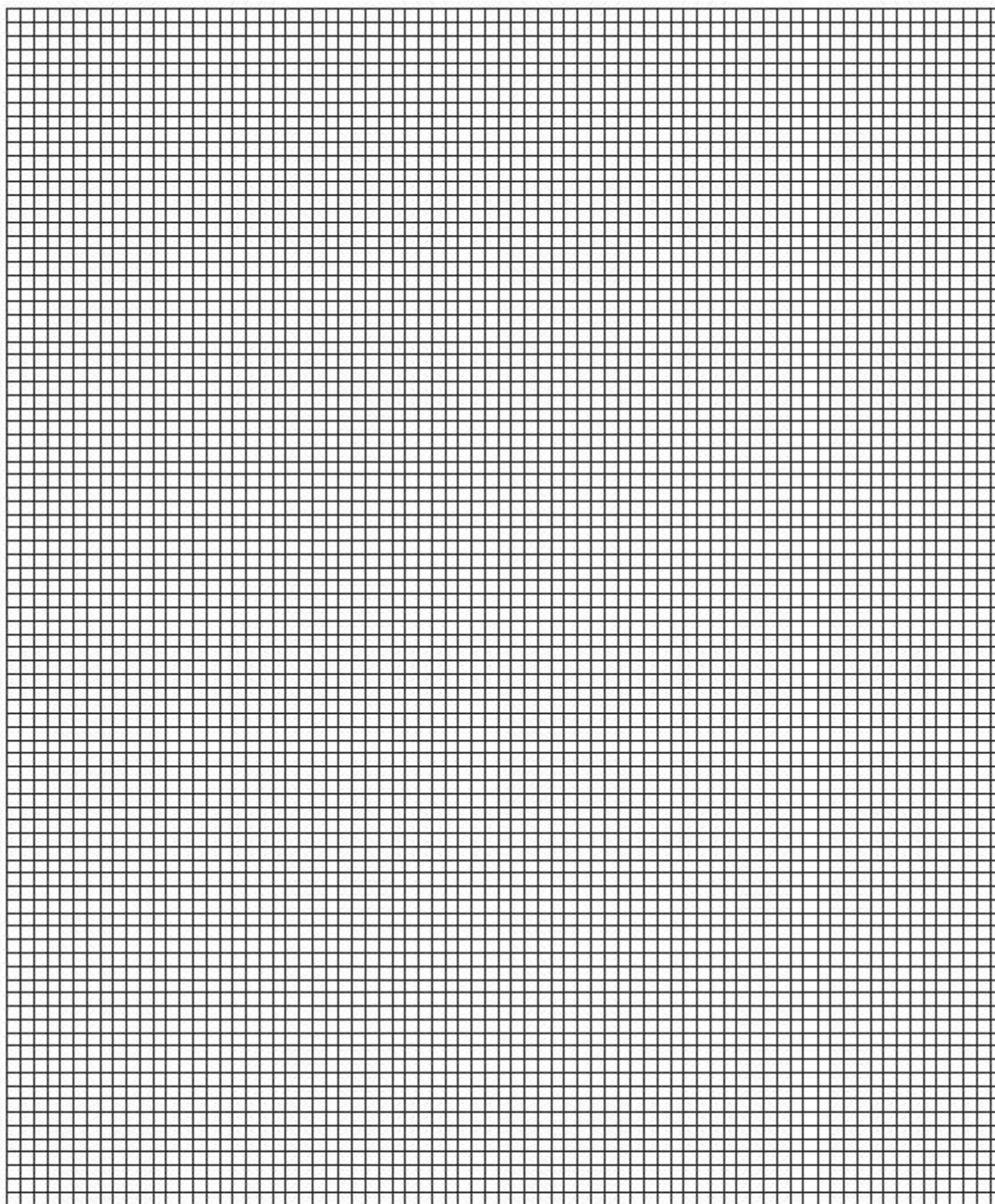
- Weigh the stoppered tube containing **FA 2**. Record the mass.
- Support the plastic cup in the 250 cm³ beaker.
- Use the measuring cylinder to transfer 25 cm³ of **FA 1** into the plastic cup.
- Measure the temperature of **FA 1** in the plastic cup and start the stop clock. Record this temperature as being the temperature at time = 0.
- Measure, and record, the temperature of this **FA 1** every half minute for 2 minutes.
- At time = 2½ minutes add the **FA 2** to the acid and stir carefully to reduce acid spray.
- Measure the temperature of the mixture in the cup at time = 3 minutes and then every half minute up to time = 7 minutes.
- Continue stirring occasionally throughout this time.
- Weigh the stoppered tube that had contained **FA 2**. Record the mass.
- Calculate and record the mass of **FA 2** added to the sulfuric acid.
- Rinse the plastic cup with water and shake to dry.

I	
II	
III	
IV	
V	
VI	

[6]



(b) (i) On the grid below plot a graph of temperature (y-axis) against time (x-axis).



(ii) Complete the graph by inserting **two, straight** lines of best fit:

- one to show the temperature up to time = $2\frac{1}{2}$ minutes,
- one to show the temperature after time = $2\frac{1}{2}$ minutes.

I	
II	
III	
IV	

- (iii) From your graph, use the two straight lines of best fit to calculate the change in temperature at time = $2\frac{1}{2}$ minutes.

temperature change = °C
[4]

(c) Calculations

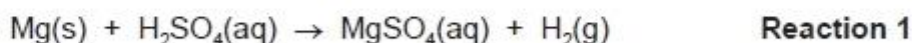
- (i) In the reaction in (a), the sulfuric acid was in excess. Without carrying out any additional tests, what observation could you have made during your experiment to confirm this?

.....
.....

- (ii) Calculate the energy change that occurred during the reaction in (a).
[Assume that 4.2 J is needed to raise the temperature of 1.0 cm³ of solution by 1.0 °C.]

energy change = J

- (iii) Use your answer to (ii) to calculate the enthalpy change, in kJ mol⁻¹, for the reaction between sulfuric acid and magnesium.
[A_r: Mg, 24.3]



enthalpy change for **Reaction 1** = kJ mol⁻¹
sign value
[4]

Determining the enthalpy change for Reaction 2



Reaction 2

(d) Method

FA 3 is 1.00 mol dm⁻³ copper(II) sulfate, CuSO₄.

FA 4 and **FA 5** are magnesium powder, Mg.

Read through the method before you start any practical work and prepare a suitable table for your results.

- Weigh the stoppered tube containing **FA 4**. Record the mass.
- Support the plastic cup in the 250 cm³ beaker.
- Use the measuring cylinder to transfer 25 cm³ of **FA 3** into the plastic cup.
- Measure the temperature of **FA 3** in the plastic cup and record the temperature.
- Add the **FA 4** to the **FA 3** in the cup and stir the mixture constantly.
- Measure and record the maximum temperature reached during the reaction.
- Calculate and record the maximum temperature change that occurred during the reaction.
- Weigh the stoppered tube that had contained **FA 4**. Record the mass.
- Calculate and record the mass of **FA 4** added to the copper(II) sulfate.
- Empty the contents of the plastic cup into the 100 cm³ beaker labelled **waste**.
- Rinse the plastic cup and shake to dry.
- Repeat this experiment using **FA 5** in place of **FA 4**.

[2]

(e) Calculations

- (i) Using your results from (d), calculate the mean temperature rise.

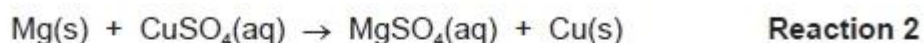
mean temperature rise = °C

- (ii) Using your results from (d), calculate the mean mass of magnesium used.

mean mass = g

- (iii) Show, using a suitable calculation, that the copper(II) sulfate was in excess in these reactions.

- (iv) Using your values from (i) and (ii), calculate the enthalpy change, in kJ mol^{-1} , for the reaction between magnesium and copper(II) sulfate.
[Assume that 4.2 J is needed to raise the temperature of 1.0 cm^3 of solution by 1.0°C .]
[A_r : Mg, 24.3]



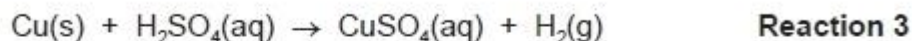
enthalpy change for **Reaction 2** = kJ mol^{-1}
sign value

[4]

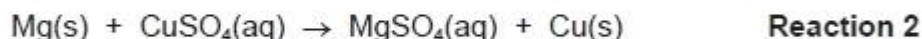
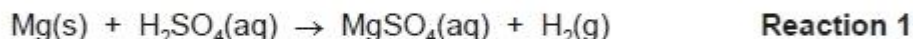


Enthalpy change for Reaction 3

Reaction 3 is shown below.



- (f) Use your values for the enthalpy changes for **Reactions 1** and **2** to calculate the enthalpy change for **Reaction 3**.



Show clearly how you obtained your answer.

(If you were unable to calculate the enthalpy changes for **Reactions 1** and **2**, you should assume that the value for **Reaction 1** is -444 kJ mol^{-1} and that the value for **Reaction 2** is -504 kJ mol^{-1} . Note: these are not the correct values.)

enthalpy change for **Reaction 3** = kJ mol^{-1}
sign value [2]

- (g) (i) The method you used to determine the enthalpy change for **Reaction 1** was more accurate than the method you used to determine the enthalpy change for **Reaction 2**. Suggest **two** reasons why the method used for **Reaction 2** was less accurate. Explain your answers.

1
.....
.....

2
.....
.....

- (ii) A student suggested that the accuracy of the method used for **Reaction 2** could be improved by using a larger volume of copper(II) sulfate. Is this a correct suggestion? Give a reason for your answer.

.....
..... [3]

[Total: 25]

- 1 Hydrogen peroxide, H_2O_2 , is unstable and decomposes to give water and oxygen. In addition to the usual units of concentration, mol dm^{-3} , the concentration of a solution of hydrogen peroxide can also be given in 'volume strength' or 'vol'. For example, in **Question 3** you will use a solution of '20 vol' H_2O_2 . This term means that when 1 dm^3 of this solution is completely decomposed it generates 20 dm^3 of oxygen at room temperature and pressure.

The aim of the following titration is to determine the volume strength of a solution of hydrogen peroxide. To do this you will titrate an acidified solution of hydrogen peroxide with potassium manganate(VII) solution.

FA 1 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 2 is aqueous hydrogen peroxide, H_2O_2 .

FA 3 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 2** into the conical flask.
- Use the measuring cylinder to add 25 cm^3 of **FA 3** to the conical flask.
- Run **FA 1** from the burette into the conical flask until the pink colour remains.
- Perform a **rough titration** and record your burette readings in the space below.

The rough titre is cm^3 .

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

I	
II	
III	
IV	
V	
VI	

[6]

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

25.0 cm³ of **FA 2** required cm³ of **FA 1**. [1]

(c) Calculations

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

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

moles of KMnO₄ = mol

- (ii) Use the following equation and your answer to (i) to calculate the number of moles of hydrogen peroxide used in each titration.



moles of H₂O₂ = mol

- (iii) Calculate the concentration, in mol dm⁻³, of H₂O₂ in **FA 2**.

concentration of H₂O₂ = mol dm⁻³

- (iv) Write an equation for the decomposition of hydrogen peroxide to produce oxygen and water.

.....

- (v) Calculate the concentration in 'volume strength' of H₂O₂ in **FA 2**. You must assume that the molar volume of oxygen is 24.0 dm³ mol⁻¹ at room temperature and pressure.

I	
II	
III	
IV	
V	

concentration of **FA 2** = 'vol'
[5]

[Total: 12]

- 1 In this experiment you are to determine the relative formula mass of an iron(II) salt by titration with potassium manganate(VII).

FA 1 is the iron(II) salt.

FA 2 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 3 is dilute sulfuric acid, H_2SO_4 .

(a) Method

Preparing a solution of FA 1

- Weigh the 250 cm^3 beaker and record the mass in the space below.
- Add all the FA 1 provided to the beaker. Weigh the beaker with FA 1 and record the mass.
- Calculate the mass of FA 1 used and record this in the space below.
- Use a measuring cylinder to add approximately 100 cm^3 of FA 3 to the beaker. Stir until all the solid has dissolved.
- Transfer the solution into the 250 cm^3 volumetric (graduated) flask labelled FA 4.
- Wash out the beaker thoroughly using distilled water and add the washings to the volumetric flask. Make the solution up to the mark using distilled water.
- Shake the flask thoroughly to mix the solution before using it for your titrations.
- This solution of the iron(II) salt is FA 4.

Titration

- Pipette 25.0 cm^3 of FA 4 into a conical flask.
- Use a measuring cylinder to add 20 cm^3 of FA 3 to the flask.
- Fill the burette with FA 2.
- Titrate FA 4 with FA 2 until the solution changes to a permanent pink colour.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

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

For
Examiner's
Use

I	
II	
III	
IV	
V	
VI	
VII	

[7]

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

25.0 cm³ of **FA 4** required cm³ of **FA 2** [1]

(c) **Calculations**

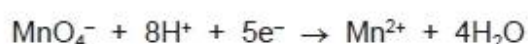
For
Examiner's
Use

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

- (i) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 2** calculated in (b).

moles of KMnO₄ = mol

- (ii) The half-equation for the reduction of a manganate(VII) ion is:



Give the half-equation for the oxidation of an iron(II) ion to an iron(III) ion.

.....

Therefore, 1 mole of manganate(VII) ions reacts with 5 moles of iron(II) ions.

(iii) Calculate the number of moles of iron(II) ions present in 25.0 cm³ of solution **FA 4**.

moles of Fe²⁺ in 25.0 cm³ of **FA 4** = mol

(iv) Calculate the number of moles of iron(II) ions present in 250 cm³ of solution **FA 4**.

moles of Fe²⁺ in 250 cm³ of **FA 4** = mol

(v) In 1 mole of the iron(II) salt, **FA 1**, there is 1 mole of iron(II) ions.
Use the mass of **FA 1** you weighed out to calculate the relative formula mass of the iron(II) salt.

relative formula mass =
[5]

I	
II	
III	
IV	
V	

(d) (i) A 25 cm³ pipette is accurate to ± 0.06 cm³.
Calculate the maximum percentage error when the pipette was used to measure solution **FA 4**.

percentage error in measuring **FA 4** = %

(ii) State the maximum error in the mass of the 250 cm³ beaker that you recorded in (a).

maximum error = g

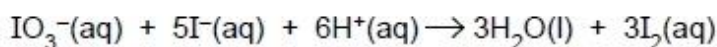
(iii) Calculate the maximum percentage error in the mass of **FA 1** used in (a).

maximum percentage error = %
[2]

[Total: 15]

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

- 1** You are to determine the concentration of hydrochloric acid, which supplies the H^+ ions in the following reaction.



In the presence of an excess of IO_3^- ions and an excess of I^- ions, the amount of I_2 liberated is directly proportional to the amount of H^+ ions present and can be determined by titration with sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

You are provided with the following reactants.

FA 1 hydrochloric acid

FA 2 containing 15.0 g dm^{-3} sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$

aqueous potassium iodate(V), KIO_3

aqueous potassium iodide, KI

(a) Method

- Fill a burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into the conical flask.
- Use a 25 cm^3 measuring cylinder to add to the flask 10 cm^3 of aqueous potassium iodate(V) **and** 10 cm^3 of aqueous potassium iodide. There is an excess of each of these reagents.
- Place the flask on a white tile.
- Titrate the liberated iodine with **FA 2**.
- During the titration the colour of the iodine in the solution will fade from red-brown to orange to yellow. The end-point occurs when the solution just goes colourless with the addition of a single drop of **FA 2**.
- You should perform a **rough titration**.

In the space below record your burette readings for this rough titration.

- The rough titre is cm^3
- Carry out as many accurate titrations as you think necessary to obtain consistent results.
 - Record in a suitable form below all of your burette readings and the volume of **FA 2** added in each accurate titration.
 - Make certain any recorded results show the precision of your practical work.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

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

For
Examiner's
Use

25.0 cm³ of **FA 1** require cm³ of **FA 2**. [1]

Calculations

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

- (c) (i) Calculate the concentration, in mol dm⁻³, of the sodium thiosulfate in **FA 2**.

FA 2 contains 15.0 g dm⁻³ Na₂S₂O₃·5H₂O.

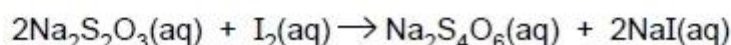
[A_r: H, 1.0; O, 16.0; Na, 23.0; S, 32.1]

The concentration of sodium thiosulfate in **FA 2** is mol dm⁻³.

- (ii) Calculate how many moles of Na₂S₂O₃ are contained in the volume of **FA 2** recorded in (b).

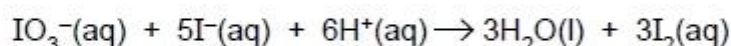
..... mol of Na₂S₂O₃

- (iii) Calculate how many moles of iodine, I₂ reacted with the Na₂S₂O₃ in (ii).



..... mol of iodine reacted with the sodium thiosulfate.

- (iv) Calculate how many moles of hydrochloric acid, HCl, reacted with an excess of potassium iodate(V) and an excess of potassium iodide to produce the amount of iodine calculated in (iii).



..... mol of HCl produced the amount of iodine calculated in (iii).

I	
II	
III	
IV	
V	

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

The concentration of HCl in **FA 1** is mol dm^{-3} .
[5]

(d)

Each reading with a burette has a maximum error of $\pm 0.05 \text{ cm}^3$.
Grade B volumetric (bulb) pipettes are calibrated to $\pm 0.06 \text{ cm}^3$.

- (i) Calculate the maximum error in the volume run from the burette recorded in any titration.

The maximum error is cm^3 .

- (ii) Express the maximum error calculated in (i) as a percentage error for the volume calculated in (b).

The maximum error is %.

- (iii) Calculate the percentage error when 25.0 cm^3 of **FA 1** was pipetted into the conical flask.

The error was %.
[2]

[Total: 15]

1 You are provided with the following reagents.

- two weighing bottles labelled **FA 1**, each containing between 2.90 g and 3.00 g of zinc powder
- **FA 2**, 0.80 mol dm⁻³ copper sulfate, CuSO₄

You are to determine the enthalpy change, ΔH , for the following reaction.



You will carry out the experimental procedure twice.

Read through the instructions below before starting the experiment.

- (a) You will weigh each bottle and later in the experiment weigh it again after the zinc powder has been tipped into copper sulfate solution.
In the space below prepare a table to record the weighings and the mass of zinc powder used in **each** experiment.

Weigh accurately, to at least one decimal place, one of the weighing bottles labelled **FA 1**.

Record this mass in the table you have prepared. [1]

(b) Procedure

- Support the plastic cup in the 250 cm³ beaker and, using a pipette, place 25.0 cm³ of **FA 2** into the plastic cup.
- Stir gently, taking a temperature reading every ½ minute until a steady temperature has been obtained for a period of at least 2 minutes. You may need to tilt the beaker in order to cover the bulb of the thermometer with solution.
- On a precise minute reading tip the zinc powder from the weighing bottle into the plastic cup.
Do not read the temperature at this time or at the following ½ minute.
- Continue to stir the mixture thoroughly. Starting 1 minute after the addition of the zinc powder, record the temperature every ½ minute until the temperature has reached a maximum value and then decreased steadily for at least 5 minutes.
- Reweigh the empty weighing bottle. Record the mass of the bottle + any residual zinc powder and the mass of zinc powder used in the experiment in the table you prepared in (a).
- Record your results in an appropriate form in the space on the following page.

Repeat the experiment using the contents of the second weighing bottle and 25.0 cm³ copper sulfate solution pipetted into a clean plastic cup.



(b) continued

Results Make certain your readings of temperature display the precision of the apparatus used.

[11]

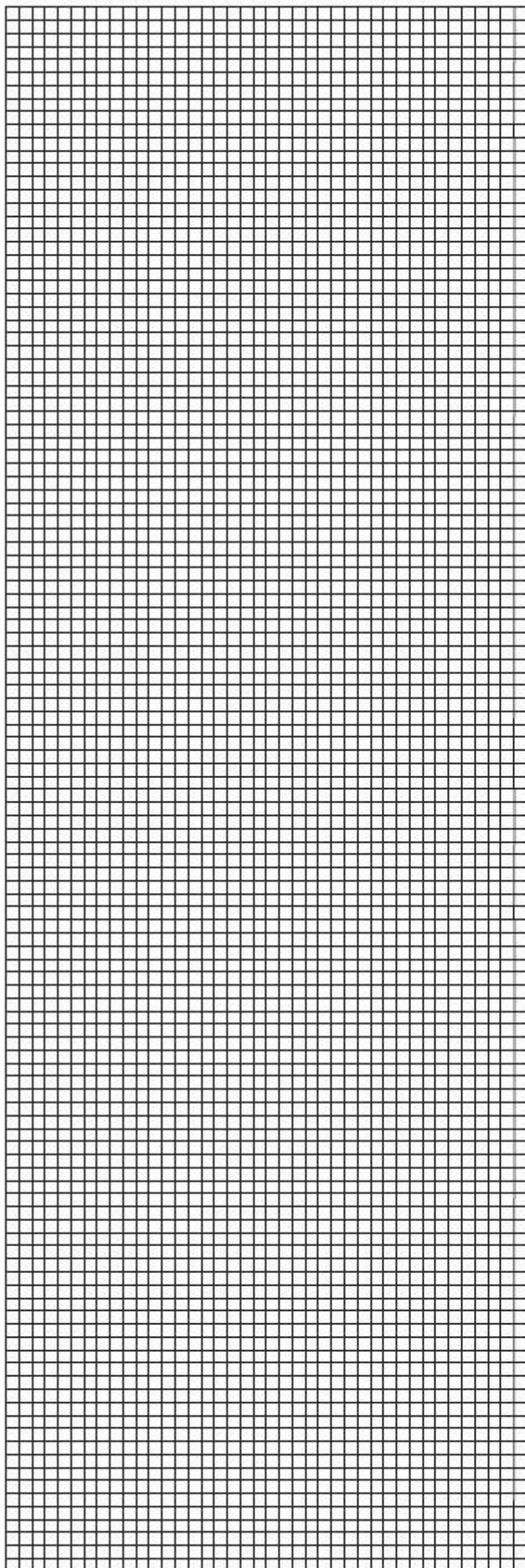
- (c) Plot your temperature and time readings separately for each experiment on the grids on the next page. Your temperature axis should extend 10°C **above** the highest temperature you recorded.
Draw lines as instructed below.

On each graph draw a horizontal straight line through the steady initial temperature.

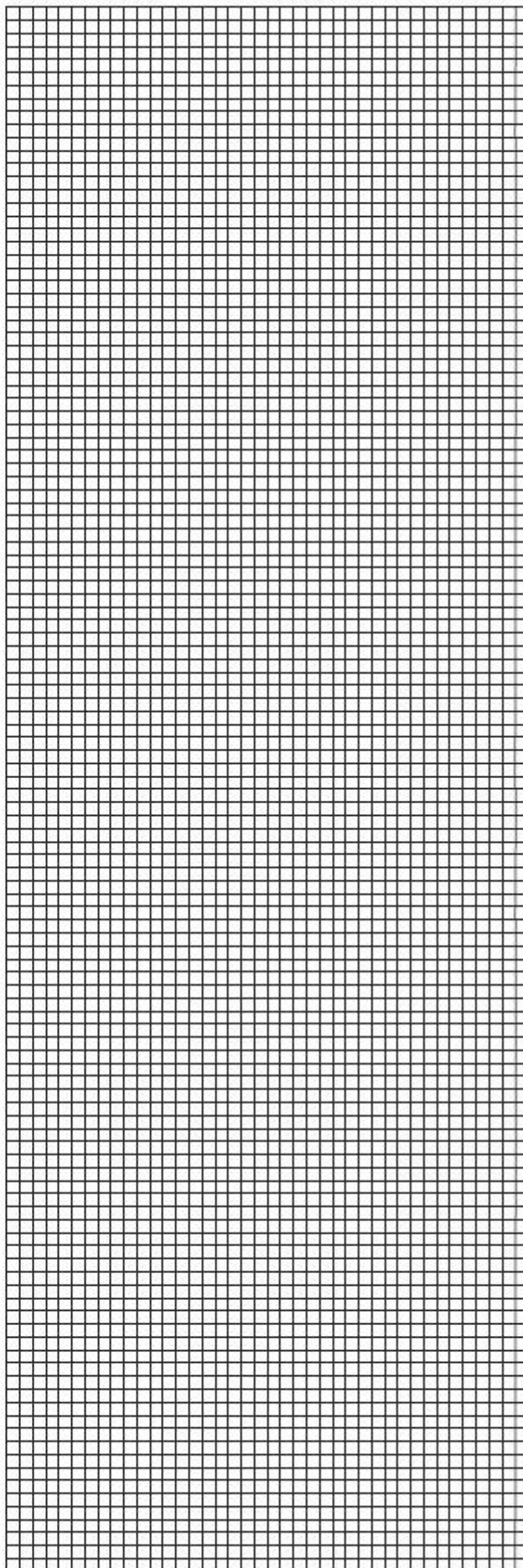
Extrapolate the cooling section of each graph back to the time when you added the zinc powder.

Draw construction lines on the graphs to deduce the “theoretical” **temperature rise** at the moment of mixing the reagents.

experiment 1



experiment 2



[4]



(d) The "theoretical" **temperature rises** are °C and °C.

The mean "theoretical" **temperature rise** is °C. [1]

Calculations

Show working and appropriate significant figures in **all** of your calculations. [2]

(e) Calculate how many moles of copper sulfate, CuSO_4 , were pipetted into the plastic cup.

..... mol of CuSO_4 were pipetted into the cup

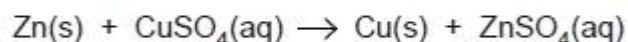
For each experiment calculate how many moles of zinc powder were added to the plastic cup.
[A_r : Zn, 65.4]

1 st experiment	2 nd experiment

In the 1st experiment mol of zinc powder were added to the plastic cup.

In the 2nd experiment mol of zinc powder were added to the plastic cup. [1]

(f) Use your answers to (e) and the equation for the reaction to determine which reagent was in excess and which was the limiting reagent. Explain your answer.



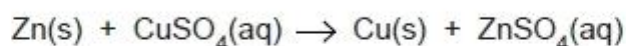
.....
.....
..... [1]

- (g) From your mean “theoretical” temperature rise at the time of mixing, calculate the heat energy released in the plastic cup by the reaction of zinc powder with copper sulfate solution.

[You may assume that 4.3 J are required to raise the temperature of 1 cm³ of any solution by 1 °C and that the mass of any solid may be ignored.]

..... of heat energy are released. [1]

- (h) Calculate, correct to 3 significant figures, the enthalpy change in kJ mol⁻¹ for the following reaction.



$\Delta H =$ kJ mol⁻¹
[2]

- (i) Identify and explain **one** source of error in the experiment you have carried out.

.....
.....
.....
..... [1]

- (j) Suggest a way in which the experimental method you used could be improved in a school or college laboratory in order to minimise this error.

.....
.....
.....
..... [1]

[Total: 26]

1 You are provided with the following.

FA 1 is 0.15 mol dm^{-3} sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 2 is aqueous copper(II) sulfate.

You are also provided with a 10% solution of potassium iodide, KI, and starch indicator.

You are required to determine the concentration, in g dm^{-3} , of hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, in **FA 2**.

Dilution of FA 2

(a) By using a burette measure between 47.00 cm^3 and 47.50 cm^3 of **FA 2** into the 250 cm^3 graduated flask labelled **FA 3**.

Record your burette readings and the volume of **FA 2** added to the flask in the space below.

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

Titration

Fill a second burette with **FA 1**.

Perform a rough (trial) titration as follows.

Pipette 25.0 cm^3 of **FA 3** into a conical flask.

Use the measuring cylinder provided to add 10 cm^3 of 10% potassium iodide to the flask.

The Cu^{2+} ions in **FA 3** oxidise the iodide ions to iodine, I_2 , which can be titrated with **FA 1**.

The flask will also contain an off-white precipitate of copper(I) iodide, CuI .

Run **FA 1** from the burette, 1 cm^3 at a time, until the brown colour of the iodine solution has changed to pale brown.

Add approximately 10 drops of starch indicator. A blue-black colour should be seen as the starch reacts with the residual iodine.

Continue to add **FA 1** 1 cm^3 at a time until the blue-black colour of the starch-iodine complex disappears and there is no further colour change.

In this rough titration cm^3 of **FA 1** were added.

Perform sufficient further titrations to obtain reliable results.

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

For
Examiner's
Use

i	
ii	
iii	
iv	
v	
vi	

[6]

- (b) From your titration results obtain a volume of **FA 1** to be used in your calculations. Show clearly how you obtained this volume.

[1]

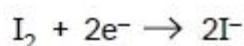
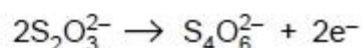
Calculations

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

- (c) Use your answer to (b) to calculate how many moles of $\text{Na}_2\text{S}_2\text{O}_3$ were run from the burette into the conical flask.

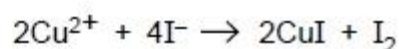
..... mol of $\text{Na}_2\text{S}_2\text{O}_3$ were run from the burette into the conical flask.

Calculate how many moles of I_2 reacted with the $\text{Na}_2\text{S}_2\text{O}_3$ run from the burette.



..... mol of I_2 reacted with the $\text{Na}_2\text{S}_2\text{O}_3$ run from the burette.

Calculate how many moles of Cu^{2+} ions reacted with iodide ions to produce this amount of I_2 .



..... mol of Cu^{2+} reacted to form the I_2 .

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

For
Examiner's
Use

The concentration of Cu^{2+} in **FA 3** is mol dm^{-3} .

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

The concentration of Cu^{2+} in **FA 2** is mol dm^{-3} .

Calculate the concentration, in g dm^{-3} , of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in **FA 2**.
[A_r : Cu, 63.5; H, 1.0; O, 16.0; S, 32.1]

i	
ii	
iii	
iv	
v	

FA 2 contains g dm^{-3} $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.
[5]

(d) The maximum error in any burette reading is $\pm 0.05 \text{ cm}^3$.

Explain how the maximum error in a titration is therefore $\pm 0.10 \text{ cm}^3$.

.....
.....
..... [1]

(e) Calculate the maximum percentage error in the average titre given in (b).

The error is % [1]

[Total: 14]

Q# 8/ Chem 6 ALVl Chemistry/2022/w/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

1(a)	I all the following data recorded - two burette readings and titre for rough titration - initial and final burette readings for two (or more) accurate titrations II titre values shown for accurate titrations and appropriate headings and units in the accurate titration table - initial / start and (burette) reading / volume - final / end and (burette) reading / volume - titre or volume / FA 2 and used / added - unit: /cm³ or (cm³) or in cm³ (for each heading) or cm³ unit given for each volume recorded III all accurate burette readings are to nearest 0.05 cm³ IV the final accurate titre recorded is within 0.10 cm³ of any other accurate titre V, VI, VII award V if $\delta \leq 0.60$ (cm³) award VI if $\delta \leq 0.40$ (cm³) award VII if $\delta \leq 0.20$ (cm³) where δ is the difference between the supervisor's and candidate's mean titre	7
1(b)	candidate calculates mean correctly to 2 decimal places (dp) - candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm³ - working / explanation must be shown or ticks must be put next to the two (or more) accurate readings selected - the mean should be quoted to 2 dp and be rounded to the nearest 0.01 cm³	1
1(c)(i)	significant figures (sf) all quoted answers in (c)(ii) – (c)(iv) are expressed to 3 or 4 sf	1
1(c)(ii)	correctly calculates amount of MnO₄⁻ used amount of MnO₄⁻ = $\frac{0.02 \times \text{vol in (b)}}{1000}$ (mol)	1
1(c)(iii)	correctly uses equation and converts volume amount of (COO⁻)₂ that reacted = (c)(ii) $\times \frac{5}{2}$ (mol) and concentration of (COO⁻)₂ in FA 1 = amount of (COO⁻)₂ $\times \frac{1000}{25}$ (mol dm⁻³)	1
1(c)(iv)	correctly uses $M_r = \frac{\text{mass}}{\text{moles}}$ $M_r = \frac{10.14}{\text{concentration from (c)(iii)}}$	1
1(c)(v)	identity of M M1: $A_r \text{ of M} = \frac{M_r \text{ from (c)(iv)} - 124}{2}$ M2: identifies M as being the Group 1 element with the nearest A_r (Li ≤ 14.9; 15.0 $\leq$ Na ≤ 31.0; 31.1 $\leq$ K ≤ 62.3; 62.3 $\leq$ Rb ≤ 111.4; 111.4 $\leq$ Cs ≤ 250)	2
1(d)	explanation for use of acid to provide H⁺ and for the reaction (to proceed) / as given in the equation / to acidify the KMnO₄	1

1(a)	I The following data must be shown - burette readings and titre for rough titration 2 × 2 'box' showing both accurate burette readings <i>'Correct' headings and units are not required for this mark</i>	1
	II Headings and units correct for accurate titration table and headings match readings. - initial/start and (burette) reading / volume + unit (allow vol but not V) - final/end and (burette) reading / volume + unit (allow value for reading) - titre or volume/FA 2 and used/added (not 'difference' or 'total' or 'amount') + unit Units: (cm ³) or /cm ³ or in cm ³ or cm ³ by every entry	1
	III All accurate burette readings to 0.05 cm ³ Do not award this mark if: 50(.00) is used as an initial burette reading; More than one final burette reading is 50(.00); Any burette reading is greater than 50(.00).	1
	IV The final accurate titre recorded is within 0.10 cm ³ of any other accurate titre. Do not award the mark if any 'accurate' burette readings (apart from initial 0) are given to zero dp.	1
	For assessment of accuracy (Q) marks, the Examiner should round any burette readings to the nearest 0.05 cm ³ . Check and correct subtractions. Then select the 'best' titres using the hierarchy: - two (or more) accurate identical titres (ignoring any that are labelled 'rough'), then - two (or more) accurate titres within 0.05 cm³, then - two (or more) accurate titres within 0.10 cm³, etc. These best titres should be used to calculate the mean titre, expressed to nearest 0.01 cm ³ . Calculate the difference (δ) between the candidate's titre and the supervisor's titre. Award the accuracy (Q) marks as shown below.	1
	Award V if $\delta \leq 0.50 \text{ cm}^3$	1
	Award VI if $\delta \leq 0.30 \text{ cm}^3$	1
	Award VII if $\delta \leq 0.20 \text{ cm}^3$	
1(b)	Candidate must average two (or more) titres that are all within 0.20 cm ³ . Working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
1(c)(i)	Answers for (c)(ii), (c)(iii), (c)(iv) to 3–4 sf	1
1(c)(ii)	Correctly calculates $n(\text{MnO}_4^-) = 0.02 \times (\text{b}) / 1000$	1
1(c)(iii)	Correctly uses $n(\text{FeSO}_4) \text{ in } 25 \text{ cm}^3 = (\text{c})(\text{ii}) \times 5 \times 40$	1
1(c)(iv)	Correctly uses $\text{mass}(\text{FeSO}_4) \text{ in } 1 \text{ dm}^3 = (\text{c})(\text{iii}) \times 151.9$	1
1(c)(v)	Correctly uses $n(\text{H}_2\text{O}) = [26.52 - (\text{c})(\text{iv})] / 18$	1
	ratio $n(\text{H}_2\text{O}) : n(\text{FeSO}_4)$ AND x given as integer OR M1: $M_r \text{ hydrated salt} = 26.52 / (\text{c})(\text{iii})$ M2: $(26.52 / (\text{c})(\text{iii}) - 151.9) / 18$ and answer as integer	1
1(d)	(as) mole / amount / volume MnO_4^- smaller or (as) mass / moles / amount Fe^{2+} smaller	1
	mass/moles/amount water larger so (mole) ratio larger so x increases Allow difference in titre/moles of $\text{MnO}_4^- / \text{Fe}^{2+}$ will be too small to change the (integer) value of x for 1 mark. Allow for 1 mark: less $\text{MnO}_4^- / \text{Fe}^{2+}$ and x increases	1

1(a)	I Clearly shows initial and final mass and both recorded to the same precision and with correct units. Units: (g) or / g or in g or g by every entry (including mass used if given) Reject weight	1
	II The following data must be shown • burette readings and titre for rough titration • 2 × 2 'box' showing both accurate burette readings	1
	III Headings and units correct for accurate titration table and headings match readings. • initial / start and (burette) reading / volume • final / end and (burette) reading / volume • titre or volume / FA 2 and used / added Units: (cm ³) or / cm ³ or in cm ³ or cm ³ by every entry Allow vol for volume, value for reading Allow change in volume Reject difference, total or amount	1
	IV All accurate burette readings are recorded to 0.05 cm ³ (including 0.00) Reject if 50(.00) is used as an initial burette reading; Reject if more than one final burette reading is 50(.00) Reject if any burette reading is > 50(.00)	1
	V The final accurate titre recorded is within 0.10 cm ³ of any other accurate titre. Ignore any titre labelled 'rough' Reject if any 'accurate' burette reading (apart from an initial 0 cm ³) is given to zero dp.	1
Check and correct titre and mass subtractions where necessary. Examiner selects the best mean titre. Apply hierarchy: 2 identical, titres within 0.05 cm ³ , titres within 0.10 cm ³ , etc. Examiner calculates supervisor's corrected average titre × supervisor's corrected mass to 1 dp. Examiner calculates candidate's corrected average titre × candidate's corrected mass to 1 dp. Subtract the candidate product value from that of the supervisor: δ		
1(a)	Award VI if $4.0 < \delta \leq 6.0 \text{ g cm}^3$	1
	Award VI and VII if $2.0 < \delta \leq 4.0 \text{ g cm}^3$	1
	Award VI, VII and VIII if $\delta \leq 2.0 \text{ g cm}^3$	1
If there is only one accurate titration award accuracy marks based on that titration without further penalty. If only a rough titration is shown award accuracy marks based on this value but cancel one accuracy mark. Apply spread penalty as follows: if titres selected (by examiner) differ $\geq 1.00 \text{ cm}^3$ then cancel one accuracy mark. If Supervisor's value $\leq 10.00 \text{ cm}^3$ then halve tolerances (3 marks: $\delta \leq 1.0$; 2 marks: $\delta \leq 2$; 1 mark: $\delta \leq 3.0 \text{ g cm}^3$)		
1(b)	Candidate must average two (or more) titres that are all within 0.20 cm ³ . Working must be shown or ticks must be put next to the two (or more) accurate titres selected.	1
1(c)(i)	Answers for (ii) and both parts of (iii) are quoted to 3–4 sf.	1
1(c)(ii)	Correctly calculates 1.25×10^{-3}	1
1(c)(iii)	Correctly uses 2.50×10^{-3} AND $2.50 \times 10^{-3} \times \frac{250}{(b)} \left(= \frac{0.625}{(b)} \right)$	1
1(c)(iv)	Correctly uses correctly calculated mass from $\frac{(a)}{\text{ans (iii)}}$	1
	Display of $\frac{(\text{ANS} - 158.2)}{18}$	1
1(c)(iv)	Uses values to calculate x to the nearest integer	1



1(d)(i)	Uncertainty in a single reading: for 1 dp balance allow the uncertainty given to be ± 0.1 or 0.05 for 2 dp balance allow the uncertainty given to be ± 0.01 or 0.005, etc. AND Display of $\left(\frac{2 \times \text{uncertainty given}}{\text{candidate mass}} \right) \times 100$	1
1(d)(ii)	Correctly uses $\left(\frac{100 - (d)(i)}{100} \right) \times \text{candidate's } M_r$ OR $\frac{(\text{mass (a)} - 2 \times (\text{single}) \text{ uncertainty})}{\text{ans (c) (iii)}}$ Allow numerator as (mass (a) – single uncertainty) if lack of doubling already penalised in (d)(i).	1
1(e)	Titre value is less because concentration of thiosulfate is greater	1
1(f)	The indicator colour change is easier to see blue-black to colourless. OR The dark colour of the aqueous iodine makes the burette harder to read.	1

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1(a)	I The following headings and data are recorded in the space provided - mass of container with FA 1 - mass of (empty) container - mass of FA 1 used, correctly subtracted - consistent decimal places for weighings (at least one d.p.)	1
	II All the following data is recorded - two burette readings and titre for the rough titration - initial and final burette readings for two (or more) accurate titrations	1
	III Titre values recorded for accurate titrations, and Appropriate headings and units in the accurate titration table - initial / start (burette) reading / volume - final / end (burette) reading / volume - titre or volume used / added / or FA 1 added (not 'difference' or 'total' or 'amount') - unit: / cm³ or (cm³) or in cm³ (for each heading) or cm³ unit given for each volume recorded	1
	IV All accurate burette readings are recorded to the nearest 0.05 cm ³ .	1
	V The final accurate titre recorded is within 0.10 cm ³ of any other accurate titre	1
	Award VI, VII and VIII if $\delta \leq 0.020$ (cm³ g⁻¹) Award VI and VII if $0.020 < \delta \leq 0.040$ Award VI, only if $0.040 < \delta \leq 0.060$	3
1(b)	Candidate calculates the mean correctly. - Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm³. - 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 cm³.	1
1(c)(i)	Correct calculation (expressed to 3 or 4 sf) No of moles of KMnO₄ used = $0.0200 \times \text{mean titre} / 1000$ The candidate's mean titre must be used in the calculation	1
1(c)(ii)	Correct use of (i) to calculate concentration of FA 4 Concentration of FA 4 = $\text{ans (i)} \times 5 \times 1000 / 25$	1
1(c)(iii)	Correct expression for M_r $M_r = \text{mass of FA 1 used} \times 4 / \text{answer (ii)}$ alternatively: $M_r = \text{ans (i)} / 4$	1



1(a)	I Titration data shown - two burette readings for the rough titration - titre for rough titration - initial and final burette readings for two (or more) accurate titrations	1
	II Titre values for accurate titrations recorded and appropriate headings and units in accurate titration table - initial / start and (burette) reading / volume - final / end and (burette) reading / volume - titre or volume / FA 1 and used / added - unit: / cm³ or (cm³) or in cm³ (for each heading) or cm³ unit given for each volume recorded	1
	III All accurate burette readings are recorded to the nearest 0.05 cm ³ .	1
	IV The final accurate titre recorded is within 0.10 cm ³ of any other accurate titre.	1
	Award V, VI and VII if $\delta \leq 0.20$ (cm ³) Award V and VI if $0.20 < \delta \leq 0.40$ Award V only if $0.40 < \delta \leq 0.60$	3
1(b)	Correctly calculates mean titre from two (or more) accurate titres where the total spread is ≤ 0.20 cm ³ AND Answer is given to 2 dp AND Working must be shown or ticks must be put next to the two (or more) accurate titres selected	1
1(c)(i)	All final answers in 1(c) are quoted to 3 or 4 significant figures Minimum of four answers attempted	1
1(c)(ii)	Correctly calculates number of moles of KMnO ₄ used = $0.03(00) \times \frac{\text{mean titre}}{1000}$	1
1(c)(iii)	Two correct multiplying factors shown - answer (ii) $\times 2.5$ (subsequent answer) (mol of H₂O₂) $\times 40 (\times \frac{1000}{25})$	1
1(c)(iv)	Correctly calculates concentration of H ₂ O ₂ = final answer in (iii) $\times 10$	1
1(c)(v)	Correctly uses (iv) to find moles of O ₂ = answer (iv) $\times 0.5$	1
	Correctly uses (iv) to find 'volume strength' = moles of O ₂ $\times 24$ Answer for default value = 12.24 vol	1
1(d)	% error pipette = 0.24 and % error burette = 0.4(0) OR 2×0.05 (cm ³) is greater (than 0.06 / pipette error) Working must be shown	1

1(a)	3 masses recorded with unambiguous headings in the space provided, with correct units mass used correctly calculated volume of gas collected or final volume recorded with correct units	1
	Award this mark if volume recorded by candidate lies within $\pm 10\%$ of supervisor value.	1
1(b)(i)	Correctly calculates volume of gas in cm ³ / 24 000 answer to 2–4 sf	1
1(b)(ii)	Correct use of: $2 \times$ AND ans (b)(i) / 0.025 (answer to 2–4 sf)	1
1(b)(iii)	Correctly uses ans (b)(i) $\times 24.3$ and answer to 2–4 sf	1
1(c)	Student correct as reaction now slower so less gas lost (while bung is being fitted).	1
	Student incorrect as Mg is in excess. or Student incorrect as reaction is faster so more gas lost	1
1(d)	gas volume / amount / moles lower so concentration is lower	1

2(a)	I	Uses a volume between 40.00 and 45.00 cm ³ and answer to at least 1 dp	1
	II	The following data must be shown • burette readings <i>and</i> 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 (<i>not</i> '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 $20 < \delta \leq 30$ cm ³	1
		Award VII if $10 < \delta \leq 20$ cm ³	1
		Award VIII if $\delta \leq 10$ 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

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1(a)	I	All the following data is recorded • both burette readings <i>and</i> the titre for the rough titration • initial and final burette readings for two (or more) accurate titrations <i>Headings and units are not required for this mark</i>	1
	II	Titre values recorded for accurate titrations, <i>and</i> appropriate headings and units in the accurate titration table • initial / start (burette) reading / volume / value • final / end (burette) reading / volume / value • titre or volume / FA 4 <i>and</i> used / added • unit: / cm ³ or (cm ³) or in cm ³ (for each heading) or cm ³ unit given for each volume recorded	1
	III	All accurate burette readings are to the nearest 0.05 cm ³ . <i>The requirement to record to 0.05 applies to burette readings, including 0.00 cm³ (if this was the initial reading), but it does not apply to the titre.</i> <i>Do not award this mark if:</i> • 50(.00) is used as an initial burette reading • more than one final burette reading is 50(.00) • any burette reading is greater than 50(.00)	1
	IV	The final accurate titre recorded is within 0.10 cm ³ of any other accurate titre.	1
		Examiner rounds any accurate burette readings to the nearest 0.05 cm ³ , checks subtractions and then selects the "best" titres using the hierarchy: • identical titres <i>then</i> • accurate titres within 0.05 cm ³ , <i>then</i> • accurate titres within 0.10 cm ³ , <i>etc.</i> These best titres should be used to calculate the mean titre, expressed to nearest 0.01 cm ³ . Examiner compares candidate's mean titre value with that of the Supervisor.	
		Award V, VI and VII if $\delta \leq 0.20$ (cm ³)	1
		Award V and VI if $0.20 < \delta \leq 0.40$	1
		Award V, only, if $0.40 < \delta \leq 0.60$	1

1(b)	Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm³. - Working / explanation must be shown <i>or</i> 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 cm³. (e.g. 26.666 cm³ must be rounded to 26.67 cm³) Two special cases, where the mean need not be to 2 dp: - Allow mean expressed to 3 dp only for 0.025 or 0.075 (e.g. 26.325 cm³) - Allow mean if expressed to 1 dp, if all accurate burette readings were given to 1 dp and the mean is exactly correct. (e.g. 26.0 and 26.2 = 26.1 is allowed) (e.g. 26.0 and 26.1 = 26.1 is wrong – should be 26.05) Do not award this mark if: - The rough titre was used to calculate the mean. - The candidate did only one accurate titration. - Burette readings were incorrectly subtracted to obtain any of the accurate titre values. - All burette readings used to calculate the mean were recorded as integers	1
1(c)(i)	Correctly calculates No of moles of thiosulfate used = $0.105 \times \frac{\text{mean titre}}{1000}$ to 3 or 4 sf	1
1(c)(ii) and (iii)	Correct use of data in both parts (ii) moles I₂ = 0.5 × ans (i) and (iii) moles FA1 = 0.025 × 0.0197 (= 0.000493, 0.0004925)	1
1(c)(iv)	Correctly calculates answer, expressed as integer No of moles = $\frac{0.05}{200}$	1
1(c)(v)	Correct balancing and value of x First mark: integer in answer (iv) shown in front of I₂ and correct number of moles of I⁻ entered in equation	1
	Second mark: any equation fully balanced $\text{IO}_3^- + 5\text{I}^- + 6\text{H}^+ \rightarrow 3\text{I}_2 + 3\text{H}_2\text{O}$	1
1(c)(vi)	Oxidation state = 2x – 1.	1

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1(a)	I: All the following data is recorded - rough titration: both burette readings and the titre - initial and final burette readings for two (or more) accurate titrations Headings and units are not required for this mark	1
	II: Titre values recorded for accurate titrations, and Appropriate headings and units in the accurate titration table - initial / start (burette) reading / volume - final / end (burette) reading / volume - titre or volume used / added (<i>not</i> "difference") - unit: / cm³ or (cm³) or in cm³ (for each heading) or cm³ unit given for each volume recorded	1
	III: All accurate burette readings are recorded to the nearest 0.05 cm³. The requirement to record to 0.05 applies to burette readings, including 0.00 cm³ (if this was the initial reading), but it does not apply to the titre. Do not award this mark if: 50(.00) is used as an initial burette reading - more than one final burette reading is 50(.00) - any burette reading is greater than 50(.00)	1
	IV: Final uncorrected titre is within 0.10 cm³ of any previous uncorrected accurate titre.	1

Examiner rounds any accurate burette readings to the nearest 0.05 cm³, check subtractions and then select the "best" titres using the hierarchy: - identical titres <i>then</i> - accurate titres within 0.05 cm³, <i>then</i> - accurate titres within 0.10 cm³, <i>etc.</i> These best titres should be used to calculate the mean titre, expressed to nearest 0.01 cm³. Examiner compares candidate's titre value with that of the Supervisor.		
	Award V, VI and VII if $\delta \leq 0.30$ (cm ³)	1
	Award V and VI if $0.30 < \delta \leq 0.50$	1
	Award V, only, if $0.50 < \delta \leq 0.80$	1
1(b)	Candidate calculates the mean correctly. - Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm³. - 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 cm³. (e.g. 26.667 cm³ must be rounded to 26.67 cm³)	1
1(b)	Two special cases, where the mean need not be to 2 dp: - Allow mean expressed to 3 dp only for 0.025 or 0.075 (e.g. 26.325 cm³) - Allow mean if expressed to 1 dp, if all accurate burette readings were given to 1 dp and the mean is exactly correct. (e.g. 26.0 and 26.2 = 26.1 is allowed) (e.g. 26.0 and 26.1 = 26.1 is wrong – should be 26.05) Do not award this mark if: - The rough titre was used to calculate the mean. - The candidate did only one accurate titration. - Burette readings were incorrectly subtracted to obtain any of the accurate titre values. - All burette readings used to calculate the mean were recorded as integers Note: the candidate's mean will sometimes be marked correct even if it was different from the mean calculated by the Examiner for the purpose of assessing accuracy.	
1(c)(i)	No of moles of thiosulfate used = $0.110 \times \frac{\text{mean titre}}{1000}$ (expressed to 3 or 4 sig fig)	1
1(c)(ii) + (iii)	Equation balanced $I_2 + 2Na_2S_2O_3 \rightarrow Na_2S_4O_6 + 2NaI$ and no of moles of I ₂ = 0.5 × ans. in (i)	1
1(c)(iv)	Correct answer, No of moles of copper(II) ions = 2 × answer (iii) (expressed to 3 or 4 sig fig)	1
1(c)(v)	$M_r = \frac{26.0}{\text{ans (iv)}} \times \frac{25}{1000}$	1
Total:		12

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2(a)	I initial and final burette readings and volume added recorded for rough titre AND accurate titre details tabulated	1
	II initial and final burette readings recorded and volume of FA 3 added recorded for each accurate titration - all headings and units correct for accurate titrations - initial / final (burette) reading / volume OR reading / volume at start / finish - titre OR volume FA 3 added / used (cm³) OR / cm³ OR in cm³ by every entry	1
	III all accurate burette readings are recorded to the nearest 0.05 cm ³	1
	IV final titre within 0.10 cm ³ of any previous accurate titre	1
	V, VI and VII award V, VI and VII for $\delta \leq 0.20$ cm³ award V and VI for $0.20 \text{ cm}^3 < \delta \leq 0.30$ cm³ award V for $0.30 \text{ cm}^3 < \delta \leq 0.50$ cm³	3
2(b)	mean titre correctly calculated from clearly selected values: - candidate must average two (or more) titres where the total spread is ≤ 0.20 cm³ - working must be shown or ticks must be put next to the two (or more) accurate readings selected - the mean should normally be quoted to 2 d.p. rounded to the nearest 0.01 Note: the candidate's mean will sometimes be marked as correct even if it is different from the mean calculated by the examiner for the purpose of assessing accuracy.	1

2(c)	M1 correctly calculates $\frac{0.030 \times (b)}{1000}$	1
	M2 correctly uses (i) $\times 5/2$	1
	M3 correctly uses (ii) $\times 1000/25$	1
	M4 all final answers to 3 or 4 sig. fig. (minimum two parts attempted)	1

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1 (a)	I Initial and final readings and titre value given for rough titre and initial and final readings for two (or more) accurate titrations (minimum of 2×2 box)	1	
	II Titre values recorded for accurate titrations and Appropriate headings for the accurate titration table and cm^3 units. - initial / start burette reading / volume / value - final / end burette reading / volume / value (<i>not amount</i>) - titre or volume / FA 4 and used / added - unit: / cm^3 or (cm^3) or in cm^3 (for each heading)	1	
	III All accurate burette readings are to the nearest 0.05 cm^3 . <i>Do not award this mark if:</i> 50(.00) is used as an initial burette reading - more than one final burette reading is 50.(00) - any burette reading is greater than 50.(00) - there is only one accurate titration.	1	
	IV There are two uncorrected accurate titres within 0.10 cm^3 - Do not award this mark if, having performed two titres within 0.10 cm^3, a further titration is performed which is more than 0.10 cm^3 from the closer of the initial two titres, unless a further titration, within 0.10 cm^3 of any other, has also been carried out. - Do not award the mark if any "accurate" burette readings (apart from initial 0 cm^3) are given to zero dp	1	
	Examiner rounds any burette readings to the nearest 0.05 cm^3 , checks subtractions and then selects the " best " titres using the hierarchy: - two (or more) accurate identical titres, <i>then</i> - two (or more) accurate titres within 0.05 cm^3, <i>then</i> - two (or more) accurate titres within 0.10 cm^3, <i>etc</i> These best titres are used to calculate the mean titre, expressed to nearest 0.01 cm^3 . Examiner calculates the difference (δ) between the mean titres obtained by the candidate and the Supervisor. Accuracy marks are awarded as shown. Award V, VI and VII if $\delta \leq 0.20 \text{ (cm}^3\text{)}$ Award V and VI if $0.20 < \delta \leq 0.30$ Award V, only, if $0.30 < \delta \leq 0.50$ Spread penalty: if the two "best" (corrected) titres used by the Examiner were $\geq 0.50 \text{ cm}^3$ apart, cancel one accuracy mark.	3	[7]

(b)	Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20cm^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 0.01cm^3. Two special cases, where the mean need not be to 2 dp: - Allow mean expressed to 3 dp only for 0.025 or 0.075 (e.g. 26.325cm^3) - Allow mean if expressed to 1 dp, if all accurate burette readings were given to 1 dp and the mean is exactly correct. (e.g. 26.0 and $26.2 = 26.1$ is allowed) (e.g. 26.0 and $26.1 = 26.1$ is wrong – should be 26.05) Note: the candidate's mean will sometimes be marked correct even if it was different from the mean calculated by the Examiner for the purpose of assessing accuracy.	1	[1]
(c)(i)(ii)	Correctly calculates $n(\text{thio}) = 0.10 \times (\text{b}) / 1000$ $n(\text{I}_2) = 0.5 \times (\text{i})$ Both answers must be given to 3 or 4 significant figures	1	[5]
(iii)	Correctly calculates $n(\text{KMnO}_4) = 0.025 \times 0.018 = 0.00045 \text{ or } 0.000450 \text{ or } 0.0004500$	1	
(iv)	Correct expression, with answer given to 2, 3 or 4 sig fig $n(\text{I}_2) = \frac{(\text{ii})}{(\text{iii})} \times 2$ Theoretical answer = 5.0 (for 2.0 mol KMnO_4)	1	
(v)	Correct equation ticked, corresponding to (iv)	1	
(vi)	Allow any one of the following answers: - An iodide ion loses one electron $2\text{I}^- - 2\text{e}^- \rightarrow \text{I}_2$ (ionic equation must be correctly balanced) - Oxidation number of iodine increases from $-1/ 1-$ (in iodide ion) to 0 (in iodine)	1	
(d) (i)	$\% \text{ error} = \frac{0.06}{25} \times 100 = 0.24 \%$	1	
(ii)	The student is wrong, since KI / FA 3 is in excess.	1	[2]
Qn 1	[Total: 15]		

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2 (a)	I Table with unambiguous headings and correct units All readings must be included.	1	
	II All temperatures recorded to .0 or .5 °C. Must include at least one ending in .0 and one ending in .5.	1	
Examiner calculates candidate's ΔT max from table.			

	III Award if the difference between candidate and Supervisor is within 4.0 °C	1	
	IV Award if the difference between candidate and Supervisor is within 2.0 °C	1	[4]
(b) (i)	Axes labelled temperature or T or °C or temperature and time or minutes or min or t. Linear scales chosen to use more than half of each axis and to include 5 °C more than the maximum temp. All points recorded (minimum of 10). Correct plotting – each point accurately plotted (within $\frac{1}{2}$ small square and in the correct square).	1	
(ii)	All three straight lines drawn	1	
	Lines of best fit and extrapolated	1	
(iii)	Correct ΔT from graph to within .2 °C of examiner value using the candidate's lines.	1	[5]

Question	Indicative material	Mark	Total
(c) (i)	Correct answer to $4.2 \times 40 \times \text{ans(b)(iii)}$. Allow answers to 2–4 sf	1	
(ii)	Correct answer to (i) / 219000 Allow answers to 2–4 sf	1	
(iii)	Expression (ii) / 0.040 Allow answers to 2–4 sf	1	[3]
(d) (i)	Correct answer correct to number of sf shown (min 2 sf): $0.5 / \text{highest temp} \times 100$	1	
(ii)	Do not agree as the zinc is in excess	1	
(iii)	Incorrect as temperature rise is the same or Incorrect as (a smaller volume) has a greater % error ORA	1	[3]
Qn 2	Total		[15]

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1 (a)	I Initial and final burette readings and titre unambiguously recorded in rough and accurate titrations. <i>Minimum of 2×2 boxes for accurate.</i> II Headings and units correct for accurate titration and headings match readings. <i>Headings: initial/ final (burette) reading/ volume or Reading/ volume/ vol/ value at start/ finish and Volume/ vol/ FA 1 added/ used or titre [not "difference or "total"]</i> <i>and Units: (cm³) or / cm³ or in cm³ or cm³ by every entry</i>	1	
		1	

Examiner rounds all all burette readings to the nearest 0.05 cm^3 and checks subtractions. Examiner selects the 'best' titres using the hierarchy:
two (or more) identical,
then two (or more) within 0.05 cm^3 ,
then two (or more) within 0.1 cm^3 , etc.



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1 (a)	I Two balance readings and correct mass of magnesium recorded. Table to show temperature and time. Headings and units – must be temperature /°C, (°C), in °C and time/s, (s), or time in seconds or /min, /minutes, ... and /g, (g), ...	1	
	II Thermometer readings to $\pm 0.5^{\circ}\text{C}$ (at least 1 ending in .5 or .0) (Minimum 8 readings)	1	
	III All specified readings taken and balance readings to the same number of dp	1	
	Difference between temperature at 2 minutes and highest temperature (in table) calculated and compared with ΔT of Supervisor.		
	IV, V and VI ΔT within 10% of Supervisor IV and V ΔT within 15% of Supervisor IV only ΔT within 20% of Supervisor	3	[6]
(b) (i)	I Axes labelled, linear scales chosen so that more than half the available space is used on both axes for plotted points.	1	
	II Plotted points should be drawn clearly with a sharp pencil. Points should be plotted to within half a small square and in the correct square for y-axis and on line for x-axis.	1	
(ii)	III Correctly extrapolated best fit straight lines drawn up to time $2\frac{1}{2}$ minutes and after $2\frac{1}{2}$ minutes.	1	
(iii)	IV Examiner calculates ΔT from graph and checks answer is within 0.25°C of candidate's stated answer	1	[4]
(c) (i)	All the magnesium/solid dissolved/disappeared or all solid /Mg has gone/been used up or no solid/ Mg left	1	
	(ii) Correctly calculates $25 \times 4.2 \times \Delta T$	1	
(iii)	Correctly calculates (ii) $\div$ number of moles of magnesium and converts to kJ ($\frac{\text{(ii)} \times 24.3}{1000 \times \text{mass Mg}}$) and final answer to 2–4 sf	1	
	Sign is negative in (c)(iii) and (e)(iv)	1	[4]
(d)	8 readings (in space below printed area) 4 $\times$ balance readings 2 $\times$ initial temp 2 $\times$ highest/max temp with unambiguous headings	1	
	Correctly calculates both masses of Mg and both ΔT s.	1	[2]

(e) (i) & (ii)	Correctly calculates	1	
	- mean ΔT - mean mass		
	(iii) Moles $\text{CuSO}_4 = \frac{25 \times 1}{1000} = 0.025$	1	
	Moles $\text{Mg} = \frac{\text{(ii) or max mass Mg}}{24.3}$ so CuSO_4 in excess or <0.025	1	
(iv)	Working to calculate ΔH using mean values of mass Mg and ΔT $\left(\frac{\Delta T(\text{i}) \times 25 \times 4.2 \times 24.3}{(\text{ii}) \times 1000} \right)$ or $\left(\frac{\Delta T(\text{i}) \times 25 \times 4.2}{\text{mol Mg from (iii)} \times 1000} \right)$	1	[4]
(f)	Attempt at use of Hess' law either by cycle or reverse reaction 2	1	
	Correctly calculates $\Delta H \text{ reaction 3} = \Delta H \text{ reaction 1} - \Delta H \text{ reaction 2}$	1	[2]
(g) (i)	Any 2 of Lower ΔH and so higher % error No correction made for loss of heat on cooling Some bubbles / gas / H_2 in reaction 2 so wrong reaction taking place Not all Mg reacts / reaction does not go to completion in 2 (so not all energy released) Reaction 2 slower so more heat loss	1 1	
	(ii) No, since (larger volume of solution means) smaller ΔT OR Yes, since there would be a smaller T rise so less heat would be lost.	1	[3]
Qn 1	Total		[25]

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1 (a)	PDO Layout	I Initial and final readings and titre value given for rough titre and initial and final readings for two (or more) accurate titrations (<i>minimum of 2 x 2 box</i>)	1	
	PDO Recording	II Appropriate headings and units for all accurate data. and volume FA 1 added recorded for each accurate titre. Headings should match readings. - initial/start (burette) reading/volume - final/end (burette) reading/volume - titre or volume/FA 1 used/added (<i>not "difference"</i>) unit: /cm³ or (cm³) or in cm³ or cm³ for each entry III All accurate burette readings recorded to 0.05cm ³ . The need to record to 0.05 applies only to the burette readings and <i>not</i> to the recorded titres. Do <i>not</i> 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 1	

	MMO Decisions	IV Has two uncorrected, accurate titres within 0.1 cm^3 <i>Do not include a reading labelled 'rough'.</i> <i>Do not award this mark if, having performed two titres within 0.1 cm^3, a further titration is performed that is more than 0.1 cm^3 from the closer of the two initial titres unless further titrations within 0.1 cm^3 of any other have also been carried out.</i> <i>Do not award the mark if any 'accurate' burette readings (apart from initial 0) are given to zero dp.</i>	1	
Examiner rounds burette readings to the nearest 0.05 cm^3, checks subtractions and then selects the 'best' titres using the hierarchy: two (or more) identical, then two (or more) within 0.05 cm^3, then two (or more) within 0.1 cm^3, etc. Examiner compares candidate mean titre with Supervisor mean titre.				
(a)	MMO Quality	Award V and VI for difference from Supervisor, $\delta \leq 0.20 \text{ cm}^3$ Award V only for $0.20 < \delta \leq 0.40 \text{ cm}^3$ <i>Spread penalty: if the two 'best' titres are $\geq 0.50 \text{ cm}^3$ apart cancel one of the Q marks.</i>	2	[6]
(b)	ACE Interpretation	Candidate must average two (or more) titres that are within 0.20 cm^3. Working must be shown or ticks must be put next to the two (or more) accurate readings selected. <i>The mean should normally be quoted to 2 dp rounded to the nearest 0.01.</i> <i>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.</i> <i>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.</i>	1	[1]
(c)	ACE Interpretation PDO Display ACE Interpretation PDO Display	I Correctly evaluates $\frac{0.0200 \times (\mathbf{b})}{1000}$ in (i) II Correctly evaluates $\frac{(\mathbf{i}) \times 5/2}{25}$ in (iii) III Correct balanced equation in (iv) IV Correctly evaluates $\text{ans (iii)} \times \frac{1}{2} \times 24.0$ in (v) (Allow ecf from incorrect equation) V All answers given to 3 or 4 sf (minimum of 3 answers attempted)	1 1 1 1 1	[5]
Qn 1	Total		[12]	

1 (a)	PDO Layout	I The following data must be given - mass of solid used (or both weighings) - volume for rough titre (or both readings) - initial and final readings for two (or more) accurate titrations.	1	
	PDO Recording	II Appropriate headings for all data given in weighing and accurate titration tables and g and cm^3 units. - mass/weight (of) beaker (empty) - mass/weight (of) beaker + FA 1/solid - initial/start (burette) reading/volume - final/end (burette) reading/volume - titre or volume/FA 2 used/added - unit: g cm^{-3} or (cm^3) or in cm^3 or cm^3 for each volume <i>If g and/or cm^3 units are not given in the heading, every entry in the table must have the correct unit.</i>	1	
	PDO Recording	III All accurate burette readings (including 0.00) are to the nearest 0.05 cm^3 . <i>The need to record to 0.05 applies only to the burette readings and not to the recorded titres. Do not award this mark if:</i> 50(.00) is used as an initial burette reading or - more than one final burette reading is 50.(00) or - any burette reading is greater than 50.(00).	1	
	MMO Decision	IV There are two uncorrected accurate titres within 0.10 cm^3 . <i>Do not include a reading if it is labelled "rough". Do not award this mark if, having performed two titres within 0.1 cm^3, a further titration is performed which is more than 0.10 cm^3 from the closer of the initial two titres, unless a further titration, within 0.1 cm^3 of any other, has also been carried out. Do not award the mark if any 'accurate' burette readings (apart from initial 0) are given to zero dp.</i>	1	
(a) (cont)	MMO Quality	Award V, VI and VII if $\delta \leq 0.03 (\text{cm}^3 \text{ g}^{-1})$ i.e. three Q marks. Award V and VI if $0.03 < \delta \leq 0.06$ i.e. two Q marks. Award V, only, if $0.06 < \delta \leq 0.10$ i.e. one Q mark. <i>Spread penalty: if the two "best" (corrected) titres used by the Examiner were $\geq 0.50 \text{ cm}^3$ apart, cancel one Q mark.</i>	1 1 1	[7]

(b)	MMO Decision	Check mean titre is correctly calculated from clearly selected values (ticks or working). - Candidate must average two (or more) titres where the total spread is $\leq 0.20 \text{ cm}^3$. - 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 (<i>ignoring initial given as 0</i>) and the mean is exactly correct. [e.g. 26.0 and 26.2 = 26.1 is correct but 26.0 and 26.1 = 26.1 is incorrect.] Do not award this mark if: - the rough titre was used to calculate the mean; - candidate carried out only 1 accurate titration; - burette readings were incorrectly subtracted to obtain any of the accurate titre values; all burette readings (resulting in titre values used in calculation of mean) are integers.	1	[1]
(c) (i)	ACE Interpretation	I Correctly calculates No. of moles of $\text{KMnO}_4 = 0.0200 \times \text{}^{(b)}/_{1000}$	1	
(ii)	ACE Conclusion	II $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{e}^- / 5\text{Fe}^{2+} \rightarrow 5\text{Fe}^{3+} + 5\text{e}^-$	1	
(iii) + (iv)	PDO Display	III Correct working shown in (iii) and (iv). <i>The answer to (i) should be multiplied by 5 to give (iii).</i> <i>The answer to (iii) should be multiplied by 10 to give (iv).</i>	1	
(v)	ACE Interpretation	IV Correct calculation of relative formula mass. $M_r = \frac{\text{correct mass of FA 1 used}}{\text{answer to (iv)}}$	1	
(v) (cont)	PDO Display	V All answers are quoted to 3 or 4 significant figures. A minimum of three answers is needed to qualify.	1	[5]
(d) (i)	ACE Interpretation	% error for pipette = $\frac{0.06}{25} \times 100 = 0.24\%$ (or 0.240%)	1	
(ii) + (iii)	ACE Interpretation	If balance displays to 1 decimal place: error in balance reading is $\pm 0.05 \text{ g}$ or $\pm 0.1(0) \text{ g}$. If balance displays to 2 decimal places: error in balance reading is $\pm 0.005 \text{ g}$ or $\pm 0.01 \text{ g}$. If balance displays to 3 decimal places: error in balance reading is $\pm 0.0005 \text{ g}$ or $\pm 0.001 \text{ g}$. % error = $2 \times \frac{\text{balance error (above)}}{\text{mass of FA 1 used}} \times 100$ Correct answer is not required, but if the “$\times 100$” factor was omitted, a correctly calculated % error answer scores the mark.	1	[2]

1	(a)	PDO layout	I	Volume given for Rough titre and accurate titre details tabulated.	1	
		MMO Collection	II	In the correct spaces, records Initial and final burette readings for Rough titre and ; Initial and final burette readings and , volume of FB 2 added recorded for each accurate titre <i>Headings should match readings.</i> <i>Do not award this mark if:</i> <i>50(.00) is used as an initial burette reading;</i> <i>More than one final burette reading is 50.(00);</i> <i>Any burette reading is greater than 50.(00)</i>	1	
		MMO Decisions	III	Has two uncorrected, accurate titres within 0.1 cm^3 <i>Do not award this mark if having performed two titres within 0.1 cm^3 a further titration is performed which is more than 0.10 cm^3 from the closer of the initial two titres, unless a fourth titration, within 0.1 cm^3 of the third titration or of the first two titres has also been carried out.</i>	1	
		PDO Recording	IV	All accurate burette readings (initial and final) recorded to nearest 0.05 cm^3 . <i>Assessed on burette readings only.</i>	1	
		MMO Quality	V, VI and VII	Round any burette readings to the nearest 0.05 cm^3 Check and correct subtractions in the titre table. Select the “best” titre using the hierarchy: two identical; titres within 0.05 cm^3 , titres within 0.10 cm^3 etc. Award V, VI and VII for a difference to Supervisor within 0.20 cm^3 Award V and VI only for a difference of $0.20+ \text{ cm}^3 - 0.40 \text{ cm}^3$ Award V only for a difference of $0.40+ \text{ cm}^3 - 0.80 \text{ cm}^3$ <i>If the selected “best” titres are $> 0.50 \text{ cm}^3$ apart, cancel one of the Q marks awarded.</i>	3	
						[7]

(b)	ACE Interpretation	Calculates the mean, correct to 2 decimal places (third decimal place maybe rounded to the nearest 0.05 cm^3) from any accurate titres within 0.20 cm^3. <i>A mean of exactly .x25 or .x75 is allowed but the candidate may round up or down to the nearest 0.05 cm^3.</i> <i>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.</i> <i>Mean of 24.3 and 24.4 = 24.35 (✓)</i> <i>Mean of 24.3 and 24.4 = 24.4 (✗)</i> <i>Mean of 24.3 and 24.5 = 24.4 (✓)</i> Titres to be used in calculating the mean must be clearly shown – in an expression or ticked in the titration table.	1	[1]
(c)	ACE Interpretation PDO Display	No additional factor/expression is allowed in any step <i>If an answer, with no working, is given in any section allow if correct.</i> I Uses $\frac{15.0}{248.2}$ only in step (i) <i>If no working shown accept only the following evaluated answers: (0.060, 0.0604 or 0.06044)</i> II Uses answer (i) $\times \frac{\text{conc average titre}}{1000}$ in step (ii) and answer (iv) $\times \frac{1000}{25}$ in step (v) III Uses answer (ii) $\times \frac{1}{2}$ in step (iii), and answer (iii) $\times 2$ in step (iv) IV Appropriate working shown in a minimum of three sections. To include equations as steps for the working mark; <i>In (iii) must see x2 or x0.5.</i> <i>In (iv) must see multiplication or division by 6, 1.2 or 2.</i> 1:6 for $\text{IO}_3^-/6\text{H}^+$, 1:1.2 for $5\text{I}^-/6\text{H}^+$, 1:2 for $6\text{H}^+/3\text{I}_2$ V 3 to 5 significant figures in final answers to <u>all sections attempted</u> – minimum of three final answers required to qualify for the award of this mark.	1 1 1 1 1	[5]

(c)	PDO Layout	Plots temperature on y-axis and time on x-axis and has at least one temperature and one time label (<i>ignore absent or incorrect units</i>) Scales used are linear and easy for the examiner to use, (3 or 4 min. per large square are acceptable) Scales should enable the temperature when zinc is added and <u>all</u> points after the addition of zinc to be plotted. <i>Points should be within a minimum of 5 large squares on temperature axis</i> If the candidate has recorded temperatures and times before zinc is added: Correctly plots on <u>each</u> graph: the last temperature/time, from results <u>before</u> zinc is added <u>or</u> the temperature and maximum temperature (associated time not required) If the candidate has only recorded the initial temperature of the solution: Correctly plots on <u>each</u> graph: the temperature when zinc is added and maximum temperature (associated time not required) Draws a cooling curve or straight line and projects the curve / line back to the time of mixing	1 1 1	
	A completely horizontal line, drawn at the initial temperature can be accepted as equivalent to plotting of initial temperature.			
	If only one graph has been drawn, the 1 st and 2 nd marks may be awarded and one further mark if the initial and maximum temperatures are correctly plotted and there is an appropriate extrapolation.			
(d)	ACE Interpretation	For experiment 1: Correctly reads the temperature rise from the graph to within 1 °C of the value obtained from the graph by the examiner. If the value is incorrect for experiment 1, check value for experiment 2. Award mark if either value is correct.	1	[4]
(e)–(h)	PDO Display	Shows working in all sections attempted – <i>minimum of three sections required</i> . Significant figures in <u>final answers</u> . 2 or 3 sf in 1(e), 2 to 4 sf in 1(g), 3 sf only in 1(h) <i>minimum of three sections required</i> .	1 1	[2]
(e)	ACE Interpretation	Correctly calculates 2.0×10^{-2} mol of CuSO_4 , and ($\frac{\text{mass zinc}}{65.4}$) for each experiment. <i>Answers correctly rounded for the number of significant figures displayed.</i> Do not award this mark if there is an error in subtraction or there are missing balance readings in section (a).	1	[1]

(f)	ACE Conclusions	To gain this mark the candidate must refer to: (i) the 1:1 <u>mole</u> ratio from the equation and (ii) the relative <u>moles</u> of Cu^{2+} and Zn(s) used, as calculated in (e) <i>If candidate states that "more moles of zinc were present" and this fits the calculated values in (e) – accept as the relative statement.</i>	1	[1]
(g)	ACE Interpretation	Shows $(25 \times 4.3 \times \text{candidate mean } \Delta T)$ with appropriate unit, J or kJ, on final answer. (Allow use of 4.2 or 4.18 without penalty) <i>Award this mark for the correct expression and unit OR where the expression is not shown, a correct evaluation of that expression and unit</i>	1	[1]
Where candidate has given a maximum temperature in (g), allow use here (ecf). Also allow use of ΔT calculated in this section.				
(h)	ACE Interpretation	No mark is awarded in this section if there is no division by (moles of zinc) or by (moles of Cu^{2+}). Calculates <u>answer to (g)</u> moles of reagent not stated as being in excess in (f) <i>If (moles of zinc) is used in this expression, candidate may use either value from (e) or the mean of the (moles of zinc).</i> Examiner evaluates the candidate expression which should be: (i) correctly rounded for sig fig displayed, (allow variation of ± 1 on 3 rd significant figure) (ii) have a -ve sign on the final answer; (iii) be correctly converted to kJ	1 1	[2]
(i)	ACE Interpretation	Candidate identifies one source of error in the experiment. This must be related to: Apparatus used or method described – no human error allowed. <i>Heat loss is most likely error to be seen</i> <i>Accept reference to the graduation (precision) of the thermometer.</i>	1	[1]
(j)	ACE Improvement	Answer must follow on from (i) Suggests a way in which method could be improved <i>e.g. Use of a lid or increased insulation to minimise heat loss.</i>	1	[1]
Qn 1	Total			[26]

Supervisor's Report

Calculate, correct to 2 dp, the titre if the Supervisor had diluted 47.25 cm^3 of FA 2.

This is given by the expression $\frac{47.25}{\text{volume diluted}} \times \text{Examiner selected titre}$

Candidate scripts

Calculate the scaled titre for 47.25 cm^3 of FA 2.

Record the value against the titration table and calculate the difference to Supervisor.

Question	Sections	Indicative material	Mark	
1 (a)	PDO Layout	(i) Tabulates initial and final burette readings and volume added in each of the tables. <i>Do not award this mark if any final and initial burette readings are inverted or 50 is used as the initial burette reading.</i>	1	
	PDO Recording	(ii) Both burette readings in the dilution table and <u>final and initial</u> burette readings for all accurate titres in the titration table recorded to the nearest 0.05 cm^3 .	1	
	MMO Collection	(iii) Follows instructions: dilutes 47.00 cm^3 to 47.50 cm^3 and has any two titres within 0.20 cm^3	1	
	MMO Decisions	(iv) Has at least two uncorrected "accurate" titres within 0.1 cm^3 <i>Do not include any titre labelled "rough"/"trial" unless the candidate has ticked that value or used it in an expression when calculating the average in (b).</i>	1	
	MMO Quality	Accuracy (v) and (vi) Give (v) and (vi) if difference to Supervisor is 0.3 or less Give (vi) only for a difference of 0.3+ to 0.5 Give neither mark for a difference greater than 0.5.	2	
				[6]
(b)	ACE Interpretation	Candidate selects/calculates appropriate "average" from any uncorrected titre values within 0.20 cm^3 . <i>Candidate is permitted to use a titre labelled "rough" or "trial".</i> <i>Titres to be used must be shown.</i> Where all titres are given to 1 decimal place the average should be calculated correct to 1 or 2 decimal places. Where any titre is recorded to 2 decimal places, the average should be calculated to 2 decimal places or rounded to the nearest 0.05 cm^3 .	1	
				[1]

(c)	ACE Interpretation	(i), (ii) and (iii) Award three marks if all steps are chemically correct. Withhold 1 mark for each chemical error – no negative marks. Count non-completed steps as chemical errors. step 1 $\frac{\text{titre}}{1000} \times 0.15$ step 2 $\times \frac{1}{2}$ step 3 $\times 2$ step 4 $\times \frac{1000}{25}$ step 5 $\times \frac{250}{\text{volume diluted}}$ step 6 $\times 249.6$	3	
	PDO Display	(iv) Working shown in at least three of the 5 steps	1	
		(v) Answers to 3 or 4 significant figures in final answer to each step attempted (minimum of three steps required)	1	[5]
(d)	ACE Interpretation	Explains that the maximum error is given by $+0.05\text{cm}^3$ on one burette reading and -0.05cm^3 on the other burette reading, or Individual errors are in opposite directions.	1	[1]
(e)	ACE Interpretation	Calculates $\frac{0.1}{\text{titre}} \times 100\%$ Answer must be correct to 2 or 3 decimal places.	1	[1]
[Total: 14]				