

NAME _____

CLASS _____

**JURONG PIONEER JUNIOR COLLEGE**
JC2 PRELIMINARY EXAMINATION 2026**CHEMISTRY****Higher 2**

Paper 4 Practical

9476/04**25 August 2026****2 hours 30 minutes****Candidates answer on the Question paper.**

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name, class and exam index number on all the work you hand in.
Give details of the practical shift and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.
Qualitative Analysis Notes are printed on pages 18, 19 and 20.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

Shift**Laboratory****For Examiner's Use**

1	13
2	12
3	25
Total	50

This document consists of **18** printed pages and **2** blank pages.

Answer **all** the questions in the spaces provided.

1 Inorganic and Organic Qualitative Analysis

For
Examiner's
Use

- (a) **FA 1** and **FA 2** are salts containing the **same** transition metal but in different oxidation states.

You are provided with solutions of **FA 1** and **FA 2**.

You are also provided with **Solution S**, 1% starch solution (*Keep for use in Question 2*).

You will perform tests to identify the transition metal contained in **FA 1** and **FA 2**.

- (i) Perform the tests described in Table 1.1, and record your observations in the table.

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved. If there is no observable change, write **no observable change**.

Table 1.1

/brown

	tests	observations
1	To 1 cm depth of FA 1 in a test-tube add 1 cm depth of dilute sulfuric acid, followed by 1 cm depth of aqueous potassium iodide. To the resulting mixture, add a few drops of Solution S .	<u>Purple solution turns brown/ black deposits in brown solution. (✓₁)</u> <u>With starch, solution turns blue-black/ black/ purplish black. (✓₂)</u>
2	To 1 cm depth of FA 2 in a test-tube add aqueous sodium hydroxide dropwise, with shaking, until in excess. Leave the mixture on standing for 2 minutes.	<u>Off-white/ light brown/ brown/ cream ppt. (✓₃)</u> <u>ppt. insoluble in excess NaOH. (✓₄)</u> <u>ppt. turning darker brown/darkened/brown. (✓₅)</u>
	To the resultant mixture, add 1 cm depth of hydrogen peroxide.	<u>ppt. turns black/ dark brown. (✓₆)</u> <u>Brisk effervescence/ gas bubbles noted. (✓₇)</u> <u>O₂ (✓₈) gas relights a glowing splint. (✓₉)</u>

[4]

8-9(✓)[4]; 6-7(✓)[3]; 4-5(✓) [2]; 2-3(✓) [1]

- (ii) Explain the observations in Test 2 as fully as you can, with reference to the reactions occurring.

Identify the transition metal ion present in **FA 2**.

The transition metal ion present in FA2: Mn^{2+} .

[3]

- Off-white/ light brown/brown/cream ppt Mn(OH)_2 formed with NaOH
- Oxidation causes darkening of ppt. (or formed Mn(OH)_3)
- H_2O_2 oxidises ppt./ Mn(OH)_2 / Mn(OH)_3 to MnO_2 / compound of higher oxidation state
- H_2O_2 undergoes catalytic decomposition to give O_2 gas.

Answer for students:

In Test 2, $\text{Mn}^{2+}(\text{aq})$ present in **FA 2** reacts with $\text{NaOH}(\text{aq})$ to form off-white $\text{Mn(OH)}_2(\text{s})$, which oxidises to brown $\text{Mn(OH)}_3(\text{s})$ upon standing in air.

Upon addition of $\text{H}_2\text{O}_2(\text{aq})$, the H_2O_2 oxidises both $\text{Mn(OH)}_2(\text{s})$ and $\text{Mn(OH)}_3(\text{s})$ to dark brown $\text{MnO}_2(\text{s})$, while itself being reduced to H_2O .

The $\text{MnO}_2(\text{s})$ formed then catalyses the decomposition of the remaining H_2O_2 , producing brisk effervescence of O_2 .

- (iii) State, with supporting evidence, the nature of **FA 1**.

Nature of FA 1: oxidising or oxidising agent

Evidence: FA 1 oxidises I^- / KI to I_2 in Test 1/with KI .

[2]

(b) Before starting this analysis, ensure your Bunsen burner is turned off.

You are provided with an organic liquid sample **FA 3**.

The molecular formula of **FA 3** is $C_3H_6O_2$.

You will perform tests to deduce the structure of **FA 3**.

- (i) Perform the tests described in Table 1.2, and record your observations in Table 1.2.

Observations in Test 4 have been recorded. **Do not perform this test.**

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured.

If there is no observable change, write **no observable change**.

Table 1.2

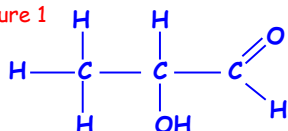
	tests	observations
1	To a 1 cm depth of FA 3 in a test-tube, add 2 cm depth of dilute sulfuric acid. Then add 2–3 drops of aqueous potassium manganate(VII). Warm the mixture in the hot water bath for two minutes.	Purple $KMnO_4$ decolourises.
2	Add 1 cm depth of aqueous silver nitrate to a test-tube. Then slowly add 1 cm depth of aqueous sodium hydroxide.	Brown ppt.
	Add aqueous ammonia slowly, with shaking, until the precipitate just dissolves. You may use a clean glass rod to stir the mixture and help dissolve the precipitate.	Colourless solution
	Add 1 cm depth of FA 3 to this mixture and shake the tube. Warm the mixture in the hot water bath for two minutes.	Silver mirror/grey ppt formed.
	Important: After about 3 minutes, pour the mixture down the sink and wash out the test-tube several times with tap water.	
3	To a 1 cm depth of FA 3 in a test-tube, add 10 drops of aqueous sodium hydroxide. Now add iodine solution dropwise, until a permanent yellow/orange colour is obtained. Warm the mixture in the hot water bath for two minutes.	The structure proposed must be structure 1 or 3) Upon warming, a pale yellow ppt formed.
4	To a 1 cm depth of FA 3 in a test-tube, cautiously add a small piece of sodium metal.	Effervescence observed. H_2 gas produced extinguishes a lighted splint with a "pop" sound.

[3]

- (ii) The molecular formula of **FA 3** is $C_3H_6O_2$. Use the observations recorded in Table 1.2 to deduce a possible structure of **FA 3**.

ecf correct structure based on student's tests' results

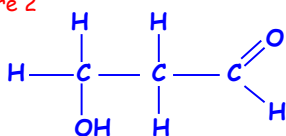
Structure 1



This structure gives

- Positive Test 1
- Positive Test 2
- Positive Test 3

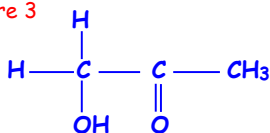
Structure 2



This structure gives

- Positive Test 1
- Positive Test 2
- Negative Test 3

Structure 3



This structure gives

- Positive Test 1
- Negative Test 2
- Positive Test 3

[1]

[Total: 13]

2 Investigating the kinetics of the reaction between iodate(V) ions and hydrogensulfite ions

For
Examiner's
Use

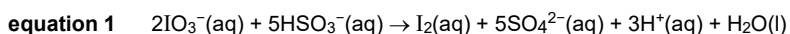
FA 4 is $0.100 \text{ mol dm}^{-3}$ potassium iodate(V), KIO_3 .

FA 5 is $0.0500 \text{ mol dm}^{-3}$ sodium hydrogensulfite, NaHSO_3 .

You are also provided with:

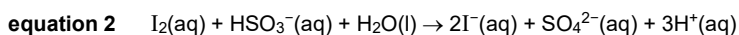
- **Solution S**, 1% starch solution
- deionised water
- a waste beaker containing sodium carbonate solution

Iodate(V) ions, $\text{IO}_3^-(\text{aq})$ react with hydrogensulfite ions, $\text{HSO}_3^-(\text{aq})$ as shown in **equation 1**.



In this experiment, the rate of the reaction is studied by measuring the rate of formation of iodine using a 'clock' method. You will vary the concentration of iodate(V) ions and measure the time taken for a fixed amount of iodine to be produced, which will be indicated by the formation of a blue-black colour in the presence of starch.

The blue-black/ purple colour does not appear immediately because the iodine, $\text{I}_2(\text{aq})$, produced can be reacted immediately with unreacted hydrogensulfite ions, $\text{HSO}_3^-(\text{aq})$, in a competing reaction (fast) as shown in equation 2.



When all the hydrogensulfite has been consumed, any additional iodine that forms will turn the starch indicator blue-black.

You will perform a series of five experiments. For each experiment, you will need to ensure that the same total volume of reaction mixture is used by adding deionised water as required. For each experiment, you will measure the time, t , for the blue-black colour to appear. You should avoid inhaling any gases produced.

(a) In the space provided on page 8, prepare a table, to record the following, to an appropriate level of precision:

- all volumes of **FA 4** ($V_{\text{FA 4}}$), **FA 5** ($V_{\text{FA 5}}$) and deionised water (V_{water}) used
- all values of t , to the nearest second
- calculated values of $\frac{1000}{t}$ to 3 significant figures

Procedure

Experiment 1

1. Use a teat pipette to add 10 drops of **Solution S** to a 100 cm³ conical flask.
2. Use a 10 cm³ measuring cylinder to measure 2.0 cm³ of **FA 4** into the conical flask.
3. Use a 25 cm³ measuring cylinder to measure 16.0 cm³ of deionised water into the same conical flask.
4. Use a second 10 cm³ measuring cylinder to measure 2.0 cm³ of **FA 5**.
5. Pour the **FA 5** into the same conical flask, starting the stopwatch during this addition.
6. Mix the contents thoroughly by swirling the flask several times. Then place the flask on the white tile.
7. Stop the stopwatch at the first appearance of a blue-black colour.
8. Record the time taken, t , to the nearest second, in your table.
9. Discard the reaction mixture immediately into the waste beaker containing sodium carbonate solution.
10. Wash out the flask thoroughly with tap water and then with deionised water. Stand the flask upside down on a paper towel to drain.

Experiments 2 to 5

Carry out four further experiments to investigate how the reaction time, t , changes with different volumes of potassium iodate(V), **FA 4** in step 2.

Volumes of **FA 4** used should not be higher than 10 cm³ and should not be lower than 2 cm³.

In each experiment, you should adjust the volume of deionised water in step 3 to ensure the **same total volume** of reaction mixture is used.

You should alternate the use of the two 100 cm³ conical flasks.

Record all volumes, the time taken and the calculated values of $\frac{1000}{t}$ in your table.

Results

Expt no.	$V_{\text{FA4}} / \text{cm}^3$	$V_{\text{FA5}} / \text{cm}^3$	$V_{\text{water}} / \text{cm}^3$	t / s	$\frac{1000}{t} / \text{s}^{-1}$
1	2.0	2.0	16.00	57	17.5
2	4.0	2.0	14.00	32	31.3
3	6.0	2.0	12.00	22	45.5
4	8.0	2.0	10.00	18	55.6
5	10.0	2.0	8.00	14	71.4

using
10 cm³ m.c.

using
25 cm³
m.c.

[5]

Single table with all required headers with units
(expt no. is not required)

Correct precision of recordings

- all $V_{FA\ 4}$ and ($V_{FA\ 5}$) to 1 d.p. (nearest 0.1 cm^3 as the smallest interval is 0.2 cm^3)
- all V_{water} to 2 d.p. (nearest 0.25 cm^3 as the smallest interval is 0.5 cm^3)
- all t to nearest seconds (whole no.) (as stated in the question)

Correctly calculate all values of $1000/t$ to 3 s.f.

Enter 5 sets of data + correct volumes of deionised water

- $2.0\text{ cm}^3 < V_{FA\ 4} \leq 10.0\text{ cm}^3$
- volume of H_2O such that $V_{FA\ 4} + V_{\text{water}} = 18.0\text{ cm}^3$

Correct trend: t decreases with increasing $V_{FA\ 4}$

- (b) (i) Plot a graph of $\left(\frac{1000}{t}\right)$ on the y-axis against V_{FA4} on the x-axis on the grid in Figure 2.1. Include the origin, (0,0), in your scale. Draw a line of best-fit.

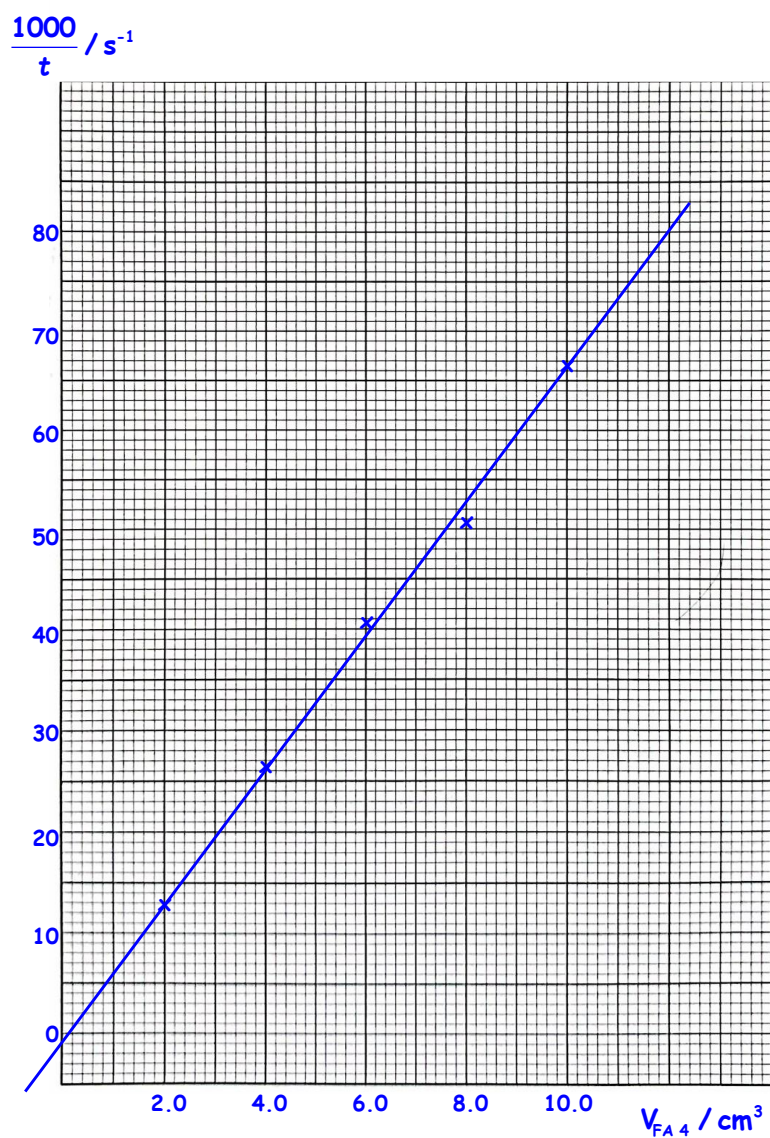


Figure 2.1

[3]

Gives axes correct way round + correct labels with units + uses proper linear uniform scale (plotted points, including the origin, occupy at least half of the given grid in both directions). Do not award this mark if student uses awkward scale (e.g. 1 for 3/7)

Plots all points to within $\frac{1}{2}$ small square (check any 3 points)

Draws a best-fit line (considered points should within 1 small squares in both x and y direction) + circles anomalous point if any (allow only one) + the graph must extrapolate until to cut the y-axis.

- (ii) $\left(\frac{1000}{t}\right)$ is a measure of the rate of reaction. By referring to your graph in Figure 2.1, explain how the rate of reaction is affected by the concentration of the iodate(V) ions, $[\text{IO}_3^-]$.

$$\text{Rate} \propto \frac{1}{t} \text{ and } V_{\text{FA4}} \propto [\text{IO}_3^-]$$

- *A straight line with positive gradient that passes through the origin is obtained.
- Hence, the rate is directly proportional to $[\text{IO}_3^-]$
or rate $\propto [\text{IO}_3^-]$
or the reaction is first order w.r.t. $[\text{IO}_3^-]$.

OR,

- *A straight line with positive gradient that does not pass through the origin is obtained if line does not cut the origin
- Hence, the rate is proportional to $[\text{IO}_3^-]$
or as the $[\text{IO}_3^-]$ increases, the rate increases.

OR,

- *A curve with increasing positive gradient that passes through the origin is obtained.
- Hence, as the $[\text{IO}_3^-]$ increases, the rate increases more
or the rate is not directly proportional to $[\text{IO}_3^-]$
or the reaction is higher than first order w.r.t. $[\text{IO}_3^-]$

*Comment must refer to the shape of line drawn.

[2]

Commented [KYSJ(1): Corrected to FA4

- (c) A student suggests modifying the experiment by varying the volume of **FA 5** while keeping the total volume and volume of **FA 4** constant, to investigate the effect of $[\text{HSO}_3^-]$ on the reaction rate. Explain why this approach would not work.

- HSO_3^- is completely consumed at the appearance of blue-black colour.
- Changing $[\text{HSO}_3^-]/V_{\text{FA 5}}$ changes the amount of iodine that needs to be produced for the blue-black colour to appear.
or The amount of iodine produced is not constant across each reaction mixture when blue-black colour appears.

- The time measured/ t would not correspond to a fixed extent of reaction (or Different experiments would have different endpoints).

Hence, $1/t$ (or $1000/t$) is not a valid measure of the reaction rate.

Answer for students:

- HSO_3^- is completely consumed at the appearance of blue-black colour.
- Changing $V_{\text{FA 4}}$ (or $[\text{HSO}_3^-]$) changes the amount of iodine that needs to be produced for the blue-black colour to appear.
- The time measured, t , would not correspond to a fixed extent of reaction (i.e. different experiments would have different endpoints).
- Hence, $1/t$ (or $1000/t$) is not a valid measure of the reaction rate.

[2]

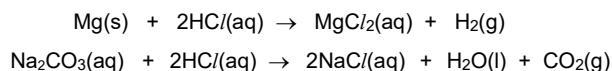
[Total: 12]

3 Determining the relative atomic mass (A_r) of magnesium

FA 6 is an aqueous solution prepared by reacting 0.210 g of magnesium ribbon, Mg, with 30.0 cm³ of 1.00 mol dm⁻³ hydrochloric acid, HCl, and made up to 250 cm³ with deionised water. You are provided with **FA 6**.

FA 7 is aqueous sodium carbonate containing 2.68 g dm⁻³ Na₂CO₃.

In this question, you will titrate **FA 7** with **FA 6** to determine how much HCl was left over after the reaction with Mg.



Using the experimental results, you will determine the A_r of magnesium.

(a) Titration of **FA 7** against **FA 6**

1. Fill the burette with **FA 6**.
2. Use a pipette to transfer 25.0 cm³ of **FA 7** into a 250 cm³ conical flask.
3. Add a few drops of methyl orange indicator.
4. Run **FA 6** from the burette into the conical flask until the yellow colour of the solution changes to orange.
5. Record your titration results, to an appropriate level of precision, in the space provided.
6. Repeat points 2 to 5 until consistent results are obtained.

Results

Final burette reading / cm ³	23.80	47.80
Initial burette reading / cm ³	0.00	24.00
Volume of FA 6 used / cm ³	23.80	23.80

✓ ✓

Gives a proper table with correct headings ('burette' must be stated) and units. Accept "burette volume". If headers have no units, then each reading must have units stated.

Do not award if any final and initial burette readings are inverted.

Records all burette readings to the nearest 0.05 cm³ (2 d.p.) + computes all titres correctly to 2 d.p.

Do not award if 50 is used as initial burette reading or burette reading is > 50.

Obtains at least two uncorrected titres within 0.10 cm³ + places tick (✓)
OR shows selected titres in exact form in the average working in (b).

Examiners reading: 22.55cm³

Accuracy: Deviation in titre btw Supervisor's and student's titre, δ :

$$\delta \leq 0.20 \text{ cm}^3$$

$$0.20 < \delta \leq 0.50 \text{ cm}^3$$

Award the accuracy mark based on the two titres according to the following hierarchy:

- identical
- within 0.05 cm³
- within 0.10 cm³

[5]

- (b) From your titrations, obtain a suitable volume of **FA 6**, $V_{\text{FA 6}}$, to be used in your calculations. Show clearly how you obtained this volume.

$$V_{\text{FA 6}} = \frac{23.80 + 23.80}{2} = 23.80 \text{ cm}^3$$

shows average working from at least 2 uncorrected titres (*quoted in exact form) within 0.20 cm^3 + obtains correct average to 2 d.p.

*Do not award this mark if the titres used are not identified either in the table (by ticks) or in the calculation.

$$V_{\text{FA 6}} = \underline{23.80 \text{ cm}^3} \quad [1]$$

Note: For calculations, the principle of no double penalty (error carried forward) applies. For connecting parts, marking from point of first penalty onwards will be based on correct method only.

- (c) (i) Calculate the amount of Na_2CO_3 in the 25.0 cm^3 of **FA 7** used in each titration. [A_r : Na, 23.0; C, 12.0; O, 16.0]

$n(\text{Na}_2\text{CO}_3)$ in 25.0 cm^3 of **FA 7**

$$= \frac{25.0}{1000} \times \frac{2.68}{106.0} = 6.321 \times 10^{-4} \text{ mol}$$

$$\text{Amount of } \text{Na}_2\text{CO}_3 \text{ in } 25.0 \text{ cm}^3 \text{ of FA 7} = \underline{6.32 \times 10^{-4} \text{ mol}} \quad [1]$$

- (ii) Use your answer in (c)(i) to calculate the amount of hydrochloric acid present in 250 cm^3 of **FA 6**.

$n(\text{HCl})$ left unreacted in 250 cm^3 of **FA 6**

$$= \frac{250}{\text{ans. (b)}} \times 2 \times \text{ans. (c)(i)}$$

$$= \frac{250}{23.80} \times 2 \times 6.321 \times 10^{-4} = 0.01328 \text{ mol}$$

$$\text{Amount of HCl present in } 250 \text{ cm}^3 \text{ of FA 6} = \underline{0.0133 \text{ mol}} \quad [1]$$

- (iii) Calculate the amount of hydrochloric acid that reacted with the magnesium.

$n(\text{HCl})$ reacted with Mg

$$= \left(\frac{30}{1000} \times 1.00 \right) - \text{ans. (c)(ii)}$$

$$= \left(\frac{30}{1000} \times 1.00 \right) - 0.01328 = 0.01672 \text{ mol}$$

$$\text{Amount of HCl that reacted with the magnesium} = \underline{0.0167 \text{ mol}} \quad [1]$$

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- (iv) Hence calculate the relative atomic mass, A_r , of magnesium.

$$A_r \text{ of Mg} = \frac{0.210}{\frac{1}{2} \times \text{ans. (c)(iii)}}$$

$$= \frac{0.210}{\frac{1}{2} \times 0.01672} = 25.12$$

A_r of magnesium = 25.1 (no units) [1]

- (d) The A_r of magnesium given in the Periodic Table is 24.3. Use this value given in the Periodic Table to calculate the percentage error of your A_r value of Mg obtained in (c)(iv).

$$\% \text{ error} = \frac{|\text{ans(c)(iv)} - 24.3|}{24.3} \times 100\%$$

$$= \frac{|25.12 - 24.3|}{24.3} \times 100\% = 3.37 \%$$

percentage error = 3.37 %

Shows working in all calculations in (c)(i)-(iv) & (d) (calculations must be relevant although may not be complete/correct).

Gives appropriate significant figures (3 sf) in all final answers in (c)(i)-(iv) & (d).

Gives correct units in (b)[cm³], (c)(i)-(iii)[mol], (iv)[no units], (d)[%].

Any calculation not attempted loses these three marks.

[4]

- (e) A solution of NaOH was prepared at the same concentration, in mol dm⁻³, as **FA 7**. A student repeated the titration but replaced **FA 7** with this NaOH solution. Explain the effect that replacing **FA 7** with this solution of NaOH would have on the volume of **FA 6** needed for the titration.

Half the volume of **FA 6** is required since NaOH and HCl react in a mole ratio of 1:1 while Na₂CO₃ and HCl react in a mole ratio of 1:2.

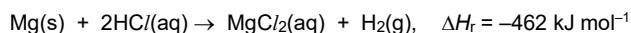
[1]

For
Examiner's
Use

(f) Planning

The relative atomic mass, A_r , of magnesium can be determined using an alternative method based on calorimetry.

When magnesium ribbon reacts with hydrochloric acid, an exothermic reaction occurs as follows:



The maximum temperature change, ΔT_{max} , occurring during this reaction can be determined graphically and can be used to calculate the heat change, q , for this experiment.

Using the value of q and the literature value for the enthalpy of reaction, the relative atomic mass of magnesium can be determined.

In this question, you are to plan a procedure that would provide sufficient data to allow you to determine the relative atomic mass of magnesium.

- (i) Plan an investigation to determine the maximum temperature change, ΔT_{max} , **graphically** for the reaction between magnesium and hydrochloric acid.

Measurements should be taken:

- before the reaction starts,
- during the reaction,
- some time after the reaction is complete.

You may assume that you are provided with:

- about 1 g of magnesium ribbons,
- 200 cm³ of 1.00 mol dm⁻³ hydrochloric acid,
- the apparatus normally found in a school laboratory,

In your plan you should include brief details of:

- the apparatus you would use
- the quantities you would use, so that there is an excess of hydrochloric acid
- the procedure you would follow
- the measurements you would make to allow a suitable temperature-time graph to be drawn
- how you would ensure that an accurate and reliable value of ΔT_{max} is obtained.

[A_r : H, 1.0; Cl, 35.5, Mg, 24.3]

[6]

1. Weigh an empty weighing bottle using an electronic weighing balance which is precise to 2 (or 3) decimal places.
2. Weigh accurately *0.165 g of solid Mg ribbons into the weighing bottle and record the total mass, m_1 g
3. Using a 50 cm³ measuring cylinder, add *50.0 cm³ of hydrochloric acid into the Styrofoam/polystyrene/plastic cup supported in a beaker.
4. Stir the solution in the cup using the 0.2 °C interval thermometer and record the initial temperature of the solution.
5. At a convenient time, start the stopwatch. Record the temperature of the solution in the Styrofoam/polystyrene/plastic cup at 30 s intervals until 2.5 min.
6. At exactly 3 min, tip the weighed Mg ribbons into the Styrofoam cup.
7. Stir the contents in the Styrofoam/polystyrene/plastic cup with the thermometer and record the temperature of the solution at 3.5 min. Continue to stir the contents in the Styrofoam cup and record the temperature of the solution at 30 s intervals until the temperature has dropped for at least 5 min e.g. until 10 min.
8. Re-weigh the weighing bottle with any residual Mg to find out the actual mass of Mg added to the Styrofoam cup.
Record the mass, m_2 g,

Actual mass of Mg added into the cup = $m_1 - m_2 = m$ g

[6]

- *State the mass of Mg (accept a range) and appropriate volume (reject $< 20 \text{ cm}^3$) of HCl used; ensure that HCl is used in excess (check with calculations).
- Measure mass of Mg (limiting reagent) using a weighing balance (reject "balance/weighing scale") + correct weighing steps to determine actual mass of Mg added into the cup. {step 2 & 8}
- Measure volume of HCl(aq) using an appropriate accurate apparatus e.g. measuring cylinder (reject "beaker"; accept "burette" "pipette").
- Measure the initial temperature of HCl(aq) before mixing. {step 4}

Start the stop-watch and take *temperature measurements at fixed time-intervals (accept 10 s to 1 min) before mixing. {step 5}

State the time of mixing and take *temperature measurements at fixed time-intervals (accept 10 s to 1 min) after mixing until to an appropriate end-time (until the temperature has dropped for at least 5 min and with minimum 6 data points) {step 6 & 7}.

*Reject: measure "temperature change"

- (ii) Sketch, on Figure 3.1, the graph you would expect to obtain using the measurements you planned to make in (f)(i).

Show clearly how $\Delta T_{\max}$ can be determined from your graph, including any lines you would draw.

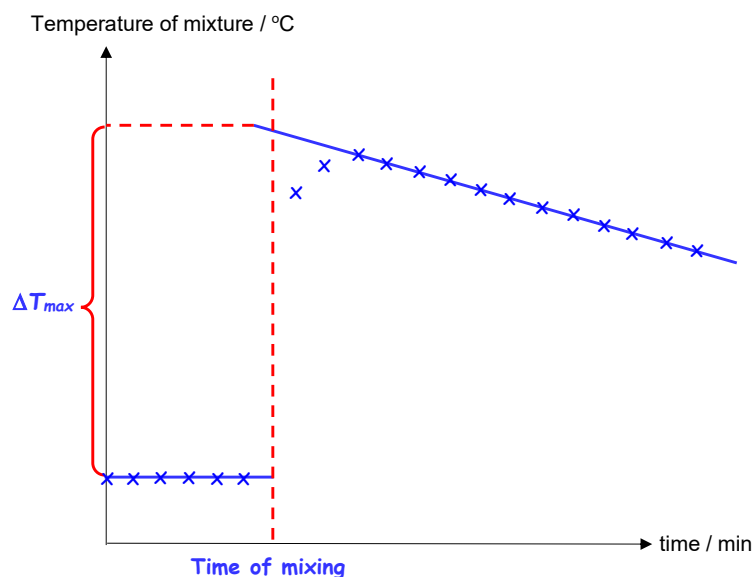


Figure 3.1

- shows correct measurements (plotted points)
or, shows correct trend line
or, shows two straight lines
 - one horizontal line before time of mixing
 - one decreasing line (cooling curve) starting above the first line after time of mixing and does not decrease below the first line
- shows clearly how $\Delta T_{\max}$ is obtained from the graph:
 - draws one horizontal line before time of mixing
 - draws one decreasing line (cooling curve) after time of mixing
 - indicates the time of mixing and $\Delta T_{\max}$ correctly on the graph.

[2]

- (iii) Outline how you would use your $\Delta T_{\max}$ value and the literature enthalpy change value to calculate the relative atomic mass of magnesium.

In your calculations, let m g be the actual mass of magnesium used and V cm³ be the volume of hydrochloric acid used.

It is not necessary to simplify the expression in your final answer.

You should assume that the specific heat capacity of the final solution is 4.2 J g⁻¹ K⁻¹ and its density is 1.00 g cm⁻³.

Given: $\text{Mg(s)} + 2\text{HCl(aq)} \rightarrow \text{MgCl}_2\text{(aq)} + \text{H}_2\text{(g)}$, $\Delta H_r = -462 \text{ kJ mol}^{-1}$

$$q = (V \times 1.00) \times 4.2 \times \Delta T_{\max} \\ = 4.2V\Delta T_{\max} \text{ J}$$

$$\Delta H_r = - \frac{\left(\frac{4.2V\Delta T_{\max}}{1000} \right)}{\left(\frac{m}{A_r(\text{Mg})} \right)} = -462$$

$$\text{Or, } \frac{\left(\frac{4.2V\Delta T_{\max}}{1000} \right)}{\left(\frac{m}{A_r(\text{Mg})} \right)} = 462$$

[2]

[Total: 25]

Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	Reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	ammonia produced on heating	–
barium, Ba ²⁺ (aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. with high [Ca ²⁺ (aq)]	no. ppt.
chromium(III), Cr ³⁺ (aq)	grey–green ppt. soluble in excess giving dark green solution	grey–green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red–brown ppt. insoluble in excess	red–brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off–white ppt. rapidly turning brown on contact with air insoluble in excess	off–white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

Anion	Reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$);
bromide, $\text{Br}^-(\text{aq})$	gives pale cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$);
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$);
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown NO_2 in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	SO_2 liberated on warming with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

(c) Tests for gases

gas	test and test results
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	"pops" with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns acidified aqueous potassium manganate(VII) from purple to colourless

(d) Colour of halogens

halogen	colour of element	colour in aqueous solution	colour in hexane
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas/liquid	orange	orange-red
iodine, I_2	black solid/purple gas	brown	purple

(e) Tests for organic compounds

organic compounds	reactions
alkene	decolourises orange $\text{Br}_2(\text{aq})$
chloroalkane	heat with $\text{NaOH}(\text{aq})$, white ppt. formed on adding dilute HNO_3 , followed by $\text{Ag}^+(\text{aq})$
bromoalkane	heat with $\text{NaOH}(\text{aq})$, pale cream ppt. formed on adding dilute HNO_3 , followed by $\text{Ag}^+(\text{aq})$
iodoalkane	heat with $\text{NaOH}(\text{aq})$, yellow ppt. formed on adding dilute HNO_3 , followed by $\text{Ag}^+(\text{aq})$
alcohol	- forms white fumes with solid PCl_5 - decolourises purple acidified $\text{KMnO}_4(\text{aq})$ on heating (for primary and secondary alcohols) - gives pale yellow ppt. with alkaline $\text{I}_2(\text{aq})$ on warming (for alcohols with $\text{CH}_3\text{CH}(\text{OH})-$ group)
phenol	decolourises orange $\text{Br}_2(\text{aq})$ and forms a white ppt.
carbonyl compounds (aldehydes and ketones)	- gives orange ppt. with 2,4-dinitrophenylhydrazine - gives pale yellow ppt. with alkaline $\text{I}_2(\text{aq})$ on warming (for carbonyl compounds with $\text{CH}_3\text{CO}-$ group) - gives red-brown ppt. with Fehling's solution on warming (for aliphatic aldehydes) - gives silver mirror with Tollens' reagent on warming (for aldehydes)
carboxylic acid	CO_2 liberated by $\text{Na}_2\text{CO}_3(\text{aq})$ - gives white fumes with solid PCl_5
phenylamine	decolourises orange $\text{Br}_2(\text{aq})$ and forms a white ppt.
primary amide	NH_3 liberated on heating with $\text{NaOH}(\text{aq})$