

TEMASEK JUNIOR COLLEGE
2026 JC2 PRELIMINARY EXAMINATION
Higher 2



CANDIDATE
NAME

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CLASS

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CENTRE
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INDEX
NUMBER

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Chemistry

9476/04

Paper 4 Practical

27 August 2026

2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name, CG, centre number and 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 an HB pencil for any diagrams or 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 to 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	
2	
3	
4	
Total	

This document consists of **20** printed pages.

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

1 Qualitative analysis

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

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

Test and identify any gases evolved.

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

No additional tests for ions present should be attempted.

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

- (a) **FA 1** is a mixture of two salts, each of which contains a single cation and a single anion from those listed in the Qualitative Analysis Notes on pages 18 to 20.

Do the following tests and record your observations in Table 1.1 below.

2[✓] = 1 mark

Table 1.1

test	observations
(i) Place a small spatula of FA 1 in a test-tube. Carefully add dilute sulfuric acid until the reaction is complete. → Test for gas	<u>Effervescence</u> and colourless <u>CO₂ gas</u> forms <u>white ppt with limewater</u> ✓ <u>Light blue solution</u> obtained ✓ 
Then add aqueous sodium hydroxide with shaking, until the aqueous sodium hydroxide is in excess. → Test for cation	<u>blue ppt formed</u> and is <u>insoluble in excess</u> NaOH ✓ 
(ii) To a 3 cm depth of deionised water in a boiling tube, add the remaining sample of FA 1. Stir and then filter the mixture into a clean boiling tube. You will use this solution for tests (iii) – (v).	

(iii) Add 1 cm depth of the solution from (ii) into a clean test-tube. Add aqueous sodium hydroxide slowly, until the aqueous sodium hydroxide is in excess. → Test for cation	<u>white ppt formed</u> and is <u>insoluble in excess</u> NaOH ✓
(iv) Add 1 cm depth of the solution from (ii) into a clean test-tube. Add aqueous ammonia slowly, until the aqueous ammonia is in excess. → Test for cation	<u>white ppt formed</u> and is <u>insoluble in excess</u> NaOH ✓
Then add a spatula full of ammonium chloride.	<u>white ppt soluble in excess</u> NH_4Cl to give a <u>colourless solution</u>. ✓
(v) Add 1 cm depth of the solution from (ii) into a clean test-tube. Add 1 cm depth of aqueous barium nitrate. Add dilute nitric acid until the nitric acid is in excess. → Test for sulfate/sulfite	<u>white ppt formed</u> ✓ <u>white ppt is insoluble in excess</u> HNO_3 ✓

[4]

(vi) Complete Table 1.2 to identify the cations and anions present in **FA 1**.

Table 1.2

	FA 1
Cations present	
Anions present	

[2]

	FA 1
Cations present	Cu^{2+} ✓ Mg^{2+} ✓
Anions present	CO_3^{2-} ✓ SO_4^{2-} ✓

2[✓] = [1]

- (vii) With the aid of an equation, explain your observation in part (a)(i) that allows you to identify one of the cations. [1]

Blue ppt of $\text{Cu}(\text{OH})_2$ formed with NaOH(aq) ✓ and insoluble in excess NaOH(aq) suggest the presence of Cu^{2+} .



2[✓] = [1]

- (viii) Give one reason why it is necessary to perform (a)(ii) before (a)(iii) and (a)(iv). [1]

To separate Mg^{2+} from Cu^{2+} so that the white ppt, $\text{Mg}(\text{OH})_2$, formed using NaOH and aq. NH_3 can be easily observed. [1]

(b) Organic analysis

FA 2, FA 3 and FA 4 are aqueous solutions of organic compounds.

All **FA 2, FA 3 and FA 4** contain carbon, hydrogen and oxygen only and they each contain one type of functional group.

You will carry out tests to identify the functional groups present in **FA 2, FA 3 and FA 4** and to deduce the structure of **FA 2 and FA 4**.

- (i) Perform the tests described in Table 1.3. Some of the observations have been completed for you. There is no need to carry out these tests. Record your observations in Table 1.3.

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

When organic solutions are to be heated, a hot water bath should be used.

Table 1.3

test		observations		
		FA 2	FA 3	FA 4
1	Add 1 cm depth of the FA solution in a test-tube. Add a small spatula of sodium carbonate to the test-tube. → Test for COOH via CO_2 gas evolved	<u>Effervescence and Colourless CO_2 gas forms white ppt with limewater</u> ✓	<u>Effervescence and Colourless CO_2 gas forms white ppt with limewater</u> ✓	<u>no observable change</u> ✓ or no effervescence
2	Add 1 cm depth of the FA solution in a test-tube. Add 5 cm depth of 2,4-dinitrophenylhydrazine solution to the test-tube.	no observable change	no observable change	orange precipitate observed
3	Add a few drops of the FA solution in a test-tube. Add a spatula of PCl_5 to the test-tube.	white fumes observed	white fumes observed	no observable change

4	Add 1 cm depth of the FA solution in a test-tube. Add 15 drops of dilute sulfuric acid followed by 1 drop of acidified potassium manganate(VII). Place the test-tube in the hot water bath and leave to stand.	<u>Purple KMnO₄ decolourises</u> ✓	<u>no observable change</u> ✓ or purple KMnO₄ remained	<u>Purple KMnO₄ decolourises</u> ✓
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3[✓] = [1]

[2]

- (ii) Using your observations from Table 1.3, deduce the functional group present in both **FA 2** and **FA 3**. [1]

Carboxylic acid since both undergo acid-base reaction with Na₂CO₃ as effervescence was seen in test 1. [1]

- (iii) Hence, suggest a possible structure of **FA 2** that is consistent with all the observations in Table 1.3. [1]

HCO₂H [1] **accept (COOH)₂**

FA 2 is a carboxylic acid that can be further oxidised.

- (iv) The relative molecular mass of **FA 4** is determined to be 58.0.
Using your observations from Table 1.3, suggest the structure of **FA 4**.
Give evidence to support your conclusion.

[Ar: H, 1.0; C, 12.0; O, 16.0]

[1]

CH₃CH₂CHO. Orange ppt is formed in test 2 and purple KMnO₄ decolourised in test 4. Hence **FA 4** is an aldehyde since it can undergo condensation reaction with 2,4-DNPH and can undergo oxidation with KMnO₄. [1]

Mentioning of only one reaction will not gain this mark.

[Total: 13]

2 Investigate the kinetics of the reaction between M^{3+} ions and iodide ions

FA 5 is $0.0500 \text{ mol dm}^{-3}$ aqueous potassium iodide, KI.

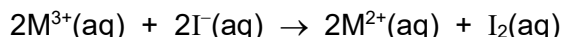
FA 6 is an acidified solution of $M^{3+}(\text{aq})$.

FA 7 is $0.00500 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

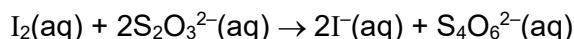
You are also provided with:

- starch solution
- deionised water

In acidic solutions, M^{3+} ions react with iodide ions according to the equation shown.



In this experiment, the rate of the reaction can be investigated by using starch indicator, which turns blue-black in the presence of iodine. Sodium thiosulfate is added to the reaction mixture to react with iodine as it is formed. When all the thiosulfate has reacted, the black-blue colour is observed.



You will perform a series of five experiments to investigate how the rate of reaction is affected by changing the concentration of the iodide ions. You will measure the time, t , for the blue-black colour to appear. For each experiment, you will need to ensure that the total volume of reaction mixture used is constant, by adding deionised water as required.

(a) Prepare a table in the space provided on page 8 in which to record, to an appropriate degree of precision:

- the volumes of **FA 5**, **FA 7** and deionised water used
- all values of t
- calculated values of rate

Experiment 1

1. Use a 25 cm^3 measuring cylinder to place 20.0 cm^3 of **FA 5** in a 100 cm^3 beaker.
2. Use appropriate measuring cylinders to add the following to the same beaker.
 - 20.0 cm^3 of **FA 7**
 - 10.0 cm^3 of **starch**
3. Use an appropriate measuring cylinder to measure 10.0 cm^3 of **FA 6**.
4. Add this **FA 6** to the same 100 cm^3 beaker and start the stopwatch immediately.
5. Stir the mixture once and place the beaker on a white tile.
6. Stop timing as soon as the solution turns blue-black. Ignore any colour changes that occur before the intense blue-black colouration.
7. Record this reaction time to the nearest second.
8. Wash the beaker and dry it with a paper towel.

Experiment 2

1. Use a 25 cm³ measuring cylinder to measure 10.0 cm³ of **FA 5** in a 100 cm³ beaker.
2. Use appropriate measuring cylinders to add the following to the same beaker.
 - 10.0 cm³ of deionised water
 - 20.0 cm³ of **FA 7**
 - 10.0 cm³ of **starch**
3. Use an appropriate measuring cylinder to measure 10.0 cm³ of **FA 6**.
4. Add this **FA 6** to the same 100 cm³ beaker and start the stopwatch immediately.
5. Stir the mixture once and place the beaker on a white tile.
6. Stop timing as soon as the solution turns blue-black. Ignore any colour changes that occur before the intense blue-black colouration.
7. Record this reaction time to the nearest second.
8. Wash the beaker and dry it with a paper towel.

Experiments 3-5

Carry out three further experiments to investigate how the reaction time changes with different volumes of potassium iodide, **FA 5**. In each case, you will need to ensure that the total volume of the **FA 5** and deionised water is always 20.0 cm³. Do not use a volume of **FA 5** that is less than 6.0 cm³.

Results

The rate of the reaction can be calculated as shown.

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

[5]

Expt	V _{FA 5} /cm ³	V _{H₂O} /cm ³	V _{FA 7} /cm ³	t /s	rate / s ⁻¹
1	20.0	0.0	20.0	15	66.7
2	10.0	10.0	20.0	60	16.7
3	7.0	13.0	20.0	95	10.5
4	13.0	7.0	20.0	39	25.6
5	17.0	3.0	20.0	23	43.5

[1] tabulates data with headers and units

[1] volume to 1dp and time to nearest second

[1] three additional experiments with volume of FA 5 between 6 – 20 cm³ and no volume less than 2.0 cm³ close to another volume.

[1] total volume of FA 5 and water is 20 cm³

[1] correctly calculates rate to 3 s.f.

- (b) Explain why $\left(\frac{1000}{\text{time}}\right)$ is indicative of the rate of reaction. [1]

Analysis: time is measured for the blue-black colour to appear which is due to iodine, so rate of reaction $\propto \frac{\text{amount of iodine produced}}{\text{time taken}} \propto \frac{1}{\text{time taken}}$ only if amt of iodine produced is constant

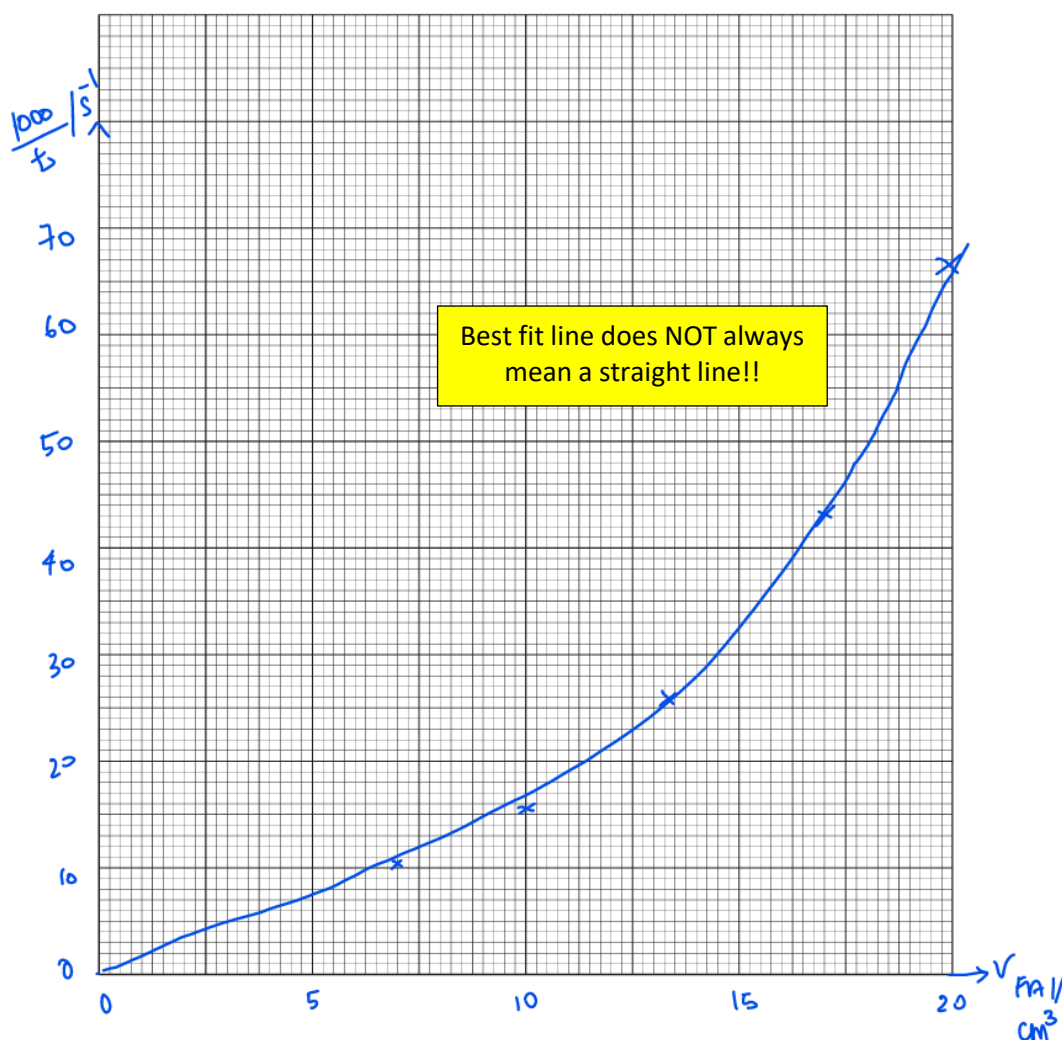
Since a constant amount of $\text{S}_2\text{O}_3^{2-}$ is used for every experiment, constant amount of iodine is produced for every experiment and hence, the rate is inversely proportional to time. [1]

Note: factor of 1000 is merely to scale up the value of rate so it's more convenient for plotting (nothing to do with indication of rate or conversion of volume to cm^3 or dm^3)

- (c) Plot a graph of rate, on the y-axis, against volume of **FA 5**, on the x-axis, on the grid in Fig. 2.1, and include the origin (0,0). Draw a line of best fit through the points. [3]

Note: plot of rate vs volume is the similar to rate vs conc

Rate = $k[\text{I}]^n$ is similar to $y = mx^n$ graph (must cut through origin)



[1] axes correct way round, correct labels, plotted points must occupy at least half the given grid in both directions

[1] points should be plotted to within half a small square

[1] line of best fit and use a minimum of 3 points, ignore points that are circled or labelled as anomalous results. Reject if a point has been shown at the origin and the line of best fit does not pass within 5 small squares of (0,0).

- (d) Use your graph to calculate the time that the reaction would have taken if 5.0 cm³ of **FA 5** had been used. [1]

From graph, when volume of FA 5 is 5.0 cm³, $\frac{1000}{\text{time}} = 7.5$

$$\text{Time} = \frac{1000}{7.5} = 133 \text{ s (3sf, not 1 dp) [1]}$$

- (e) Using data from Experiment 1 and 2, show by calculation that the volume of aqueous potassium iodide, FA 5, used was directly proportional to the concentration of iodide ions. [2]

Total volume of mixture

$$= 10 \text{ cm}^3 \text{ FA6} + 20 \text{ cm}^3 \text{ FA5} + 20 \text{ cm}^3 \text{ FA7} + 10 \text{ cm}^3 \text{ starch} = 60 \text{ cm}^3$$

$$[\text{FA 5}] \text{ in expt 1} = \frac{\frac{20}{1000} \times 0.0500}{\frac{60}{1000}} = 1.67 \times 10^{-2} \text{ mol dm}^{-3}$$

$$[\text{FA 5}] \text{ in expt 2} = \frac{\frac{10}{1000} \times 0.0500}{\frac{60}{1000}} = 8.33 \times 10^{-3} \text{ mol dm}^{-3}$$

[1] both concentrations

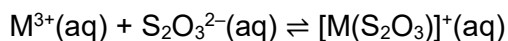
$$\frac{[\text{FA5}]_1}{[\text{FA5}]_2} = \frac{1.67 \times 10^{-2}}{8.33 \times 10^{-3}} = 2$$

$$\frac{[\text{Vol of FA5}]_1}{[\text{Vol of FA5}]_2} = \frac{20}{10} = 2$$

Hence, volume of FA 5 is directly proportional to the concentration of iodide ions.

[1] comparing volume of FA 5 to concentration

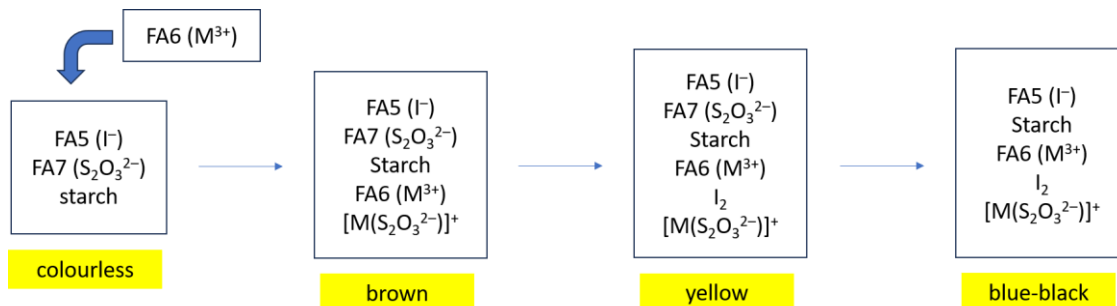
- (f) M^{3+} ions reacts with thiosulfate to form a purple complex $[M(S_2O_3)]^+$.



When **FA 6** (M^{3+}) was first added to the solution in step 4 of (a), the colourless mixture turns brown then yellow before turning blue-black.

Suggest an explanation for the colour change in terms of the chemistry involved. [2]

Tracking colour change:



Brown solution: [1] mixture of purple complex $[M(S_2O_3)]^+$ and yellow $M^{3+}(aq)$.

Yellow solution: Since the I_2 formed reacted immediately with thiosulfate, [1] $[S_2O_3^{2-}(aq)]$ decreased, and the position of equilibrium of $M^{3+}(aq) + S_2O_3^{2-}(aq) \rightleftharpoons [M(S_2O_3)]^+(aq)$ shifts left, hence $[M(S_2O_3)]^+$ decreases / $[M^{3+}]$ increases / producing more M^{3+} .

[Total: 14]

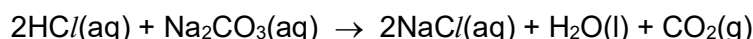
3 Determination of the percentage purity of a sample of sodium carbonate

In this question, you will determine the percentage purity of a sample of contaminated sodium carbonate.

A sample of contaminated sodium carbonate is dissolved in deionised water and diluted.

You will titrate the diluted solution of the contaminated sodium carbonate with hydrochloric acid of known concentration. You may assume that the impurities do not react with acid.

Sodium carbonate reacts with hydrochloric acid according to the equation shown.



FA 8 was prepared as follows:

- 45.8 g of the contaminated sodium carbonate sample was dissolved in deionised water and the solution was made up to 1 dm³.
- 28.00 cm³ of the solution was then made up to 250 cm³ with deionised water.

FA 9 is 0.100 mol dm⁻³ hydrochloric acid, HCl.

Solution I is methyl orange indicator.

(a) (i) Titration of FA 8 against FA 9

1. Fill the burette with **FA 9**.
2. Use the pipette to transfer 25.0 cm³ of **FA 8** into a 250 cm³ conical flask.
3. Add a few drops of **Solution I** to the same conical flask.
4. Titrate the mixture in the conical flask until the end-point is reached.
5. Record your titration results, to an appropriate level of precision, in the space provided below.
6. Repeat steps 2 to 5 until consistent results are obtained.

Titration results

final burette reading / cm ³	21.20	21.20
initial burette reading / cm ³	0.00	0.00
volume of FA 9 / cm ³	21.20	21.20
	✓	✓

Correct headers with units [1]

All burette readings to 0.05 cm³ [1]

Correct calculation of titre volumes i.e. final – initial burette reading and at least two consistent results within 0.10 cm³. [1]

Accuracy [2]2 marks if difference is $\leq 0.20 \text{ cm}^3$ 1 mark if difference is $\leq 0.40 \text{ cm}^3$ 0 mark if difference is $> 0.40 \text{ cm}^3$ **Supervisor's reading: 19.60 cm^3**

- (ii) From your titrations, obtain a suitable volume of **FA 9** to be used in your calculations. Show clearly how you obtained this volume.

Average titre volume = $(21.20 + 21.20)/2 = 21.20 \text{ cm}^3$ [1]

Use (at least two) titre values within 0.20 cm^3 to correctly calculate average volume of **FA 9**. Working must be shown or ticks put next to the two (or more) consistent titres selected.

- (b) (i) Calculate the amount of sodium carbonate in 25.0 cm^3 of **FA 8**.

$$\text{Amount of HC/ used} = \frac{(21.20)(0.100)}{(1000)} = 2.12 \times 10^{-3} \text{ mol}$$



$$\text{Amount of Na}_2\text{CO}_3 = \frac{0.00212}{2} = 1.06 \times 10^{-3} \text{ mol} \quad [1]$$

- (ii) Calculate the concentration, in mol dm^{-3} , of sodium carbonate in the contaminated sample solution used to prepare **FA 8**.



45.8 g of contaminated sodium carbonate dissolved in deionised water, made up to 1 dm^3



28 cm^3 was made up to 250 cm^3 with deionised water



25 cm^3 of diluted sodium carbonate solution reacts with 21.20 cm^3 of HCl

Amount of Na_2CO_3 in 28.00 cm^3 of the undiluted solution of contaminated sample

= Amount of Na_2CO_3 in 250 cm^3 of the diluted solution

$$= \frac{0.00106}{25.0} \times 250 = 0.0106 \text{ mol [1]}$$

Concentration of Na_2CO_3 in the contaminated sample = $0.0106 / \frac{28.00}{1000}$

$$= 0.379 \text{ mol dm}^{-3} \text{ [1]}$$

- (iii) Calculate the percentage purity by mass of the sodium carbonate in the contaminated sample.

[Ar: H, 1.0; C, 12.0; O, 16.0; Na, 23.0]

Mass of Na_2CO_3 in 1 dm^3 of contaminated sample solution

$$= 0.379 \times [2(23.0) + 12.0 + 3(16.0)] = 40.2 \text{ g}$$

Percentage purity by mass of Na_2CO_3 in the contaminated sample

$$= \frac{40.2}{45.8} \times 100\% = 87.8\%$$

$$\text{[1]} \frac{\text{ans in (b)(ii)} \times 106.0}{45.8} \times 100\%$$

[1] final answers to 2dp and 3sf with correct units respectively for 3(a)(ii) and 3(b)

[1] working shown with clear statements for 3(a)(ii) and 3(b)

- (c) A student suggested using $0.100 \text{ mol dm}^{-3}$ sulfuric acid in place of the $0.100 \text{ mol dm}^{-3}$ hydrochloric acid used in the experiment above.

Explain what effect this change would have on the percentage error of the experiment.

FA 8 was prepared using the same procedure and quantities described on page 11. [1]

The percentage error (in the titre value) increases as the volume of sulfuric acid needed is smaller [1] since sulfuric acid is a dibasic acid.



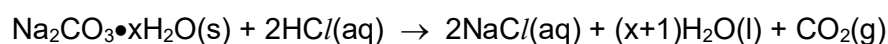
[Total: 13]

4 Planning

When sodium carbonate is crystallised from solution, it forms crystals of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

- (a) The value of x in a sample of sodium carbonate crystals, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, is determined to be 10 via titration.

The value of x can also be determined by adding the sample to an **excess** of hydrochloric acid and measuring the volume of carbon dioxide gas formed.



- (i) Using $x = 10$, calculate the mass of sodium carbonate crystals required to form 75 cm^3 of carbon dioxide gas.

Assume that the percentage purity of the sample is 100 % and the molar volume of gas under experimental conditions is $24 \text{ dm}^3 \text{ mol}^{-1}$. [1]

[A_r: H, 1.0; C, 12.0; O, 16.0; Na, 23.0]

$$\text{Amount of CO}_2 = \frac{75}{24000} = 3.125 \times 10^{-3} \text{ mol}$$

$$\text{Amount of Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O} = 3.125 \times 10^{-3} \text{ mol}$$

Using $x = 10$,

$$\text{Mass of Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O required} = 3.125 \times 10^{-3} \times 286.0 = 0.894 \text{ g [1]}$$

- (ii) Hence, calculate the minimum volume of $0.100 \text{ mol dm}^{-3} \text{ HCl}(\text{aq})$ required for the experiment. [1]

$$\text{Amount of HCl required} = 3.125 \times 10^{-3} \times 2 = 6.25 \times 10^{-3} \text{ mol}$$

$$\text{Minimum volume of HCl required} = \frac{0.00625}{0.100} = 0.0625 \text{ dm}^3 = 62.5 \text{ cm}^3 \text{ [1] ecf (i)}$$

- (b) Using your answers in (a), plan an investigation to determine the value of x in the sample of sodium carbonate crystals by adding it to an excess of hydrochloric acid and measuring the volume of carbon dioxide gas formed using a gas syringe.

You may assume that you are provided with:

- the sample of sodium carbonate crystals, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, in (a)
- $0.100 \text{ mol dm}^{-3}$ hydrochloric acid, HCl
- 100 cm^3 gas syringe with glass tubing
- the equipment normally found in a school or college laboratory.

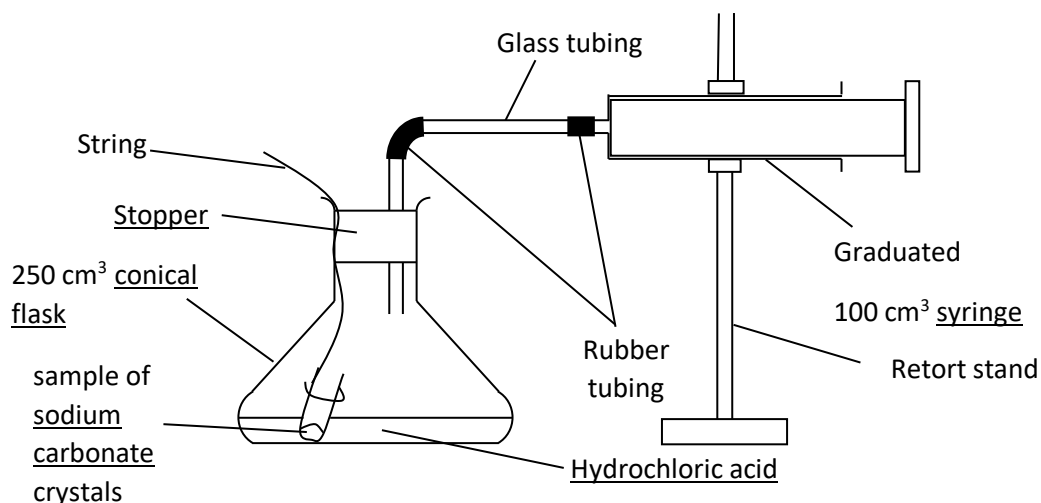
In your plan, you should include brief details of:

- the apparatus you would use
- the quantities you would use
- the procedure you would follow
- the measurements you would make
- how you would ensure that an accurate and reliable value of x is obtained.

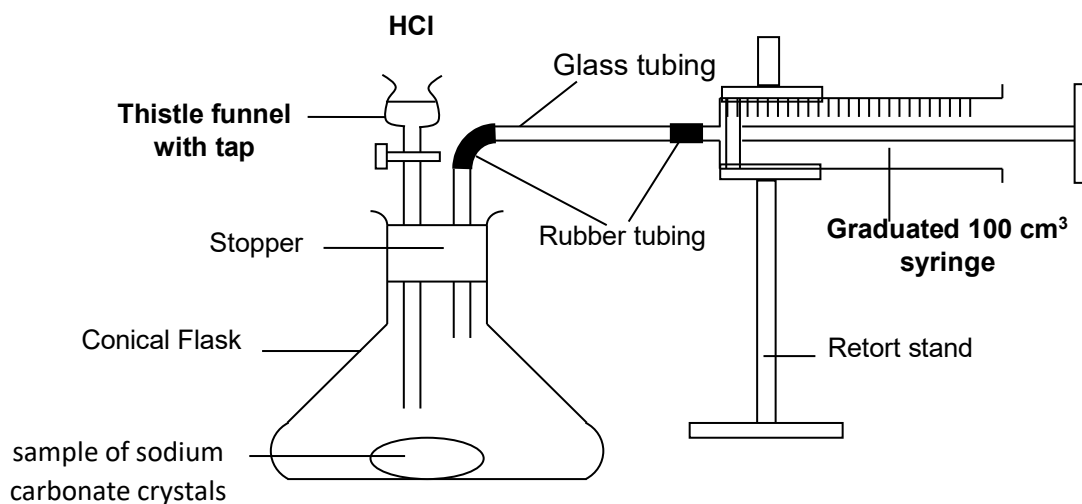
Your plan should include a well-labelled diagram of the apparatus set-up.

[5]

[2] Set-up for gas collection



or



Marking points:

1m Labels + reactants

1m Acceptable drawings for apparatus and set up, including the use string or thistle funnel

Experimental Procedure [3]

1. Using an electronic balance, weigh 0.894 or 0.89 or 0.9 g [✓] sodium carbonate crystals in a clean, dry weighing bottle/container/test tube [✓]. (accept between 0.80g and 1.0g, or student's calculated value in (a(i), with excess HCl)

2. Using a 100 cm³ measuring cylinder [✓], measure approximately 70 cm³ [✓] of HCl and transfer it to a 250 cm³ conical flask. (or other vol in excess of student's calculated value in (a)(ii))
 3. Assemble the set-up as shown in the diagram.
 4. Record the initial reading [✓] of a 100 cm³ gas syringe.
 5. Remove the stopper slightly to release string and allow the sodium carbonate sample to react with the HCl solution. Immediately attach back the stopper.
- OR Record the initial reading [✓] of a 100 cm³ gas syringe before adding the acid into the conical flask containing the powder. [if thistle method]
6. When the piston stops moving (i.e. the reaction is complete), allow time for the temperature and pressure of the gas to equilibrate to that of the surroundings. *[✓] this point must be in the answer
 7. Record the final reading [✓] of the gas syringe and the maximum volume of gas collected.

Marking points:

measuring mass of sodium carbonate crystals [✓] and vol of acid [✓] to be added using suitable apparatus [✓][✓]

recording the initial [✓] and final reading [✓] of the syringe

allow time to equilibrate after the reaction is complete [✓]* (this point must be present)

2✓ : 1m

[✓]* + 5[✓] = 3 marks

- (c) Given that the amount of carbon dioxide gas collected is **y** mol and the mass of sodium carbonate crystals, Na₂CO₃•xH₂O, added is **m** g, show how you would calculate a value for x. [1]

Amount of Na₂CO₃•xH₂O = amount of CO₂ collected = y mol

$$M_r \text{ of Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O} = \frac{m}{y}$$

$$x = \left(\frac{m}{y} - 106.0 \right) / 18.0 \quad [1]$$

- (d) One of the errors associated with this method is caused by the loss of carbon dioxide gas. State the effect of this error, if any, on the value of x calculated. Explain your answer.

[2]

There is loss of CO₂ gas so volume / amount of CO₂ formed is lower than expected. The amount of Na₂CO₃•xH₂O is lower than expected [✓]. Hence the M_r of Na₂CO₃•xH₂O calculated is higher than expected [✓] and the value of x calculated is higher than expected [✓].

3[✓] = 2 marks

2[✓] = 1 mark

[Total: 10]

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 aqueous anions

<i>anion</i>	<i>reaction</i>
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 with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

(c) Test for gases

<i>gas</i>	<i>test and test result</i>
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 aqueous acidified potassium manganate(VII) from purple to colourless

(d) Colour of halogens

<i>halogen</i>	<i>colour of element</i>	<i>colour in aqueous solution</i>	<i>colour in hexane</i>
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) Test for organic compounds

<i>organic compound</i>	<i>reaction</i>
alkene	decolourises orange Br ₂ (aq)
chloroalkane	heat with NaOH(aq), white ppt. formed on adding dilute HNO ₃ , followed by Ag ⁺ (aq)
bromoalkane	heat with NaOH(aq), pale cream ppt. formed on adding dilute HNO ₃ , followed by Ag ⁺ (aq)
iodoalkane	heat with NaOH(aq), yellow ppt. formed on adding dilute HNO ₃ , followed by Ag ⁺ (aq)
alcohol	- forms white fumes with solid PCl₅ - decolourises purple acidified KMnO₄(aq) on heating (for primary and secondary alcohols) - gives pale yellow ppt. with alkaline I₂(aq) on warming (for alcohols with CH₃CH(OH)– group)
phenol	decolourises orange Br ₂ (aq) and forms a white ppt.
carbonyl compounds	- gives orange ppt. with 2,4-dinitrophenylhydrazine - gives pale yellow ppt. with alkaline I₂(aq) on warming (for carbonyl compounds with CH₃CO– 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	- CO₂ liberated with Na₂CO₃(aq) - forms white fumes with solid PCl₅
phenylamine	decolourises orange Br ₂ (aq) and form a white ppt.
primary amide	NH ₃ liberated on heating with NaOH(aq)