

**NATIONAL JUNIOR COLLEGE**  
**SH 2 Prelim Practical Examination**  
Higher 2

CANDIDATE  
NAME

SUBJECT  
CLASS

REGISTRATION  
NUMBER

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**CHEMISTRY**

**9729/04**

Paper 4 Practical

**Monday 1 September 2025**

Candidate answer on the Question paper.

**2 hours 30 minutes**

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**READ THESE INSTRUCTIONS FIRST**

Write your identification number and name.

Give details of the practical shift and laboratory where appropriate, in the boxes provided.

Write in blue or black pen.

<b>Shift</b>	
<b>Laboratory</b>	
<b>For Examiner's use</b>	
<b>1</b>	/ 15
<b>2</b>	/ 14
<b>3</b>	/ 14
<b>4</b>	/ 11
<b>Presentation</b>	/1
<b>Total</b>	/ 55

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 20 and 21.

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

**Presentation [1] shows appropriate units and 3 or 4 sf in all final ans in Q1 & 2.**

**Any calculations not attempted loses this mark.**

This paper consists of **20** printed pages including this cover page.

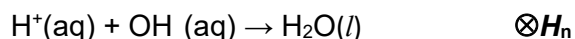
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**1 Determination of the concentration of a solution of sodium hydroxide and the enthalpy change of neutralisation,  $\Delta H_n$**

**FA 1** is  $1.0 \text{ mol dm}^{-3}$  sulfuric acid,  $\text{H}_2\text{SO}_4$ .

**FA 2** is a solution of sodium hydroxide,  $\text{NaOH}$ , of unknown concentration.

According to the *Arrhenius* theory of acids and bases, an acid produces  $\text{H}^+(\text{aq})$  ions and a base produce  $\text{OH}^-(\text{aq})$  ions, in aqueous solution. Using the *Arrhenius* theory, an acid-base neutralisation reaction involves reacting these two ions together to produce water molecules. The equation for this neutralisation reaction is given below.



In this question, you will carry out a series of experiments where different volumes of **FA 1** and **FA 2** are mixed together.

You will determine the temperature change of the mixture,  $\Delta T$  of each experiment and then analyse your results graphically in order to determine the

- concentration of  $\text{NaOH}$  in **FA 2**
- maximum temperature change,  $\Delta T_{\text{max}}$
- value for the enthalpy change of neutralisation,  $\Delta H_n$

**(a) Method**

- 1 Support the Styrofoam cup in a 250 cm<sup>3</sup> beaker.
- 2 Using the measuring cylinder labelled **FA 2**, place 10.0 cm<sup>3</sup> of **FA 2** into the Styrofoam cup.
- 3 Measure the temperature of **FA 2** in the Styrofoam cup. Record the initial temperature of the solution of **FA 2** as  $T_{\text{initial}}$ .
- 4 Place 50.0 cm<sup>3</sup> of **FA 1** into another measuring cylinder.
- 5 Transfer the **FA 1** in the measuring cylinder into the Styrofoam cup, stir and record the maximum temperature obtained in the reaction as  $T_{\text{max}}$ .
- 6 Rinse and dry the Styrofoam cup and the thermometer.
- 7 Repeat steps 2 to 6 using volumes of **FA 2** listed in **Table 1.1**. Fill in **Table 1.1** with the appropriate volumes of **FA 1** to be used in each experiment such that the total volume of the reaction mixture is 60.0 cm<sup>3</sup>.

**Table 1.1**

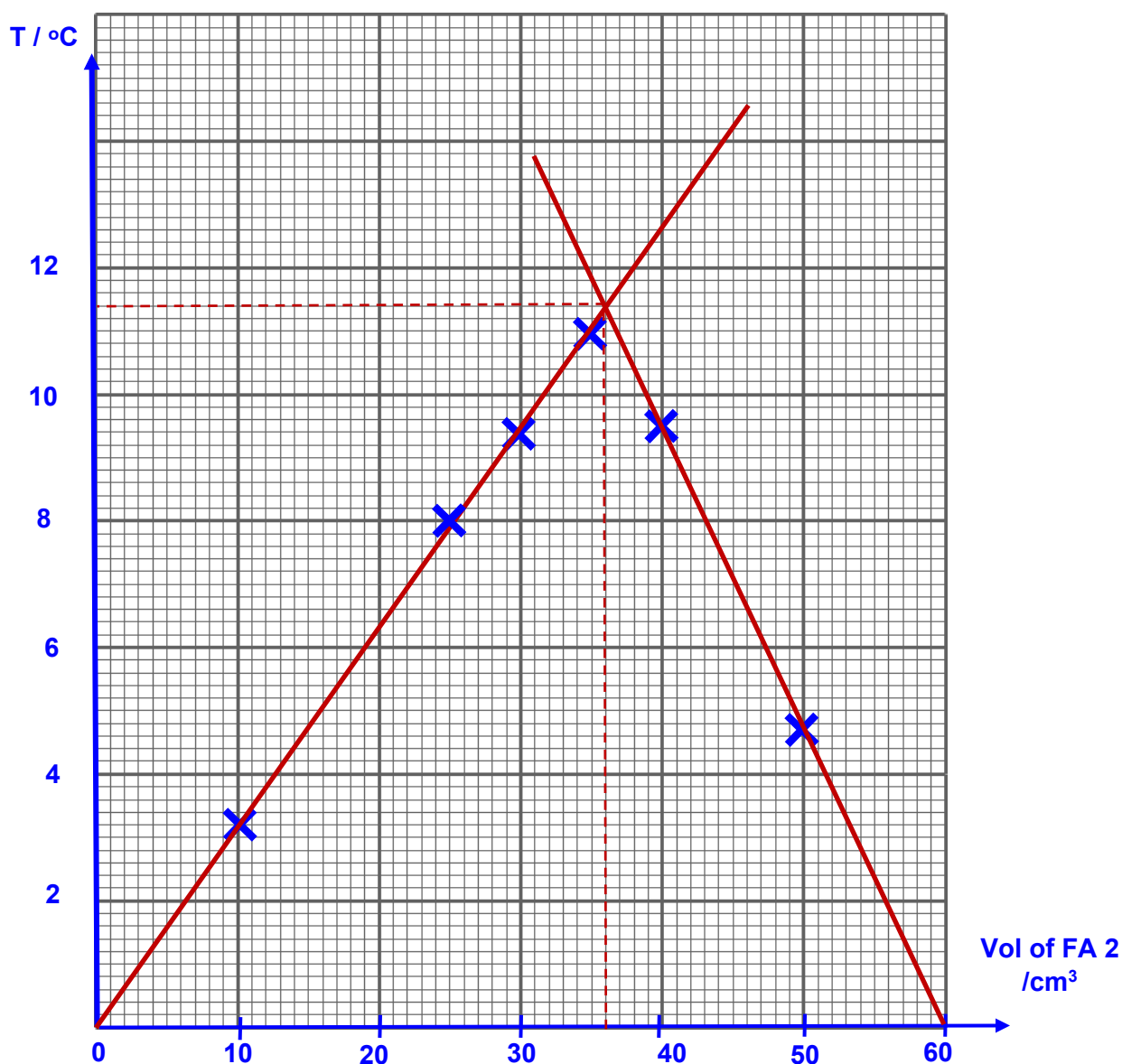
Experiment	1	2	3	4	5	6
Volume of <b>FA 1</b> / cm <sup>3</sup>	50.0	35.0	30.0	25.0	20.0	10.0
Volume of <b>FA 2</b> / cm <sup>3</sup>	10.0	25.0	30.0	35.0	40.0	50.0
Initial temperature, $T_{\text{initial}}$ / °C	28.4	28.4	28.4	28.4	28.4	28.4
Maximum temperature, $T_{\text{max}}$ / °C	31.6	36.4	37.8	39.4	37.9	33.1
$\Delta T$ / °C	+3.2	+8.0	+9.4	+11.0	+9.5	+4.7

In Table 1.1, record the following for each experiment

- the initial temperature,  $T_{\text{initial}}$
- the maximum temperature,  $T_{\text{max}}$
- the change in temperature,  $\Delta T$

[3]

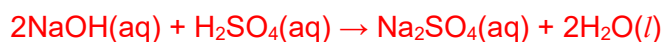
- (b) (i) On the grid given below, plot a graph of  $\otimes T$  (y-axis) against volume of **FA 2** used (x-axis) using the data you have obtained in (a).
- (ii) Given that  $\otimes T = 0$  at volume of **FA 2** = 0.0 and 60.0 cm<sup>3</sup>, draw two straight lines of best fit. The first best fit line should be drawn using the plotted points where  $\otimes T$  is increasing and the second best fit line should be drawn using the plotted points where  $\otimes T$  is decreasing. Extrapolate these two lines until they cross. [3]



- (ii) From your graph, determine the maximum temperature change,  $\otimes T_{\max}$ , and the volume of **FA 2** required to obtain this.

$$\Delta T_{\max} = \dots\dots\dots +11.4 \dots\dots\dots ^\circ\text{C}$$

$$V_{\text{FA2}} = \dots\dots\dots 36.0 \dots\dots\dots \text{cm}^3$$

**Calculations****(c)** Using your answers in **b(ii)**,**(i)** calculate the concentration of NaOH in **FA 2**

$$\text{Using } V_{\text{FA2}} = 36.0 \text{ cm}^3$$

$$\text{volume of H}_2\text{SO}_4 \text{ reacted} = 60.0 - 36.0 = 24.0 \text{ cm}^3$$

$$\text{Amount of H}_2\text{SO}_4 \text{ reacted} = 24.0/1000 \times 1.00 = 0.0240 \text{ mol}$$

$$\text{Amount of NaOH reacted} = 0.0240 \times 2 = 0.0480 \text{ mol}$$

$$\text{Concentration of NaOH} = \times 1000 = 1.333 = 1.33 \text{ mol dm}^{-3}$$

$$\text{concentration of NaOH in FA 2} = \dots\dots\dots 1.33 \text{ mol dm}^{-3}$$

[2]

**(ii)** calculate the heat evolved at  $\otimes T_{\text{max}}$ .

You may assume that the specific heat capacity of the reaction mixture is  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$  and that its density is  $1.00 \text{ g cm}^{-3}$ .

$$\text{heat evolved} = 60.0 \times 4.18 \times 11.4 = 2859.12 = 2860 \text{ J}$$

$$\text{heat evolved} = \dots\dots\dots 2860 \text{ J}$$

[1]

**(d)** Using your answer in **(c)(ii)**, calculate the enthalpy change of neutralisation,  $\otimes H_{\text{n}}$ .

$$\text{Amount of water produced} = \text{amount of NaOH reacted} = 0.0480 \text{ mol}$$

$$H_{\text{n}} = - = -59565 \text{ J mol}^{-1} = -59.6 \text{ kJ mol}^{-1}$$

$$\otimes H_{\text{n}} = \dots\dots\dots -59.6 \text{ kJ mol}^{-1}$$

[1]

## Analysis and Evaluation

- (e) State and explain the effect on the magnitude of  $\Delta T_{\max}$  if ethanedioic acid of the same concentration was used instead of sulfuric acid in the experiment in (a).

Effect on the magnitude of  $\Delta T_{\max}$ :..... The magnitude of  $T_{\max}$  decrease

explanation:.....

..Ethanedioic acid is a weak acid and does not dissociate completely in aqueous solution.

..Energy will be required to further ionise the undissociated ethanedioic acid.

..Hence, for the same mass of solution and same amount of  $\text{H}_2\text{O}$  formed, the amount of heat

change will be smaller / lesser heat evolved.

.....  
.....

[2]

- (f) Student **A** carefully performed the same experiment and correctly processed the data using the same method. His calculated value of  $\Delta H_{\text{r}}$  is  $-65.0 \text{ kJ mol}^{-1}$  while the published value for this enthalpy change is  $-57.7 \text{ kJ mol}^{-1}$ .

The specific heat capacity of the Styrofoam cup has not been taken into consideration in calculating  $\Delta H_{\text{r}}$ .

Explain whether this omission could have been the reason for the discrepancy between the value obtained by Student **A** and the one published.

.....  
Omission of the specific heat capacity of the cup could not have been the reason for the  
discrepancy. Since the cup also absorbs heat, the heat absorbed by the water is less  
than expected. As a result, the measured temperature rise will be smaller than  
expected, resulting in a less exothermic  $H_{\text{r}}$ .  
.....

[2]

[Total: 15]

## 2 To determine the concentration of a solution of copper(II) sulfate.

**FA 3** is aqueous copper(II) sulfate,  $\text{CuSO}_4(\text{aq})$ , of unknown concentration.

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

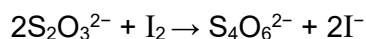
**FA 5** is a 10% solution of potassium iodide,  $\text{KI}$ .

You are also provided with a starch indicator.

When an excess of potassium iodide is added to copper(II) sulfate, iodine and copper(I) iodide are formed. All the copper is precipitated as copper(I) iodide and the iodine turns the solution brown.



The iodine produced in this reaction may be titrated against a standard solution of sodium thiosulfate. The equation for this reaction is shown below.



When **FA 5** is added to **FA 3**, the solution turns brown due to the formation of iodine. As **FA 4** is added to this mixture, this brown colour fades. If starch indicator is added when the colour is pale brown, the solution immediately turns blue-black as the starch reacts with the residual iodine.

The end-point of this titration is reached when the blue-black colour **just** disappears. The off-white precipitate of copper(I) iodide does not interfere with the reactions involved in this titration. This precipitate may be a light beige at the end-point.

### Dilution of FA 3

- (a) You will now follow the instructions given below to prepare a diluted solution of **FA 3**. This diluted solution is **FA 6**.

Using a burette, measure between  $42.50 \text{ cm}^3$  and  $43.00 \text{ cm}^3$  of **FA 3** into the  $250 \text{ cm}^3$  graduated flask.

Record your burette readings and the volume of **FA 3** added to the flask in the space below.

Final burette reading / $\text{cm}^3$	42.50
Initial burette reading / $\text{cm}^3$	0.00
Volume of <b>FA 3</b> added / $\text{cm}^3$	42.50

[1]



Make up the contents of the flask to the 250 cm<sup>3</sup> mark with deionised water. Place the stopper in the flask and mix the contents thoroughly by slowly inverting the flask a number of times.

### Titration

- 1 Fill a second burette with **FA 4**.
- 2 Pipette 25.0 cm<sup>3</sup> of **FA 6** into a conical flask.
- 3 Use the measuring cylinder to add 10.0 cm<sup>3</sup> of **FA 5** to the flask. An off-white precipitate forms in a brown solution.
- 4 Run **FA 4** from the burette into the flask until the brown colour of the iodine becomes pale brown.
- 5 Add about 10 drops of starch indicator to the flask and continue adding **FA 4** carefully until the blue-black colour **just** disappears, leaving behind the off-white precipitate.
- 6 Record your titration results in the space provided below. Make certain that your recorded results show the precision of your working.
- 7 Repeat steps 1 to 6 as necessary until consistent results are obtained.

Titration number	1	2
Final burette reading / cm <sup>3</sup>	24.00	24.00
Initial burette reading / cm <sup>3</sup>	0.00	0.00
Volume of <b>FA 4</b> added / cm <sup>3</sup>	24.00	24.00

[4]

- (b) From your titrations, obtain a suitable volume of **FA 4** to be used in your calculations. Show clearly how you obtained this volume.

Average volume of **FA 4** used = 24.00 cm<sup>3</sup>

[1]

### Calculations

- (c) Calculate the concentration of **FA 6** in mol dm<sup>-3</sup> in (b), and hence



No of moles of  $\text{S}_2\text{O}_3^{2-}$  in 24.00 cm<sup>3</sup> of **FA 4** used =  $\frac{24.00}{1000} \times 0.100 = 2.40 \times 10^{-3}$

= No of moles of  $\text{Cu}^{2+}$  in 25.0 cm<sup>3</sup>

No of moles of  $\text{Cu}^{2+}$  in 250 cm<sup>3</sup> =  $2.40 \times 10^{-2}$

[ $\text{Cu}^{2+}$ ] in **FA 6** =  $\frac{2.40 \times 10^{-2}}{0.250} \times 1000 = 0.0960 \text{ mol dm}^{-3}$

[Cu<sup>2+</sup>] in **FA 6** = .....

[2]

- (d) Calculate the concentration of CuSO<sub>4</sub> in **FA 3**.

No of moles of Cu<sup>2+</sup> in 42.50 cm<sup>3</sup> =  $2.40 \times 10^{-2}$

[Cu<sup>2+</sup>] in **FA 3** =  $\times 1000 = 0.5647$

= 0.565 mol dm<sup>-3</sup>

the concentration of CuSO<sub>4</sub> in **FA 3** = .....

Hence, calculate the mass of CuSO<sub>4</sub>.5H<sub>2</sub>O crystals required to prepare a 1 dm<sup>3</sup> solution of **FA 3**.

[A<sub>r</sub>: Cu, 63.5; H, 1.0; O, 16.0; S, 32.1]

M<sub>r</sub> of CuSO<sub>4</sub>.5H<sub>2</sub>O = 249.6

Mass of CuSO<sub>4</sub>.5H<sub>2</sub>O =  $0.5647 \times 249.6 = 140.95 = 141 \text{ g}$

the mass of CuSO<sub>4</sub>.5H<sub>2</sub>O in **FA 3** = .....

[2]

### Analysis and Evaluation

- (e) A teacher performs this same experiment, using the quantities described earlier, and obtains a mean titre volume of 24.85 cm<sup>3</sup>.

Calculate the percentage error incurred when measuring the mean titre volume of 24.85 cm<sup>3</sup>.

% error for burette =  $\times 100 = \pm 0.402\%$

Must show the  $\pm$  to be awarded the mark

percentage error = .....%

[1]

- (f) A second student performs this experiment using the quantities described earlier. Unfortunately, she was provided with a 9% solution of **FA 5** (KI concentration = 90 g dm<sup>-3</sup>) instead of the 10% KI solution you used (KI concentration = 100 g dm<sup>-3</sup>).

Predict, using calculations, whether her titre volumes will be affected.

[A<sub>r</sub>: K, 39.1; I, 126.9]

$M_r$  of KI = 166.0

No of moles of  $I^-$  used =  $\times = 5.42 \times 10^{-3}$

Given that  $2CuSO_4 + 4KI \rightarrow 2CuI + 2K_2SO_4 + I_2$

No of moles of  $I^-$  is still in excess (since > 2 times the amt of  $Cu^{2+}$ ;  $2.345 \times 10^{-3}$ )

hence accuracy of her titre volumes is not affected.

.....  
 .....[2]

(g) Identify two different chemical processes that use iodide ions in this experiment.

Reduction (of  $Cu^{2+}$  to  $Cu^+$ )/ Oxidation (of  $I^-$  to  $I_2$ )/ Redox

...

Precipitation (of CuI from  $Cu^+$  and  $I^-$ ).

[1]

4]

### 3 Investigation of some inorganic reactions.

You are provided with solutions **FA 7**, **FA 8** and **FA 9**.

You are to perform the tests described in **Tables 3.1 to 3.4**, and record your observations in the tables.

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

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test
- if there is no observable change, write **no observable change**.

You should indicate clearly at which stage in a test a change occurs, recording your observations alongside the relevant tests.

In all tests, the reagents should be added gradually until no further change is observed unless you are instructed otherwise. If any solution is warmed, a **boiling tube** must be used. Rinse and reuse test-tubes where possible.

**No additional or confirmatory tests for ions present should be attempted.**

**FA 7**, **FA 8** and **FA 9** are salt solutions.

Each salt solution contains **one** cation and **one** anion, all of which are different.

- **FA 7** contains a halide ion.
- **FA 8** and **FA 9** contains either a sulfur-containing anion or a nitrogen-containing anion.
- **FA 9** contains  $Na^+$  cation.

(a)

Table 3.1

	Test	Observations
(i)	<p>Add 1 cm depth of <b>FA 7</b> to a test-tube.</p> <p>Add aqueous sodium hydroxide slowly, with shaking, until no further change is seen.</p> <p>Transfer the mixture into a <b>boiling tube</b> and <b>carefully</b> warm the boiling tube and its contents. Do <b>not</b> heat until the mixture boils.</p>	<p>No observable change OR colourless solution OR no precipitate formed.</p> <p>On warming, colourless gas evolved turned moist red litmus paper blue.</p>

Identify the cation present in **FA 7** from your observations in **Table 3.1**. If the test you carried out did not allow you to identify the cation, write 'unknown' in the space.

Cation present in **FA 7**: .....

$\text{NH}_4^+$  , no ecf for wrong conclusion due to wrong observations

[2]

(b) From the bench reagents provided, suggest reagents you would use to identify the halide ion present in **FA 7**. Carry out the test and record your observations in **Table 3.2**.

reagents used: Add aqueous silver nitrate, followed by aqueous ammonia in excess.....

Table 3.2

Test	Observations
<p>Add 1 cm depth of <b>FA 7</b> to a test-tube.</p> <p>Add 1 cm<sup>3</sup> of <u>aqueous silver nitrate</u>, with shaking.</p> <p><u>Add aqueous ammonia</u>, with shaking, until no further change is seen.</p>	<p>White precipitate observed.</p> <p>White precipitate soluble in excess aqueous <math>\text{NH}_3</math> to give colourless solution.</p>

Halide ion present in **FA 7**: Chloride/  $\text{Cl}^-$  .....

no ecf for wrong conclusion due to wrong observations

[3]

(c)

Table 3.3

Test	Observations	
	FA 8	FA 9
To separate test-tubes each containing 1 cm depth of <b>FA 8</b> and <b>FA 9</b> ,  add 1 cm depth of dilute sulfuric acid, followed by <b>one drop</b> of aqueous potassium manganate(VII).	Purple/ Pale pink $\text{KMnO}_4$ remains / No observable change/ Colourless solution turns purple/ pale pink	Purple/ Pale pink $\text{KMnO}_4$ remains / No observable change/ Colourless solution turns purple/ pale pink

Using the information below about redox properties and your observations in **Table 3.3**, identify the possible sulfur-containing anion and nitrogen-containing anion present in **FA 8** and **FA 9**.

anion	property
nitrite	easily oxidised
nitrate	cannot be oxidised
sulfite	easily oxidised
sulfate	cannot be easily oxidised

Possible anions present in **FA 8**:  $\text{SO}_4^{2-}$  and  $\text{NO}_3^-$  .....

Possible anions present in **FA 9**:  $\text{SO}_4^{2-}$  and  $\text{NO}_3^-$  .....

[3]

no ecf for wrong conclusion due to wrong observations

(d)

Table 3.4

Test	Observations	
	FA 8	FA 9
Add 1 cm depth of <b>FA 8</b> to a test-tube. Add aqueous ammonia slowly, with shaking, until no further change is seen.	White precipitate formed which is soluble in excess $\text{NH}_3(\text{aq})$ to give colourless solution.	
To separate boiling tubes each containing 1 cm depth of <b>FA 8</b> and <b>FA 9</b> ,  add aqueous sodium hydroxide slowly, with shaking, until no further change is seen.	White precipitate formed which is soluble in excess $\text{NaOH}(\text{aq})$ .	No observable change.

Warm the mixture gently.	No observable change OR no gas evolved.	No observable change OR no gas evolved. Moist red litmus paper remains (no need to test for it since it is known that $\text{Na}^+$ is the cation).
Then carefully add a piece of aluminium foil to the mixture.	No observable change. OR no gas evolved.	Colourless gas evolved turned moist red litmus paper blue.

Using your deductions in (c) and observations in **Table 3.4**, identify the anion present in **FA 8** and **FA 9** and the cation present in **FA 8**.

	FA 8	FA 9
Anion	$\text{SO}_4^{2-}$	$\text{NO}_3^-$
Cation	$\text{Zn}^{2+}$	

[5]

no ecf for wrong conclusion due to wrong observations

- (e) The following tests were carried out on another solution, **solution P**. Using the observations given in **Table 3.5** as well as the Qualitative Analysis Notes on pages 19–20, deduce the identity of **solution P**.

[**solution P** contains a cation listed in the Qualitative Analysis Notes]

**Table 3.5**

	Test	Observations
		<b>solution P</b>
(i)	Add aqueous ammonia to 1 cm depth of <b>solution P</b> , until in excess.	No observable change.
(ii)	Add aqueous sodium hydroxide to 1 cm depth of <b>solution P</b> , until in excess.  If no precipitate forms, transfer the mixture into a <b>boiling tube</b> and <b>carefully</b> warm the boiling tube and	No observable change.  No gas evolved.

	its contents. Do <b>not</b> heat until the mixture boils.	
(iii)	In a separate test-tube, add 1 cm depth of dilute hydrochloric acid to 1 cm depth of aqueous sodium carbonate. Bubble the gas evolved into 1 cm depth of <b>solution P</b> .	Colourless odourless gas evolved, formed white precipitate in <b>solution P</b> .

Identify the cation in **solution P**:  $\text{Ca}^{2+}$  /  $\text{Ba}^{2+}$  / calcium/ barium .....

Identity of **solution P**:  $\text{Ca}(\text{OH})_2$  /  $\text{Ba}(\text{OH})_2$  .....

Note, for identify cation involving transition metals, have to write Fe(III) or Fe(II) for example<sup>[1]</sup>  
no ecf for wrong conclusion due to wrong observations [Total: 14]

#### 4 Planning: Determining the kinetics of an acid-carbonate reaction

Calcium carbonate reacts with hydrochloric acid to form carbon dioxide gas.



The rate of the reaction may be followed by an experiment involving the continuous method, by adding excess calcium carbonate solid to hydrochloric acid solution.

As the rate of reaction can be monitored by measuring the volume of carbon dioxide gas produced at various time of the reaction, the order of reaction with respect to hydrochloric acid can hence be determined. You are required to plan a procedure to confirm that the order of reaction with respect to hydrochloric acid is first order.

- (a) The carbon dioxide gas produced in the reaction can be collected using either a frictionless gas syringe or water displacement method. The use of a frictionless gas syringe, however, is preferred.

State a source of error for the water displacement method to measure the volume of gas collected.

[1]

Some of the gas produced will dissolve in water, resulting in the measurement to be smaller than expected.

- (b) Calculate the volume of hydrochloric acid required to react with the calcium carbonate tablet to produce  $80 \text{ cm}^3$  of carbon dioxide at room temperature and pressure. The concentration of HCl used is  $0.160 \text{ mol dm}^{-3}$ .

[molar volume of gas at room temperature and pressure =  $24 \text{ dm}^3 \text{ mol}^{-1}$ ]

[Ar: C, 12.0, H, 1.0, O, 16.0, Cl, 35.5]

$$\begin{aligned}\text{amount of CO}_2 &= \frac{80 \times 10^{-3}}{24} = 0.003333 \text{ mol} \\ \text{amount of HCl} &= 0.003333 \times 2 = 0.006667 \text{ mol} \\ \text{volume of HCl} &= \frac{0.006667}{0.160} = 0.04167 \text{ dm}^3 \approx \underline{\underline{41.7 \text{ cm}^3}}\end{aligned}$$

- (c) Plan an investigation to determine the order of reaction with respect to hydrochloric acid graphically.

You may assume you are provided with:

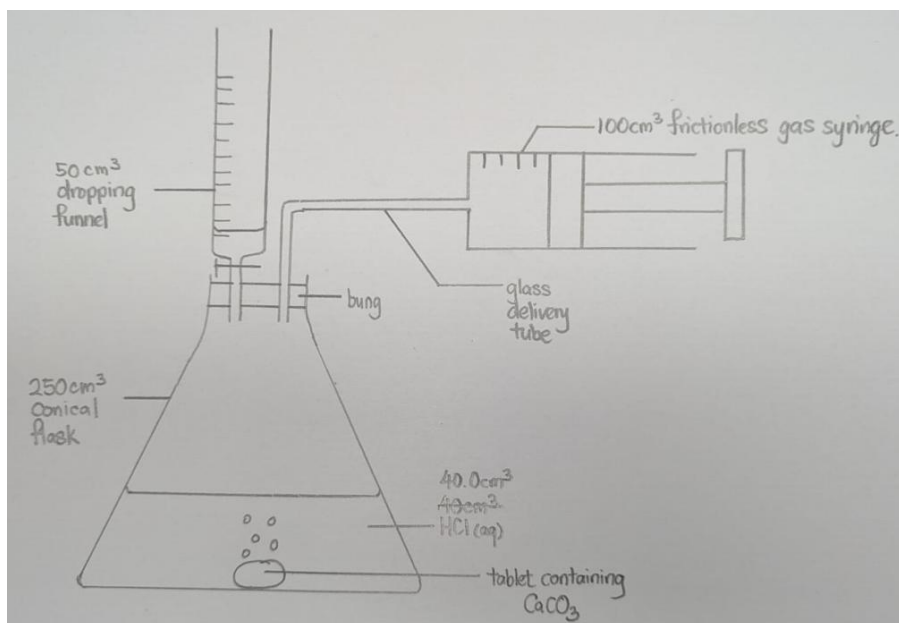
- 50 cm<sup>3</sup> of 0.160 mol dm<sup>-3</sup> hydrochloric acid, HCl
- 1 tablet containing large excess of calcium carbonate, CaCO<sub>3</sub>
- 50 cm<sup>3</sup> graduated dropping funnel
- 100 cm<sup>3</sup> frictionless gas syringe with glass delivery tube connected to a rubber bung
- the equipment normally found in a school or college laboratory

Your plan should include brief details of:

- the apparatus you would use
- the quantities you would use
- the procedure you would follow
- the diagram of your experimental setup
- the measurements you would take to allow a suitable volume of CO<sub>2</sub>-time graph to be drawn

In your plan you should attempt to minimise the loss of carbon dioxide gas when introducing the hydrochloric acid and calcium carbonate tablet to start the reaction.



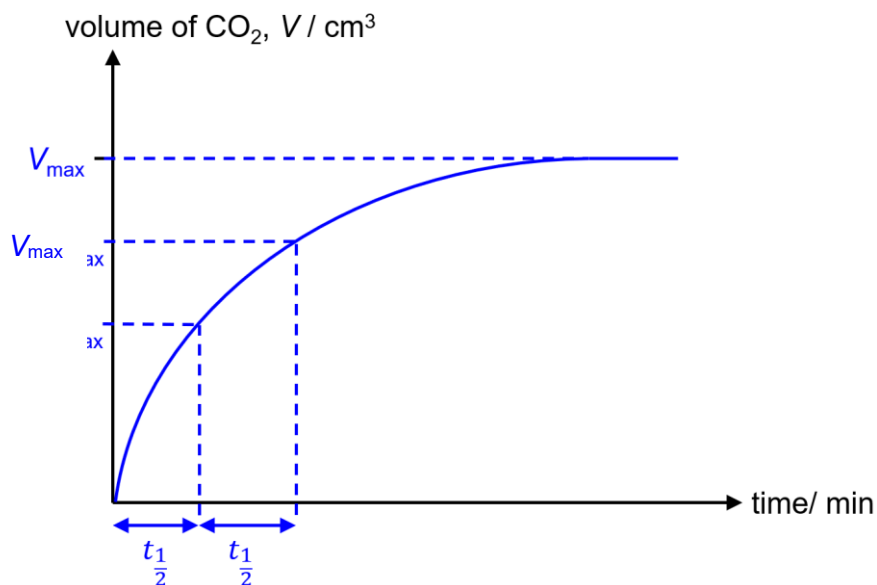


1. Transfer one tablet containing large excess of calcium carbonate,  $\text{CaCO}_3$  into a dry  $250 \text{ cm}^3$  conical flask.
2. Insert the bung with the  $50 \text{ cm}^3$  dropping funnel and  $100 \text{ cm}^3$  frictionless gas syringe attached, into the conical flask.
3. Using the  $50 \text{ cm}^3$  graduated dropping funnel, add  $40.0 \text{ cm}^3$  of  $0.1600 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}$  to dry conical flask and swirl before leaving it to stand.
4. Immediately start the stopwatch. Read and record the initial gas volume in the gas syringe.
5. Once you have started the stopwatch, allow it to continue running for the duration of the experiment.
6. At  $t = 1 \text{ min}$ , read and record the gas volume in the gas syringe,  $V$ , and the time,  $t$ , in the table.
7. Record the gas volume in the gas syringe every  $1.0 \text{ min}$ , for a total of  $10 \text{ min}$ / until the piston stopped moving.

Table of  $t / \text{min}$  and  $V / \text{cm}^3$  (not required)

time, $t / \text{min}$	volume of $\text{CO}_2$ , $V / \text{cm}^3$
0.0	
1.0	
2.0	
3.0	
4.0	
5.0	
6.0	

- (i) Sketch the graph that you would expect to obtain on the axes in Fig. 4.1.



[1]

- (ii) Complete on the graph in Fig.4.1 by labelling the appropriate values of  $V$  and  $t$  and explain how the values can be used to show that the reaction is first order with respect to hydrochloric acid.

[2]

The **constant value of the half-life** will indicate that the order of reaction with respect to hydrochloric acid is first order.

[Total: 11]

### Qualitative Analysis Notes

[ppt. = precipitate]

#### (a) Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH <sub>3</sub> (aq)
aluminium, Al <sup>3+</sup> (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH <sub>4</sub> <sup>+</sup> (aq)	ammonia produced on heating	—
barium, Ba <sup>2+</sup> (aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca <sup>2+</sup> (aq)	white ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess

copper(II), $\text{Cu}^{2+}(\text{aq})$ ,	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), $\text{Fe}^{2+}(\text{aq})$	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess
iron(III), $\text{Fe}^{3+}(\text{aq})$	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, $\text{Mg}^{2+}(\text{aq})$	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), $\text{Mn}^{2+}(\text{aq})$	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, $\text{Zn}^{2+}(\text{aq})$	white ppt. soluble in excess	white ppt. soluble in excess

**(b) Reactions of anions**

<i>anion</i>	<i>Reaction</i>
carbonate, $\text{CO}_3^{2-}$	$\text{CO}_2$ 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, $\text{NO}_3^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; $\text{NO}$ liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ 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, $\text{SO}_3^{2-}(\text{aq})$	$\text{SO}_2$ liberated with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

**(c) Tests for gases**

<i>Gas</i>	<i>test and test result</i>
ammonia, $\text{NH}_3$	turns damp red litmus paper blue
carbon dioxide, $\text{CO}_2$	gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ )
chlorine, $\text{Cl}_2$	bleaches damp litmus paper
hydrogen, $\text{H}_2$	"pops" with a lighted splint
oxygen, $\text{O}_2$	relights a glowing splint
sulfur dioxide, $\text{SO}_2$	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 aq. solution</i>	<i>colour in hexane</i>
chlorine, $\text{Cl}_2$	greenish yellow gas	pale yellow	pale yellow
bromine, $\text{Br}_2$	reddish brown gas / liquid	orange	orange-red
iodine, $\text{I}_2$	black solid / purple gas	brown	Purple