

NANYANG JUNIOR COLLEGE
JC2 PRACTICAL PRELIMINARY EXAMINATION
Higher 2

CANDIDATE
NAME

Mark Scheme

CLASS

--	--	--	--

CENTRE
NUMBER

S				
---	--	--	--	--

INDEX
NUMBER

--	--	--	--

CHEMISTRY

Paper 4 Practical

9476/04

14 August 2026

2 hour 30 minutes

Candidates answer on the Question Paper

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number, name and class 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 23 and 24.

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	/ 12
2	/ 15
3	/13
4	/ 10
Total	/50

1 Identification of two cations and two anions

FA 1 and **FA 2** each contain one cation and one anion. The ions in the two compounds are different.

You will carry out tests to identify the ions in **FA 1** and **FA 2**.

The volumes given in Table 1.1 and Table 1.2 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**.

(a) Tests on FA1

Carry out the tests described in Table 1.1.

Carefully record your observations **at each stage** of the tests in Table 1.1.

Table 1.1

Test		Observations
1	Add 1 cm depth of FA 1 into a clean test tube. Add aqueous sodium hydroxide slowly with shaking until the aqueous sodium hydroxide is in excess. Keep the reaction mixture for test 2.	• White ppt formed • dissolves in excess NaOH.
2	Pour the reaction mixture from test 1 into a boiling tube. Add 1 cm depth of aqueous sodium hydroxide to the reaction mixture. Warm the mixture. Add a piece of aluminium foil to the reaction mixture.	• No observable change. / No ppt • No observable change. / No gas evolved that turns red litmus blue. (No NH₃ has evolved) (Vigorous / violent / Effervescence) • Gas evolved turns red litmus blue. • Gas is NH₃.
3	Add 1 cm depth of FA 1 into a clean test-tube. Add aqueous ammonia slowly with shaking until the aqueous ammonia is in excess.	• White ppt • soluble in excess NH₃.

[3]

6, 7 points: 3 marks; 4 to 5 points: 2 marks; 3 points: 1 mark

(b) Tests on FA2

Carry out the tests described in Table 1.2.

Carefully record your observations **at each stage** of the tests in Table 1.2.

Table 1.2

Test		Observations
1	Add 1 cm depth of FA 2 into a clean test tube. Add aqueous sodium hydroxide slowly with shaking until the aqueous sodium hydroxide is in excess.	• Grey-green ppt formed • dissolves in excess NaOH to give a dark green solution.
2	Add 1 cm depth of FA 2 into a clean test-tube. Add aqueous ammonia slowly with shaking until the aqueous ammonia is in excess.	• Grey-green ppt • insoluble in excess NH_3.
3	Add 1 cm depth of FA 2 into a clean test-tube. Add 1 cm depth of dilute nitric acid followed by aqueous silver nitrate.	• No observable change. / No gas evolved. • White ppt formed (in light blue/grey-blue solution).

[2]

5, 6 points: 2 marks; 3, 4 points: 1 marks

(c) (i) Complete Table 1.3 to identify the ions present in **FA 1** and **FA2**.

Table 1.3

	FA1	FA2
cation present	Zn^{2+}	Cr^{3+}
anion present	$\text{NO}_3^- / \text{NO}_2^-$	Cl^- (Also accept Br^-)

[2]

(ii) Write **two** ionic equations to explain the chemistry of Test 3 on **FA1**.

.....
 [2]

$\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$ (not required)

Eqn 1: $\text{Zn}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Zn}(\text{OH})_2(\text{s})$ (must show state symbols for precipitation reaction)

Eqn 2: $[\text{Zn}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Zn}(\text{NH}_3)_4]^{2+} + 6\text{H}_2\text{O}$ (preferred)

OR $\text{Zn}(\text{OH})_2 + 4\text{NH}_3 \rightarrow [\text{Zn}(\text{NH}_3)_4]^{2+} + 2\text{OH}^-$

(d) (i) Carry out the following test on **FA2**.

Add 1 cm depth of FA 2 into a clean test-tube. Add FA3 slowly with shaking until FA3 is in excess.	• Grey-green ppt insoluble in excess FA3. • Effervescence • Gas evolved gives white ppt in limewater. • Gas is CO₂
---	--

[2]

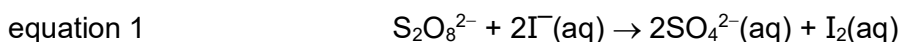
4 points: 2 marks; 2, 3 points: 1 marks

(ii) Identify the anion in **FA3**.CO₃²⁻ [1]

[Total: 12]

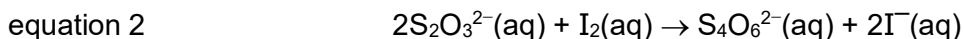
2 Investigating the kinetics of the reaction between peroxydisulfate ions and iodide ions

Equation 1 represents the reaction between iodide ions and peroxydisulfate ions.



When starch is added to the reaction mixture, a blue-black colour is immediately seen due to the formation of an iodine-starch complex.

If a small amount of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, is also present in the reaction mixture, the formation of the blue-black colour is delayed. The $\text{Na}_2\text{S}_2\text{O}_3$ reacts with I_2 as shown in equation 2.



FA 4 is $0.100 \text{ mol dm}^{-3}$ potassium peroxydisulfate, $\text{K}_2\text{S}_2\text{O}_8$.

FA 5 is 0.20 mol dm^{-3} potassium iodide, KI .

FA 6 is $0.0050 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

Solution S is starch indicator

You will perform a series of four experiments. You will add a fixed amount of **FA 5** and **FA 6** to each of your experiments. You will add an amount of deionised water so that the total volume is 50 cm^3 . The time taken for the blue-black colour to form allows the reaction rate to be determined. You should avoid inhaling any gases produced.

(a) Prepare a table on page 6 to record, to an appropriate degree of precision:

- volumes of **FA 4** (V_{FA4}) and deionised water (V_{water}) used
- all values of t
- calculated values of $100/t$

Experiment 1

The end-point of the reaction is the **first** appearance of a blue-black colour.

Note: Insufficient swirling of the reaction mixture may lead to a blue-black colour appearing before the true end-point is reached.

1. Fill a burette with **FA 6**.
2. Use a 50 cm^3 measuring cylinder, measure 25 cm^3 of **FA 4** and top it up to the 30 cm^3 mark with deionised water. Transfer the contents in this measuring cylinder into a 250 cm^3 conical flask.
3. Add to the conical flask 5.00 cm^3 of **FA 6** from the burette and 5 cm^3 of starch indicator from a 10 cm^3 measuring cylinder.
4. Use a second 10 cm^3 measuring cylinder to measure 10 cm^3 of **FA 5**.
5. Pour the **FA 5** into the same conical flask, start the stopwatch during this addition.
6. Swirl the flask to ensure even mixing and place the flask on a white tile.
7. Stop the stopwatch when the solution **first** turns blue-black.
8. Record the time taken, t , to the nearest second in your table.
9. Wash out the flask thoroughly with tap water and then with deionised water. Stand the flask upside down on a paper towel to drain.

Repeat Experiments 2 – 4

Carry out **three** further experiments to investigate the effect of changing the concentration of $\text{S}_2\text{O}_8^{2-}(\text{aq})$ by altering the volume of $\text{K}_2\text{S}_2\text{O}_8$, **FA 4**, used.

You should not use a volume of **FA 4** that is less than 10 cm^3 and more than 25 cm^3 .

In each experiment, you should adjust the volume of deionised water in step 2 to ensure the **same total volume** of reaction mixture is used.

You should alternate the use of the two 250 cm^3 conical flasks. You should keep **FA 5** and **FA 6** for use in Question 3.

Record volumes, the time taken and the calculated values of $100/t$ in your table.

Results optional

Experiment	FA 5 / cm^3	FA 6 / cm^3	Solution S / cm^3	V_{FA4} / cm^3	V_{water} / cm^3	t / s	$100/t / \text{s}^{-1}$
1	10	5.00	5	25	5		
2	10	5.00	5	20	10		
3	10	5.00	5	15	15		
4	10	5.00	5	10	20		

[4]

- Headers and units
- t recorded to nearest second + precision of data presented
- $100/t$ correctly calculated and presented to 3 s.f
- Chosen volume of FA 4 that is not less than 10 cm^3 and not more than 25 cm^3 and volume of water correctly calculated
- Good range of V_{FA4} chosen + at least 2 cm^3 apart
- Total four experiments + Total $V_{\text{FA4}+\text{water}} = 30 \text{ cm}^3$

6 points: 4 marks; 4-5 points: 3 marks; 3 points: 2 marks; 2 points: 1 mark

- (b) The relative rate of reaction for the above experiments is related to the time taken for the blue-black colour to appear according to the following formula.

$$\text{relative rate} = \frac{100}{t}$$

- (i) Explain why the relative rate is proportional to $\frac{1}{t}$.

.....
 [1]

$$\text{Rate} = \frac{\Delta [\text{I}_2]}{\text{time}}$$

The constant volume of $\text{S}_2\text{O}_3^{2-}$ used in all experiments ensured that amount of I_2 formed is constant at the moment when the reaction mixture turns blue-black [1],

$$\text{Rate} = \frac{\text{constant}}{\text{time taken}} \Rightarrow \text{Rate} \propto \frac{1}{t}$$

- (ii) Plot a graph of $100/t$ on the y-axis against V_{FA4} on the x-axis, on the grid in Fig. 2.1.
Start each of the axes at zero.
 Draw a best-fit line to prove that the reaction is first order with respect to $\text{S}_2\text{O}_8^{2-}$ ions.

Fig. 2.1

[3]

1 mark

Axes correct way round + correct labels + units + scale.

Scales must start at (0,0) as prompted in question.

Sensible scales must be used. The plotted points must occupy at least half of the graph grid in both x and y directions. Avoid scale like 1:4 or 1:2.5 for y-axis as 1:5 or 1:2 should work (to use at least 3 out of 5.5 big squares) and plotting is much easier/faster for 1:5 and 1:2.

1 mark

Plotting – all points correctly plotted within $\pm \frac{1}{2}$ small square.

Check all of the points and put ticks if correct.

1 mark

Graph line must be best-fit **straight** line (that passes through the origin – this will be marked as accuracy under (c)).

Interpretation of best-fit lines:

- 1) Line cuts through as many points as possible
- 2) Almost equal number of points above and below the line
- 3) Points above or below the line should be as close to the line as possible (within one small square away from the line)
- 4) There should only be zero or only one anomalous point

Award mark based on what the student has plotted (do not re-plot for wrongly plotted points).

Markers **must not** alter or adjust a poorly drawn student's line.

Comments:

This is marked very leniently. Giving the correct trend is awarded with 1 mark.

- (iii) Use your graph in (b)(ii) to explain why the reaction is first order with respect to $\text{S}_2\text{O}_8^{2-}$ ions.

.....

 [2]

Since total volume constant, Volume of FA4 added $\propto [\text{S}_2\text{O}_8^{2-}]$ in reaction mixture.

(Proven in b(i) that relative rate = $100 / t$)

The graph obtained is a linear line/upward sloping straight line that passes through the origin.

Hence the rate of reaction of equation 1 is (**directly**) proportional to $[\text{S}_2\text{O}_8^{2-}]$.

The order of reaction with respect to potassium peroxydisulfate is 1.

1st mark: describing shape of graph clearly (linear or upward sloping straight line) & inferring relationship: rate proportional to $[S_2O_8^{2-}]$.

2nd mark: accuracy mark whereby the line drawn by student passes through the origin on the graph in (b)(ii). Will award the mark so long as student draw a best-fit line that passes through the origin even if he did not describe "passes through the origin" in (b)(iii).

- (c) The rate of reaction can be found by calculating the change in concentration of $S_2O_8^{2-}(aq)$ that occurred when enough iodine was produced to change the colour of the starch indicator to blue-black.

Use your data and the equations on **page 5** to carry out the following calculations.

- (i) Calculate the amount in moles of iodine, I_2 , that react with the amount of thiosulfate ions, $S_2O_3^{2-}$ used in each experiment in (a). [phrasing follows 2023 P4]

$$n(S_2O_3^{2-}) = \frac{5.00}{1000} \times 0.0050 = 2.500 \times 10^{-5} \text{ mol}$$

$$n(I_2) = 2.500 \times 10^{-5} \times \frac{1}{2} = 1.250 \times 10^{-5} \approx 1.25 \times 10^{-5} \text{ mol}$$

amount of iodine, I_2 = [1]

- (ii) When the amount of peroxydisulfate ions, $S_2O_8^{2-}$, that was used to produce the amount of I_2 in part (i) reacted, a change in $[S_2O_8^{2-}]$ occurred. Calculate this change in $[S_2O_8^{2-}]$. Hence deduce the rate of change of $[S_2O_8^{2-}]$ for experiment 1, in $\text{mol dm}^{-3} \text{ h}^{-1}$.

$$\text{change in } [S_2O_8^{2-}] = \frac{1.250 \times 10^{-5}}{\frac{50}{1000}} = 2.500 \times 10^{-4} \approx 2.50 \times 10^{-4} \text{ mol dm}^{-3}$$

change in $[S_2O_8^{2-}]$ =

rate of change of $[S_2O_8^{2-}]$ for experiment 1

$$= \frac{2.500 \times 10^{-4}}{\text{time for expt 1}} \times 3600 = 4 \text{ sf truncated ans} \approx 3 \text{ sf truncated ans mol dm}^{-3} \text{ h}^{-1}$$

rate of change of $[S_2O_8^{2-}]$ for experiment 1 = $\text{mol dm}^{-3} \text{ h}^{-1}$
[2]

- Recognising that $S_2O_8^{2-} : I_2$ is 1 : 1
- Dividing by $\frac{72}{1000}$
- Multiplying by $\frac{3600}{t}$ for expt 1

3 pts – 2 marks, 2 pts – 1 mark

- (d) It was found, by carrying out experiments similar to those used in (a), that increasing the concentration of I^- increased the rate of the reaction.

A student suggested conducting Experiment 1 in (a) by halving all the volumes used. State and explain the effect this would have on the reaction time in Experiment 1 and the possible errors in the measurements.

.....
 [2]

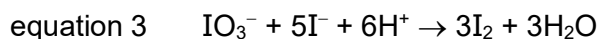
- No effect on the reaction time in Experiment 1.
- The proportion of the reactants is constant hence the concentration of the reactants in the reaction mixture remains constant.
- The percentage error in measuring the volumes of the reagents will increase
- as the percentage error is inversely proportional to the volume measured.

4 pts – 2 marks, 2 pts – 1 mark

[Total: 15]

3 To determine the concentration of hydrochloric acid, HCl in FA 8

In the presence of acid, iodate(V) ions react with iodide ions to form iodine and water as shown in equation 3.



If sodium thiosulfate is present in the reaction mixture the iodine formed is immediately reduced back to iodide and the solution remains colourless.

Iodate(V) ions can therefore be titrated against acid in the presence of an excess of iodide and thiosulfate ions.

You are to use this method to determine the concentration of the hydrochloric acid, HCl in **FA 8**.

FA 5 is 0.20 mol dm^{-3} potassium iodide, KI.

FA 6 is $0.0050 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 7 is aqueous potassium iodate(V) containing 0.214 g dm^{-3} of KIO_3 .

FA 8 is an aqueous solution of hydrochloric acid, HCl.

Solution B is bromophenol blue indicator.

(a) (i) Dilution of FA 8

Use a pipette to transfer 10.0 cm^3 of **FA 8** into a 250 cm^3 volumetric flask.

Make the solution up to the mark with deionised water. Label this solution **FA 9**. This is a solution of hydrochloric acid of a concentration suitable for the titration.

Titration of FA 7 against FA 9

1. Fill the burette with **FA 9**.
2. Use a pipette to transfer 25.0 cm^3 of **FA 7** into a 250 cm^3 conical flask.
3. Add to the conical flask:
 - approximately 10 cm^3 of **FA 5** using a 10 cm^3 measuring cylinder
 - approximately 30 cm^3 of **FA 6** using a 50 cm^3 measuring cylinder
 - 5 drops of **Solution B**
4. Run **FA 9** from the burette into the conical flask. The end-point is reached when the colour of **Solution B** changes to a very faint yellow.
5. Record your titration results, to an appropriate level of precision, in the space provided on **page 11**.
6. Discard the reaction mixture via the sink.
7. Repeat steps 2 to 6 until consistent results are obtained.

Titration results

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

[3]

1 mark

Tabulates initial and final burette readings and volume added in the titration table.

Table has correct headers and units.

Tabulation may be vertical or horizontal; lines are not essential but there should be no absences of headers. Where units have not been included in the header, there should be appropriate unit for each entry in the table. Do NOT award this mark if any final and initial burette readings are inverted or 50 is used as the initial burette reading.

1 mark

All the final/initial burette readings, for all accurate titres in the titration table, are recorded to the nearest 0.05 cm³.

Treat all titres as “accurate” unless labelled ‘rough’ or first titre is recorded to a lower precision than subsequent titres.

1 mark

Has at least two uncorrected titres for end-point within 0.10 cm³

Note:

- *Do not award this mark if having performed two titres within 0.1 cm³ a further titration is performed which is more than 0.10 cm³ from the closer of the initial two titres, unless a fourth titration, within 0.1 cm³ of the third titration or of the first two titres has also been carried out. [9701_w10_ms31]*

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

$$\text{volume of FA 9} = \frac{21.20 + 21.20}{2} = 21.20 \text{ cm}^3$$

volume of **FA 9** = [3]

1 mark

Student obtains appropriate “average”, to 2 d.p., from any experiments with uncorrected end-point titre values within 0.20 cm³.

Do not award this mark if the titres used are not identified either in the table (by, for example, a tick) or in a calculation.

Do not award this mark if there are arithmetic errors in the table.

2 marks

Accuracy of titres obtained

Cal diff = difference betw student's titre & teacher's titre (=19.75)

If diff ≤ 0.75, award 2 marks

If 0.75 < diff ≤ 1.75, award 1 mark

- (b) (i) Calculate the amount in moles of potassium iodate(V), KIO_3 , that were pipetted into the conical flask.

[Ar: K, 39.1; I, 126.9; O, 16.0]

$$n(\text{KIO}_3) = \frac{25.0}{1000} \times \frac{0.214}{214.0} = 2.500 \times 10^{-5} \approx 2.50 \times 10^{-5} \text{ mol}$$

amount of potassium iodate(V), KIO_3 = [1]

- (ii) Calculate the amount of hydrochloric acid, HCl that reacted with KIO_3 in the flask during the titration.

$$n(\text{HCl}) = 6 \times 2.500 \times 10^{-5} = 1.500 \times 10^{-4} \approx 1.50 \times 10^{-4} \text{ mol}$$

amount of hydrochloric acid, HCl = [1]

- (iii) Calculate the concentration of HCl in **FA 8**.

Method 1:

$$[\text{HCl}] \text{ in FA9} = \frac{1.500 \times 10^{-4}}{\frac{21.20}{1000}} = 0.007075 \text{ mol dm}^{-3}$$

$n(\text{HCl})$ before dilution = $n(\text{HCl})$ after dilution

$$[\text{HCl}] \text{ in FA8} \times \frac{10.0}{1000} = [\text{HCl}] \text{ in FA9} \times \frac{250}{1000}$$

$$[\text{HCl}] \text{ in FA8} = 0.007075 \times \frac{250}{21.20}$$

$$= 0.1768 \approx 0.177 \text{ mol dm}^{-3}$$

Method 2:

$n(\text{HCl})$ in 250 cm^3 of **FA9**

$$= \frac{1.500 \times 10^{-4}}{\frac{21.20}{1000}} \times \frac{250}{1000} = 0.001768 \text{ mol}$$

$n(\text{HCl})$ in 10 cm^3 of **FA8** = $n(\text{HCl})$ in 250 cm^3 of **FA9**

$$[\text{HCl}] \text{ in FA8} \times \frac{10.0}{1000} = 0.001768$$

$$[\text{HCl}] \text{ in FA8} = \frac{0.001768}{\frac{10.0}{1000}}$$

$$= 0.001768 = 0.1768 \approx 0.177 \text{ mol dm}^{-3}$$

concentration of HCl in **FA 8** = [4]

- Dividing by $\frac{21.20}{1000}$
 - Multiplying by 250
 - Dividing by 10.0
- 3 pts – 2 marks, 2 pts – 1 mark

2 marks for presentation, units and s.f.

- 2(c)(i) 5.00; 3(b)(i) 25.0; 3(b)(i) 214.0; 3(b)(iii) 10.0; 3(b)(iii) apply titre value in 2 d.p
- 2(c)(i), 2(c)(ii), 3(b)(i) & 3(b)(ii) intermediate value to 4 s.f. truncated
- 2(c)(i), 2(c)(ii), 3(b)(ii), (iii) presented intermediate value to 4 s.f. truncated from 2(c)(i), 2(c)(ii), 3(b)(i) & (ii) respectively in working
- 3 s.f. in final ans for 2(c)(i), 2(c)(ii) & 3(b)(i) to (iii)
- Units for 2(c)(i), 2(c)(ii), 3(a)(ii) & 3(b)(i) to (iii)

- (c) Suggest how the titration would be affected if sodium thiosulfate is **not** added in excess.

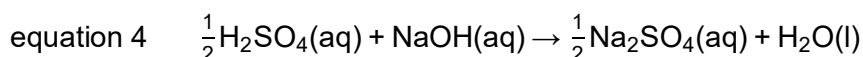
.....
..... [1]

At the onset of producing I_2 , yellow colour will appear. End-point will reach earlier than expected or end-point cannot be determined accurately. [1]

[Total: 13]

4 Planning

When sulfuric acid neutralises sodium hydroxide, water is produced.



The neutralisation process is exothermic, and the heat change, q , depends on the amount of water formed.

It is possible to determine the concentration of sulfuric acid and the enthalpy change of neutralisation by measuring the temperature rise obtained when different volumes of sulfuric acid are added to a fixed volume of a known concentration of sodium hydroxide in a series of experiments. The total volume of the reaction mixture for each experiment is not kept constant.

The data obtained is plotted and two best-fit lines are drawn. One line is drawn using data before the equivalence point and the second line using the remaining data. These lines are then extrapolated until they intersect each other.

In this question, you are to plan an investigation that would provide sufficient data to allow you to determine:

- the concentration of sulfuric acid,
- the maximum temperature change, ΔT_{max} ,
- the enthalpy change of neutralisation, ΔH_{n} .

You may assume that you are provided with:

- 1.50 mol dm⁻³ aqueous sodium hydroxide,
- sulfuric acid of approximately 1 mol dm⁻³ concentration,
- the equipment normally found in a school or college laboratory.

You may also assume that:

- the density of all solutions is 1.00 g cm⁻³,
- the specific heat capacity of all solutions is 4.18 J g⁻¹ K⁻¹.

- (a) Plan an investigation in which different volumes of sulfuric acid are added to a fixed volume of sodium hydroxide.

In your plan you should include brief details of:

- how you would select suitable volumes of sulfuric acid,
- the quantities of solutions you would use,
- the apparatus you would use and their precision,
- the procedure you would follow,
- the table of results you would prepare to allow a suitable graph to be drawn to determine the equivalence point accurately.

[6]

Justification of quantities of solutions used

Let the fixed volume of NaOH be 25.00 cm³.

$$n(\text{NaOH}) = \frac{25.00}{1000} \times 1.50 = 0.0375 \text{ mol}$$

$$n(\text{H}_2\text{SO}_4) = 0.0375 \times \frac{1}{2} = 0.01875 \text{ mol}$$

$$V(\text{H}_2\text{SO}_4) = \frac{0.01875}{1.00} \times 1000 = 18.75 \text{ cm}^3$$

Hence, the volumes of H₂SO₄ solution are selected (as shown in the table) such that there will be 3 points before and 3 points after the equivalence point when $V(\text{H}_2\text{SO}_4) = 18.75 \text{ cm}^3$. [1] or shown in the table

Procedure

1. Using a 50 cm³ measuring cylinder, add 25 cm³ of NaOH into a styrofoam cup. Place the cup in a 250 cm³ beaker to prevent it from tipping over.
2. Record the initial temperature of NaOH solution, T_i , using a 0.2 °C division thermometer.
3. Using another 50 cm³ measuring cylinder, add 5 cm³ of H₂SO₄ to the NaOH solution in the styrofoam cup. Use the thermometer to stir the mixture.
4. Record the highest temperature, T_h , of the mixture.
5. Calculate the change in temperature, ΔT , by subtracting T_i from T_h . ($\Delta T = T_h - T_i$)
6. Wash and dry the styrofoam cup.
7. Repeat step 1 to 6 but vary the volume of H₂SO₄ according to the table below.

Use appropriate apparatus to measure the volumes of NaOH and H₂SO₄ – [1]

Use appropriate thermometer to measure the temperature – [1]

Volume of H ₂ SO ₄ added / cm ³	Volume of NaOH added / cm ³	T_i / °C	T_h / °C	ΔT / °C
5.00	25.00			
10.00	25.00			
15.00	25.00			
20.00	25.00			
25.00	25.00			
30.00	25.00			

Indicate the measurements of the volume of H₂SO₄, volume of NaOH, and T_i – [1]

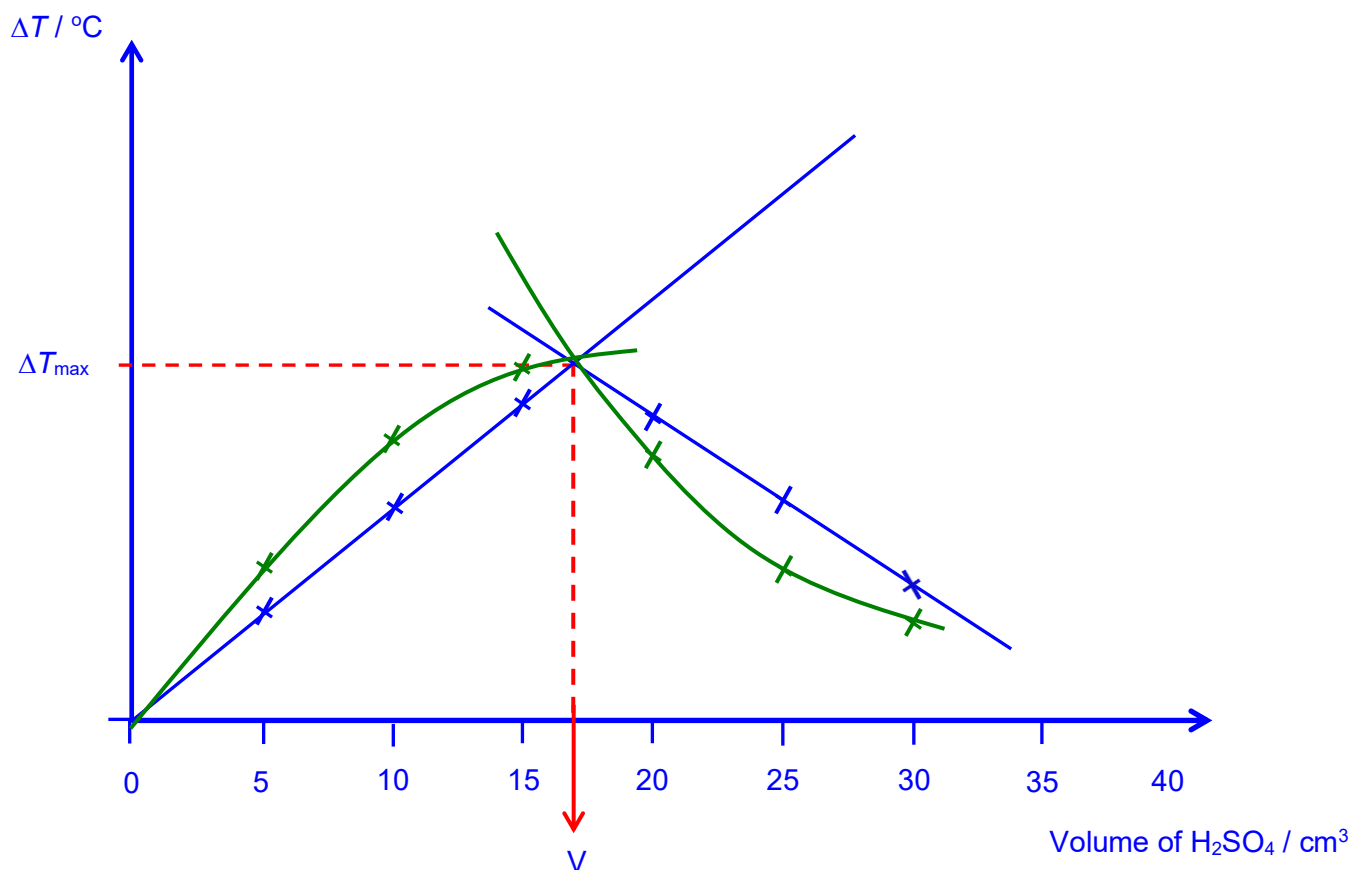
Record T_h and calculate ΔT – [1]

8. Plot a graph of the change in temperature, ΔT , against the volume of H₂SO₄ added. Draw two best fit lines before 15 cm³ of H₂SO₄ added and after 20 cm³ of H₂SO₄ added.
9. The equivalence point can be determined from the intersection of the two best fit lines.

Plot a graph of ΔT against $V(\text{H}_2\text{SO}_4)$ +

2 best fit lines to determine the equivalence point – [1]

- (b) (i) Sketch a suitable graph you would expect to obtain using the measurements you planned to make in 4(a). Indicate on the graph the volume of H_2SO_4 at equivalence point, V , and ΔT_{max} . [2]



- correct axes labels
 - two best fit lines (straight (blue) or curve (green) lines are acceptable)
 - label V and ΔT_{max}
- 3 pts – 2 marks, 2 pts – 1 mark

- (ii) Describe how you would use your ΔT_{max} value to calculate a value for q and hence determine a value for ΔH_{r} for this reaction. [2]

You do not need to perform any calculations.

$$q = mc\Delta T = (V + 25) \times c\Delta T = (V + 25) \times 1.00 \times 4.18 \times \Delta T_{\text{max}} = 4.18(V + 25)\Delta T_{\text{max}} \quad [1]$$

$$\Delta H_{\text{r}} = -\frac{q}{n(\text{H}_2\text{O})} = -\frac{4.18(V + 25)\Delta T_{\text{max}}}{\frac{25}{1000} \times 1.50} = -\frac{(V + 25)\Delta T_{\text{max}}}{0.0375} \quad [1]$$