# ANDERSON SERANGOON JUNIOR COLLEGE

## 2023 JC 2 PRELIMINARY EXAMINATION

**NAME:**_____ ( ) **CLASS:** 23 /____

**CHEMISTRY** **9729/04**

Paper 4 Practical **24 August 2023**

**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 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 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.
Quantitative Analysis Notes are printed on pages 19 and 20.

| Shift |
|---|
| |
| **Laboratory** |
| |

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.

| For Examiner's Use | |
|---|---|
| **1** | **/ 14** |
| **2** | **/ 12** |
| **3** | **/ 16** |
| **4** | **/ 13** |
| **Total** | **/ 55** |

This document consists of **19** printed pages and **1** blank page.

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

## 1 Determination of the kinetics of a redox reaction

Equation 1 presents the redox reaction between iodide ions and acidified hydrogen peroxide, $H_2O_2$, to form iodine.

equation 1 $\quad H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l)$

If $[H^+]$ and $[I^-]$ are kept constant, a simplified rate equation can be obtained.

$$\text{rate} = k' [H_2O_2]^n \quad \text{where } k' \text{ is } k [H^+]^a [I^-]^b$$

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 but constant amount of sodium thiosulfate, $Na_2S_2O_3$, is also present in the reaction mixture, the formation of the blue-black colour is delayed. The $Na_2S_2O_3$ reacts with the $I_2$ as shown in equation 2.

equation 2 $\quad I_2 + 2Na_2S_2O_3 \longrightarrow 2NaI + Na_2S_4O_6$

**FA 1** is 0.100 mol $dm^{-3}$ hydrogen peroxide, $H_2O_2$.
**FA 2** is 0.150 mol $dm^{-3}$ potassium iodide, KI.
**FA 3** is 1.00 mol $dm^{-3}$ dilute sulfuric acid, $H_2SO_4$.
**FA 4** is 0.050 mol $dm^{-3}$ sodium thiosulfate, $Na_2S_2O_3$.
Starch solution

You will perform a series of four experiments and add a fixed amount of sodium thiosulfate, **FA 4**, to each of the experiment. You will need to ensure that the same total volume of reaction mixture is used by adding deionised water as required.

The rate of this reaction is studied by measuring the time taken, $t$, for the blue-black colour to appear with a constant quantity of sodium thiosulfate present. You will then graphically analyse your results to determine the order of reaction with respect to hydrogen peroxide.

For each experiment, you will note the volume of **FA 1** added, $V_{\mathbf{FA\ 1}}$, volume of $H_2O$, $V_{H_2O}$ and the time taken for the blue-black colour to appear.

You will then calculate values for

- $1/t$
- $\lg(1/t)$
- $\lg(V_{\mathbf{FA\ 1}})$

**(a)** Fill Table 1.1 on page 4 with

- all volumes of **FA 1,** $V_{\mathbf{FA\ 1}}$ and water, $V_{H_2O}$
- all values of $t$, to the nearest second
- all calculated values of $1/t$, $\lg(1/t)$ and $\lg(V_{\mathbf{FA\ 1}})$ recorded to 3 significant figures.

**Experiment 1**

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

1. Fill a burette with **FA 4**.

2. Transfer 10.00 $cm^3$ of **FA 4** from the burette into a 250 $cm^3$ conical flask. Place the conical flask on a white tile.

3. Using appropriate measuring cylinders, transfer to the 250 $cm^3$ conical flask
   - 25.0 $cm^3$ of **FA 2**
   - 25.0 $cm^3$ of deionised water
   - 3.0 $cm^3$ of starch solution

4. Using appropriate measuring cylinders, transfer to a 100 $cm^3$ beaker
   - 50.0 $cm^3$ of **FA 1**
   - 20.0 $cm^3$ of **FA 3**

5. Pour the mixture in the beaker rapidly into the conical flask. Start the stopwatch when **half the contents** of the beaker are added.

6. Mix the contents thoroughly by swirling the flask.

7. Stop the stopwatch when the blue–black colour appears.

8. Record the time taken, *t,* in Table 1.1.

9. Discard the reaction mixture. Carefully wash out the beaker and conical flask. Stand the conical flask upside down on a paper towel to drain.

**Experiment 2 to 4**

Carry out three further experiments using a volume of 40.0 $cm^3$, 30.0 $cm^3$ and 25.0 $cm^3$ of **FA 1,** respectively at **point 4**.

In each case, you will need to ensure that the same total volume of reaction mixture is used by adding deionised water as required.

You should alternate the use of the two conical flasks.

Record all required volumes, time taken and calculated values in Table 1.1.

**Results**

**Table 1.1**

*These are the marking points for **(a)**.*

| Experiment | $V_{FA\,1}$ / $cm^3$ | | $V_{H_2O}$ / $cm^3$ | $t$ / s | $1/t$ / $s^{-1}$ | lg(1/$t$) | lg($V_{FA\,1}$) |
|---|---|---|---|---|---|---|---|
| 1 | 50.0 | √ | 25.0 | 20 | 0.0500 | –1.30 | 1.70 |
| 2 | 40.0 | √ | 35.0 | 26 | 0.0385 | –1.41 | 1.60 |
| 3 | 30.0 | √ | 45.0 | 34 | 0.0294 | –1.53 | 1.48 |
| 4 | 25.0 | √ | 50.0 | 43 | 0.0233 | –1.63 | 1.40 |
| | √ | | √ | √ | √ | √ | √ |

[5]

**[1]**: total volume of **FA 1** and $H_2O$ used = 75.0 $cm^3$; no mark if $V_{H_2O}$ is missing or any of $V_{FA1}$ is wrong *[√between columns 2 and 3]*
**[1]**: $t$ increases as $V_{FA1}$ decreases *[√beside each t reading]*
**[1]**: volumes recorded to nearest 0.5 $cm^3$ (based on ½ smallest division of the measuring cylinder used); $t$ to nearest 1s; ALL calculated values to 3 s.f. *[√below each column]*
**[1]**: correctly calculated values (ignore s.f.) *[√beside each value]*
**[1]**: accuracy mark [A = $100(2t_1 - t_4)/t_4 \leq 15\%$]; rebased for those who used wrong $V_{FA1}$

**(b) Graphical determination of order of reaction**

In a series of experiments, where volume of one of the reactants added is changed, the total volume of the mixture is kept constant and the same end-point (appearance of the dark blue colour) is timed:

- $\frac{1}{\text{time}}$ (1/$t$) can be used as a measure of rate
- the volume of the reactant which is changed in each experiment can provide a measure of its concentration.

In these experiments, only the concentration of hydrogen peroxide, $[H_2O_2]$, in the reaction mixture has been changed. The simplified rate equation is

$$\text{rate} = k' [H_2O_2]^n$$

- taking logarithms of the factors in this equation gives

$$\lg(\text{rate}) = n \times \lg([H_2O_2]) + \lg(k')$$

- by substituting for rate and $[H_2O_2]$, as described above, we get

$$\lg(1/t) = n \times \lg(V_{FA\,1}) + \lg(k')$$

By plotting a graph of lg(1/$t$) on the $y$-axis against lg($V_{FA\,1}$) on the $x$-axis, you will be able to draw a straight line of best fit, the gradient of which is the required order of reaction, $n$.

**(i)** Plot a graph of lg(1/$t$) on the $y$-axis against lg($V_{FA\,1}$) on the $x$-axis on the grid in Fig 1.1.
Draw the best-fit straight line taking into account all of your plotted points.

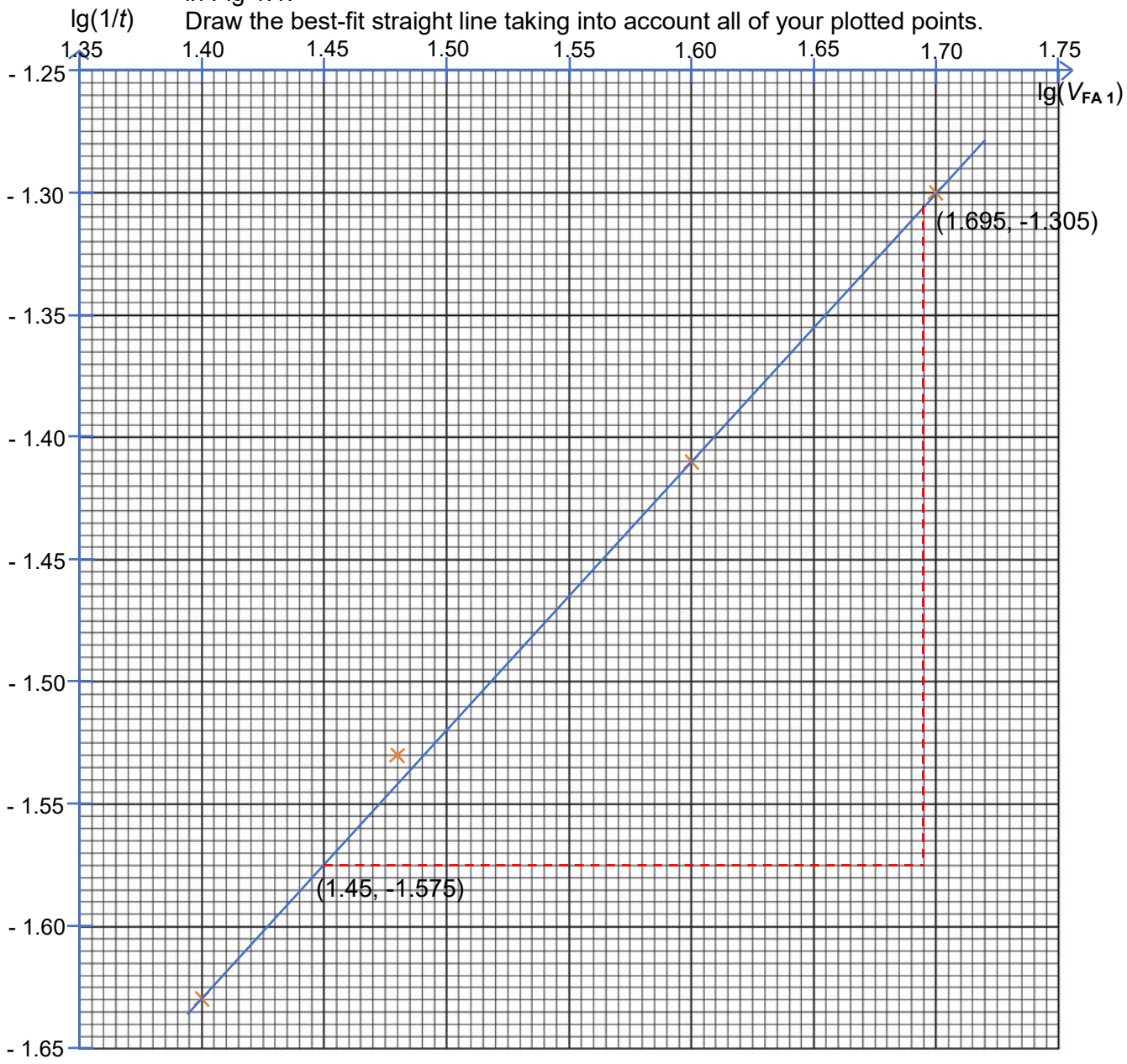


**Fig. 1.1**

[3]

**[1]** Axes correct way round **+** correct labels **+** NO units **+** scale. Scales chosen so that plotted points occupy at least half the graph grid in both $x$ and $y$ directions. (i.e. more than or equal to 4 big squares for the x-scale and y-scale)
**[1]** Plotting – within ±½ small square.
**[1]** All points joined up in a best fit upwards slopping line. This mark is not awarded if a curve is drawn.

**(ii)** Calculate the gradient of the line, showing clearly how you did this. Hence, deduce the order of reaction with respect to $[H_2O_2]$.

**[1]** Clear indication of **correct** co-ordinates from graph (measured to ±½ small square) and triangle drawn should be at least half the number of grids in x & y direction of the line drawn. (i.e. more than or equal to 4 big squares for the x & y directions)

**[1]** Positive gradient correctly calculated. This mark will not be awarded if a curve is shown.

**[1]** Correct conclusion of order of reaction (1st order) with a straight-line graph. This mark will not be awarded if a curve is shown.

$$\text{Gradient} = \frac{(-1.305-(-1.575))}{(1.695-1.45)} = 1.10$$

Order of reaction = 1

gradient = .....

order of reaction = .....
[3]

**(c)** Explain why it is necessary to use a burette to measure the volume of **FA 4**. [1]

This is to ensure that an accurate and constant amount of $Na_2S_2O_3$, is used in each experiment and time taken is measured for same extent of reaction / same amount of $I_2$ is reacting with $S_2O_3^{2-}$ for each experiment.

**(d)** A student repeated the four experiments using the same reagents the next day. The student noticed that the time taken for the first appearance of a blue-black colour was longer for each experiment.

Give a possible reason for the longer timing. [1]

Decomposition of $H_2O_2$ occurs and result in lowering in the $[H_2O_2]$. Since order of reaction is dependent on $[H_2O_2]$, rate of reaction will decrease, and longer timing required for appearance of blue-black.
(accept oxidation of KI; decrease in [KI] and rate)

**Improvement** (not required for this question): Store $H_2O_2(aq)$ at low temperature, make up fresh $H_2O_2(aq)$, keep $H_2O_2(aq)$ in dark/dim light

**(e)** Point **9** of Experiment 1 in **1(a)** instructs you to wash **and** drain the conical flask before it is used again.

Deduce and explain the likely effect on time taken, *t*, if a student had failed to wash the conical flask but had drained it before starting another experiment. [1]

effect on *t*: time would be shorter

explanation:
residual $H_2O_2$ and acid from the previous experiment would react with KI in new

experiment before mixing (Point **3**) to form $I_2$ which would leave less $Na_2S_2O_3$ **or** residual acid from the previous experiment would react with the $NaS_2O_3$ in the new experiment, leaving less $Na_2S_2O_3$ in the reaction mixture.
(accept explanation in terms of increased concentration leading to faster rate)

[1]: idea of reaction starting before mixing resulting in less $Na_2S_2O_3$ and faster appearance of blue-black / residual chemical (except starch/$Na_2S_2O_3$) increases its concentration and hence rate of reaction
[FYI: rate equation for equation 1 is rate = $k$ $[H_2O_2]$ $[I^-]$ $[H^+]$ and hence explanation in terms of increased concentration was accepted]

[Total: 14]

**2 To determine the composition of a mixture of sodium carbonate and sodium hydrogen carbonate**

**FA 5** contains 3.90 g $dm^{-3}$ of a mixture of sodium carbonate, $Na_2CO_3$ and sodium hydrogen carbonate, $NaHCO_3$.
**FA 6** is 0.0700 mol $dm^{-3}$ hydrochloric acid, HC*l*.
Solution **S** is screened methyl orange indicator.
Solution **T** is thymolphthalein indicator.

Sodium carbonate in aqueous solution acts as a Brønsted base. It reacts with acid in two stages. In the first stage, it accepts a proton to form sodium chloride and sodium hydrogencarbonate. In the second stage, sodium hydrogencarbonate combines with another proton to form sodium chloride, carbon dioxide and water.

Stage 1 $Na_2CO_3(aq) + HCl(aq) \rightarrow NaCl(aq) + NaHCO_3(aq)$

Stage 2 $NaHCO_3(aq) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l)$

The end-point for Stage 1 occurs at pH 8.3 and is determined using thymolphthalein indicator.

The end-point for Stage 2 occurs around pH 3.7 and is determined using screened methyl orange indicator.

You are required to determine the concentrations of sodium carbonate, and of sodium hydrogen carbonate, in **FA 5**.

**(a) Titration of FA 5 against FA 6**

1. Fill the burette labelled **FA 6**, with **FA 6**.

2. Use a pipette to transfer 25.0 $cm^3$ of **FA 5** into a 250 $cm^3$ conical flask.

3. Add a few drops of solution **T** to the conical flask.

4. Run **FA 6** from the burette into the conical flask. The end-point is reached when the solution changes from blue to colourless.

5. Record your titration results in Table 2.1.

   **Do not discard this solution.**

6. To **this** solution, add a few drops of solution **S**.

7. Run **FA 6** from the burette into this conical flask. The end-point is reached when the solution changes from green to grey. If the solution becomes violet, you have passed the end-point.

8. Record your titration results in Table 2.1.

9. Repeat points 1 to 8 as necessary until consistent results are obtained for the **second end-point.**

**Results**

**Table 2.1**

| Titration | 1 | 2 | | |
|---|---|---|---|---|
| Initial burette reading / $cm^3$ | 0.00 | 0.00 | | |
| Final burette reading 1 (first end–point) / $cm^3$ | 8.10 | 8.10 | | |
| Final burette reading 2 (second end–point) / $cm^3$ | 23.05 | 23.05 | | |
| Volume of **FA 6** used to complete Stage 1 / $cm^3$ | 8.10 | 8.10 | | |
| Volume of **FA 6** used to complete Stages 1 and 2 / $cm^3$ | 23.05 | 23.05 | | |

[2]

**[1]** All the burette readings are recorded to the nearest 0.05 $cm^3$.
*Treat all titres as "accurate" unless labelled rough.*

**[1]** Has at least two titres for **second** end-point within 0.10 $cm^3$

**(b)** Using your titration results, obtain suitable volumes of **FA 6** for the:
- first end-point (volume of **FA 6** used to complete stage 1)
- second end-point (total volume of **FA 6** used to complete stages 1 and 2)

Consider only volume of **FA 6** for the second end-point when deciding which set of titration results are consistent.

Show clearly how you obtained these volumes.

Volume of **FA 6** used to obtain first end-point = $\frac{8.10+8.10}{2}$ = 8.10$cm^3$

Volume of **FA 6** used to obtain second end-point = $\frac{23.05+23.05}{2}$ = 23.05 $cm^3$

Calculation of Volume of **FA 6** used **[1]**
**Hierarchy to be used in calculating mean titres**
- Value of 2 identical titres
- Average of titres within 0.05 $cm^3$
- Average of titres within 0.1 $cm^3$, etc

Accuracy **[2]**
[2] 22.60 $cm^3$ ≤ Volume of **FA 6** ≤ 23.40 $cm^3$
[1] 22.40 $cm^3$ ≤ Volume of **FA 6** ≤ 23.60 $cm^3$

volume of **FA 6** used for first end-point = ……$cm^3$

volume of **FA 6** used for second end-point = ……$cm^3$
[3]

**(c) (i)** Calculate the amount, in moles, of sodium carbonate, $Na_2CO_3$, and sodium hydrogen carbonate, $NaHCO_3$, present in 25.0 $cm^3$ of **FA 5**.

Volume of **FA 6** used to obtain first end-point in (c)= $V_1$

Volume of **FA 6** used for second end-point in (c) = $V_2$

Volume of HC*l* neutralising original $NaHCO_3$
= $V_2 - 2V_1$
= $V_3$

Amount of $Na_2CO_3$ = $0.0700 \times \frac{V_1}{1000}$ = ***x*** mol **[1]**

Amount of original $NaHCO_3$ = $0.0700 \times \frac{V_3}{1000}$ = ***y*** mol **[1]**

(allow ecf based on volume calculated in (b)

amount of $Na_2CO_3$ in 25.0 $cm^3$ of **FA 5** =.....

amount of $NaHCO_3$ in 25.0 $cm^3$ of **FA 5** =.....
[2]

**(ii)** Calculate the concentrations, in mol $dm^{-3}$, of $Na_2CO_3$ and $NaHCO_3$ in **FA 5**.

[$Na_2CO_3$] in **FA 5** = ***x*** $\times \frac{1000}{25.0}$ mol $dm^{-3}$

[$NaHCO_3$] in **FA 5** = ***y*** $\times \frac{1000}{25.0}$ mol $dm^{-3}$ **[1] (allow ECF)**

**If no y values were given in (i), no marks for (ii).**

concentration of $Na_2CO_3$ in **FA 5** =.....

concentration of $NaHCO_3$ in **FA 5** =.....
**[1]** Shows appropriate significant figures (3 or 4 sf,) in **all** final answers in **part (c)(i) –(c)(ii)**. Any calculations not attempted in part **(c)** loses this mark.
**[1]** Shows appropriate units in **all** final answers in **part (c)**. Any calculations not attempted in part **(d)** loses this mark.
[3]

**(d)** Explain why screened methyl orange can be used as the indicator for Stage 2.
[1]

The working pH range of screened methyl orange lies within the range of rapid pH change for the titration. [1]

**(e)** A student used 25.0 $cm^3$ of **FA 5** and obtained an **FA 6** titre of 35.15 $cm^3$ for the second end point.

The errors (uncertainties) associated with each apparatus is given below.

| | |
|---|---|
| pipette | ±0.1 $cm^3$ |
| burette | ±0.05 $cm^3$ |

Use the above data to calculate the maximum total percentage error (uncertainty) of the student's titre for the second end point**.**
[1]

% error in pipette = $\frac{0.1 \times 100}{25}$ = 0.400%

% error in burette = $\frac{0.05 \times 2 \times 100}{35.15}$ = 0.284%

Total % error = 0.400 + 0.284 = 0.684%

[1] Both calculation

[Total: 12]

## 3 Investigation of some inorganic and organic reactions

**FA 7** contains two cations and two anions listed in the Qualitative Analysis Notes on pages 19 and 20.

**FA 8** is an organic compound containing C, H and O atoms only with $M_r$ between 40 – 50.

You will perform tests to identify the two cations and two anions in **FA 7** and the identity of **FA 8.**

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.**

**(a) (i)** Carry out the following tests on **FA 7**. Carefully record your observations in Table 3.1.

**Table 3.1**

| | tests | observations |
|---|---|---|
| 1 | Add 2 cm depth of **FA 7** into a clean test-tube.<br><br>Add aqueous ammonia, slowly with shaking, until 4 cm depth of aqueous ammonia has been added. | ✓*Cream/ Off-white ppt insoluble in excess*<br><br>✓*Cream/ Off-white ppt rapidly turning brown* on contact with air |
| 2 | Filter the mixture from test 1 into a clean test-tube. Collect the filtrate for later test.<br><br>Leave the residue on the filter paper and observe it again after several minutes. Continue with the remaining parts of Question 3. | ✓*Colourless/ brown/ light brown/ off-white filtrate*<br><br>✓*brown residue* |
| 3 | Using a teat pipette, extract about 1 cm depth of the filtrate from test 2 into a clean test-tube.<br><br>Add dilute sulfuric acid until no further change is seen. | ✓*White ppt formed*<br><br>✓ *White ppt soluble in excess acid to give a colorless solution*<br><br>Unacceptable:<br>**no observable change** |

[3]

Across 3 tests.
6✓: 3 marks 4✓: 2 marks 2✓: 1 mark

**(ii)** Using your observations from Table 3.1, identify the two cations present in **FA 7**.

**FA 7** contains the cations …… and …… [1]

$Mn^{2+}$ and $Zn^{2+}$ [1]

**(b) (i)** Carry out the following tests on **FA 7**. Carefully record your observations in Table 3.2.

Test 2 has been conducted for you and the observation is recorded.

You are to devise **two additional** tests on **FA 7** based on the Qualitative Analysis Notes on pages 19 and 20 to identify the two anions present.

You should only use bench reagents provided. Record your tests and observations for the two additional tests (tests 3 and 4) below.

**Table 3.2**

| | tests | observations |
|---|---|---|
| 1 | Add 1 cm depth of **FA 7** into a clean test-tube.<br><br>Add 2 cm depth of aqueous hydrochloric acid. | *No effervescence observed/ no observable change* [1] |
| 2 | Add 1 cm depth of **FA 7** into a clean test-tube.<br><br>Add 2 cm depth of aqueous NaOH, followed by a small piece of Al foil with warming. | Effervescence observed.<br>Gas evolved turns moist red litmus turns blue. |
| 3 | Add 1 cm depth of **FA 7** into a clean test-tube.<br><br>Add 3 drops of aqueous silver nitrate. [1] | *No ppt / no observable change* /Solution remains colourless [1] |
| 4 | To 1 cm depth **FA 7** into a clean test-tube.<br><br>Add 3 drops of aqueous barium nitrate. [1]<br><br>Then add 1 cm depth of aqueous nitric acid/ hydrochloric acid/strong acid/$H^+$.<br><br>(no marks awarded if $H_2SO_4$ was used in place of other SA) | *White ppt insoluble in acid* [1] |

[5]

**(ii)** Using your observations in Table 3.2, identify the two anions present in **FA 7**.

**FA 7** contains the anions $NO_3^-$ and $SO_4^{2-}$ [1]

**(c)** **(i)** Carry out the following tests on **FA 8**. Carefully record your observations in Table 3.3.

Test 1 has been conducted for you and the observation is recorded.

**Table 3.3**

| | tests | observations |
|---|---|---|
| 1 | Add a small piece of sodium. | no observable change |
| 2 | To 1 cm depth of aqueous iodine in a clean test-tube add 1 cm depth of aqueous sodium hydroxide to get a pale yellow solution.<br><br>Add 1 cm depth of **FA 8** and shake the test-tube. Leave to stand. | *(Pale) white/ yellow ppt formed*<br>*(Ignore if student states that ppt dissolves)*<br>[1] |
| 3 | To 1 cm depth of **FA 8** in a clean test-tube add 1 cm depth of sulfuric acid.<br><br>Add 2 drops of potassium manganate(VII).<br><br>Warm the test-tube in a beaker of hot water for two minutes. | *Purple $KMnO_4$ decolourised*<br><br>[1] |

[2]

**(ii)** Using the observations from each test in Table 3.3, suggest the structural features of **FA 8**.

test 1 ……..

test 2 ……..

test 3 ……..... [3]

Test 1: does not contain –OH OR not an alcohol OR not a carboxylic acid OR not hydroxyl group [1] (do not accept phenol as it will exceed the suggested $M_r$)

Test 2: contains $-CH_3C{=}O$ (or $-CH(OH)CH_3$) group [1]

Test 3: is an aldehyde/ has -CHO (or a 1º or 2º alcohol) [1] ignore aliphatic/aromatic.

**(iii)** Use your deductions in **3(c)(ii)** to suggest the identity of **FA 8**.

**FA 8** is …….. [1]

**FA 8** is ethanal/ $CH_3CHO$ [1] (do not allow ECF)

*(Hint: containing C, H and O atoms only with $M_r$ between 40 – 50*
*It cannot be alcohol and must have the structure of $-CH_3C=O$*
*It also can be oxidised this ethanal is the best option.)*

[Total: 16]

## 4 Planning: Determining the $A_r$ for an unknown metal, M

M is a Group 1 metal. When MOH is added to $H_2SO_4$, an exothermic reaction occurs.

$$2MOH + H_2SO_4 \rightarrow M_2SO_4 + 2H_2O \qquad \Delta H < 0 \text{ kJ mol}^{-1}$$

The maximum temperature change when stoichiometric amounts of MOH and $H_2SO_4$ react, may be determined graphically by using temperature changes from a series of **six** experiments where different volumes of MOH and $H_2SO_4$ are mixed while keeping the total volume of solution constant.

The volume of $H_2SO_4$ required for complete neutralisation of MOH can then be determined and used to calculate the relative atomic mass, $A_r$, of M in the unknown metal hydroxide.

**(a)** Plan an investigation to determine the maximum temperature change, $\Delta T_{max}$, graphically for the reaction between MOH and $H_2SO_4$.

Measurements should be taken

- Before the reaction starts
- During the reaction

You may assume that you are provided with

- 200 $cm^3$ of 42.3 g $dm^{-3}$ aqueous MOH solution
- 200 $cm^3$ of 0.500 mol $dm^{-3}$ sulfuric acid, $H_2SO_4$
- 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 volume of MOH and $H_2SO_4$ you would use for **each** experiment
- the procedure you would follow
- the measurements you would make to allow a suitable $\Delta T$–volume graph to be drawn
- how you would ensure that an **accurate** and **reliable** value of $\Delta T_{max}$ is obtained.

Calculations are not required.

**Procedure**

1. Place a clean and dry polystyrene cup inside a second polystyrene cup which is placed in a 250 $cm^3$ glass beaker to prevent the cups from tipping over. Use a 50 $cm^3$ measuring cylinder to transfer 10.0 $cm^3$ of $H_2SO_4$ into the polystyrene cup and put the lid on.
2. Insert a thermometer through the lid and ensure that the bulb of the thermometer is fully immersed in $H_2SO_4$. Use the thermometer to measure the initial temperature, $T_1$, of $H_2SO_4$.
3. Using another 50 $cm^3$ measuring cylinder, measure 40.0 $cm^3$ of MOH.
4. Open the lid of the cup and transfer the 40.0 $cm^3$ of MOH into the polystyrene cup containing $H_2SO_4$. Replace the lid quickly.

5. Using the thermometer, stir the mixture continuously until it reaches its **highest** temperature. Record this temperature, $T_2$.
6. Discard the contents of the polystyrene cup. Wash and dry it carefully.
7. Repeat steps 1 to 6 using the following volumes.

| Volume of $H_2SO_4$/ $cm^3$ | Volume of MOH / $cm^3$ |
|---|---|
| 15.0 | 35.0 |
| 20.0 | 30.0 |
| 25.0 | 25.0 |
| 30.0 | 20.0 |
| 35.0 | 15.0 |
| 40.0 | 10.0 |

8. Record all measurements of volume, temperature and temperature change, $\Delta T$, in an appropriate format.

| | |
|---|---|
| **[1]** | **Apparatus (All 3)**<br>• Polystyrene cup<br>• Thermometer<br>• Measuring Cylinder/ Burette (reject pipette) |
| **[2]** | **Volume of $H_2SO_4$ and MOH you would use for each experiment**<br>• 6 experiments with a total volume < 400 $cm^3$ (66 $cm^3$ max per expt) for each chemical.<br>• Table showing exact volume of $H_2SO_4$ and MOH to use for **each** experiment.<br>• Keeping the total volume a constant for each experiment<br>• Choosing 6 sets of volumes with good spread.<br>**(any 3 points – 2 marks, 2 points – 1 mark)**<br><br>No marks awarded once deionised water was used to keep the total volume a constant. |
| **[1]** | **Procedure followed** |

| | |
|---|---|
| | • Measure volume of Reagent A<br>• Take temperature of Reagent A<br>• Measure volume of Reagent B<br>• Transfer Reagent B<br>• Take temperature of reaction mixture<br>• Record/input temperatures<br><br>Student can have the flexibility of having $H_2SO_4$ or MOH in the polystyrene cup at the start of the experiment. |
| **[1]** | **Measurements taken**<br>• initial temperature of reactant in cup, $T_1$ (can be marked in table if not written in procedure)<br>• **highest** temperature reached, $T_2$ (can be marked in table if not written in procedure)<br><br>*Temperature change cannot be measured. It is a calculated value. |
| **[2]** | **Reliability**<br>• dry polystyrene cup inside a second polystyrene cup which is placed in a 250 $cm^3$ glass beaker<br>• At least 10 $cm^3$ of reagent placed in polystyrene cup for each experiment so that bulb is covered by thermometer<br>• Replace the lid quickly.<br>• Stir the mixture continuously<br>• Wash and dry cup before next experiment.<br>• Use of burette instead of measuring cylinder to measure the exact volume.<br>• Showing formula for taking weighted in the weighted average initial temperature, $T_{av}$, of the two solutions used if initial temperature of both solutions are measured and recored.<br>$T_{av} = \frac{\text{(volume MOH} \times \text{initial temp MOH) + (volume } H_2SO_4 \times \text{initial temp H}}{\text{total volume of reaction mixture}}$<br><br>**(any 5 points – 2 marks, 3 points – 1 mark)** |

.....[7]

**(b)** **(i)** Sketch, on Fig. 4.1, the shape of the graph you would expect to obtain using the results from your plan in **4(a)**.

Extrapolate your graph until it touches both axes.

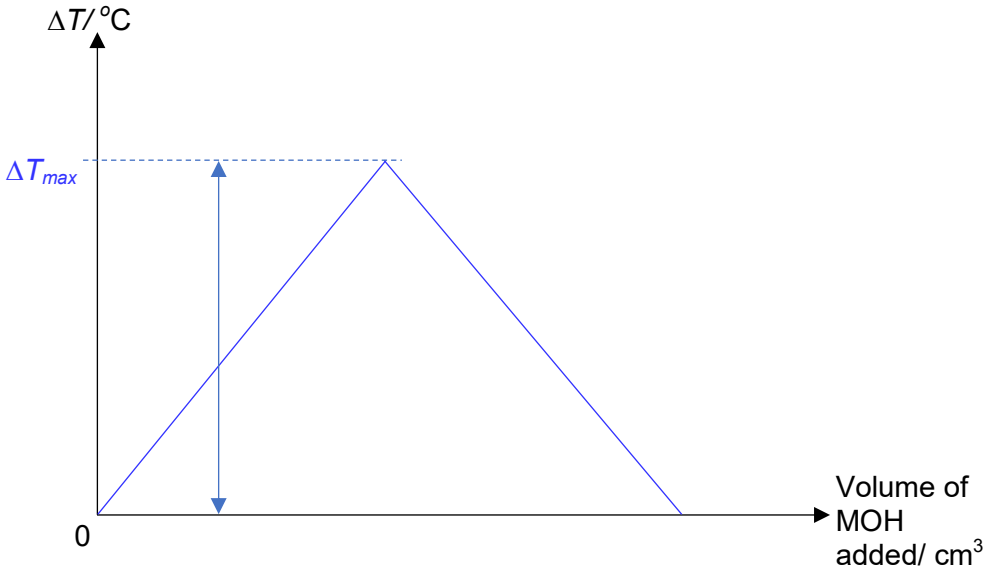


**Fig. 4.1**

[1] for shape + intercept at origin and x-axis.

**(ii)** Show how the maximum temperature change, $\Delta T_{max}$, can be determined from Fig. 4.1. [1]

1 extrapolated line to the Y-axis with label $\Delta T_{max.}$

**(c)** Suggest how the magnitude of the $\Delta H_{neut}$ obtained using the $\Delta T_{max}$ obtained above would compare to the true $\Delta H_{neut}$. Explain your answer. [2]

Smaller/ lower / less exo .[1]

Due to heat loss to surroundings/ Styrofoam cup and hence lower $\Delta T_{max}$.[1]

**(d)** A student repeated the procedure described in **4(a)** but kept the total volume constant at 100 $cm^3$ instead for each experiment. The volume of MOH used at maximum temperature change was found to be 57.0 $cm^3$.

**(i)** Calculate the concentration of MOH in mol $dm^{-3}$.

Amount of $H_2SO_4$ = 0.500 x $\frac{(100-57)}{1000}$ = 0.0215 mol

Amount of MOH = 0.0430 mol

[MOH] = $\frac{0.0430}{\frac{57}{1000}}$ = 0.754 mol $dm^{-3}$ [1]

[1]

**(ii)** Hence, calculate the relative atomic mass, $A_r$ of M.
[$A_r$: O: 16.0; H: 1.0]

$M_r$ of MOH = $\frac{42.3}{0.754}$ = 56.1

$A_r$ of M = 56.1 – 17.0 = 39.1 [1]

Additional
**Unknown is K**
$2KOH + H_2SO_4 (aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

[1]

[Total: 13]

**Qualitative Analysis Notes**
*[ppt. = precipitate]*

## (a) Reactions of aqueous cations

| ***cation*** | ***reaction with*** | |
|---|---|---|
| | NaOH(aq) | $NH_3$(aq) |
| aluminium, $Al^{3+}$(aq) | white ppt.<br>soluble in excess | white ppt.<br>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.<br>soluble in excess<br>giving dark green solution | grey–green ppt.<br>insoluble in excess |
| copper(II), $Cu^{2+}$(aq) | pale blue ppt.<br>insoluble in excess | blue ppt.<br>soluble in excess<br>giving dark blue solution |
| iron(II), $Fe^{2+}$(aq) | green ppt., turning brown on contact with air<br>insoluble in excess | green ppt., turning brown on contact with air<br>insoluble in excess |
| iron(III), $Fe^{3+}$(aq) | red–brown ppt.<br>insoluble in excess | red–brown ppt.<br>insoluble in excess |
| magnesium, $Mg^{2+}$(aq) | white ppt.<br>insoluble in excess | white ppt.<br>insoluble in excess |
| manganese(II), $Mn^{2+}$(aq) | off–white ppt., rapidly turning brown on contact with air<br>insoluble in excess | off–white ppt., rapidly turning brown on contact with air<br>insoluble in excess |
| zinc, $Zn^{2+}$(aq) | white ppt.<br>soluble in excess | white ppt.<br>soluble in excess |

## (b) Reactions of anions

| *anion* | *reaction* |
|---|---|
| carbonate, $CO_3^{2-}$ | $CO_2$ liberated by dilute acids |
| chloride, $Cl^-$(aq) | gives white ppt. with $Ag^+$(aq) (soluble in $NH_3$(aq)) |
| bromide, $Br^-$(aq) | gives pale cream ppt. with $Ag^+$(aq) (partially soluble in $NH_3$(aq)) |
| iodide, $I^-$(aq) | gives yellow ppt. with $Ag^+$(aq) (insoluble in $NH_3$(aq)) |
| nitrate, $NO_3^-$(aq) | $NH_3$ liberated on heating with $OH^-$(aq) and Al foil |
| nitrite, $NO_2^-$(aq) | $NH_3$ liberated on heating with $OH^-$(aq) and Al foil<br>NO liberated by dilute acids<br>(colourless NO $\rightarrow$ (pale) brown $NO_2$ in air) |
| sulfate, $SO_4^{2-}$(aq) | gives white ppt. with $Ba^{2+}$(aq) (insoluble in excess dilute strong acids) |
| sulfite, $SO_3^{2-}$(aq) | $SO_2$ liberated with dilute acids;<br>gives white ppt. with $Ba^{2+}$(aq) (soluble in dilute strong acids) |

## (c) Tests for gases

| *gas* | *test and test result* |
|---|---|
| ammonia, $NH_3$ | turns damp red litmus paper blue |
| carbon dioxide, $CO_2$ | gives a white ppt. with limewater<br>(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

| *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 |