



TAMPINES MERIDIAN JUNIOR COLLEGE

PRELIMINARY EXAMINATION

CANDIDATE
NAME

ANSWERS

CIVICS GROUP

H2 CHEMISTRY

Practical

9729/04

29 August 2023

2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the page.

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 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.

Shift

Laboratory

For Examiner's Use

1 / 11

2 / 16

3 / 17

4 / 11

Total / **55**

This document consists of **21** printed pages.



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

1 Investigation of organic and inorganic compounds

- (a) **FA 1**, **FA 2**, **FA 3** and **FA 4** are aqueous solutions known to be hydrochloric acid, ethanoic acid, methanoic acid and sulfuric acid. All the solutions have the same concentration.

Note: the order of **FA 1** to **FA 4** does **not** correspond to the order of identities given above.

- (i) Carry out the following tests for **FA 1** to **FA 3**. Record your observations in Table 1.1.

Observations for **FA 4** have already been recorded in Table 1.1. There is no need to carry out the tests for **FA 4**.

The volumes given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

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



Table 1.1

test	observations			
	FA 1 (H_2SO_4)	FA 2 (HCl)	FA 3 (HCOOH)	FA 4 (ethanoic acid)
1. Add about 2 cm depth of FA 1 in a test-tube. Add a piece of magnesium into FA 1 . Repeat using FA 2 and FA 3, in place of FA 1.	There is vigorous/faster effervescence observed. Gas evolved “pops” with a lighted splint. Gas is hydrogen.	There is vigorous/faster effervescence observed. Gas evolved “pops” with a lighted splint. Gas is hydrogen.	There is slower effervescence observed. Gas evolved “pops” with a lighted splint. Gas is hydrogen.	There is slower effervescence observed. Gas evolved “pops” with a lighted splint. Gas is hydrogen.
2. To a 1 cm depth of dilute sulfuric acid in a test-tube, add 2 drops of aqueous potassium manganate(VII). Then add 2 cm depth of FA 1 . Place the test-tube in a hot water bath. Repeat using FA 2 and FA 3, in place of FA 1.	No observable change.	No observable change.	Purple KMnO_4 decolorised to form a colourless solution. (or Purple KMnO_4 turned yellow / orange / brown)	No observable change.

[3]

M1
M2
M3



- (ii) Complete Table 1.2 with the identities of **FA 3** and **FA 4**. Give evidence from the observations in Table 1.1 to support your conclusions.

Table 1.2

	identity	evidence
FA 3	HCOOH	FA 3 undergoes acid-metal displacement / redox reaction with Mg with slow effervescence of H₂ gas. FA 3 undergoes oxidation and decolourised purple KMnO₄ (allow yellow / brown solution formed).
FA 4	CH ₃ COOH	FA 4 undergoes acid-metal displacement / redox reaction with Mg with slow effervescence of H₂ gas. FA 4 did not undergo oxidation with KMnO₄ and no observable change with purple KMnO₄ / purple KMnO₄ remained purple.

[2]

M4
M5

- (iii) Carry out **one** additional test that allows you to distinguish between **FA 1** and **FA 2**. Your tests should be based on the Qualitative Analysis Notes on pages 20–21 and should use only the bench reagents provided. Record your tests and observations in the space below.

Test	Observations	
	FA 1	FA 2
Test for Cl⁻ To 1 cm depth of FA 1 in a test-tube, add 1 cm depth of AgNO₃(aq) in a test-tube Repeat using FA 2 instead of FA 1 .	No observable change/ No ppt formed.	White ppt formed.

OR

Test for SO₄²⁻ To 1 cm depth of FA 1 in a test-tube, add 1 cm depth of Ba(NO₃)₂ (aq) . Repeat using FA 2 instead of FA 1 .	White ppt formed.	No observable change/ No ppt formed.
---	-------------------	---

FA 1 is H₂SO₄

FA 2 is HCl

[2]

M6
M7



- (b) In this question, you will investigate the chemistry of vanadium ions.

FA 5 contains vanadate(V) ions, VO_3^- .

When **FA 5** is acidified and reacted with a metal **M**, a series of colour changes can be observed during the reaction.

You will carry out tests to study the reaction of acidified **FA 5** with the metal **M**. Record your observations in Table 1.3.

In these reactions, you do **not** need to test for any gas that is evolved.

Table 1.3

	Tests	Observations
(i)	Place 2 cm depth of FA 5 into a boiling tube. Add 4 cm depth of sulfuric acid to the same boiling tube. Mix well and record any colour changes that occur.	<u>Colourless FA 5 solution turned (orange then) yellow</u> on acidification.
(ii)	Using a spatula, add metal M , a very small amount (about half spatula) at each time, into the boiling tube. Swirl after each addition. You are required to make 4 additions of metal M . Note: it is important to add M in small amounts in order to obtain accurate observations. You may leave the mixture to stand, swirling the boiling tube from time to time and observe the solution until no further changes are seen.	<u>Effervescence</u> observed. <u>Blue or green</u> solution formed. Then, <u>green / turquoise / blue-green / grey-blue</u> solution is formed. Then, <u>lilac/purple</u> solution formed. <div style="border: 1px solid red; padding: 5px; margin-top: 10px;">colours may vary, the 2nd colour should be of a darker shade than the colour before it. It does not matter at which addition of Zn the colour change or effervescence is observed.</div>
While you are waiting, continue with the other questions.		

M8

M9

[2]



- (c) The half equations that represent the stepwise reduction of VO_3^- ions are shown below.

Electrode reaction	E^\ominus / V
$\text{VO}_3^- + 4\text{H}^+ + \text{e}^- \rightleftharpoons \text{VO}^{2+} + \text{H}_2\text{O}$	+1.00
$\text{VO}^{2+} + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{V}^{3+} + \text{H}_2\text{O}$	+0.34
$\text{V}^{3+} + \text{e}^- \rightleftharpoons \text{V}^{2+}$	-0.26
$\text{V}^{2+} + 2\text{e}^- \rightleftharpoons \text{V}$	-1.20

The ions VO^{2+} , V^{3+} and V^{2+} have different colours.

A student suggested that metal **M** could be platinum, silver or zinc.

$[E^\ominus_{\text{Pt}^{2+}/\text{Pt}} = +1.18 \text{ V}; E^\ominus_{\text{Ag}^+/\text{Ag}} = +0.80 \text{ V}; E^\ominus_{\text{Zn}^{2+}/\text{Zn}} = -0.76 \text{ V}]$

With reference to the E^\ominus values and your observations in test (ii) of Table 1.3, give **two** reasons why metal **M** is likely to be zinc.

From (b)(ii), a colour change was observed. Since $E^\ominus_{\text{Pt}^{2+}/\text{Pt}}$ is more positive than $E^\ominus_{\text{VO}_3^-/\text{VO}^{2+}}$, Pt is not expected to reduce VO_3^- . Hence **M** is not Pt.

There is also more than one colour change. Since $E^\ominus_{\text{Ag}^+/\text{Ag}}$ is less positive than $E^\ominus_{\text{VO}_3^-/\text{VO}^{2+}}$ but more positive than $E^\ominus_{\text{VO}^{2+}/\text{V}^{3+}}$, Ag reduces VO_3^- to VO^{2+} only/reduces by only 1 step. Hence **M** is not Ag.

There were 3 colour changes observed. Since $E^\ominus_{\text{Zn}^{2+}/\text{Zn}}$ is less positive than $E^\ominus_{\text{V}^{3+}/\text{V}^{2+}}$ but more positive than $E^\ominus_{\text{V}^{2+}/\text{V}}$, Zn reduces VO_3^- to V^{2+} /reduces by 3 steps. Hence **M** is likely to be Zn.

**any two of the above [accept if E_{cell} is computed to justify]
accept any other chemically sound arguments**

M10

M11

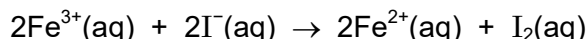
[2]

: 11]

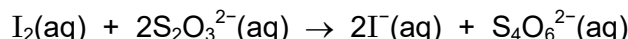


2 Investigation of the effect of concentration on rate of reaction

In acidic solutions, iron(III) ions oxidise iodide ions, I^- , to iodine, I_2 .



The rate of this 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. The blue-black colour is seen when all the thiosulfate has reacted.



You will investigate how the rate of reaction is affected by changing the concentration of the iodide ions.

FA 6 is $0.0500 \text{ mol dm}^{-3}$ potassium iodide, KI.

FA 7 is $0.0500 \text{ mol dm}^{-3}$ acidified iron(III) chloride, FeCl_3 .

FA 8 is $0.00500 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 9 is starch indicator.

You should read through the whole method before starting any practical work.

(a) Method

Experiment 1

- Fill a burette with **FA 6**.
- Run 20.00 cm^3 of **FA 6** into a 100 cm^3 beaker and place it on a white tile.
- Use a 50.0 cm^3 measuring cylinder to add the following to the same 100 cm^3 beaker:
 - 20 cm^3 of **FA 8**
 - 10 cm^3 of **FA 9**
- Use the 10 cm^3 measuring cylinder labelled **FA 7** to measure 10.0 cm^3 of **FA 7**.
- Add this **FA 7** into the same 100 cm^3 beaker and start timing immediately.
- Stir the mixture once with a glass rod.
- Stop timing as soon as the solution turns blue-black. Ignore any colour changes that occur before the intense blue-black colouration.
- Record this reaction time to the nearest second in Table 2.1.
- Wash out the beaker and dry it with a paper towel. Rinse and dry the glass rod.

Experiment 2

- Run 10.00 cm^3 of **FA 6** into the 100 cm^3 beaker.
- Use a second 10.0 cm^3 measuring cylinder to add deionised water into the beaker containing **FA 6**.
- Use the 50.0 cm^3 measuring cylinder to add the following to the same 100 cm^3 beaker:
 - 20 cm^3 of **FA 8**
 - 10 cm^3 of **FA 9**
- Use the 10 cm^3 measuring cylinder labelled **FA 7** to measure 10.0 cm^3 of **FA 7**.
- Add this **FA 7** into the same 100 cm^3 beaker and start timing immediately.
- Stir the mixture once with a glass rod.
- Stop timing as soon as the solution turns blue-black. Ignore any colour changes that occur before the intense blue-black colouration.
- Record this reaction time to the nearest second in Table 2.1.
- Wash out the beaker and dry it with a paper towel. Rinse and dry the glass rod.



Experiments 3 and 4

- Carry out **two** further experiments to investigate how the reaction time changes with different volumes of **FA 6**.
The combined volume of **FA 6** and deionised water must always be 20.0 cm³.
Use volumes of **FA 6** that are between 10.00 and 20.00 cm³.

Results

The rate of reaction can be calculated as shown:

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

Use this expression to calculate the rate for each of your experiments and record the values in Table 2.1. Give your answer to 3 significant figures.

Table 2.1

SAMPLE RESULTS

Expt	volume of FA 6 / cm ³	volume of FA 7 / cm ³	volume of deionised water / cm ³	reaction time / s	rate / s ⁻¹
1	20.00	10.0	0.0	14	71.4
2	10.00	10.0	10.0	44	22.7
3	13.00	10.0	7.0	29	34.5
4	17.00	10.0	3.0	18	55.6

[1] Precision - All times are recorded to the nearest second, burette measurements to 2 d.p. and measuring cylinder measurements to 1 d.p.

[1] Volumes of **FA 6** for experiment 3 & 4 are chosen such that they are between 10.00 & 20.00 cm³ (excluding) and all readings are more than 2 cm³ apart.
In all experiments, water is added to keep the total volume of **FA 6** and water at 20.0 cm³.

[1] All relative rates correctly computed and given to 3 s.f.

[2] Accuracy
Compare ratio of (time for 10.00 cm³ **FA 6**) / (time for 20.00 cm³ **FA 6**) with that of supervisor.

[5] M12

M13

M14

M15

M16



- (b) On the grid in Fig. 2.1. below, plot a graph of rate of reaction against volume of **FA 6** added. Include the origin as one of your data points.

Draw a line of best fit. Label any points you consider anomalous.

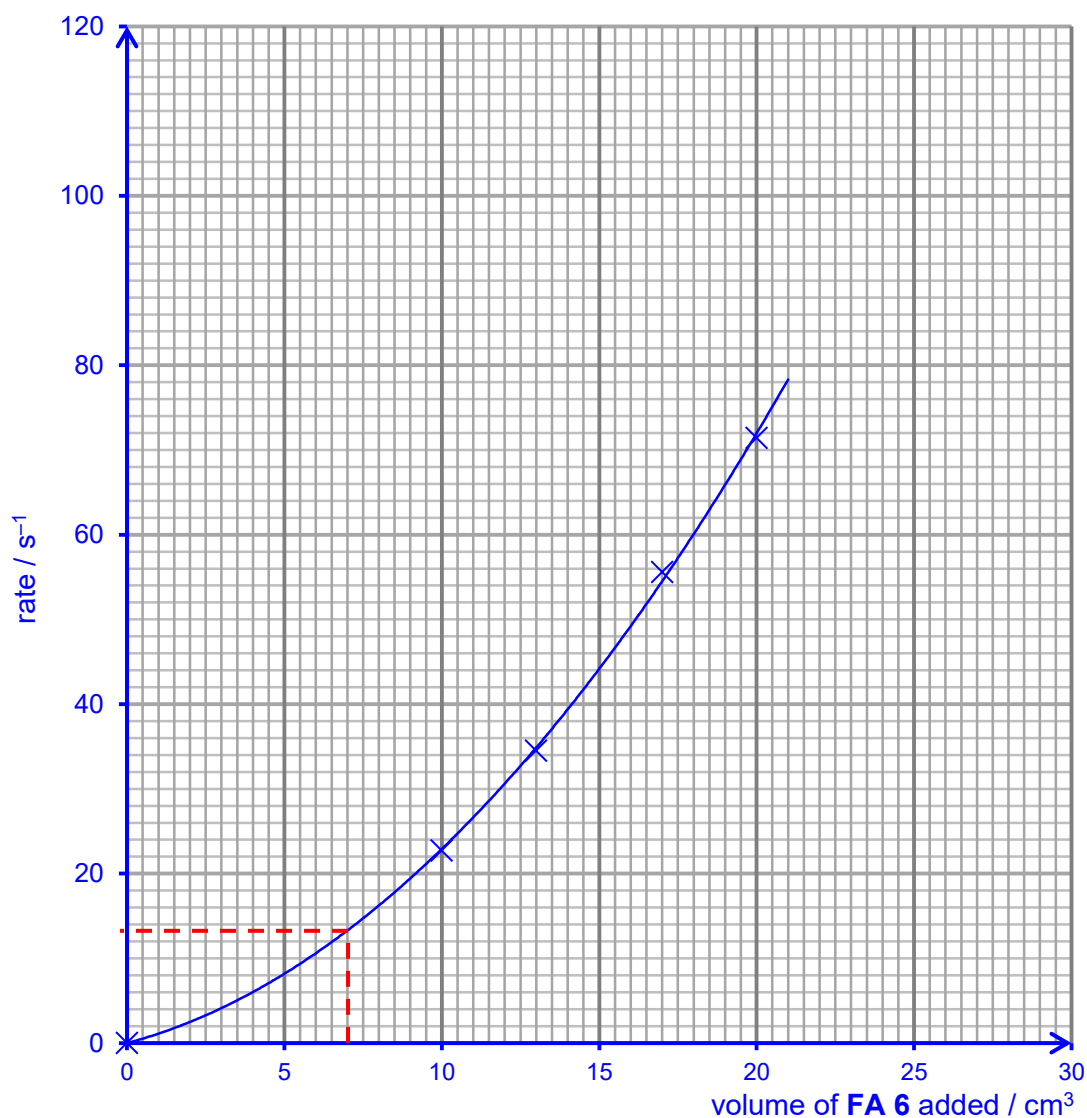


Fig 2.1

[3]

- (c) (i) Using data from **Experiments 1** and **2**, show by calculation that the volume of aqueous potassium iodide, **FA 6**, used was directly proportional to the concentration of iodide ions.

$$[\text{I}^-] \text{ in expt 1} = \frac{20.0}{60.0} \times 0.0500 = 0.00167 \text{ mol dm}^{-3}$$

$$[\text{I}^-] \text{ in expt 2} = \frac{10.0}{60.0} \times 0.0500 = 0.000833 \text{ mol dm}^{-3}$$

Since $\frac{0.00167}{0.000833} = \frac{20.0}{10.0} = \frac{2}{1}$, volume of **FA 6** used is directly proportional to $[\text{I}^-]$ in reaction mixture.

[2]

M17
M18
M19
M20
M21



- (ii) Explain, with reference to the shape of your graph, how the rate of reaction is affected by an increase in the concentration of aqueous potassium iodide, **FA 6**.

If a curve is drawn: The line drawn is a curve with increasing gradient (or rate increases more than conc.) \Rightarrow rate is not directly proportional to concentration / rate increases at a greater rate than concentration.

If a straight line is drawn, passing through / near the origin: rate is directly proportional to concentration of iodide ions as the graph is a straight line with positive gradient passing through origin.

M22

[1]

- (d) A student carried out the same experiment but used 7.00 cm^3 of **FA 6**. The student recorded a value for the reaction time of 70 seconds.

- (i) Use your graph to calculate the time, to the nearest second, that you would have expected to record if you had carried out an experiment using 7.00 cm^3 of **FA 6**.
Show the construction lines on your graph and show your working in the calculation.

From the graph, when volume of **FA 6** used = 7.00 cm^3 , rate = 13 s^{-1}

Hence reaction time = $1000/13 = \underline{77 \text{ s}}$

M23

M24

time = **77** s [2]

- (ii) Calculate the percentage difference between your value and that of the student, as a percentage of the student's value.

% difference = $(7/70) \times 100 = \underline{10.0 \%}$

M25

percentage difference = **10.0** % [1]

- (d) A fifth experiment is to be carried out where the concentrations of potassium iodide, sodium thiosulfate and starch indicator are the same as in **Experiment 2**, but the concentration of iron(III) ions should be twice the value that it is in **Experiment 2**.

State the volume of each solution that should be used for this fifth experiment.

You do not need to carry out this experiment.

reagent	volume / cm^3
FA 6	10.00
FA 7	20.0
FA 8	20.0
FA 9	10.0
distilled water	0.0

M26



[1]

- (e) Thiosulfate ions can also reduce iron(III) ions.

A student carries out the same investigation as in (a) but the solutions are mixed in a different order. The student places **FA 6** and an appropriate volume of distilled water in one beaker and all the other reactants in a second beaker. The student then transfers the mixture from the second beaker to the first and starts timing.

The student proposed that, even though thiosulfate ions are known to reduce iron(III) ions, his method was as good as the method used in (a). Suggest why his assessment is appropriate.

Although $\text{S}_2\text{O}_3^{2-}$ reacts with Fe^{3+} , the decrease in $[\text{S}_2\text{O}_3^{2-}]$ is consistent throughout the runs and so the effect is cancelled out.

OR

Since $[\text{S}_2\text{O}_3^{2-}]$ is very low, the reaction between $\text{S}_2\text{O}_3^{2-}$ and Fe^{3+} is very slow. Hence there is negligible change in $[\text{S}_2\text{O}_3^{2-}]$ and/or $[\text{Fe}^{3+}]$ before transferring to the second beaker.

M27

[1]

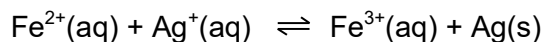
Total: 16]



3 Determination of the equilibrium constant of a reaction

Aqueous iron(II) ions, $\text{Fe}^{2+}(\text{aq})$, are usually kept in acidic conditions to prevent them readily oxidising to aqueous iron(III) ions, $\text{Fe}^{3+}(\text{aq})$.

$\text{Fe}^{2+}(\text{aq})$ ions react with $\text{Ag}^+(\text{aq})$ ions in a redox reaction. The following equilibrium is established.



The concentration of $\text{Fe}^{2+}(\text{aq})$ at equilibrium can be found by titration with a standard solution of aqueous potassium manganate(VII), $\text{KMnO}_4(\text{aq})$.

The equilibrium constant for the reaction can be found using the following equation:

$$K_c = \frac{[\text{Fe}^{3+}(\text{aq})]_{\text{eqm}}}{[\text{Fe}^{2+}(\text{aq})]_{\text{eqm}} \times [\text{Ag}^+(\text{aq})]_{\text{eqm}}}$$

(a) An experiment to find the value of the above K_c can be carried out as follows:

1. Equal volumes of $0.200 \text{ mol dm}^{-3} \text{ Ag}^+(\text{aq})$ solution and $0.200 \text{ mol dm}^{-3} \text{ Fe}^{2+}(\text{aq})$ solution are mixed in a large conical flask **A** and shaken.
2. Conical flask **A** is stoppered and left for four hours and shaken intermittently.
3. Conical flask **A** is then left untouched for a further hour to allow any solids to settle.
4. The solution in flask **A** is then carefully decanted into a second conical flask **B**, taking care to leave any solids behind.
5. Solid NaCl is carefully added to conical flask **B** to precipitate all the Ag^+ as AgCl . The resulting mixture is then filtered.

(i) Suggest why conical flask **A** is left for four hours in step 2.

The flask is left for four hours to allow the mixture to reach equilibrium.

[1]

M28

(ii) State the identity of the solid that is found at the bottom of conical flask **A** in step 3.

Ag/silver

[1]

M29

(b) The filtrate obtained from step 5 in (a) contains $\text{Fe}^{2+}(\text{aq})$ ions. The concentration of the $\text{Fe}^{2+}(\text{aq})$ ions in the filtrate can be determined by titrating with KMnO_4 in the presence of acid.

FA 10 is the filtrate from step 5 in (a) which contains $\text{Fe}^{2+}(\text{aq})$ ions.

FA 11 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

Solution A is 1 mol dm^{-3} sulfuric acid.

In this question, you will carry out the titration to determine the concentration of $\text{Fe}^{2+}(\text{aq})$ in **FA 10**.



(i) Titration of FA 10 against FA 11

1. Fill the burette labelled **FA 11** with **FA 11**.
2. Use a pipette to transfer 25.0 cm^3 of **FA 10** into a 250 cm^3 conical flask.
3. Use the measuring cylinder labelled **A** to add 25.0 cm^3 of **Solution A** into the same conical flask.
4. Titrate the mixture in the conical flask until a permanent pale pink colour is obtained.
5. Record your titration results, to an appropriate level of precision, in the space provided below.
6. Repeat points 2 to 5 until consistent results are obtained.

Titration results

Final burette reading / cm^3	<div style="border: 1px solid black; padding: 5px; text-align: center; color: green; font-weight: bold;">SAMPLE RESULTS</div>	
Initial burette reading / cm^3		
Volume of FA 11 used / cm^3	21.10 ✓	21.10 ✓

M30
M31
M32

[3]

- (ii) From your titration, obtain a suitable volume of **FA 11** to be used in your calculations.
Show clearly how you obtained this volume.

Average volume of **FA 6** = $(21.10 + 21.10) \div 2 = \underline{21.10}$

volume of **FA 11** = $\underline{21.10} \text{ cm}^3$ [3]

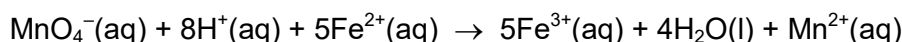
M33
M34
M35

[Turn over]





- (c) The ionic equation for the reaction in the titration is shown.



Calculate the concentration of $\text{Fe}^{2+}(\text{aq})$ in **FA 10**.

$$\begin{aligned}\text{Amount of MnO}_4^- &= 0.0200 \times (21.10/1000) \quad [\text{conc of KMnO}_4 \times \text{titre value in (ii)}] \\ &= 4.22 \times 10^{-4} \text{ mol}\end{aligned}$$



$$\begin{aligned}\text{Amount of Fe}^{2+} \text{ in } 25.0 \text{ cm}^3 \text{ of FA 10} &= 5(4.22 \times 10^{-4}) = 2.11 \times 10^{-3} \text{ mol} \\ &\quad 5 \times \text{mol. of KMnO}_4\end{aligned}$$

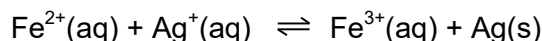
$$\begin{aligned}[\text{Fe}^{2+}(\text{aq})] &= (2.11 \times 10^{-3}) \div (25.0/1000) \\ &= \underline{\underline{0.0844 \text{ mol dm}^{-3}}}\end{aligned}$$

M36

M37

concentration of $\text{Fe}^{2+}(\text{aq})$ in **FA 10** = mol dm⁻³ [2]

- (d) The equilibrium is shown.



- (i) Given that the answer you have obtained in (c) is the concentration of $\text{Fe}^{2+}(\text{aq})$ in the equilibrium mixture, $[\text{Fe}^{2+}(\text{aq})]_{\text{eqm}}$, determine the concentration of $\text{Fe}^{3+}(\text{aq})$ in the equilibrium mixture, $[\text{Fe}^{3+}(\text{aq})]_{\text{eqm}}$.

	$\text{Fe}^{2+}(\text{aq}) + \text{Ag}^+(\text{aq}) \rightleftharpoons \text{Fe}^{3+}(\text{aq}) + \text{Ag}(\text{s})$		
Initial conc.	0.100	0.100	0
Eqm conc.	0.0844		

$$\begin{aligned}[\text{Fe}^{3+}(\text{aq})] &= 0.100 - 0.0844 = \underline{\underline{0.0156 \text{ mol dm}^{-3}}} \\ &\quad 0.100 - \text{ans(b)}\end{aligned}$$

M38

$[\text{Fe}^{3+}(\text{aq})]_{\text{eqm}} = \dots\dots\dots \text{mol dm}^{-3}$ [1]

- (ii) Suggest why it is **not** necessary to measure $[\text{Ag}^+(\text{aq})]_{\text{eqm}}$, the concentration of $\text{Ag}^+(\text{aq})$ ions in the equilibrium mixture, experimentally.

Since the initial concentrations of $\text{Ag}^+(\text{aq})$ and $\text{Fe}^{2+}(\text{aq})$ were the same

and the reacting mole ratio is 1:1, concentration of $\text{Ag}^+(\text{aq})$ at

equilibrium is the same as $\text{Fe}^{2+}(\text{aq})$.

[1]

M39



- (iii) Determine the value of K_c . Include units in your answer.

$$K_c = \frac{[\text{Fe}^{3+}(\text{aq})]_{\text{eqm}}}{[\text{Fe}^{2+}(\text{aq})]_{\text{eqm}} \times [\text{Ag}^+(\text{aq})]_{\text{eqm}}}$$

$$= \frac{0.0156}{0.0844 \times 0.0844} = \underline{2.19 \text{ dm}^3 \text{ mol}^{-1}}$$

$\text{ans(c)(i)} \div [\text{ans(b)}]^2$

M40
M41
M42

$K_c = \dots\dots\dots$ [3]

- (e) In step 5 of the experiment describe in part (a), addition of a large excess of sodium chloride would result in inaccurate titre values obtained for the titration. Suggest how the titre value would be affected. Explain your answer.

The titre value would be larger as the excess chloride ions would also react with the KMnO_4 titrant.

M43

[1]

- (f) A student proposed that the titration should be carried out using KMnO_4 of a lower concentration in order to obtain a larger titre.

Suggest one reason why a larger titre is better than a smaller titre.

A larger titre will result in a lower percentage error.

M44

[1]

[Total: 17]



4 Planning

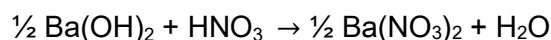
FA 12 is a saturated solution of $\text{Ba}(\text{OH})_2$.

FA 13 is concentrated HNO_3 .

The reaction between an acid and a metal hydroxide is exothermic, making it possible to determine the equivalence point of a neutralisation reaction through thermometric titration.

By monitoring the temperature change as **FA 12** is gradually added to a fixed volume of **FA 13** solution, distinct temperature patterns emerge. A graph of temperature against volume of **FA 12** added allows for the graphical determination of the equivalence point and the maximum temperature reached through careful extrapolation.

A thermometric titration can therefore be performed to determine the concentration of **FA 12** and the enthalpy change of neutralisation for the following reaction:



- (a) To prepare **FA 12**, a saturated solution of $\text{Ba}(\text{OH})_2$, an excess amount of solid $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ is typically dissolved in a specific volume of water. The resulting solution is then filtered to obtain the saturated solution as the filtrate.

The solubility of $\text{Ba}(\text{OH})_2$ at laboratory conditions is in the range of $0.17 - 0.19 \text{ mol dm}^{-3}$.

Determine the maximum mass of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ that can be dissolved in 100 cm^3 of water.
[A_r : Ba, 137.3; O, 16.0; H, 1.0]

Maximum amount of $\text{Ba}(\text{OH})_2$ in 1 dm^3 of saturated solution of $\text{Ba}(\text{OH})_2 = 0.19 \text{ mol}$

Amount of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O} \equiv \text{Ba}(\text{OH})_2 = 0.19 \text{ mol}$

M_r of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O} = 137.3 + 18 + 160 = 315.3$

Maximum mass of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ in 1000 cm^3 of water = $315.3 \times 0.19 = 59.9 \text{ g}$

Maximum mass of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ in 100 cm^3 of water = $315.3 \times 0.19 = 5.99 \text{ g}$

Maximum mass of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O} = \dots\dots\dots [2]$

M45
M46



- (b) Using the mass of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$, that you have determined in (a), you are to plan a thermometric titration experiment of 10 cm^3 of **FA 13** with **FA 12** to determine the enthalpy change of neutralisation, ΔH_n , for the reaction between barium hydroxide and nitric acid.

You are provided with:

- 10 g of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$,
- 30 cm^3 of **FA 13**,
- Styrofoam cup,
- digital probe thermometer,
- any other equipment normally found in a school or college laboratory.

Outline how you would carry out the proposed thermometric titration using only the materials provided.

In your plan, you should include:

- the details of how you would prepare 100 cm^3 **FA 12** solution,
- brief, but specific, details of the apparatus you would use, considering the levels of precision they offer,
- the quantities you would use,
- measurements you would make to allow for a graph of temperature against volume of **FA 12** added to be drawn, in order to determine the value of ΔH_n for this reaction, and
- how you would recognise that the equivalence point had been passed.

• the apparatus you would use	
<input type="checkbox"/> appropriate apparatus (beaker, glass rod/stirrer, measuring cylinder, filter funnel for FA 12 preparation, Styrofoam cup, burette, digital probe thermometer) [at least 5]	M47
• the quantities you would use	
<input type="checkbox"/> specify volume of FA 13 as 10 cm ³ <input type="checkbox"/> mass of solid Ba(OH) ₂ .8H ₂ O used (use mass from (a) or adds solid until ppt formed/does not dissolve) <input type="checkbox"/> 100 cm ³ of water to form FA 12 (if other volume used, the amount of Ba(OH) ₂ .8H ₂ O must tally correspond)	M48
• the procedure you would follow to make 100 cm ³ of FA 4 solution	
general procedure includes: <input type="checkbox"/> addition of sufficient solid so that some remains undissolved and filtering to form saturated solution of FA 12 <input type="checkbox"/> stirring to ensure the formation of saturated solution <input type="checkbox"/> allowing solution to stand/equilibrate (1 minute or more) and then filtering	M49
• the procedure you would follow to do a thermometric titration	
<input type="checkbox"/> general procedure of adding suitable volume of FA 12 to fixed volume of FA 13 and use thermometer to measure the temperature,	M50
• the measurements you would make	
<input type="checkbox"/> takes the following temperature measurements: 1. Initial temperature 2. Highest temperature after <u>each</u> addition of FA 12	M51
• how you would recognise the equivalence point had been passed	
<input type="checkbox"/> continue to add portion of FA 12 to the solution and measure the temperature even after the temperature starts to drop. <input type="checkbox"/> adds at least 3 more portions of FA 12 to the solution after the temperature starts to drop.	M52



Sample Answer

1. Using a 100 (or 250) cm^3 measuring cylinder, transfer 100 cm^3 of deionised water into a 250 cm^3 beaker.
2. Add solid $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ in small increments with a spatula into the water, stirring the solution with a glass rod after each addition.
3. Repeat step 2 until precipitation of solid is seen/some solid remains insoluble. Allow the solution to stand for 1 to 2 minutes.

Or

2. Add in all the given $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ into the water, stir the solution well with a glass rod.
3. Allow the solution to stand for 1 to 2 minutes.
4. Using filter paper and filter funnel, filter the solution into a clean 250 cm^3 beaker to remove the undissolved solid. The filtrate obtained is **FA 12**.
5. Using 10 cm^3 pipette (or 10 cm^3 measuring cylinder), transfer 10.0 cm^3 of FA 13 into a Styrofoam cup placed inside a 250 cm^3 beaker. Use a digital probe thermometer to measure and record the initial temperature of the **FA 13** solution.
6. Fill a burette with **FA 12**.
7. Add 5.00 cm^3 of FA 12 from a burette into the Styrofoam cup containing the **FA 13** solution. Stir the mixture and record the highest temperature reached.
8. Repeat step 7 until the recorded temperature begins to decrease. Afterward, add 3-5 more 5.00 cm^3 portions of FA 12, recording the highest temperature reached after each addition.

M47

M48

M49

M50

M51

M52

[6]

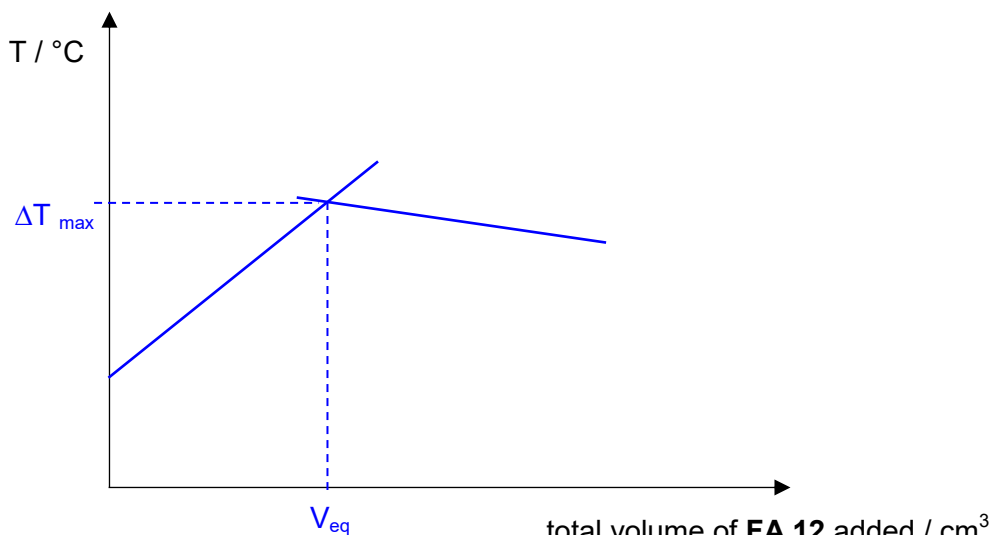


- (c) From the thermometric titration, a graph of temperature against total volume of **FA 12** added can be plotted.

On the axes below, sketch the graph you would expect to obtain.

You should also indicate on your graph,

- the volume of **FA 12** added at equivalence point, V_{eq} , and
- the maximum temperature reached, T_{max} .



M53
M54
[2]

- (d) Outline how you would use the measurements in your plan in (b) and your graph to determine the value for ΔH_n , the enthalpy change of neutralisation between barium hydroxide and nitric acid.

You may use the following symbols:

- V_{eq} : volume of **FA 12** added at equivalence point (cm^3)
 T_{ini} : initial temperature ($^{\circ}\text{C}$)
 T_{max} : maximum temperature reached ($^{\circ}\text{C}$)
 n_{HNO_3} : amount of nitric acid (mol)

Assume that 4.18 J is required to raise the temperature of 1 cm^3 of the solution by 1 $^{\circ}\text{C}$.

$$Q = mc\Delta T = (10 + V_{\text{eq}}) \times 4.18 \times (T_{\text{max}} - T_{\text{ini}})$$

$$\text{Amount of H}_2\text{O} = \text{Amount of HNO}_3 = n_{\text{HNO}_3}$$

$$\Delta H_n = - \left(\frac{(10 + V_{\text{eq}}) \times 4.18 \times (T_{\text{max}} - T_{\text{ini}})}{n_{\text{HNO}_3}} \right)$$

[1]

M55

[Total: 11]



Qualitative Analysis Notes*[ppt. = precipitate]***(a) Reactions of aqueous cations**

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



(b) Reactions of anions

<i>ion</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 excess dilute strong acids)

(c) Tests 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

