NAME **Mark Schemes** CLASS **21S**

JURONG PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION 2022

CHEMISTRY **9729/04**

Higher 2

Paper 4 Practical

16 August 2022

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 exam 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, graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

Qualitative Analysis Notes are printed on pages 18 and 19.

At the end of the examination, fasten all your work securely together.

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

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
4	
Total	

This document consists of **19** printed pages.

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

1 Determination of the percentage by mass of iron in a sample of iron wire

Iron wire contains impurities. You will investigate the percentage by mass of iron in a sample of iron wire.

A sample of iron wire is reacted with an excess of sulfuric acid to produce a solution of iron(II) sulfate.

$$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$$

You will titrate the solution of iron(II) sulfate with potassium manganate(VII) of known concentration to determine the amount of iron(II) ions present and hence the percentage by mass of iron in the wire. You may assume the impurities do not form any products that react with potassium manganate(VII).

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

FA 1 is a solution of $FeSO_4$ prepared by reacting 3.03 g of iron wire with sulfuric acid to make 500 cm^3 of solution.

FA 2 is 3.16 g dm^{-3} potassium manganate(VII), $KMnO_4$.

FA 3 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Method

1. Fill the burette labelled "**FA 2**" with **FA 2**.
2. Pipette 25.0 cm^3 of **FA 1** into a conical flask.
3. Use the 50 cm^3 measuring cylinder to transfer 25 cm^3 of **FA 3** to the same conical flask.
4. Titrate this mixture with **FA 2** 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.

Results

Final burette reading / cm^3	25.30	25.30
Initial burette reading / cm^3	0.00	10.00
Volume of FA 2 used / cm^3	25.30	25.30
	✓	✓

[1] Gives a **proper table with correct headings** ('**burette**' must be stated) **and units**. Do **not** award if any final and initial burette readings are inverted.

[1] Records **all burette readings** to the **nearest 0.05 cm^3 (2 d.p.)** + **computes all titres correctly**. Do **not** award if 50 is used as initial burette reading or burette reading is > 50.

[1] Obtains **two uncorrected titres within 0.10 cm^3** + **places tick (✓) or shows selected titres in exact form in the average working in (b)**. [3]

(b) From your titrations, obtain a suitable volume of **FA 2**, $V_{FA\,2}$, to be used in your calculations. Show clearly how you obtained this volume.

$V_{FA\,2} = \frac{25.30 + 25.30}{2} = 25.30\ cm^3$

[1] Obtains **average correctly to 2.d.p.** from any expts with uncorrected end-point titre values **within 0.20 cm^3**.

Do **not** award this mark if the **titres used are not identified either in the table (by ticks) or in the calculation**.

Accuracy:
Round any burette readings to the nearest 0.05 cm^3.
Check and correct subtractions in the titre table.
Select the "best" titre using the hierarchy:
two identical; titres within 0.05 cm^3, titres within 0.10 cm^3 etc.

Supervisor's average titre = 25.20 cm^3

[2] within 0.2
[1] within 0.4

$V_{FA\,2}$ = **25.30 cm^3** [3]

(c) **(i)** Calculate the amount of $KMnO_4$ present in the volume of **FA 2**, $V_{FA\,2}$, calculated in **(b)**.

[A_r: O, 16.0; K, 39.1; Mn, 54.9]

$n(KMnO_4) = \frac{3.16}{158.0} \times \frac{V_{FA\,2}}{1000}$ **[1]**

$= \frac{3.16}{158.0} \times \frac{25.30}{1000} = 5.06 \times 10^{-4}$ mol

amount of MnO_4^- present = **5.06×10^{-4} mol** [1]

(ii) Calculate the amount of Fe^{2+} ions in 25.0 cm^3 of **FA 1**.

$n(Fe^{2+})$ in 25.0 cm^3 of FA 1
= 5 × ans.(c)(i) **[1]**
$= 5 \times 5.06 \times 10^{-4} = 2.53 \times 10^{-3}$

$KMnO_4$	:	$FeSO_4$
1	:	5

amount of Fe^{2+} ions = **2.53×10^{-3} mol** [1]

(iii) Calculate the percentage by mass of iron in the sample of iron wire.

[A_r: Fe, 55.8]

$n(Fe^{2+})$ in 500 cm^3 of FA 1

$= \text{ans.(c)(ii)} \times \frac{500}{25.0}$ [1]

$= 2.53 \times 10^{-3} \times \frac{500}{25.0} = 0.0506$ mol

% mass of Fe $= \frac{0.0506 \times 55.8}{3.03} \times 100 = 93.2$ % [1] ecf

percentage by mass of iron in the wire = 93.2 % [3]

[1] Shows appropriate workings for (c)(i)-(iii)
+ gives correct units for (b) and (c)(i)-(iii)
+ gives all final ans to 3sf in (c)(i)-(iii)

(d) The maximum error in any single burette reading is ±0.05 cm^3.

(i) State the maximum possible error in the volume run from the burette recorded in any titration.

± 0.10 cm^3 [1] with sign [1]

(ii) Explain how an error of (**–0.10**) cm^3 may arise when using a burette to obtain an individual titre value.

Initial burette reading has an error of +0.05 cm^3 and the final burette reading has an error of –0.05 cm^3. [1]

Total error = Final – initial = (-0.05) – (+0.05) = -0.10 cm^3 [1]

(e) A student suggested that when a piece of iron wire was dissolved in a known volume and concentration of sulfuric acid, the number of moles of iron that reacted with the acid could be determined by working out how much acid was left after the reaction. The amount of excess acid could be determined by titrating the mixture with a known concentration of sodium hydroxide.

Explain whether the student was correct.

The student was incorrect as sodium hydroxide would also react with Fe^{2+} in the mixture to form $Fe(OH)_2$ ppt. [1] OWTTE

Furthermore, the impurities in the wire might react with sodium hydroxide. [1]

[Total: 14]

2 Investigation of the kinetics of the reaction between $I^-(aq)$ and $Fe^{3+}(aq)$

Iron(III) ions, $Fe^{3+}(aq)$, and iodide ions, $I^-(aq)$, react to give iodine, $I_2(aq)$, in the presence of acid.

reaction 2 $2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$

If acidified iron(III) chloride and potassium iodide are mixed in the presence of starch indicator and sodium thiosulfate, the iodine liberated reacts immediately with the thiosulfate ions and is reduced back to iodide ions.

reaction 3 $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

When all the thiosulfate ions have reacted, the iodine which continues to be produced then turns the starch indicator blue-black. The rate of *reaction 2* may be determined by timing how long it takes for the reaction to turn blue-black.

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

FA 4 is 0.0500 mol dm^{-3} potassium iodide, KI(aq)
FA 5 is 0.0500 mol dm^{-3} acidified iron(III) chloride, $FeCl_3(aq)$,
FA 6 is 0.00500 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3(aq)$
FA 7 is starch indicator.

Read through the whole method carefully and prepare a table for your results on page 6 before starting any practical work.

(a) Method

Experiment 1

1. Fill the burette labelled "**FA 4**" with **FA 4**.
2. Run 20.00 cm^3 of **FA 4** into the 100 cm^3 beaker.
3. Use the 50 cm^3 measuring cylinder to add the following to the same 100 cm^3 beaker:
   - 20.0 cm^3 of **FA 6**
   - 10.0 cm^3 of **FA 7**
4. Place the beaker on the white tile and stir the contents of the beaker using a glass rod.
5. Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 5**.
6. Add this **FA 5** into the same 100 cm^3 beaker and start timing immediately at the instant of mixing.
7. Stir once. The reaction mixture will turn *light brown* and then *pale yellow* before a sudden intense blue-black colouration is observed. Stop timing as soon as the solution turns blue-black.
8. Record this reaction time, **t**, to the nearest 0.1 s.
9. Wash out the beaker and dry it with a paper towel.

Experiment 2

1. Fill another burette with deionised water.
2. Run 7.00 cm^3 of **FA 4** into the 100 cm^3 beaker.
3. Run 13.00 cm^3 of deionised water into the beaker containing **FA 4**.
4. Use the 50 cm^3 measuring cylinder to add the following to the same 100 cm^3 beaker:
   - 20.0 cm^3 of **FA 6**
   - 10.0 cm^3 of **FA 7**
5. Place the beaker on the white tile and stir the contents of the beaker using a glass rod.
6. Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 5**.
7. Add the **FA 5** to the same 100 cm^3 beaker and start timing immediately at the instant of mixing.
8. Stir once and stop timing as soon as the solution turns blue-black.
   Note: This may take **more than 2 minutes**.
9. Record this reaction time, **t**, to the nearest 0.1 s.
10. Wash out the beaker and dry it with a paper towel.

Experiments 3 – 5

Carry out three further experiments to investigate how the reaction time, **t**, changes with different volumes of potassium iodide, **FA 4**.
The combined volume of **FA 4** and deionised water must always be 20.00 cm^3.
Do not use a volume of **FA 4** that is less than 6.00 cm^3.

Record all your results in a single table in the space provided below. You should include the experiment number, volume of **FA 4**, $V_{\mathbf{FA\ 4}}$, volume of water, V_{water}, and the reaction time, **t**.

You should also include the 'rate of reaction' which is to be calculated as shown:

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

For each experiment, the value of the 'rate of reaction' is to be recorded to 3 significant figures.

Results

Experiment No.	$V_{FA\ 4}$ / cm^3	V_{water} / cm^3	t / s	Rate of reaction / s^{-1}
1	20.00	0.00	20.9	47.8
2	7.00	13.00	144.9	6.90
3	10.00	10.00	77.1	13.0
4	14.00	6.00	41.3	24.2
5	17.00	3.00	29.1	34.4

[1] gives **a single table** with correct **required headers with units**.
(units can be stated with **each entry** of data).

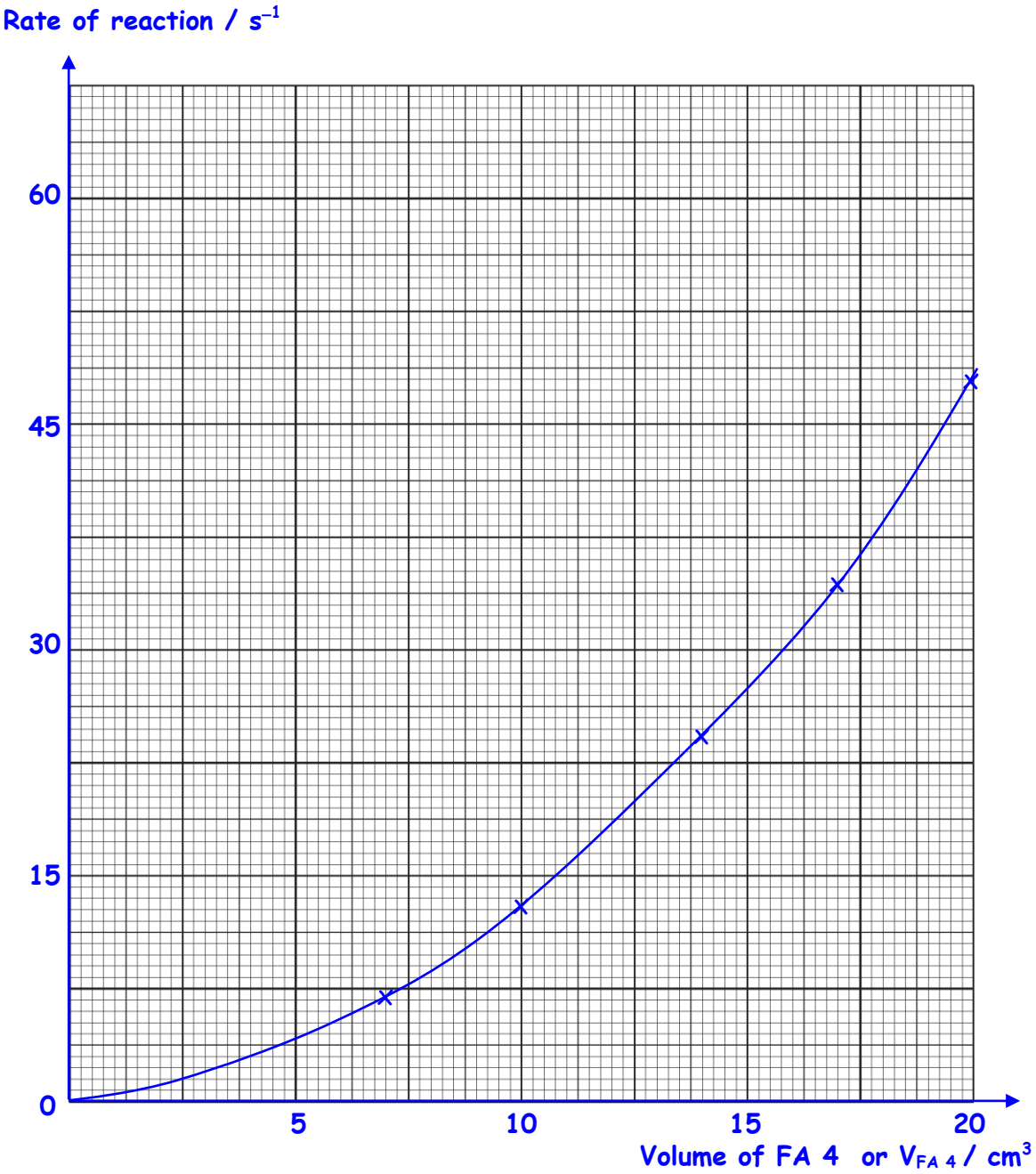
[1] records **all $V_{FA\ 4}$ and V_{water} to the nearest 0.05 cm^3**
+ **all *t* to the nearest 0.1 s**

[1] **correctly calculates all rates to 3 significant figures**

[1] gives **three additional expts** with **6.00 cm^3 < $V_{FA\ 4}$ < 20.00 cm^3**
+ **no $V_{FA\ 4}$ < 3 cm^3 close to another volume**
+ **$V_{FA\ 4}$ + V_{water} = 20.00 cm^3**

[1] obtains correct trend of **$V_{FA\ 4}$ increases, t decreases** [5]

(b) (i) On the grid below, plot a graph of rate of reaction (y-axis) against volume of **FA 4** (x-axis). Include the origin, (0,0), in your scale. Circle any points you consider anomalous and draw a line of best fit.



[1] Labels axes correct way round with correct units + uses linear scales that include plotted points & (0,0) which cover more than half of the given grid in both directions + scale includes (0,0). Do not award this mark if awkard scale is used (e.g. 1 for 3/7).

[1] Plots all points correctly within correct ½ small square.
Do not award this mark if awkard scale is used or the scale used is too small such that plotting is done through estimation or non-linear scale is used.

[1] Draws a straight-line or a smooth curve of best-fit (considered points should not be more than 1 small square from the chosen line and should not include the origin) + circle anomalous point if any (allows only one).

(b) **(ii)** Explain, by referring to your graph, how the rate of reaction is affected by an increase in the concentration of aqueous potassium iodide, **FA 4**.

Since the total volume of each reaction mixture is kept constant, volume of FA 4 used is directly proportional to the initial [KI] in the reaction mixture.

- **A straight line with positive gradient that passes through the origin** **[1]** is obtained. Hence, the **rate is directly proportional to [KI]** (or **rate ∝ [KI]** or **rate is first order w.r.t. [KI]**) **[1] OWTTE**
- **A straight line with positive gradient** **[1]** that does not pass through the origin is obtained. Hence, the **rate is proportional to [KI]**.**[1] OWTTE**
- **A curve with increasing gradient** **[1]** is obtained. Hence, **as the [KI] increases, the rate increases more**. **[1] OWTTE** [2]

(c) Thiosulfate ions can also react with acid to form sulfur, sulfur dioxide and water.

(i) Write an ionic equation for the reaction between thiosulfate ions and hydrogen ions in aqueous solution. Include state symbols.

$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(aq)/(g) + H_2O(l)$ **[1] with s.s.** [1]

(ii) A student carries out the same investigation as in **(a)** but the solutions are mixed in different order. The student places **FA 4** and appropriate volume of deionised water in one beaker and all other reactants in a second beaker. The student then transfers the mixture from the second beaker to the first and starts timing.

Tick the box for the statement you consider correct. Explain your answer.

The student's method is better than in **(a)**.	☐
The two methods are equally good.	☐
The student's method is not as good as that in **(a)**.	✓

Reason: **H^+/Fe^{3+}/FA 5 will react away some $S_2O_3^{2-}$/FA 6**. **Less $S_2O_3^{2-}$/FA 6 will be left** in the reaction mixture before starting the experiment. So the **reaction time** for each experiment will be **shorter than expected**. **[1]**

OR, The two methods are equally good. ✓

Reason: **Concentration of $S_2O_3^{2-}$/FA 6 is very small such that the reaction between $S_2O_3^{2-}$/FA 6 and H^+/FA 5 is very slow**. So there is **negligible/no effect on the reaction time/t** for each expt. **[1]** [1]

(d) Another student investigates the effect of iron(III) concentration on the rate of this reaction.

The student carries out another experiment, **Experiment 6**, and the rate is compared to that of **Experiment 2**.

In **Experiment 2**, the volumes used were:

reagent	Volume / cm^3
FA 4	7.00
FA 5	10.0
FA 6	20.0
FA 7	10.0
deionised water	13.00

(i) Suggest the volumes the student could use for **Experiment 6**.

reagent	Volume / cm^3
FA 4	**7.00**
FA 5	**20.0**
FA 6	**20.0**
FA 7	**10.0**
deionised water	**3.00**

[1] To change $V_{FA\ 5}$; keeping $V_{FA\ 4}$, $V_{FA\ 6}$ & $V_{FA\ 7}$ all unchanged; and $V_{FA\ 5} + V_{water} = 23\ cm^3$
(To ignore precision of all volume measurements) [1]

(ii) This student records a time of 140 s for **Experiment 2.**

The rate of reaction is directly proportional to the concentration of iron(III) ions.

Suggest how long it would take the reaction mixture proposed for **Experiment 6** in **(d)(i)** to turn blue-black. Assume that **Experiment 6** is carried out at the same temperature as **Experiment 2**.

Do not carry out **Experiment 6**.

Since rate $\propto [Fe^{3+}]^1$, reaction time = $\frac{10}{V_{FA\ 5}} \times 140 = 70\ s$

[1] to the nearest s/ 0.1 s/ 3 s.f.

reaction time = **70** s [1]

(e) When **FA 4**, **FA 5** and **FA 6** are mixed, the following three reactions occur.

reaction 1 $Fe^{3+}(aq) + 2S_2O_3^{2-}(aq) \rightleftharpoons [Fe(S_2O_3)_2]^-(aq)$
yellow *purple*

reaction 2 $2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$

reaction 3 $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

When **FA 5** was added to the solution prepared in step 6 of **Experiment 1**, the reaction mixture turned *light brown* and then *pale yellow* before the blue–black colour appeared.

The *light brown* colour is due to a mixture of purple $[Fe(S_2O_3)_2]^-(aq)$ and yellow $Fe^{3+}(aq)$ in the reaction mixture. Explain why the *light brown* solution turns *pale yellow* before the appearance of blue-black colour.

As the reaction 2 proceeds, both **[Fe^{3+}] and [$S_2O_3^{2-}$] decreases** **(✓)** and cause the **position of equilibrium/poe of reaction 1 to shift left** to form back some Fe^{3+} and $S_2O_3^{2-}$. **(✓)** Hence the solution gradually became pale yellow due to increase in [$Fe^{3+}(aq)$].

2(✓) [1] [1]

[Total: 15]

3 Qualitative Analysis

Solid **FA 8** contains the polyatomic anion, X^{2-}, and one cation from the ions listed in the *Qualitative Analysis Notes*.

FA 9 is an aqueous solution containing a sodium salt of the polyatomic anion, X^{2-}.

FA 10 is organic solution containing one functional group.

You will perform tests to

- identify the cation present in **FA 8**
- deduce the nature of **FA 8**
- deduce the identity of X^{2-}
- identify the functional group present in **FA 10**

(a) (i) Perform the tests described in Table 3.1, and record your observations in the table. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

Table 3.1

	tests	observations
1	Place a spatula measure of **FA 8** in a test-tube and add 1-2 cm depth of aqueous iron(II) sulfate. Shake the tube well until all **FA 8** dissolves.	• solution turns yellow/ brown/ orange-brown/ orange. (✓)
2	Place a spatula measure of **FA 8** in a boiling tube and add 1 cm depth of dilute nitric acid to dissolve the solid. Then add 1 cm depth of aqueous manganese(II) sulfate and 4 drops of aqueous silver nitrate to act as a catalyst. Heat cautiously to bring the mixture to boiling.	• Colourless solution. (✓) • Upon heating, solution turns brown (✓) to a dark-brown/ black ppt. (✓)
3	To a spatula measure of **FA 8** in a boiling tube, add 1–2 cm depth of aqueous sodium hydroxide. Heat cautiously.	• No ppt./ colourless solution/ no observable change. (✓) • Upon heating, pungent NH_3 (✓) gas evolved and • turns damp red litmus paper blue.(✓)

6-7(✓) [3]; 3-5(✓) [2]; 2(✓) [1] [3]

(ii) Identify the cation in **FA 8**.

cation: NH_4^+ **[1]** [1]

(iii) State, with supporting evidences, the nature (*acidic, basic, amphoteric, oxidising or reducing*) of **FA 8**.

nature of **FA 8**: **oxidising or oxidising agent** **[1]**

evidence: **FA 8 oxidises pale green Fe^{2+} in $FeSO_4(aq)$/Test 1 to yellow/brown Fe^{3+}** and **oxidises colourless Mn^{2+} in $MnSO_4(aq)$/Test 2 to brown Mn^{3+} and dark brown/black MnO_2.** **[1]** [2]

(b) **(i)** **FA 9** is an aqueous solution containing a sodium salt of the polyatomic anion, $\mathbf{X^{2-}}$.

In aqueous solution, $\mathbf{X^{2-}}$ reacts very slowly with water to produce anion **P**, H^+ ions and oxygen gas.

reaction 4 $2H_2O(l) + 2\mathbf{X^{2-}}(aq) \rightarrow 4\mathbf{P}(aq) + 4H^+(aq) + O_2(g)$

Perform the tests described in Table 3.2, and record your observations in the table. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

Table 3.2

tests		observations
1	Test solution **FA 9** with Universal Indicator paper.	UI paper turns **dark orange/ orange-brown** (✓), **pH 2/2-3/3** (✓)
2	To 1 cm depth of **FA 9** in a boiling tube, add 1 cm depth of aqueous sodium hydroxide and a piece of aluminium foil. Warm the mixture cautiously.	**Effervescence/Bubbles** (✓) of H_2 noted. **No NH_3/no observable change** (✓) with damp red litmus paper.
3	To 1 cm depth of **FA 9** in a test-tube, add 1 cm depth of aqueous barium nitrate. Then add dilute nitric acid until no further change occurs.	**White ppt.** (✓) ppt. **insoluble in** excess dilute nitric **acid**. (✓)

5-6(✓) [3]; 3-4(✓) [2]; 2(✓) [1] [3]

(ii) Identify the anion **P**. Hence, use *reaction 4* equation to deduce the identity of $\mathbf{X^{2-}}$.

Anion **P**: SO_4^{2-} **[1]**

$2H_2O + 2S_2O_8^{2-} \rightarrow 4SO_4^{2-} + 4H^+ + O_2$

$\mathbf{X^{2-}}$ is $S_2O_8^{2-}$ **[1]** [2]

(c) You are provided with an organic solution **FA 10** which contains one functional group.

> **Care: FA 10 is flammable. Do not use Bunsen burner for heating. Use the hot water provided if heating is required.**

FA 10 gives a positive test with 2,4–dinitrophenylhydrazine.

Devise one other confirmatory test using the bench reagents provided to identify the functional group present in **FA 10**.

Carry out the test. Record details of the test performed and observations made in Table 3.3.

Table 3.3

Confirmatory Test	*Observations*
To 1 cm depth of **FA 10** in a test-tube, **add** 1-2 cm depth of **dilute H_2SO_4 and** a few drops of **$KMnO_4$(aq)**. **Heat** in hot water-bath. **[1]**	**Purple** $KMnO_4$ **decolourised**. **[1]**
To 1 cm depth of **aqueous $AgNO_3$** in a test-tube, **add** 1 cm depth of **aqueous NaOH**. Then **add aqueous NH_3** until the precipitate just dissolves. To this mixture, **add** 1 cm depth of **FA 10**. **Heat** the mixture in the hot water-bath. **[1]**	Brown Ag_2O ppt. dissolves to give a colourless solution of $Ag(NH_3)_2^+(aq)$. A **silver mirror/grey ppt.** is formed. **[1]**

Functional group present in **FA 10**: **aldehyde** **[1]**

- **If the test result is negative, accept ketone but award [0] for observations.**

[3]

[Total: 14]

4 Planning

Enthalpy change of neutralisation, ΔH_n, is the heat evolved when one mole of water is formed from the reaction of an acid and an alkali.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l) \qquad \Delta H_n < 0$$

When aqueous hydrochloric acid, HC*l*(aq) is mixed with aqueous sodium hydroxide, NaOH(aq), the neutralisation reaction releases heat causing a rise in the temperature of the solution.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) \qquad \Delta H_n < 0$$

A series of experiments can be performed where increasing volumes of HC*l*(aq) and decreasing volumes of NaOH(aq) are mixed and the temperature rise, ΔT, for each experiment is determined.

In each of the experiments using different volumes of HC*l*(aq) and NaOH(aq), the total volume has to be kept constant. Since the total volume of mixture remains the same, the temperature rise, ΔT, is a direct measure of the heat liberated by the reaction. The maximum amount of heat is evolved when all the acid present is exactly neutralised by all the alkali present.

Plotting a graph of ΔT against the volume of HC*l*(aq) used will give 2 straight lines of best–fit.

Extrapolation of the two straight lines will produce a point of intersection from which the concentration of HC*l*(aq) and the enthalpy change of neutralisation, ΔH_n, between HC*l*(aq) and NaOH(aq) can be determined.

The volume of HC*l*(aq) used should be at least 10.00 cm^3 and the total volume of the reaction mixture should be kept constant at 50.00 cm^3 for all experiments.

(a) Using the information given, you are required to write a plan to determine the concentration of HC*l*(aq) and the enthalpy change of neutralisation, ΔH_n, between HC*l*(aq) and NaOH(aq).

You may assume that you are provided with:

- 250 cm^3 of HC*l*(aq) of unknown concentration
- 250 cm^3 of 1.50 mol dm^{-3} NaOH(aq),
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of:

- the apparatus you would use,
- the quantities you would use, including suggested volumes of HC*l*(aq) and NaOH(aq),
- the procedure you would follow,
- the measurements you would make to allow a suitable ΔT against the volume of HC*l*(aq) graph to be drawn.

1. **Fill the burette with *HCl*(aq)**.
2. Place the styrofoam cup in a 250 cm^3 beaker to prevent it from tipping over. **Transfer 10.00 cm^3 of *HCl*(aq) into the styrofoam cup**. **Measure the temperature of the *HCl*(aq)** in the cup **using the** 0.2 °C interval **thermometer**. **Record the initial temperature of *HCl*(aq) as T_1**.
3. Wash and dry the thermometer.
4. **Use a 50 cm^3 measuring cylinder to measure 40.0 cm^3 of NaOH(aq)**. **Measure the temperature of the NaOH(aq)** in the measuring cylinder using the thermometer. **Record the initial temperature of NaOH(aq) as T_2**.
5. ***Add* NaOH(aq) from the measuring cylinder to *HCl*(aq) in the cup**. **Stir the mixture using the thermometer and record the maximum temperature reached, T_{max}**.

[1] uses appropriate apparatus

- **burette/50 cm^3 measuring cylinder for *HCl***
- **burette/50 cm^3 measuring cylinder for NaOH**
- **styrofoam/plastic/polystyrene cup**
- **thermometer**

[1] measures initial temp. of *HCl* & NaOH before mixing (step 2 & 4).

[1] measures the maximum temp. reached after mixing (step 5).

6. Wash and dry the styrofoam cup.
7. **Repeat steps 2 to 6 using 15.00 cm^3, 20.00 cm^3, 25.00 cm^3, 30.00 cm^3, 35.00 cm^3 and 40.00 cm^3 of *HCl*(aq) and appropriate volumes of NaOH(aq) each time, such that the total volume of the reacting mixture is 50 cm^3**. (OR **Repeat steps 2 to 6 using the volumes of *HCl*(aq) and NaOH(aq) stated in the table below**.)

[1] uses volume of *HCl* between (10-45) cm^3;
uses volume of NaOH between (5-40) cm^3;
total volume = 50 cm^3;

[1] obtains min 6 data points.

8. For **each reaction mixture, ΔT is calculated based on the following**:

$$\Delta T = T_{max} - T_{initial}$$

$$\text{where } T_{initial} = \frac{(\text{Volume of } HCl(aq) \times T_1) + (\text{Volume of NaOH(aq)} \times T_2)}{50}$$

[1]

Volume of HCl(aq) / cm^3	Volume of NaOH(aq) / cm^3	T_1 / °C	T_2 / °C	T_{max} / °C	$T_{initial}$ / °C	ΔT / °C
10.00	40.0					
15.00	35.0					
20.00	30.0					
25.00	25.0					
30.00	20.0					
35.00	15.0					
40.00	10.0					
45.00	5.0					

[6]

(b) Sketch on Fig 4.1 the graph you would expect to obtain from your results.

Indicate clearly on your sketch how you would determine:

- V_{neut}, the volume of HCl(aq) needed to just completely neutralise (50 – V_{neut}) cm^3 of NaOH(aq).
- ΔT_{max}, the maximum temperature rise when stoichiometric amount of HCl(aq) and NaOH(aq) reacted.

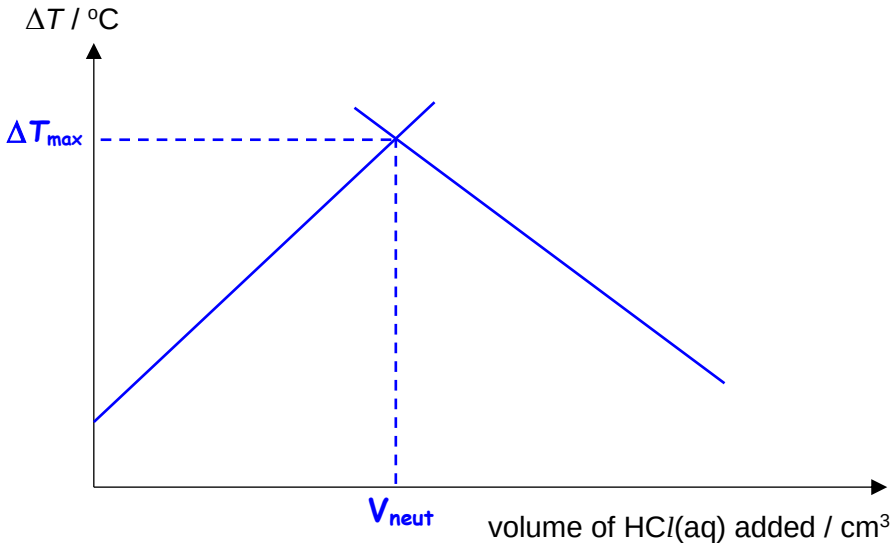


Fig 4.1

[1] gives correct graph
[1] indicates V_{neut} and ΔT_{max} correctly

[2]

(c) Outline how you would use your answers from **(b)** to determine

(i) the concentration, in mol dm^{-3}, of HC*l*(aq).

Express your results in terms of V_{neut}. It is not necessary to simplify the expression in your final answer.

Amount of NaOH in $(50-V_{neut})$ cm^3
= amount of HCl in V_{neut} cm^3
$= \left(\frac{50 - V_{neut}}{1000} \times 1.50\right)$ mol [1]

Concentration of HCl
$= \frac{1000}{V_{neut}} \times \left(\frac{50 - V_{neut}}{1000} \times 1.50\right)$ mol dm^{-3} [1]

Max [1] if student uses V_{neut} for V_{NaOH} and $(50-V_{neut})$ for V_{HCl}. [2]

(ii) the enthalpy change of neutralisation, ΔH_n, for this reaction.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) \qquad \Delta H_n$$

Express your answers in terms of ΔT_{max} and V_{neut}. It is not necessary to simplify the expression in your final answer.

You should assume that the specific heat capacity of the final solution is 4.18 J g^{-1} K^{-1} and its density is 1.00 g cm^{-3}.

Heat change, $q = mc\Delta T$
$= (50.0 \times 1.00)(4.18)(\Delta T_{max})$
$= 209\Delta T_{max}$ J $= 0.209\Delta T_{max}$ kJ [1] ans. in J or kJ

Amount of water formed = n(NaOH) reacted
= n(HCl) reacted
$= \left(\frac{50 - V_{neut}}{1000} \times 1.50\right)$ mol (ecf from (i))

$\Delta H_{neut} = - \frac{(0.209\Delta T_{max})}{\left(\frac{50 - V_{neut}}{1000} \times 1.50\right)}$ kJ mol^{-1} [1] ecf + sign + units

[2]

[Total: 12]

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

Anion	***Reaction***
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
choride, 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; NO liberated by dilute acids (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 on warming with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids)

(c) Tests for Gases

gas	***Test and test results***
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 acidified aqueous 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