NAME **Mark Scheme** CLASS **22S**

JURONG PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION 2023

CHEMISTRY **9729/04**

Higher 2

Paper 4 Practical

15 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 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.

For Examiner's Use

1 Determination of the kinetics of the reaction between iodide ions and peroxodisulfate ions

FA 1 is 0.0200 mol dm^{-3} potassium peroxodisulfate, $K_2S_2O_8$.

FA 2 is 1.00 mol dm^{-3} potassium iodide, KI.

FA 3 is 0.00500 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.

starch indicator.

Equation 1 represents the reaction between peroxodisulfate ions, $S_2O_8^{2-}$, and iodide ions, I^-.

equation 1 $\quad S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$

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

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

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

You will perform a series of five experiments. Then you will graphically analyse your results in order to determine the order with respect to the concentration of the peroxodisulfate ions, $[S_2O_8^{2-}]$.

For each experiment, you will note the volume of **FA 1** added, $V_{\mathbf{FA1}}$, and the time taken, t, for the reaction mixture to turn blue-black.

In each experiment, you will add a fixed amount of sodium thiosulfate, **FA 3**, to each of your experiments. You will need to ensure that the same total volume of reaction mixture is used by adding deionised water as required.

You will then calculate values for

- $1/t$,
- $\lg(1/t)$,
- $\lg(V_{FA1})$

Prepare a table in the space provided on page 4 in which to record, to an appropriate level of precision:

- all volumes, except the volumes of **FA 2**, **FA 3** and starch indicator,
- all values of t,
- all calculated values of $1/t$, $\lg(1/t)$, $\lg(V_{\mathbf{FA1}})$ to 3 significant figures.

BLANK PAGE

(a) Experiment 1

1. Fill the burette labelled **FA 1**, with **FA 1**.
2. Run 20.00 cm^3 of **FA 1** into a 100 cm^3 beaker labelled **Beaker A**.
3. Using appropriate measuring cylinders, add the following to the second 100 cm^3 beaker labelled **Beaker B**:
   - 20.0 cm^3 of **FA 2**
   - 10.0 cm^3 of **FA 3**
4. Add 10 drops of starch indicator to **Beaker B**.
5. Add the contents of **Beaker A** to **Beaker B** and start timing immediately.
6. Stir the mixture thoroughly using the glass rod and place the beaker on a white tile.
7. Stop timing as soon as the solution turns blue-black.
8. Record the time taken, *t*, to the nearest 0.1 s in your table.
9. Wash out both beakers thoroughly with water and shake dry. Rinse and dry the glass rod.

Experiments 2 to 5

Repeat experiment 1 four times, adding 18.00, 14.00, 10.00 and 6.00 cm^3 respectively, of **FA 1** at point 2.

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

Record all required volumes, time taken and calculated values in your table.

Results

Expt	V_{FA1}/ cm^3	V_{water}/ cm^3	t/ s	$1/t$ / s^{-1}	lg(1/*t*)	lg(V_{FA1})
1	20.00	0.00	13.4	0.0746	-1.13	1.30
2	18.00	2.00	14.9	0.0671	-1.17	1.26
3	14.00	6.00	19.4	0.0515	-1.29	1.15
4	10.00	10.00	27.3	0.0366	-1.44	1.00
5	6.00	14.00	48.3	0.0207	-1.68	0.778

[1] single table with correct headers and units

[1] correct precision of recording.

- **Recorded volumes to 2.d.p (nearest 0.05 cm^3)**
- **all t to nearest 0.1s**
- **1/*t*, lg(1/*t*), lg(V_{FA1}) correctly calculated to 3.s.f.**

[1] 5 sets of data + correct volumes of deionised water [4]

- V_{FA1} as stated in the question
- $V_{FA1} + V_{water} = 20.00\ cm^3$

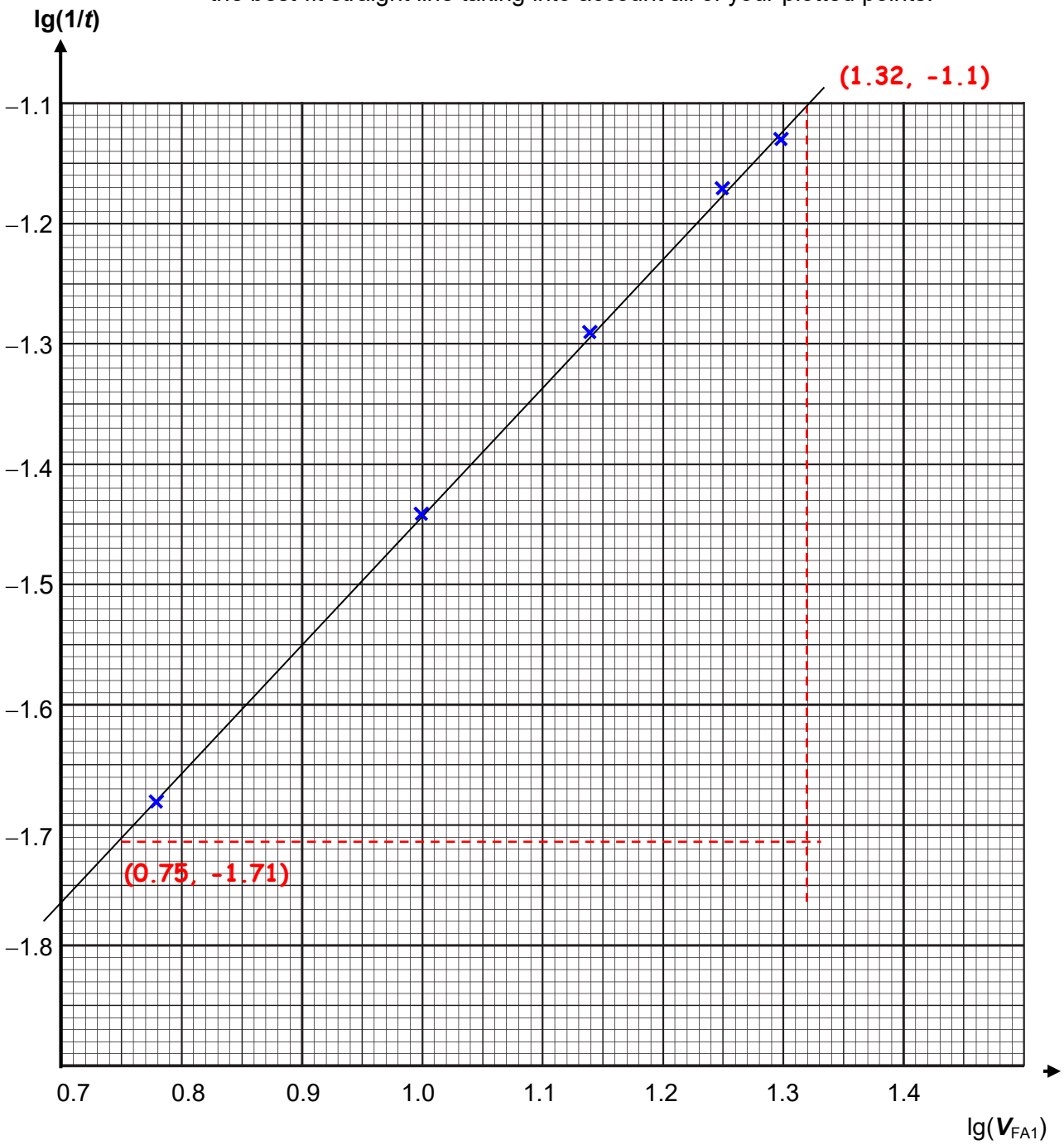
Accuracy:

Deviation in ratio of time for 10.00 cm^3 FA 1 / time for 20.00 cm^3 FA 1 btw Supervisor and student's titre, δ:

$$\delta \leq 0.10 \quad [1]$$

(b) (i) Plot a graph of lg(1/t) on the y-axis against lg(V_{FA1}) on the x-axis. Draw

the best-fit straight line taking into account all of your plotted points.



[1] Axes correct way round + correct labels with units + proper scale (plotted points occupy at least half of the given grid in both directions. Do not award this mark if student uses awkward scale (e.g. 1 for 3/7)
[1] All points clearly plotted to within correct ½ small square.
[1] Draw a line of best fit
Do not award this mark if:
- there is clearly a better line that could have been drawn through the points

[3]

(ii) Calculate the gradient of the line to three significant figures, showing clearly how you did this. Hence, deduce the order of the reaction with

respect to $[S_2O_8^{2-}]$.

Gradient = $\frac{(-1.10)-(-1.71)}{1.32-0.75}$ = **1.07**

[1] construction lines drawn on the graph.

- **The hypotenuse of the constructed "triangle" should cover at least half of the length of the line drawn by the candidate**
- **correctly reads to nearest ½ small square**

[1] calculates gradient correctly using the values read from the graph

$1/t \propto$ rate, $V_{FA1} \propto [S_2O_8^{2-}]$,

Rate = $k'[S_2O_8^{2-}]^n$

$1/t = k'(V_{FA1})^n$

$\lg(1/t) = \lg k' + n\lg(V_{FA1})$

$\lg(1/t) = n\lg(V_{FA1}) + \lg k'$ (y=mx+c graph)

n= gradient of line.

Order of reaction w.r.t. $[S_2O_8^{2-}]$ = **1** **[1]**

[1] correct conclusion of order

Gradient = ...

Order = ... [3]

(c) (i) A student thought that the experiment could be made more accurate by having longer reaction times. To do this, he repeated Experiment 1 with the same volumes but using 0.100 mol dm^{-3} sodium thiosulfate instead of

FA 3. He found that the reaction never turned blue-black. Explain why.

sodium thiosulfate is **in excess**. **All the iodine reacts** with the thiosulfate/ **no iodine produced** to turn blue-black). **[1]** [1]

(ii) Other than errors involving measurements of volume and time, suggest an additional source of error in these experiments and what improvement could be made to reduce this error.

Error: **Temperature** was **not** kept **constant**. **[1]**

Improvement: Use a **thermostatically controlled water bath** to **keep the temperature of the solutions constant**. **[1]** [2]

(d) **(i)** The experimental method can be modified to enable the rate of reaction with respect to $[I^-]$ to be investigated.

Equation 1 $S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$

In the first line in Table 1.1 below, the volumes of **FA 1**, **FA 2**, **FA 3** and deionised water used in **Experiment 1** are recorded.

Complete the following table, suggesting volumes for each of the reagents that could be used in one further experiment to investigate how the rate of reaction varies with a change in volume of potassium iodide, **FA 2**.

Do not carry out this experiment.

Table 1.1

Experiment	V_{FA1}/ cm^3	V_{FA2}/ cm^3	V_{FA3}/ cm^3	V_{water}/ cm^3
1	20	20	10	0
6	**20**	**15**	**10**	**5**

[1]

[1] only V_{FA2} and V_{H2O} changes, the rest of the volumes remain constant.

V_{FA2} + V_{H2O} = 20 cm^3

(ii) The overall order for the reaction in equation 1 is second order. Using your answer in **1(b)(ii)**, write a rate equation for the reaction.

Rate = k$[S_2O_8^{2-}][I^-]$ **[1] ecf from (b)(ii).** [1]

[Total: 15]

2. Determination of the percentage of mass of copper in FA 4

When excess of potassium iodide, KI, is added to the solution of Cu^{2+} ions, iodine, I_2,

and a precipitate of CuI is produced. The I_2 turns the solution brown.

equation 3 $2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$

I_2 has a relatively low solubility in water. However, the presence of an excess of I^- ions in the reaction mixture allows the soluble tri-iodide ion, I_3^-, to form as shown by equation 4. This ensures that the I_2 formed as shown in equation 3 is fully dissolved.

equation 4 $I_2 + I^- \rightarrow I_3^-$

The I_3^- ions formed may be titrated against a standard solution of $Na_2S_2O_3$ as shown in equation 5.

equation 5 $I_3^- + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 3I^-$

FA 4 is a solid compound containing Cu^{2+}.

FA 6 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.

You are also provided with

FA 2, 1.00 mol dm^{-3} potassium iodide, KI,

Starch indicator.

In this experiment, you will first prepare a solution of $Cu^{2+}(aq)$ using the **FA 4** provided. You will then perform a titration to determine the percentage by mass of copper in **FA 4**. You may assume that the no other components in **FA 4** take part in any of the reactions mentioned.

(a) (i) Preparation of FA 5 from FA 4

1. Weigh the weighing bottle containing **FA 4** and record this mass in Table 2.1.
2. Tip the **FA 4** into the 250 cm^3 beaker. Reweigh the weighing bottle including any residual **FA 4** and record this mass in Table 2.1.
3. Calculate the mass of **FA 4** used for the preparation of **FA 5**.

Table 2.1

Mass of **FA 4** and weighing bottle / g	10.482
Mass of weighing bottle and residual **FA 4** / g	5.487
Mass of **FA 4** used / g	4.995

4. Add approximately 150 cm^3 of deionised water to the beaker and stir until the **FA 4** has dissolved.
5. Transfer the solution and washings into a 250 cm^3 volumetric flask.
6. Make up to the mark with deionised water.
7. Stopper and shake the flask to obtain a homogeneous solution. Label this solution **FA 5**.

(ii) Titration of FA 5 against FA 6

1. Fill a burette with **FA 6**.

2. Use a pipette to transfer 25.0 cm^3 of **FA 5** into a 250 cm^3 conical flask.
3. Use the 25 cm^3 measuring cylinder to add 15 cm^3 of **FA 2**, an excess of KI, to the conical flask. A white precipitate forms in a brown solution.
4. Run **FA 6** from the burette into this conical flask. Near the end-point, when the brown solution becomes pale, add 10 drops of starch indicator. The mixture will turn blue-black.
5. Continue adding **FA 6** slowly. The end-point is reached when the **solution** first becomes colourless. The white precipitate remains.
6. Record your titration results, to an appropriate level of precision, in the space provided.
7. Repeat points 2 to 6 in **2(a)(ii)** until consistent results are obtained.

Titration results

Titration number	1	2
Final burette reading / cm^3	**19.60**	**39.30**
Initial burette reading / cm^3	**0.00**	**5.00**
Volume of FA6 used / cm^3	**19.60**	**19.70**
	✓	✓

[1] table with correct headings and units. (Do not award if any final and initial burette readings are inverted or *50 is used as initial burette reading.*)

[1] All burette readings are recorded to the nearest 0.05 cm^3 + correct computation of titres & M_{FA4} + all mass measurements to 3.d.p.

[1] Has two uncorrected titres for end-point within 0.10 cm^3. [3]

(iii) From your titrations, obtain a suitable volume of **FA 6**, $V_{FA\,6}$, to be used in your calculations. Show clearly how you obtained this volume.

$V_{FA\,6} = \frac{19.60+19.70}{2}$ = **19.65** cm^3 **[1] 2.d.p**

Accuracy:

Deviation btw Supervisor and student's V/m, δ:

$\delta \leq 0.03$ $cm^3 g^{-1}$ **[2]**

$0.03 < \delta \leq 0.06$ $cm^3 g^{-1}$ **[1]**

$V_{FA\,6}$ = **19.65** cm^3 [3]

(b) (i) Calculate the amount of thiosulfate present in $V_{FA\,6}$.

Amount of $S_2O_3^{2-} = \frac{19.65}{1000} \times 0.100 =$ **0.00197** mol **[1]** [1]

Amount of $S_2O_3^{2-}$ in $V_{FA\ 6}$ = **0.00197** mol

(ii) Calculate the mass of copper in **FA 4** that is used to prepare 250 cm^3 of **FA 5**. [A_r: Cu, 63.5]

$2S_2O_3^{2-} \equiv I_3^- \equiv 2Cu^{2+}$

nCu^{2+} in 25.0 cm^3 of FA 5 = 0.00197 mol

nCu^{2+} in 250 cm^3 of FA 5 = $0.00197 \times \frac{250}{25.0}$ mol

= **0.0197 mol** = nCu in sample of brass **[1]**

Mass of Cu in sample of FA 4 = 0.0197× 63.5 = **1.25 g [1]**

mass of Cu in **FA 4** used = ... [2]

(iii) Hence, determine the percentage by mass of copper in the sample of **FA 4** used.

% by mass of Cu in **FA 4** = $\frac{1.25}{4.995} \times 100$= **25.0** % **[1]**

percentage by mass of Cu in **FA 4** = ... [1]

(c) Calculate the percentage error of $V_{FA\ 6}$ calculated in **2(a)(iii).**

% error = $\pm\frac{2(0.05)}{19.65} \times 100$= ± **0.509 %** **[1]** [3]

[1] Shows working in all calculations AND

Shows appropriate significant figures (3sf) in all final answers in 1(b)(ii), 2(b)(i),(ii),(iii) and 2(c).

Any calculation not attempted loses this mark.

[1] Shows correct units in 2(a)(iii)[cm^3], 2(b)(i) [mol], 2(b)(ii) [g], 2(b)(iii) [%], 2(c) [%]

Any calculation not attempted loses this mark.

[Total: 13]

3 Investigation of some inorganic reactions and the identity of an organic compound

(a) **FA 7** is an aqueous solution containing Fe^{3+} and one anion from the ions listed in the *Qualitative Analysis Notes*.

You are also provided with

FA 6, 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.

Hydrogen peroxide, H_2O_2.

Carry out the tests described in Table 3.1. Some of the observations have been completed for you. There is no need to carry out those tests. Carefully record your observations in Tables 3.1.

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 3.1

	tests	observations
1	Add 2 cm depth of H_2O_2 into a test-tube. Add about a 2 cm depth of **FA 7** to the same test-tube and shake the mixture thoroughly. Observe the mixture until no further changes are seen.	Yellow **solution turns brown** (✓) then **turns** back to **yellow**. (✓) **Effervescence** (✓) observed. O_2 **gas relights glowing splint**. (✓)
2	Add 1 cm depth of **FA 7** into a test-tube. Add about a 2 cm depth of **FA 6** to the same test-tube and shake the mixture thoroughly. Observe the mixture **closely** until no further changes are seen.	**Solution turns deep purple** (✓) then pale brown then **pale yellow/ colourless**. (✓)
	Add aqueous sodium hydroxide slowly to the resulting solution, with shaking, until no further change is seen.	dirty **green ppt. insoluble in excess** (✓) turning brown on standing.
3	Add 1 cm depth of sodium thiosulfate, $Na_2S_2O_3$, into a test-tube. Add about a 1 cm depth of sulfuric acid to the same test-tube and shake the mixture thoroughly.	yellow precipitate is obtained. gas liberated which turns acidified potassium manganate(VII) from purple to colourless.

[3]

7(✓) [3]; 4-6(✓) [2] ; 1-3(✓) [1]

(i) A possible mechanism for the reaction between H_2O_2 and **FA 7** in test 1 from Table 3.1 is shown below.

step 1 $[Fe(H_2O)_6]^{3+}(aq) + H_2O_2(aq) = [Fe(H_2O)_5(O_2H)]^{2+}(aq) + H_3O^+(aq)$

step 2 $[Fe(H_2O)_5(O_2H)]^{2+}(aq) \rightarrow OH^-(aq) + [Fe(H_2O)_5(O)]^{3+}(aq)$

step 3 $[Fe(H_2O)_5(O)]^{3+}(aq) + H_2O_2(aq) \rightarrow [Fe(H_2O)_6]^{3+}(aq) + O_2(g)$

step 4 $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$

Using evidence from your observations in Table 3.1 and the mechanism, deduce the role of $[Fe(H_2O)_6]^{3+}(aq)$ ions in this reaction.

$[Fe(H_2O)_6]^{3+}(aq)$ is a catalyst. [1]

Yellow(✓) $[Fe(H_2O)_6]^{3+}(aq)$ is reacted (✓) in step 1 to form **brown $[Fe(H_2O)_5(O_2H)]^{2+}(aq)$/ intermediate(✓)**.

Then yellow **$[Fe(H_2O)_6]^{3+}(aq)$ regenerated (✓)** in step 3.

4(✓) [2]; 2-3(✓) [1] [3]

(ii) $S_2O_3^{2-}$ ions undergo two chemical reactions with Fe^{3+} ions in test 2 from Table 3.1. One reaction involves the formation of a deeply coloured $[Fe(S_2O_3)_2]^-$ complex.

Deduce the different roles played by $S_2O_3^{2-}$ ions in the two chemical reactions in test 2.

Ligand and **reducing agent [1]** [1]

(iii) From the observations provided for test 3 in Table 3.1, elemental sulfur and a gas is produced after the reaction of $S_2O_3^{2-}$ ions and H^+ ions.

Write a balanced ionic equation including state symbols for the reaction that occurred in test 3.

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

(iv) Devise and perform some simple tests to identify the anion in **FA 7**.

Your tests should be based on the *Qualitative Analysis Notes* on pages

23–24 and should use only the bench reagents provided.

Because **FA 7** is coloured, you may want to consider removing the Fe^{3+} present in **FA 7** so that it does not interfere with the anion tests.

Record the tests performed, the procedures used and the observations in the space below.

Any test requiring heating MUST be performed in a boiling tube.

The anion is not a nitrate, nitrite or sulfide ion.

tests	observations
To about 1 cm depth of **FA 7** in a test-tube, **add excess NaOH**(aq) (✓)	**Reddish brown ppt.** formed **insoluble in excess** (✓)
Filter(✓) the mixture into a clean test-tube	Reddish brown residue colourless filtrate
To 1cm depth of the filtrate add in equal volume of HNO_3(aq). Then add few drops of **$AgNO_3$**(aq) (✓) **followed by** excess **NH_3(aq)** (✓)	**White ppt.** (✓) **soluble in NH_3(aq)** (✓)

7(✓) [3]; 4-6(✓) [2] ; 1-3(✓) [1]

OR

tests	observations
To about 1 cm depth of **FA 7** in a test-tube, **add** a few drops of **$AgNO_3$**(aq) (✓)	**White ppt.** formed (✓)
Filter(✓) the resulting mixture into a test-tube and wash the residue with some deionised water.	White residue Yellow filtrate
Use a spatula to transfer some residue into a clean test-tube. **Add** excess **NH_3(aq) to the residue**. (✓)	**White ppt. soluble in NH_3(aq)** (✓)

5(✓) [3]; 3-4(✓) [2] ; 1-2(✓) [1] [3]

(v) Use your observations in **3(a)(iii)** to deduce the identity of the anion in **FA 7**.

Anion Cl^- [1] [1]

(b) **Y**, $C_4H_6O_2$, is a cyclic 5-membered organic compound which contains only one functional group. When **Y** is heated with aqueous sulfuric acid, **FA 8** is formed as the only organic product.

Carry out the following tests on **FA 8**. Carefully record your observations in Table 3.2.

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**.

Care: FA 8 is flammable. Do not use Bunsen burner for heating. Use the hot water provided if heating is required.

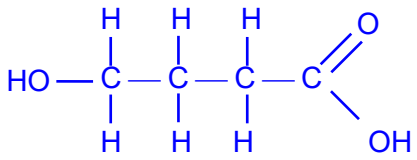
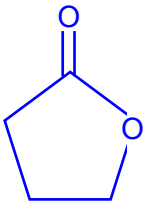
(i)

Table 3.2

	tests	observations
1	To 1 cm depth of **FA 8** in a test-tube, add a 1 cm depth of dilute sulfuric acid. Then add 1 drop of aqueous potassium manganate(VII). Place the test-tube in a beaker of hot water for two minutes.	Purple $KMnO_4$ decolourised. (✓)
2	To 2 cm depth of **FA 8** in a test-tube, carefully add half a spatula measure of sodium hydrogen carbonate.	Effervescence observed (✓) CO_2 gas gives a white ppt. with limewater. (✓)
3	Test solution **FA 8** with Universal Indicator paper.	UI paper turns red. (✓) pH=1/2 (✓)

5(✓) [3]; 3-4(✓) [2]; 1-2(✓) [1] [3]

(b) **(ii)** Use your observations in Table 3.2 and the information provided to suggest the structure of **FA 8** and hence deduce the structure of **Y**.

Structure of **FA 8**	Structure of **Y**
 [1]	 [1]

[2]

[Total: 17]

4 Planning

Citric acid, $C_6H_8O_7$, can be found in citrus fruit such as lemons and limes.

You are required to determine the enthalpy change for the reaction between citric acid and sodium hydrogencarbonate, $NaHCO_3$.

equation 6 $C_6H_8O_7(aq) + 3NaHCO_3(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l) + 3CO_2(g)$ ΔH_6

ΔH_6 is the enthalpy change when 1.00 mol of citric acid reacts completely with $NaHCO_3$.

When citric acid is mixed with $NaHCO_3$, the reaction absorbs heat causing a drop in the temperature of the solution.

A series of experiments can be performed where increasing volumes of citric acid and decreasing volumes of $NaHCO_3$ are mixed and the temperature drop, ΔT, for each experiment is determined.

In each of the experiments using different volumes of citric acid and $NaHCO_3$, the total volume has to be kept constant. The maximum amount of heat is absorbed when all the citric acid present is exactly reacted with the $NaHCO_3$ present.

Plotting a graph of ΔT against the volume of citric acid used will give 2 lines of best–fit.

Extrapolation of the two lines will produce a point of intersection from which the enthalpy change for the reaction between citric acid and $NaHCO_3$ can be determined.

The volume of citric acid 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 enthalpy change of reaction between citric acid and $NaHCO_3(aq)$, ΔH_6.

You may assume that you are provided with:

- 250 cm^3 of dilute citric acid of unknown concentration
- 250 cm^3 of 1.50 mol dm^{-3} $NaHCO_3(aq)$,
- 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 citric acid and $NaHCO_3(aq)$,
- the procedure you would follow,
- the measurements you would make,
- how the temperature drop, ΔT, is calculated to allow a suitable ΔT against the volume of citric acid graph to be drawn.

1. Fill the burette with citric acid. (✓) burette/50 cm^3 measuring cylinder to measure citric acid

2. Place the styrofoam cup in a 250 cm^3 beaker to prevent it from tipping over. Transfer 10.00 cm^3 of citric acid into the styrofoam cup. Measure the temperature of the citric acid in the cup using the 0.2 °C interval thermometer. Record the initial temperature of citric acid as T_1. (✓)Styrofoam cup (✓)thermometer (✓) measures initial temp. of citric acid before mixing

3. Wash and dry the thermometer.

4. Use a 50 cm^3 measuring cylinder to measure 40.0 cm^3 of $NaHCO_3$(aq). Measure the temperature of the $NaHCO_3$(aq) in the measuring cylinder using the thermometer. Record the initial temperature of $NaHCO_3$(aq) as T_2. (✓) burette/50 cm^3 measuring cylinder to measure $NaHCO_3$(aq) (✓) measures initial temp. of $NaHCO_3$(aq) before mixing

5. Add $NaHCO_3$(aq) from the measuring cylinder to citric acid in the cup. Stir the mixture using the thermometer and record the minimum temperature reached, T_{min}. (✓) mixing method (✓) measures the minimum temp. reached after mixing

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 citric acid and appropriate volumes of $NaHCO_3$(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 citric acid and $NaHCO_3$(aq) stated in the table below.) (✓) V_{acid} btw 10-45cm^3 V_{NaHCO3} btw 5-40cm^3 V_{total} = 50 cm^3 (can mark from table if given) (✓) min 6 data points.

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

   $\Delta T = T_{initial} - T_{min}$ (✓) ΔT calculation

   where $T_{initial} = \dfrac{(\text{Volume of citric acid} \times T_1) + (\text{Volume of } NaHCO_3\text{(aq)} \times T_2)}{50}$

   (✓) weighted $T_{initial}$

12(✓) [5]
9-11(✓) [4]
6-8(✓) [3]
4-5(✓) [2]
2-3(✓) [1]

Volume of citric acid / cm^3	Volume of $NaHCO_3$ (aq)/ cm^3	T_1 / °C	T_2 / °C	$T_{initial}$ / °C	T_{min} / °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					

[5]

(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_{eq}, the volume of citric acid needed to just completely react with $(50 - V_{eq})$ cm^3 of $NaHCO_3$(aq).
- ΔT_{max}, the maximum temperature drop when stoichiometric amounts of citric acid and $NaHCO_3$(aq) are reacted.

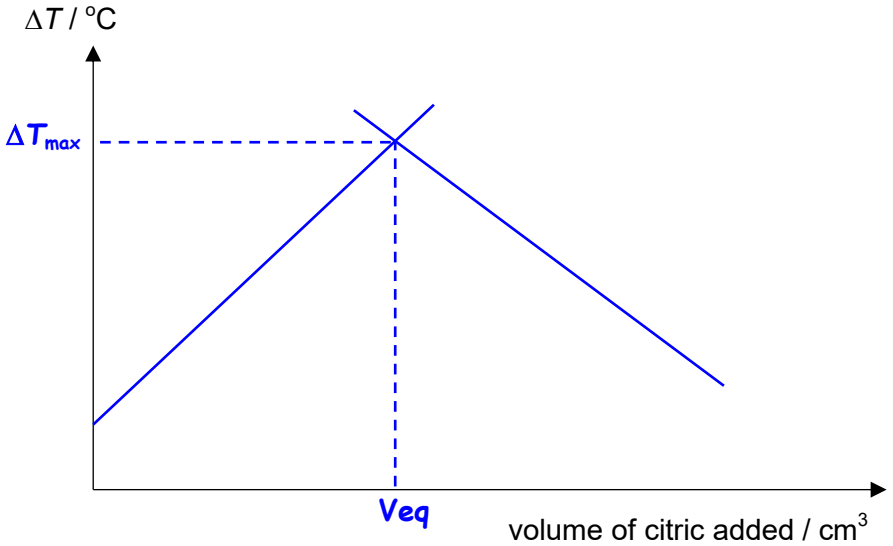


Fig 4.1

[1] gives correct straight line graph+ indicate ΔT_{max} correctly

[1] indicates V_{eq} correctly

[2]

(c) Outline how you would use your answers from **(b)** to determine the enthalpy change of reaction between citric acid and $NaHCO_3(aq)$, ΔH_6.

equation 6 $C_6H_8O_7(aq) + 3NaHCO_3(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l) + 3CO_2(g)$ ΔH_6

Express your answers in terms of ΔT_{max} and V_{eq}. 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}.

Amount of $NaHCO_3$ in $(50-V_{eq})$ cm^3
$= \left(\frac{50-V_{eq}}{1000} \times 1.50\right) mol$

amount of citric acid in V_{eq} cm^3 $= \left(\frac{50-V_{eq}}{1000} \times \frac{1.50}{3}\right)$ mol

[1]

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

$\Delta H_{neut} = + \frac{(0.209\Delta T_{max})}{\left(\frac{50-V_{eq}}{1000} \times \frac{1.50}{3}\right)}$ kJ mol^{-1} [1] ecf + sign + units

[3]

[Total: 10]

Qualitative Analysis Notes

[ppt. = precipitate]

(a) <u>Reactions of Aqueous Cations</u>

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