JURONG PIONEER JUNIOR COLLEGE JC2 PRELIMINARY EXAMINATION 2023

CHEMISTRY

Higher 2

Paper 4 Practical

9729/04

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 23 and 24.

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

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

Shift

Laboratory

For Examiner's Use		
1	15	
2	13	
3	17	
4	10	
Total	55	

This document consists of 22 printed pages and 2 blank 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, K₂S₂O₈.

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

FA 3 is 0.00500 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

starch indicator.

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

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

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

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_{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), $lg(V_{FA1})$ to 3 significant figures.

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(a) Experiment 1

- 1. Fill the burette labelled **FA 1**, with **FA 1**.
- 2. Run 20.00 cm³ of **FA 1** into a 100 cm³ beaker labelled **Beaker A**.
- 3. Using appropriate measuring cylinders, add the following to the second 100 cm³ beaker labelled **Beaker B**:
 - 20.0 cm³ of **FA 2**
 - 10.0 cm³ 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

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(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.





[3]

(b) (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

For Examiner's Use respect to $[S_2O_8^{2-}]$.

		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.		
			[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:		
		Improvement:		
		······		
			[2]	
(d)	(i)	The experimental method can be modified to enable the rate of reaction with respect to $[\Gamma]$ to be investigated.		F Exar L

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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	$V_{FA1}/ \text{ cm}^3$	$V_{FA2}/\text{ cm}^3$	V _{FA3} / cm ³	$V_{water}/ \text{ cm}^3$
1	20	20	10	0
6				

[1]

(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.

.....[1]

[Total: 15]

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
$$I_3^- + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 3I_2^-$$

FA 4 is a solid compound containing Cu²⁺.

FA 6 is 0.100 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

You are also provided with

FA 2, 1.00 mol dm⁻³ potassium iodide, KI, Starsh indicator

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 cm³ beaker. Reweigh the weighing bottle including any residual **FA 4** and record this mass in Table 2.1.

Table 2.1

3. Calculate the mass of **FA 4** used in the preparation of **FA 5**.

Mass of FA 4 and weighing bottle / g	
Mass of weighing bottle and residual FA 4 / g	
Mass of FA 4 used / g	

- 4. Add approximately 150 cm³ of deionised water to the beaker and stir until the **FA 4** has dissolved.
- 5. Transfer the solution and washings into a 250 cm³ 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**.

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

- 1. Fill a burette with **FA 6**.
- 2. Use a pipette to transfer 25.0 cm³ of **FA 5** into a 250 cm³ conical flask.
- 3. Use the 25 cm³ measuring cylinder to add 15 cm³ of **FA 2**, an excess of KI, to the conical flask. A white precipitate forms in a brown solution.

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- 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.

Results

(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.

 $V_{FA 6} = \dots [3]$

(b) (i) Calculate the amount of thiosulfate ions, $S_2O_3^{2-}$, present in $V_{FA.6}$.

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Use

percentage error of $V_{FA 6} = \dots$ [3]

[Total: 13]

For Examiner's

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9729/04/J2 PRELIMINARY EXAM/2023

Investigation of some inorganic reactions and the identity of an organic

[Turn Over

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(a)

(a) **FA 7** is an aqueous solution containing Fe³⁺ and one anion from the ions listed in the *Qualitative Analysis Notes*.

You are also provided with

compound

FA 6, 0.100 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃. Hydrogen peroxide, H₂O₂.

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 Table 3.1.

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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**.

	tests	observations			
1	Add 2 cm depth of H ₂ O 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.				
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. Add aqueous sodium hydroxide slowly to the resulting solution, with shaking, until no further change is seen.				
3	Add 1 cm depth of sodium thiosulfate, Na ₂ S ₂ O 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.			

Table 3.1

[3]

For Examiner's from Table 3.1 is shown below.

$$\begin{array}{ll} \text{step 1} & [\text{Fe}(\text{H}_2\text{O})_6]^{3^+}(\text{aq}) + \text{H}_2\text{O}_2(\text{aq}) = [\text{Fe}(\text{H}_2\text{O})_5(\text{O}_2\text{H})]^{2^+}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \\ \text{step 2} & [\text{Fe}(\text{H}_2\text{O})_5(\text{O}_2\text{H})]^{2^+}(\text{aq}) \rightarrow \text{OH}^-(\text{aq}) + [\text{Fe}(\text{H}_2\text{O})_5(\text{O})]^{3^+}(\text{aq}) \\ \text{step 3} & [\text{Fe}(\text{H}_2\text{O})_5(\text{O})]^{3^+}(\text{aq}) + \text{H}_2\text{O}_2(\text{aq}) \rightarrow [\text{Fe}(\text{H}_2\text{O})_6]^{3^+}(\text{aq}) + \text{O}_2(\text{g}) \\ \text{step 4} & \text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{I}) \end{array}$$

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.



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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 sulfite ion.

For Examiner's

[3]

.....

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

Anion:

[1]

Use

(b) Y, C₄H₆O₂, 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.

For Examiner's Use 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.	
2	To 2 cm depth of FA 8 in a test-tube, carefully add half a spatula measure of sodium hydrogen carbonate.	
3	Test solution FA 8 with Universal Indicator paper.	

[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**.

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Structure of FA 8	Structure of Y

[Total: 17]

4 Planning

Citric acid, C₆H₈O₇, 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, NaHCO₃.

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

 ΔH_6 is the enthalpy change when 1.00 mol of citric acid reacts completely with NaHCO₃.

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 NaHCO₃ are mixed and the temperature drop, ΔT , for each experiment is determined.

In each of the experiments using different volumes of citric acid and NaHCO₃, 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 NaHCO₃ 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 cm³ and the total volume of the reaction mixture should be kept constant at 50.00 cm³ 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 NaHCO₃(aq), ΔH_6 .

You may assume that you are provided with:

- 250 cm³ of dilute citric acid of unknown concentration,
- $250 \text{ cm}^3 \text{ of } 1.50 \text{ mol } \text{dm}^{-3} \text{ NaHCO}_3(\text{aq}),$
- 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 NaHCO₃(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.



	[5]			
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 $(50 V_{eq}) \text{ cm}^3$ of NaHCO₃(aq).
- ΔT_{max}, the maximum temperature drop when stoichiometric amounts of citric acid and NaHCO₃(aq) are reacted.





volume of citric added / cm³

(b)

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(c) Outline how you would use your answers from (b) to determine the enthalpy change of reaction between citric acid and NaHCO₃(aq), ΔH_6 .

equation 6 $C_6H_8O_7(aq) + 3NaHCO_3(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(I) + 3CO_2(g)$ 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 $4.18 \text{ Jg}^{-1} \text{ K}^{-1}$ and its density is 1.00 g cm^{-3} .

[3]

[Total: 10]



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Qualitative Analysis Notes

[ppt. = precipitate]

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

	Reaction with		
cation	NaOH(aq)	NH₃(aq)	
aluminium,	white ppt.	white ppt.	
A/ ³⁺ (aq)	soluble in excess	insoluble in excess	
ammonium, NH₄⁺(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.	grey–green ppt.	
	giving dark green solution	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	green ppt. turning brown on	
	insoluble in excess	insoluble in excess	
		red-brown ppt	
Fe ³⁺ (aq)	insoluble in excess	insoluble in excess	
magnesium,	white ppt.	white ppt.	
Mg ²⁺ (aq)	insoluble in excess	insoluble in excess	
manganese(II)	off-white ppt. rapidly turning	off-white ppt. rapidly turning brown	
Mn ²⁺ (aq)	brown on contact with air	on contact with air	
zinc, Zp ²⁺ (og)	white ppt.	white ppt.	
	soluble in excess	soluble in excess	

Anion	Reaction			
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids			
choride, C/⁻(aq)	gives white ppt. with Ag⁺(aq) (soluble in NH₃(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 NH₃(aq));			
nitrate, NO₃⁻(aq)	NH_3 liberated on heating with OH ⁻ (aq) and A/ foil			
pitrito	NH_3 liberated on heating with $OH^-(aq)$ and A/ foil;			
NO₂⁻(aq)	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 ₂ liberated on warming with dilute acids;			
SO ₃ ^{2–} (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids)			

(c) <u>Tests for Gases</u>

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