ANDERSON SERANGOON JUNIOR COLLEGE

2023 JC 2 PRELIMINARY EXAMINATION

NAME:

(

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CLASS: 23 /____

CHEMISTRY

Paper 4 Practical

9729/04 24 August 2023 2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.

Give details of the practical shift and laboratory where appropriate, in the boxes provided.

Write in dark blue or black pen.

You may use a HB pencil for any diagrams or graphs.

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

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

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.

Quantitative Analysis Notes are printed on pages 19 and 20.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [] at the end of each question or part question.

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

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



Answer all the questions in the spaces provided.

1 Determination of the kinetics of a redox reaction

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

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

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

rate = $k' [H_2O_2]^n$ where k' is $k [H^+]^a [I^-]^b$

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

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

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

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

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

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

For each experiment, you will note the volume of **FA 1** added, $V_{FA 1}$, volume of H₂O, V_{μ_0} and the time taken for the blue-black colour to appear.

You will then calculate values for

- 1/*t*
- lg(1/*t*)
- lg(V_{FA 1})

- (a) Fill Table 1.1 on page 4 with
 - all volumes of **FA 1**, $V_{\text{FA 1}}$ and water, $V_{\text{H,O}}$
 - all values of *t*, to the nearest second
 - all calculated values of 1/t, lg(1/t) and $lg(V_{FA1})$ recorded to 3 significant figures.

Experiment 1

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

- 1. Fill a burette with **FA 4**.
- 2. Transfer 10.00 cm³ of **FA 4** from the burette into a 250 cm³ conical flask. Place the conical flask on a white tile.
- 3. Using appropriate measuring cylinders, transfer to the 250 cm³ conical flask
 - 25.0 cm³ of **FA 2**
 - 25.0 cm³ of deionised water
 - 3.0 cm³ of starch solution
- 4. Using appropriate measuring cylinders, transfer to a 100 cm³ beaker
 - 50.0 cm³ of **FA 1**
 - 20.0 cm³ of **FA 3**
- 5. Pour the mixture in the beaker rapidly into the conical flask. Start the stopwatch when **half the contents** of the beaker are added.
- 6. Mix the contents thoroughly by swirling the flask.
- 7. Stop the stopwatch when the blue–black colour appears.
- 8. Record the time taken, *t*, in Table 1.1.
- 9. Discard the reaction mixture. Carefully wash out the beaker and conical flask. Stand the conical flask upside down on a paper towel to drain.

Experiment 2 to 4

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

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

You should alternate the use of the two conical flasks.

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

Results

Table 1.1

Experiment	V _{FA 1} / cm ³	V _{H₂0} / cm ³	t /s	1/ <i>t</i> / s ⁻¹	lg(1/ <i>t</i>)	lg(V _{FA 1})
1						
2						
3						
4						
		•	•	•	•	[5

(b) Graphical determination of order of reaction

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

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

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

rate =
$$k' [H_2O_2]^n$$

• taking logarithms of the factors in this equation gives

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

• by substituting for rate and [H₂O₂], as described above, we get

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

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

(i) Plot a graph of lg(1/t) on the *y*-axis against $lg(V_{FA 1})$ on the *x*-axis on the grid in Fig. 1.1.

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



Fig. 1.1

[3]

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

gradient =

order of reaction =

[3]

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

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

Give a possible reason for the longer timing.

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

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

effect	on
1	
explanation	
	[1]
	 [Total: 14]
	[10tal. 14]

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

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

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

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

Stage 2 NaHCO₃(aq) + HCl(aq) \rightarrow NaCl(aq) + CO₂(g) + H₂O(I)

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

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

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

(a) Titration of FA 5 against FA 6

- 1. Fill the burette labelled **FA 6**, with **FA 6**.
- 2. Use a pipette to transfer 25.0 cm³ of **FA 5** into a 250 cm³ conical flask.
- 3. Add a few drops of solution **T** to the conical flask.
- 4. Run **FA 6** from the burette into the conical flask. The end-point is reached when the solution changes from blue to colourless.
- 5. Record your titration results in Table 2.1.

Do not discard this solution.

- 6. To **this** solution, add a few drops of solution **S**.
- 7. Run **FA 6** from the burette into this conical flask. The end-point is reached when the solution changes from green to grey. If the solution becomes violet, you have passed the end-point.
- 8. Record your titration results in Table 2.1.
- 9. Repeat points 1 to 8 as necessary until consistent results are obtained for the **second end-point.**

Results

Table 2.1

Titration			
Initial burette reading / cm ³			
Final burette reading 1 (first end–point) / cm ³			
Final burette reading 2 (second end–point) / cm ³			
Volume of FA 6 used to complete Stage 1 / cm ³			
Volume of FA 6 used to complete Stages 1 and 2 / cm ³			
	•		[2]

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

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

Show clearly how you obtained these volumes.

volume of FA 6 used for first end-point =	cm ³
volume of FA 6 used for second end-point =	cm³ [3]

(c) (i) Calculate the amount, in moles, of sodium carbonate, Na_2CO_3 , and sodium hydrogen carbonate, $NaHCO_3$, present in 25.0 cm³ of **FA 5**.

amount of Na_2CO_3 in 25.0 cm ³ of FA 5 =	•
amount of NaHCO ₃ in 25.0 cm ³ of FA 5 =[2]]

(ii) Calculate the concentrations, in mol dm⁻³, of Na₂CO₃ and NaHCO₃ in **FA 5**.

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

.....[1]

(e) A student used 25.0 cm³ of **FA 5** and obtained an **FA 6** titre of 35.15 cm³ for the second end point.

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

pipette	±0.1 cm ³
burette	±0.05 cm ³

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

[1]

[Total: 12]

3 Investigation of some inorganic and organic reactions

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

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

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

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved. If there is no observable change, write **no observable change.**

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

	tests	observations
1	Add 2 cm depth of FA 7 into a clean test-tube. Add aqueous ammonia, slowly with shaking, until 4 cm depth of aqueous ammonia has been added.	
2	Filter the mixture from test 1 into a clean test-tube. Collect the filtrate for later test. Leave the residue on the filter paper and observe it again after several minutes. Continue with the remaining parts of Question 3.	
3	Using a teat pipette, extract about 1 cm depth of the filtrate from test 2 into a clean test-tube. Add dilute sulfuric acid until no further change is seen.	

Table 3.1

[3]

- (ii) Using your observations from Table 3.1, identify the two cations present in **FA 7**.
 - **FA 7** contains the cations and[1]

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

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

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

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

	tests	observations
1	Add 1 cm depth of FA 7 into a clean test-tube. Add 2 cm depth of aqueous hydrochloric acid.	
2	Add 1 cm depth of FA 7 into a clean test-tube. Add 2 cm depth of aqueous NaOH, followed by a small piece of A <i>l</i> foil with warming.	Effervescence observed. Gas evolved turns moist red litmus turns blue.
3		
4		

Table 3.2

[5]

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

FA 7 contains the anions and[1]

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

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

Table 3.3

	tests	observations
1	Add a small piece of sodium.	no observable change
2	To 1 cm depth of aqueous iodine in a clean test-tube add 1 cm depth of aqueous sodium hydroxide to get a pale yellow solution. Add 1 cm depth of FA 8 and shake the test-tube. Leave to stand.	
3	To 1 cm depth of FA 8 in a clean test-tube add 1 cm depth of sulfuric acid. Add 2 drops of potassium manganate(VII). Warm the test-tube in a beaker of hot water for two minutes.	
	(ii) Using the observations from each test in Ta features of FA 8. test 1	[2] ble 3.3, suggest the structural

test 2

test	
3	
	[3]

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

FA	8	is	
[1]			

[Total: 16]

4 Planning: Determining the *A*_r for an unknown metal, M

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

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

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

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

(a) Plan an investigation to determine the maximum temperature change, ΔT_{max} , graphically for the reaction between MOH and H₂SO₄.

Measurements should be taken

- Before the reaction starts
- During the reaction

You may assume that you are provided with

- 200 cm³ of 42.3 g dm⁻³ aqueous MOH solution
- 200 cm³ of 0.500 mol dm⁻³ sulfuric acid, H₂SO₄
- the equipment normally found in a school or college laboratory.

In your plan, you should include brief details of

- the apparatus you would use
- the volume of MOH and H₂SO₄ you would use for **each** experiment
- the procedure you would follow
- the measurements you would make to allow a suitable ΔT -volume graph to be drawn
- how you would ensure that an **accurate** and **reliable** value of ΔT_{max} is obtained.

Calculations are not required.

.....[7]

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

Extrapolate your graph until it touches both axes.



- (ii) Show how the maximum temperature change, ΔT_{max} , can be determined from Fig. 4.1. [1]
- (c) Suggest how the magnitude of the ΔH_{neut} obtained using the ΔT_{max} obtained above would compare to the true ΔH_{neut} . Explain your answer.

[1]

- (d) A student repeated the procedure described in **4(a)** but kept the total volume constant at 100 cm³ instead for each experiment. The volume of MOH used at maximum temperature change was found to be 57.0 cm³.
 - (i) Calculate the concentration of MOH in mol dm^{-3} .

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

[1]

[1]

[Total: 13]

Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

	reaction with		
cation	NaOH(aq)	NH ₃ (aq)	
aluminium, A <i>l</i> ³⁺ (aq)	white ppt. soluble in excess	white ppt. 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. 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), Fe²⁺(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	
chloride, CΓ(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, NO₂ [−] (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 with dilute acids; gives white ppt. with Ba ²⁺ (aq) (soluble in dilute strong acids)	

(c) Tests for gases

gas	test and test result	
ammonia, NH ₃	turns damp red litmus paper blue	
carbon dioxide, CO ₂	gives a white ppt. with limewater (ppt. dissolves with excess CO ₂)	
chlorine, Cl ₂	bleaches damp litmus paper	
hydrogen, H ₂	"pops" with a lighted splint	
oxygen, O ₂	relights a glowing splint	
sulfur dioxide, SO ₂	turns aqueous acidified potassium manganate(VII) from purple to colourless	

(d) Colour of halogens

halogen	colour of element	colour in aqueous solution	colour in hexane
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br ₂	reddish brown gas / liquid	orange	orange–red
iodine, I_2	black solid / purple gas	brown	purple