Catholic Junior College

JC2 Preliminary Examinations

Higher 2

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

9729/04

Paper 4 Practical

21 August 2024
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 and class in the boxes above.
Give details of the practical shift and laboratory, where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

The use of an approved 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 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.

Shift
Laboratory

For Examiner's Use	
1	**/ 16**
2	**/ 15**
3	**/ 16**
4	**/ 8**
Total	**/ 55**

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

[Turn over

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

1 Part 1: Qualitative analysis of an inorganic solid mixture

FA 1 is a solid mixture that contains two cations and two anions listed in the Qualitative Analysis Notes on pages 19 and 20.

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

1. Add 3 full spatulas of **FA 1** into a boiling tube and add 3 cm depth of deionised water.
2. Using a glass rod, stir the mixture for one minute until no more of the solid mixture can dissolve.
3. Filter the mixture into another clean boiling tube. This is the filtrate. **While waiting, you may wish to proceed to Question 2 first**.
4. When the filtration is completed, place the filter funnel containing the residue on a conical flask and **wash the residue** with a little deionised water.

Keep both filtrate and residue for tests (a) and (b) below.

Test and identify any gases evolved.

At each stage of any test, you are to record details of the following:
- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added.

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

Record your observations in Tables 1.1 and 1.2 below.

No additional tests for ions present should be attempted.

(a) Tests on the filtrate.

Table 1.1

test		observations
(i)	To 1 cm depth of the filtrate in a test-tube, add aqueous sodium hydroxide dropwise, with shaking, until no further change is observed.	

(ii)	To 1 cm depth of the filtrate in a test-tube, add aqueous ammonia dropwise, with shaking, until no further change is observed.	
(iii)	To 1 cm depth of the filtrate in a test-tube, add 5 drops of aqueous barium nitrate, followed by aqueous nitric acid.	

(b) Tests on the residue.

Table 1.2

test		observations
(i)	Place the filter funnel containing the residue (on the filter paper) into a clean boiling tube. Pour about 5 cm^3 of dilute nitric acid onto the residue. Collect 1 cm depth of the solution in the boiling tube. Remove the filter funnel and return it to the conical flask.	
(ii)	To 1 cm depth of the filtrate from **(b)(i)** in a test-tube, add aqueous ammonia dropwise, with shaking, until no further change is observed.	

[Turn over

(iii)	To 1 cm depth of aqueous potassium iodide, add 5 drops of the filtrate from **(b)(i)** and shake well. Then add 1 cm depth of aqueous sodium thiosulfate dropwise, with shaking.	

[6]

(c) **(i)** Identify the two cations and two anions in **FA 1** and state the evidence for each cation/anion by completing Table 1.3.

Table 1.3

identity of cation or anion	evidence

[4]

(ii) State the type of reaction occurring in test **(b)(iii)** when the filtrate from **(b)(i)** is added to potassium iodide, writing a suitable equation to illustrate your answer.

Type of reaction………………………… [1]

(iii) Write an equation for the reaction that occurs when sodium thiosulfate is added in test **(b)(iii)**.

………………………………………………………………………………………………..[1]

Part 2: Planning

(d) Consider the following organic compounds.

butanal   benzaldehyde   propan-1-ol   2-methylpropan-2-ol

Plan an investigation, using test-tube reactions, which would enable you to identify each of these four compounds.

Each compound should be identified by **at least one** positive test result. Hence, **four different** tests are required.

Your plan should include:

- details of the reagents and conditions to be used
- an outline of the sequence of steps you would follow
- an explanation of how you would analyse your results in order to identify each compound.

Once a compound has been clearly identified, your plan should concentrate on distinguishing the remaining compounds.

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[Total: 16]

[Turn over

2 Determination of the percentage of sodium carbonate in a mixture of sodium carbonate and sodium hydrogen carbonate

Sodium carbonate reacts with hydrochloric acid in two separate stages:

Stage 1: $Na_2CO_3 + HCl \rightarrow NaHCO_3 + NaCl$
Stage 2: $NaHCO_3 + HCl \rightarrow NaCl + CO_2 + H_2O$

The overall reaction at the end of the two stages is

$$Na_2CO_3 + 2\ HCl \rightarrow 2\ NaCl + CO_2 + H_2O$$

The percentage by mass of sodium carbonate in a mixture of sodium carbonate and sodium hydrogen carbonate can thus be determined in a double-indicator titration experiment, where two different indicators are used in the same titration experiment, as described below.

With hydrochloric acid as the titrant and the use of thymolphthalein indicator, the end-point for Stage 1 can be determined to be when the solution turns from blue to colourless.

Continuing the titration with the subsequent addition of methyl orange indicator, the end-point for Stage 2 can be determined to be when the solution turns from yellow to orange.

FA 2 is an aqueous solution prepared by dissolving a solid mixture of sodium carbonate, Na_2CO_3, and sodium hydrogen carbonate, $NaHCO_3$, in deionised water.

FA 3 is an aqueous solution containing 0.50 mol dm^{-3} of hydrochloric acid, HCl.

(a) Titration of FA 2 against FA 3

1. Fill the unlabelled burette with **FA 3**. (Do not use the burette labelled "**FA 4**".)

2. Using a pipette, transfer 25.0 cm^3 of **FA 2** into a conical flask.

3. Add 3 to 4 drops of thymolphthalein indicator and titrate with **FA 3**. The first end-point is reached when the solution turns from blue to colourless. Record your titration results on the next page. **Do not discard this solution.**

4. To the **same** solution, add 3 drops of methyl orange indicator and continue to titrate with **FA 3**. The second end-point is reached when the solution turns from yellow to orange. Record your titration results on the next page.

5. Repeat steps 2 to 4 until you obtain consistent results for the second end-point (i.e., total volume of **FA 3** used).
   (The volume of **FA 3** required to reach the first end-point need not be consistent.)

6. Ensure your titration results for both end-points are recorded in the table on the next page to an appropriate level of precision.

Titration results

experiment	1	2	3
initial burette reading / cm^3			
burette reading at first end-point / cm^3			
volume of **FA 3** used at first end-point / cm^3			
burette reading at second end-point / cm^3			
total volume of **FA 3** used / cm^3			
Tick (✓) the chosen titration results:			

[5]

Using the pairs of titres from two or more of your titrations, obtain suitable volumes of **FA 3** for

- the first end-point (i.e., volume of **FA 3** used at first end-point)
- the second end-point (i.e., total volume of **FA 3** used)

Show clearly how you obtained these volumes and place a tick (✓) under the titration results used.

For first end-point, volume of **FA 3** = …………………………………………

For second end-point, volume of **FA 3** = ………………………………………..

[2]

(b) **(i)** Using your volume of **FA 3** in the first end-point, calculate the amount of sodium carbonate present in 25.0 cm^3 of **FA 2**.

Amount of Na_2CO_3 in 25.0 cm^3 of **FA 2** = ………………………………………..[1]

[Turn over

(ii) Using your answer to **(b)(i)**, calculate the total amount of sodium hydrogen carbonate present in the reaction mixture that reacted in Stage 2.

Total amount of $NaHCO_3$ = ……………………………………….[2]

(iii) Hence, calculate the amount of sodium hydrogen carbonate initially present in 25.0 cm^3 of **FA 2**.

Amount of $NaHCO_3$ in 25.0 cm^3 of **FA 2** = ……………………………………….[1]

(c) Using your answers to **(b)(i)** and **(b)(iii)**, calculate the percentage by mass of sodium carbonate in the solid mixture used to form **FA 2**.
[A_r: Na, 23.0; H, 1.0; C, 12.0; O, 16.0]

% mass of Na_2CO_3 in **FA 2** = ……………………………………….[2]

(d) Calculate the maximum percentage error in your average total volume of **FA 3** needed to reach the second end-point.

Maximum % error in the average total volume of **FA 3** = ………………………………..[1]

(e) A student suggested that the presence of dissolved carbon dioxide may affect the end-point of the titration. Suggest how the dissolved carbon dioxide can be driven out of the solution as the titration is performed.

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…..…………………………………………………………………………………………...……[1]

[Total: 15]

3 Determination of the kinetics of the decomposition of thiosulfate ions

FA 4 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 5 is 2.0 mol dm^{-3} hydrochloric acid, HC*l*.

Thiosulfate ions react with acid to produce solid sulfur as one of the products, as shown in equation 1. The presence of sulfur causes the solution to eventually become opaque.

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

In this experiment, the rate of this reaction is studied by measuring the time taken for the reaction mixture to become opaque.

(a) You will perform a series of five experiments, using different concentrations of thiosulfate.

Then, you will graphically analyse your results in order to determine the order of reaction with respect to the concentration of thiosulfate ions, $S_2O_3^{2-}$.

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

In each of these experiments, you will need to place the beaker containing the reaction mixture on the provided insert. You will view the insert by looking vertically down through the mixture. You will stop the stopwatch when the mixture **first** becomes opaque and the printed text on the insert is **just** no longer visible.

For each experiment, you will note the volume of **FA 4**, $V_{\textbf{FA 4}}$, and the time taken, *t*, for the mixture to first become opaque.

You will then calculate the following values to 3 significant figures:

- $\frac{1000}{t}$
- $\lg\left(\frac{1000}{t}\right)$
- $\lg(V_{\textbf{FA 4}})$.

Prepare a table in the space provided on page 11 in which to record, to an appropriate level of precision:

- all volumes, except the volume of hydrochloric acid
- all values of *t*
- all calculated values of $\frac{1000}{t}$, $\lg\left(\frac{1000}{t}\right)$ and $\lg(V_{\textbf{FA 4}})$.

Experiment 1

1. Fill the burette labelled "**FA 4**" with **FA 4**. (Do not use the unlabelled burette.)
2. Use the burette to measure out 25.00 cm^3 of **FA 4** into a 100 cm^3 beaker.
3. Using a 10 cm^3 measuring cylinder, measure out 5.0 cm^3 of **FA 5**.
4. Pour the **FA 5** carefully but rapidly into the beaker and at the same time start the stopwatch.
5. Swirl the beaker and place it on the insert.
6. View the insert from above the beaker such that it is seen through the solution.
7. Stop the stopwatch when the solution **first** becomes opaque.
8. Record the time taken, *t*, to 0.1 s in your table.
9. Discard the reaction mixture **immediately** down the sink and rinse the beaker well.

   [Note: Small amounts of sulfur dioxide gas, SO_2, will also be produced in this reaction, as seen in equation 1. Minimise the inhalation of SO_2.]

Experiments 2 to 5

Repeat the experiment four times, using 22.50 cm^3, 20.00 cm^3, 17.50 cm^3 and 15.00 cm^3 of **FA 4** respectively, and adding appropriate volumes of deionised water for each experiment.

In each case, you will need to ensure that the **same total volume** of reaction mixture is used by adding deionised water using measuring cylinder as required. Keep the volume of **FA5** constant at 5.0 cm^3 and **add it last** in each experiment.

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

Results

[4]

[Turn over

(b) Plot a graph of $\lg\left(\frac{1000}{t}\right)$ on the y-axis against $\lg(V_{\textbf{FA 4}})$ on the x-axis. Draw the best-fit straight line taking into account all of your plotted points.

[3]

(c) State the relationship between rate of reaction and the time taken for the reaction mixture to first turn opaque, *t*.

…..……………………………………………………………………………………………… [1]

(d) State the relationship between [$S_2O_3^{2-}$] and the volume of **FA 4**, $V_{\textbf{FA 4}}$, used.

…..……………………………………………………………………………………………… [1]

(e) By drawing suitable construction lines on your graph, show clearly how you determine the gradient of the graph to three significant figures. Hence, deduce the order of the reaction with respect to [$S_2O_3^{2-}$].

gradient = …………………………………………

order = ………………………………………..

[3]

(f) The rate of this reaction relative to [$S_2O_3^{2-}$] can be determined using the following expression.

$$\text{rate} = \left|\frac{\Delta[S_2O_3^{2-}]}{\Delta t}\right|$$

The data that you now have from your experiments is not sufficient to allow you to use this expression to calculate the rate of reaction.
Identify the other data you would need in order to calculate a rate for this experiment.

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……….……………………………………………………………………………………..

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[Turn over

(g) The order of reaction with respect to the concentration of hydrogen ions, H^+, can be determined by modifying the above experiment.

Complete the table below with the volumes used in Experiment 5, and another experiment (Experiment 6) so that the order of reaction with respect to $[H^+]$ can be determined.

Do not carry out this experiment.

Experiment	Volume of **FA 4**/ cm^3	Volume of deionised water/ cm^3	Volume of **FA 5**/ cm^3
5	15.00		5.0
6			

[1]

(h) A student found that the reaction was first order with respect to $[H^+]$.
Predict and explain how the value of *t* in Experiment 1 would be affected if sulfuric acid of the same concentration had been used instead of **FA 5**.

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…..……………………………………………………………………………………………… [1]

(i) Predict and explain how the value of *t* in Experiment 1 would be affected if a 250 cm^3 beaker with larger base area was used instead of the 100 cm^3 beaker.

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[Total: 16]

4 Planning

Hydrogen peroxide decomposes to form water and oxygen gas. The reaction occurs very slowly, but can be catalysed by many transition element compounds, including manganese dioxide, MnO_2.

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}\, O_2(g)$$

The kinetics of the decomposition reaction can be studied by monitoring the rate of production of the oxygen gas evolved.

Write a plan for a single experiment, conducted at room temperature and pressure, to study the kinetics of the decomposition of hydrogen peroxide as catalysed by manganese dioxide, MnO_2. You are to use your experiment to prove the order of reaction with respect to hydrogen peroxide, H_2O_2, is first order in this reaction.

You may assume that you are provided with the following materials:

- 0.100 mol dm^{-3} $H_2O_2(aq)$ solution
- MnO_2 powder
- 100 cm^3 gas syringe
- The equipment normally found in a school or college laboratory.

Your plan should include:

- calculations to justify the volume of $H_2O_2(aq)$ you will use, assuming 1 mole of gas occupies 24 dm^3 under experimental conditions
- a labelled diagram of the set-up
- brief, but specific details of the apparatus used
- the procedures to obtain your results
- the measurements made
- a sketch of the graph from the results obtained
- an explanation of how the order of reaction with respect to hydrogen peroxide can be obtained from the graph.

You are **not** required to carry out your plan.

Calculation:

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Diagram:

Procedure:

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Graph and Explanation:

[8]

[Total: 8]

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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

[Turn over

(b) Reactions of aqueous anions

ion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $Cl^-(aq)$	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 A*l* foil
nitrite, $NO_2^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and A*l* foil; NO liberated by dilute acids (colourless NO → (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