



Catholic Junior College

JC2 Preliminary Examinations

Higher 2

CANDIDATE
NAME

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CLASS

2T

CHEMISTRY

Paper 4 Practical

9729/04

August 2021

2 hour 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 15 and 16.

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	/ 21
2	/ 18
3	/ 16
Total	/ 55

This document consists of **16** printed pages and **0** blank page.

[Turn over

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

1 To determine the stoichiometry of two redox reactions.

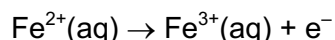
FA 1 is $0.0395 \text{ mol dm}^{-3}$ ammonium iron(II) sulfate, $(\text{NH}_4)_2\text{SO}_4 \cdot \text{FeSO}_4 \cdot 6\text{H}_2\text{O}$.

FA 2 is $0.0150 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 3 is $0.0250 \text{ mol dm}^{-3}$ hydrogen peroxide, H_2O_2 .

You are also provided with dilute sulfuric acid, H_2SO_4 .

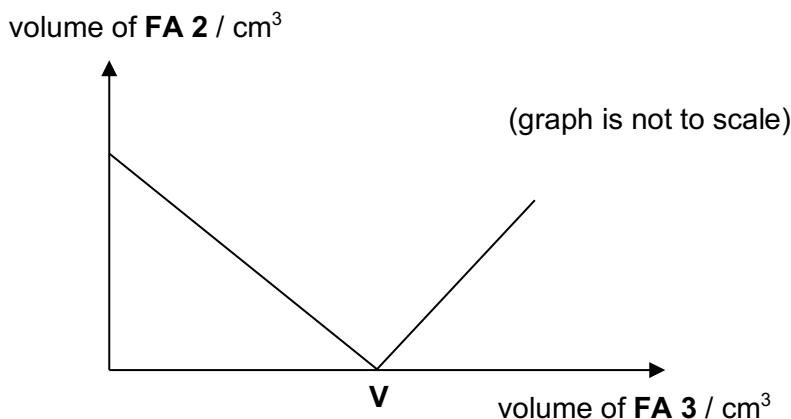
Potassium manganate(VII), **FA 2**, and hydrogen peroxide, **FA 3**, are both able to oxidise the $\text{Fe}^{2+}(\text{aq})$ ions in acidified **FA 1**.



In the presence of acid, potassium manganate(VII), **FA 2**, can also oxidise hydrogen peroxide, **FA 3**, forming oxygen gas.

In this question, you will prepare five mixtures, each containing different volumes of **FA 3** added to 25.0 cm^3 portions of **FA 1**. This mixture will then be acidified by adding sulfuric acid and titrated against **FA 2**.

A graph of the results can then be drawn.



Graphical analysis of your results will enable you to determine

- the volume, **V**, of **FA 3** which reacts with 25.0 cm^3 of **FA 1**,
- the mole ratio for the reaction between $\text{Fe}^{2+}(\text{aq})$ and $\text{H}_2\text{O}_2(\text{aq})$, and
- the mole ratio for the reaction between $\text{MnO}_4^-(\text{aq})$ and $\text{H}_2\text{O}_2(\text{aq})$.

Each titration is to be performed **once only**, so great care should be taken that you do not overshoot the end-points.

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

- volume of **FA 3** added in each mixture, V_{FA3} ,
- all burette readings,
- volume of **FA 2** added, V_{FA2} .

(a) Method

- (i)** Perform **Experiment 1 and 2** as described below. Record your results (V_{FA3} , all burette readings and V_{FA2}) to an appropriate level of precision, in your table.

Experiment 1

1. Fill the burette labelled **FA 3** with **FA 3**.
2. Fill the other burette with **FA 2**.
3. Pipette 25.0 cm³ of **FA 1** into a 250 cm³ conical flask.
4. Use a measuring cylinder to add 10 cm³ of sulfuric acid into the conical flask.
5. Titrate the **FA 1** solution in the conical flask with **FA 2**.
End-point is reached when a permanent **pale pink** colour is obtained.

Experiment 2

In this experiment, a very small volume of **FA 2** will be required.

6. Repeat steps 3 to 5 but, at step 5, add 12.00 cm³ of **FA 3** from the burette into the conical flask and then titrate the mixture with **FA 2**.
- (ii)** The volume of **FA 3** added in **Experiment 2** was insufficient to react with all the Fe²⁺ ions in **FA 1**. Use your results from **Experiment 1** and **2** to estimate a value for the volume of **FA 3** at point **V**.
(Sketching a graph of V_{FA2} against V_{FA3} or otherwise may help in calculating the volume of **FA 3** at point **V**.)

estimated volume of **FA 3** at point **V** = [1]

(iii) Experiment 3 to 5

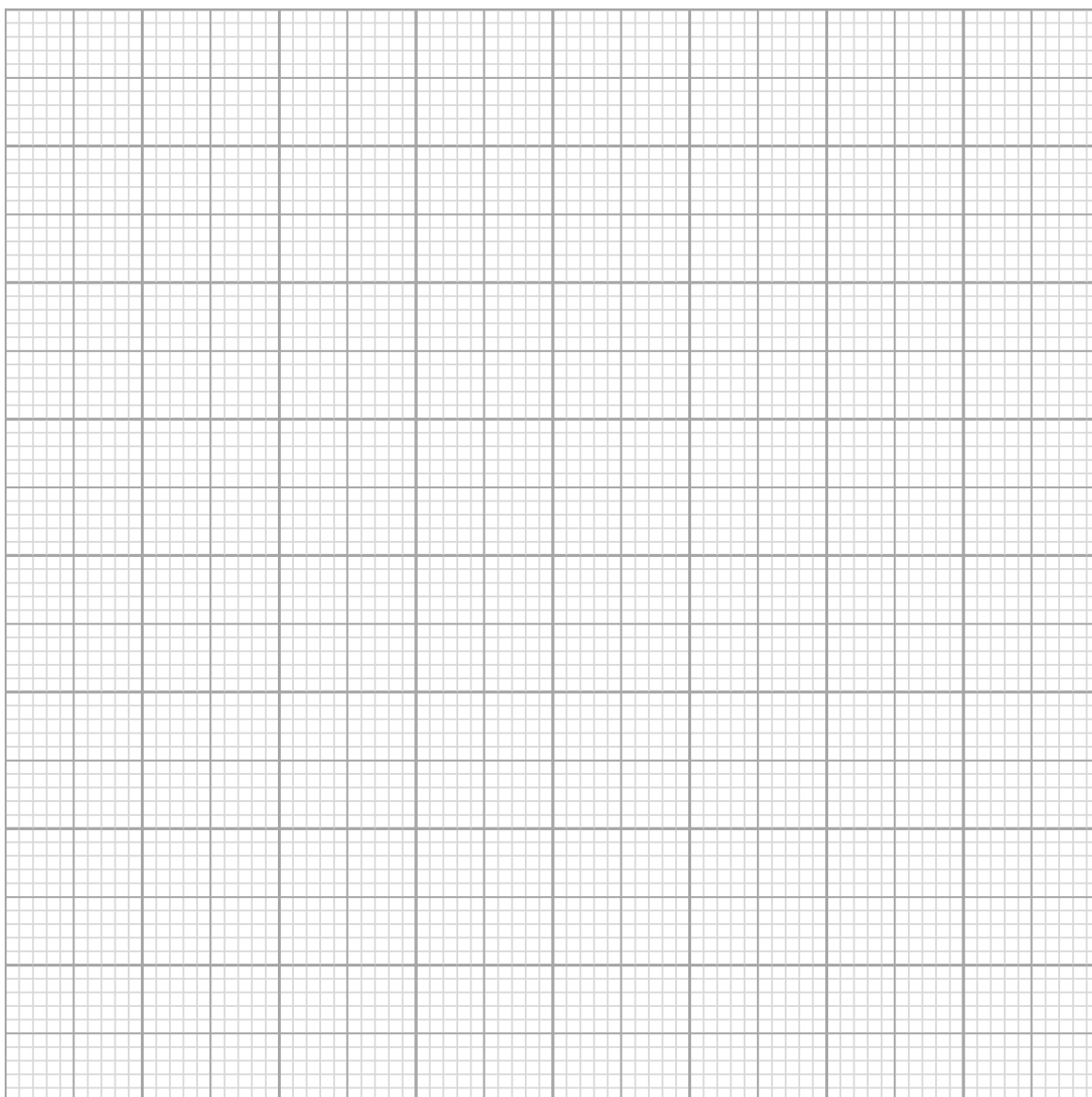
Use your answer from **(a)(ii)** to select **three** further volumes of **FA 3** in order to produce a graph of the type shown in page 2.

Repeat **Experiment 2** but use your selected volumes of **FA 3** at step 5 and then titrate each mixture with **FA 2**.

Results:

[5]

- (b) Plot on the grid below, a graph of V_{FA2} on the y -axis against V_{FA3} on the x -axis.
 Draw **two** best-fit straight line for the point before and after **V**. Hence, obtain a value for the volume at **V**.



volume of **FA 3** at point **V** = [5]

- (c) (i) Calculate the amount of H_2O_2 present in $V \text{ cm}^3$ of **FA 3** and hence deduce the amount of H_2O_2 that will react exactly with 1.00 mol of Fe^{2+} ions. Give your answers to three significant figures.

amount of H_2O_2 present in $V \text{ cm}^3$ of **FA 3** = [1]

amount of H_2O_2 that reacts exactly with 1.00 mol of Fe^{2+} ions = [1]

- (ii) Calculate the gradient of the **line to the right of V** to three significant figures, showing clearly how you did this.

gradient = [2]

- (iii) Use the following relationship to calculate the mole ratio for the reaction between H_2O_2 and MnO_4^- ions.

$$\text{gradient} = \frac{\text{mol of MnO}_4^- \times [\text{FA 3}]}{\text{mol of H}_2\text{O}_2 \times [\text{FA 2}]}$$

mole ratio $\text{H}_2\text{O}_2 : \text{MnO}_4^-$ = [1]

(d) Explain, in terms of the chemistry involved, the direction of the slope of your graph

(i) to the **left of V**

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

(ii) to the **right of V**

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

(e) A student repeated the experiment described in (a) but used $0.0395 \text{ mol dm}^{-3}$ hydrogen peroxide instead of **FA 3**.

Suggest what effect this would have on the value of **V**, explain your answer clearly.

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

(f) (i) One source of potential error in this experiment involves taking readings from a burette. A student carried out **Experiment 2** and recorded the initial and final burette readings as 16.50 cm^3 and 21.85 cm^3 respectively. Calculate, to three significant figures, the maximum percentage error in his titre value.

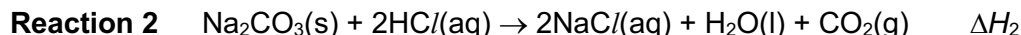
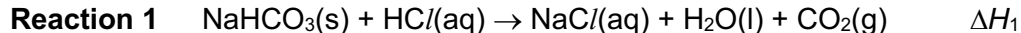
maximum percentage error =% [1]

(ii) Suggest one improvement to the method described in (a) which could significantly improve the accuracy of the experiment.

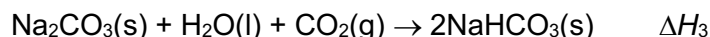
.....
..... [1]

[Total: 21]

- 2 The enthalpy change for the reaction of sodium carbonate, Na_2CO_3 , with water and carbon dioxide to form sodium hydrogencarbonate, NaHCO_3 , cannot be determined directly. However both $\text{Na}_2\text{CO}_3(\text{s})$ and $\text{NaHCO}_3(\text{s})$ react with dilute hydrochloric acid.



In this experiment you will determine the enthalpy change ΔH_1 for **reaction 1** and ΔH_2 for **reaction 2**, and then use your results to calculate ΔH_3 for the reaction:

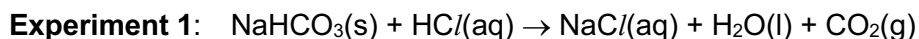


FA 4 is sodium hydrogen carbonate, NaHCO_3 .

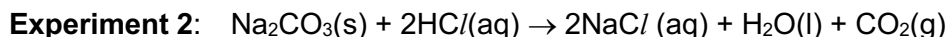
FA 5 is sodium carbonate, Na_2CO_3 .

FA 6 is 2.0 mol dm^{-3} hydrochloric acid, HCl .

(a) Method



- Use a measuring cylinder to transfer 25 cm^3 of the acid, **FA 6**, into a polystyrene cup supported in a 250 cm^3 beaker. The acid is in excess.
- Weigh the container with **FA 4** and record the balance reading.
- Place the thermometer in the acid and record its initial temperature.
- Carefully tip all the **FA 4**, in small portions, into the acid and stir to dissolve.
- Record the lowest temperature reached.
- Reweigh the container with any residual **FA 4** and record the balance reading and the mass of **FA 4** used.



- Replace the wet polystyrene cup with a clean, dry polystyrene cup.
- Repeat **Experiment 1** but use **FA 5** in place of **FA 4** and record the highest temperature reached.
- Reweigh the container with any residual **FA 5** and record the balance reading and the mass of **FA 5** used.

Results

Record **all** weighings and temperature readings in the table below.

	Experiment 1	Experiment 2
mass of container + solid sample / g		
mass of container + residual solid / g		
mass of solid added / g		
initial temperature, T_i , of FA 6 / $^{\circ}\text{C}$		
final temperature, T_f / $^{\circ}\text{C}$		
temperature change, ΔT / $^{\circ}\text{C}$		

[5]

- (b) (i) Calculate the heat energy absorbed when **FA 4** was added to the acid in **Experiment 1** and hence, the enthalpy change, in kJ mol^{-1} , when 1 mol of **FA 4**, NaHCO_3 , reacts with the acid. [Ar: H, 1.0; C, 12.0; O, 16.0; Na, 23.0]
[Assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of solution by 1.0°C .]

heat energy absorbed = J

enthalpy change, $\Delta H_1 = \dots\dots\dots \text{kJ mol}^{-1}$
[3]

- (ii) Calculate the heat energy produced when **FA 5** was added to the acid in **Experiment 2** and hence, the enthalpy change, in kJ mol^{-1} , when 1 mol of **FA 5**, Na_2CO_3 , reacts with the acid. [Ar: C, 12.0; O, 16.0; Na, 23.0].
[Assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of solution by 1.0°C .]

heat energy produced = J

enthalpy change, $\Delta H_2 = \dots\dots\dots \text{kJ mol}^{-1}$
[3]

- (iii) Using your answers to (b)(i) and (b)(ii) and the equations for **Experiment 1** and **Experiment 2**, determine the enthalpy change for the reaction:



enthalpy change, $\Delta H_3 = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

(c) Planning

You are provided with **FA 4**, solid sodium hydrogencarbonate, NaHCO_3 , and distilled water.

Using only these materials, you are to plan and carry out an additional experiment to determine a further enthalpy change, ΔH_4 , which can be put together with those from **Experiment 1** and **Experiment 2** to determine the enthalpy change for the reaction:



- Outline your plan as a series of numbered steps.

.....

.....

.....

.....

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.....

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.....

.....

- Carry out your plan and record your results, in a suitable form, in the space below.

- Show how you would use your results to determine the enthalpy change for the reaction:



[5]

[Total: 18]

3 Qualitative Analysis

You are provided with **FA 7**, an aqueous solution containing two cations and one anion.

In this question, you will carry out tests on **FA 7** to identify the ions present in the sample.

- (a) Carry out the following tests and record your observations in the table. You should test and identify any gases evolved. If there is no observable reaction, write 'No observable change' in the observations column.

test	observations
Test 1 Place a drop of FA 7 on the Universal Indicator (UI) paper and compare the colour against the UI colour chart provided.	
Test 2 Place 1 cm depth of FA 7 in a clean test-tube. Add an equal volume of dilute nitric acid slowly with shaking.	
Test 3 Place 1 cm depth of FA 7 in a clean boiling tube. Add aqueous sodium hydroxide slowly with shaking until no further change is seen. Warm the mixture gently.	
Test 4 Place 1 cm depth of potassium iodide in a clean test-tube. Add 8 drops of FA 7 . Then add 3 drops of starch solution.	
Test 5 Place 1 cm depth of hydrogen peroxide in a clean test-tube. Add an equal volume of FA 7 . Make observations for about 2 minutes before recording your results.	

[7]

- (b) (i) Identify the two cations present in **FA 7** and provide evidence to support your answer.

cation 1

evidence

.....

cation 2

evidence

.....

[2]

- (ii) Explain, in terms of ions present, the pH of the **FA 7** solution observed in **3(a)**.

.....

.....

..... [1]

- (iii) Suggest, with explanation, the nature of **FA 7** as observed in **Test 4**.

FA 7 is

explanation

..... [1]

- (iv) State the role of hydrogen peroxide in **Test 5**.

..... [1]

- (c) The anions that may be present in **FA 7** are bromide, carbonate and sulfate.

- (i) From the observations in **3(a)**, one of the above anion can be ruled out. Identify this anion and provide evidence to support your answer.

anion **not** present in **FA 7**

evidence

..... [1]

- | test | observations |
|------|--------------|
| | |

[3]

14

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

ion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives pale cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown NO_2 in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	SO_2 liberated with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (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