VICTORIA JUNIOR COLLEGE
PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME ……………………………………………….…………..

CT GROUP ……………………………..

CHEMISTRY 9729/04

Paper 4 Practical **29 Aug 2022**

Candidates answer on the Question Paper. **2 hours 30 minutes**

Additional Materials: As listed in the instructions below

READ THESE INSTRUCTIONS FIRST

Write your name and CT group 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.
Qualitative Analysis Notes are printed on pages 13 and 14.

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	**/ 9**
2	**/ 12**
3	**/ 11**
4	**/ 15**
5	**/ 8**
Total	**/ 55**

This document consists of **14** printed pages.

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

1 In acidic solutions, iron(III) ions are reduced by iodide ions to form iron(II) ions. The iodide ions are oxidised to iodine.

$$2Fe^{3+}(aq) + 2I^{-}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$$

The rate of this reaction can be investigated by using starch indicator, which turns blue-black in the presence of iodine. Sodium thiosulfate is added to the reaction mixture to react with iodine as it is formed. The blue-black colour is seen when all the thiosulfate has reacted.

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

You will investigate how the rate of reaction is affected by changing the concentration of the iodide ions.

FA 1 is 0.050 mol dm^{-3} potassium iodide, KI.
FA 2 is 0.050 mol dm^{-3} acidified iron(III) chloride, $FeCl_3$.
FA 3 is 0.0050 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 4 is starch indicator.

(a) Experiment 1

1. Use the burette **labelled FA 1** to transfer 10.00 cm^3 of **FA 1** into a 250 cm^3 conical flask.
2. Use a 25 cm^3 measuring cylinder to transfer 10 cm^3 of deionised water into the conical flask.
3. Use the burette **labelled FA 3** to transfer 20.00 cm^3 of **FA 3** and a 50 cm^3 measuring cylinder to transfer 10 cm^3 of **FA 4** to the same conical flask.
4. Use a 10 cm^3 measuring cylinder to measure 10 cm^3 of **FA 2**.
5. Add this **FA 2** into the same conical flask and start timing immediately.
6. Swirl the mixture once and place the conical flask on the white tile.
7. Stop timing as soon as the solution turns **intense** blue-black.
8. Record the time taken, ***t***, to the nearest second.
9. Wash out the conical flask and stand it upside down in a beaker to drain for use again.

Experiment 2

10. Repeat Experiment 1 but use 20.00 cm^3 of **FA 1** instead of 10.00 cm^3 in step 1 and use 0.0 cm^3 of deionised water instead of 10.0 cm^3 in step 2.

Experiments 3 to 5

11. Carry out **three** further experiments to investigate how the reaction time changes with different volumes of potassium iodide, **FA 1**.
    The combined volume of **FA 1** and deionised water must always be 20 cm^3.
    Do not use a volume of **FA 1** that is less than 6 cm^3.

In the space on the next page, prepare a table to record the following for each of the five experiments.

- ***V*,** Volume of **FA 1** used,
- Volume of water used,
- ***t***, Reaction time, to the nearest second,
- ***Vt***
- ***V²t***

Keep solutions FA 1, FA 3 and FA 4 for use in Question 2.

Results

[4]

(b) ***V*** is the volume of **FA 1** used in cm^3 and ***t*** is the time taken in seconds. On your table above, compute the values of ***Vt*** and ***V²t*** for each experiment, to 2 significant figures.

[1]

(c) The rate of the reaction in this investigation can be calculated using the following formula: **rate = 1 / reaction time**. Explain why this is so.

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

(d) Deduce the order of reaction with respect to iodide ions. Explain your answer by referring to your calculated values of ***Vt*** and ***V²t***.

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…………………………………………………………………………………………..……….. [2]

(e) Another student investigated the effect of concentration of iron(III) ions on the rate of this reaction. The student carried out another experiment, **Experiment 6**, and the rate is compared to that of **Experiment 1**. Suggest the volumes the student could use for **Experiment 6**.

reagent	volume / cm^3
FA 1	
FA 2	
FA 3	
FA 4	
deionised water	

[1]

[Total: 9]

2 In this experiment you will determine the formula of the ion, IO_x^-, To do this, you will first react IO_x^- ions with an excess of iodide ions, I^- to form iodine, I_2.

The equation for this reaction is:

$$IO_x^- + yI^- + zH^+ \rightarrow \frac{1+y}{2} I_2 + \frac{z}{2} H_2O$$

where x, y and z are all integers.

The amount of iodine produced will then be determined by titration with thiosulfate ions.

In addition to **FA 1**, **FA 3** and **FA 4** used in question **1**, you are also provided with the following.

FA 5 is a solution containing 0.00600 mol dm^{-3} IO_x^- ions.
FA 6 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Dilution of **FA 5**

1. Pipette 25.0 cm^3 of **FA 5** into the 250 cm^3 volumetric flask.
2. Make the solution up to the mark using deionised water.
3. Shake the flask thoroughly.
4. Label this diluted solution of IO_x^- as **FA 7**.

Titration

1. Pipette 25.0 cm^3 of **FA 7** into a conical flask.
2. Using the burette **labelled FA 1**, transfer 10.00 cm^3 of **FA 1** into the same conical flask.
3. Using a measuring cylinder, transfer 10 cm^3 of **FA 6** into the same conical flask.
4. Titrate the mixture in the conical flask against **FA 3** in the burette **labelled FA 3** until the solution turns yellow.
5. Add 10 drops of **FA 4** into the conical flask.
6. Continue the titration until the blue-black colour just disappears.
7. Carry out as many titrations as you deem necessary to obtain consistent results.
8. In the space provided on the next page, prepare a table to record all your burette readings and the volume of **FA 3** used in each titration.

Results

[5]

(b) **(i)** From your titration results, obtain a suitable volume of **FA 3** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 3** = ………………… cm^3 [1]

(ii) Calculate the amount of iodine formed when 25.0 cm^3 of **FA 7** reacts with 10.00 cm^3 of **FA 1**. Show your working.

amount of iodine = ………………… mol [1]

(iii) Calculate the amount of IO_x^- in 25.0 cm^3 of **FA 7**. Show your working.

amount of IO_x^- = ………………… mol [1]

(iv) Using your answer in **(b)(ii)** and **(b)(iii)**, determine the value of y. Show your working.

y = …………………[1]

(v) Using your answer in **(b)(iv)**, determine the value of z. Hence, determine the value of x.

z = ……………… and x = …………………[1]

(c) **(i)** The maximum error in the volume dispensed by the pipette is ±0.06 cm^3.
Calculate the maximum percentage error in measuring the volume of **FA 5** used.

[1]

(ii) A student suggested that a more accurate value of *x* can be determined if a 10.0 cm^3 pipette is used to measure the volume of **FA 6** rather than the measuring cylinder.

State whether you agree with this student. Explain your answer.

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

[Total: 12]

3 **FA 8** is a solid of Group 1 metal hydrogencarbonate, **L**HCO_3. When it is heated, carbon dioxide and stream are produced.

In this experiment you will determine the relative atomic mass of the metal **L** in **FA 8** using gravimetric analysis.

(a) **Gravimetric Analysis**

1. Weigh and record the mass of a dry boiling tube.
2. Transfer all the **FA 8** from the container into the boiling tube.
3. Reweigh and record the total mass of the boiling tube and **FA 8**.
4. Heat the boiling tube gently for approximately one minute and then strongly for another four minutes.
5. Leave the boiling tube to cool on a wire gauze for at least five minutes.
6. After cooling, reweigh the boiling tube and its contents.
7. Repeat the heating, cooling and weighing process until you are satisfied that the decomposition is complete. The residue is **FA 9**, keep the residue for use in **3(b)**.
8. Record your results in an appropriate form in the space below.

Results

[4]

(b) **(i)** Pour 1 cm depth of dilute hydrochloric acid into a test-tube.
Add a spatula measure of the residue, **FA 9** to the acid.

Record all your observations and identify any gas formed.

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

(ii) Use your observation in **(b)(i)** to identify the anion in **FA 9**. Assume that all the **L**HCO_3 has decomposed.

Anion in **FA 9** is …………….. [1]

(iii) Hence, write a balanced equation for the thermal decomposition of **L**HCO_3. Include state symbols.

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

(iv) Calculate the amount of carbon dioxide given off in your experiment. Show your working.

amount of CO_2 = ………………….. mol [1]

(v) Hence, determine the relative atomic mass of metal **L**. Show your working.

relative atomic mass of metal **L** = ………………… [1]

(c) **(i)** In another experiment, a student used a crucible with lid instead of a boiling tube for the heating and it was found that the results obtained were more accurate. Suggest why the crucible with lid can give a better result.

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

(ii) Another student conducted a different experiment to determine the A_r of **L** by measuring the volume of carbon dioxide formed in the following reaction.

$$\mathbf{L}HCO_3 + HCl \rightarrow \mathbf{L}Cl + CO_2 + H_2O$$

Suggest which method would give a more accurate determination of the A_r of **L**.

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

[Total: 11]

4 Qualitative Analysis

(a) **FA 10** is a solid of a metal dioxide, $\mathbf{M}O_2$.

Solution **S** is an acidic solution of sodium ethanedioate, $Na_2C_2O_4$.

You will perform tests to identify the element **M** in **FA 10**.

Perform the tests **(i)** and **(ii)** described in **Table 4.1** and record your observations in the table. The volume given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

Table 4.1

	tests	observations
(i)	Transfer all the solution **S** into a boiling tube and add one spatula of **FA 10** to the boiling tube. Warm the boiling tube cautiously. Leave the boiling tube to cool for about one minute and then filter the mixture into a test-tube.	
(ii)	To a 1 cm depth of filtrate from **(a)(i)** in a test−tube, add NaOH(aq). Leave to stand.	
(iii)	Aqueous hydrogen peroxide is added to an equal volume of H_2SO_4(aq) in a test-tube, followed by addition of one spatula of **FA 10.** The mixture is filtered into another test-tube. Leave the filtrate to stand.	Vigorous effervescence of O_2 which rekindles a glowing splint. A black/brown residue and a colourless filtrate obtained. The filtrate remains colourless.

[4]

(b) (i) Consider your observations in **(a)(ii)**, give the name of element **M** in **FA 10**. Explain your answer.

M is …………………………….

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…………………………………………………………………………………………………….….. [2]

(ii) In **(a)(i)**, the reaction between **FA 10** and ethanedioate occurred under acidic conditions. Write a balanced equation for this reaction.

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

(iii) The filtrate obtained in **(a)(i)** turned pale yellow on standing.

Compare the role of **FA 10** in **(a)(i)** and **(a)(iii)**. Explain your answer with reference to your observations in both tests.

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(c) **FA 11**, **FA 12** and **FA 13** are organic compounds with the molecular formulae C_7H_6O, C_3H_6O and C_2H_6O (not necessarily in any order).

Each compound has **only one** of the functional groups: alcohol, aldehyde and ketone.

(i) Perform the tests described in **Table 4.2** and record your observations in the table. If there is no observable change, write **no observable change**.

<u>Prepare the Tollens' reagent using the following procedure.</u>
Place a 2 – 3 cm depth of silver nitrate in a test-tube, add aqueous sodium hydroxide drop by drop until a small amount of brown precipitate is formed and then add aqueous ammonia drop by drop with shaking until the precipitate just dissolves. This is Tollens' reagent.

Table 4.2

test	observations		
	FA 11	**FA 12**	**FA 13**
Add 1 cm depth of Tollens' reagent to test-tube containing 1 cm depth of each sample and place each test-tube in a hot water bath.			

[1]

(ii) Using only the bench reagents provided, suggest **one additional** chemical test that can help you identify the functional group present in each compound.
Describe the test in the space provided in **Table 4.3**.

Perform the test and record the observations in **Table 4.3**.

Table 4.3

test	observations		
	FA 11	**FA 12**	**FA 13**

[2]

(iii) Based on your observations in **(c)(i)** and **(c)(ii),** suggest the structures of the organic compounds present in **FA 11**, **FA 12** and **FA 13**.

FA 11 is ……………………………..……

FA 12 is ……………………….…………

FA 13 is ……………………….…………

[3]
[Total: 15]

5 Planning

Self-heating food packaging is an active packaging with the ability to heat food contents without external heat sources or power. Packets typically use an exothermic chemical reaction. These packages are useful for military operations, during natural disasters or whenever conventional cooking is not available. These packages are often used to prepare main courses such as meat dishes, which are more palatable when hot.

The source of the heat is initiated by pressing on the heat pack. The heat pack is manufactured with the heating agent (anhydrous calcium chloride) separated from water by a thin breakable membrane. When pressure is applied on the packaging, a rod pierces the membrane, allowing the water and anhydrous calcium chloride to mix. The resulting reaction releases energy and thus warms the food surrounding it. The enthalpy change of solution for this dissolution process is approximately –83.0 kJ mol^{-1}.

$$CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^{-}(aq)$$

(a) Plan an investigation to determine the enthalpy change of solution when anhydrous calcium chloride is dissolved in deionised water using a non-graphical method.

You may assume that you are provided with:

- approximately 120 cm^3 of deionised water
- approximately 10 g of anhydrous calcium chloride
- a thermometer
- Styrofoam cup
- common apparatus in the laboratory

In your plan, you should include brief details of:

- calculation of a suitable mass of calcium hydroxide you would use for a temperature rise of about 12 °C to 14 °C;
- the apparatus you would use;
- the quantities of reagents you would use;
- the procedure you would follow and the measurements you would make (you may find it useful to label measurements in your plan as **M1**, **T1** etc.);
- how you would ensure that a **reliable** value of the enthalpy change of solution is obtained.

Assume that 4.18 J of heat energy raises the temperature of 1.0 cm^3 of the mixture by 1.0 °C.

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…… [6]

(b) Describe how you would use the measurements in your plan in **(a)** to calculate a value for the enthalpy of solution of anhydrous calcium chloride.
[A_r: Ca = 40.1; C*l* = 35.5]

[2]

[Total:8]

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

anion	*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