

# RIVER VALLEY HIGH SCHOOL JC 2 PRELIMINARY EXAMINATION H2 CHEMISTRY 9729 Paper 4

# 20 AUGUST 2024

# **2 HOURS 30 MINUTES**

NAME

**CLASS** 

23J ( )

INDEX NO.

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

# Read these notes carefully.

Write your name, class and index number in the spaces at the top of this page.

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 2B pencil for any diagram or graph.

Do not use staples, paper clips, highlighters, 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.

Shift
Laboratory

For Examiner's Use		
s.f.		
Units		
Total		
	55	

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

### 1 To determine the percentage by mass of Fe(NO<sub>3</sub>)<sub>2</sub> in a salt mixture

**FA 1** is a solution containing a salt mixture of two different ionic compounds. One of the compounds is  $Fe(NO_3)_2$ .

In this question, you will determine the percentage by mass of  $Fe(NO_3)_2$  in the mixture by preparing a diluted solution of **FA 1** and carry out a titration using potassium manganate(VII). The iron(II) ions,  $Fe^{2+}$ , are oxidised by the manganate(VII) ions,  $MnO_4^-$ .

 $5Fe^{2+}(aq) + MnO_4^{-}(aq) + 8H^{+}(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(I)$ 

The end-point of the titration occurs when the presence of unreacted  $MnO_{4^{-}}$  causes the colour of the solution to become orange.

The following reagents are provided.

**FA 1** is a solution containing 125.4 g dm<sup>-3</sup> of the salt mixture in sulfuric acid. **FA 2** is 0.0100 mol dm<sup>-3</sup> manganate(VII) ions,  $MnO_4^-$ . **FA 3** is 1.00 mol dm<sup>-3</sup> sulfuric acid, H<sub>2</sub>SO<sub>4</sub>.

#### (a) Determining the percentage by mass of Fe(NO<sub>3</sub>)<sub>2</sub>

- 1. Fill a burette with **FA 2**.
- 2. Use a pipette to transfer 25.0 cm<sup>3</sup> of **FA 1** into a 250 cm<sup>3</sup> volumetric flask.
- 3. Make up to the mark with deionised water and label this solution **FA 4**. Shake to obtain a homogeneous solution.
- 4. Pipette 25.0 cm<sup>3</sup> of **FA 4** into a 250 cm<sup>3</sup> conical flask.
- 5. Use the 25.00 cm<sup>3</sup> measuring cylinder to add 25.00 cm<sup>3</sup> of **FA 3** into the conical flask. **FA 3** is added in excess.
- 6. Run **FA 2** from the burette into the conical flask. The end-point is reached when the solution changes colour from yellow to orange.
- 7. Record your titration results, to an appropriate level of precision, in the space provided on the next page.
- 8. Repeat steps 4 to 7 until consistent titre values are obtained.

#### Results

1	
2	
3	
4	
5	

(b) From your titrations, obtain a suitable volume of **FA 2** to be used in your calculations. Show clearly how you obtained this volume.

		6
volume of FA	2 used =	

(c) (i) Calculate the amount of  $MnO_4^-$  used in the titration.

amount of  $MnO_4^-$  = .....

(ii) Calculate the amount of  $Fe^{2+}$  ions present in 25.0 cm<sup>3</sup> of **FA 4**.

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amount of  $Fe^{2+}$  = .....

(iii) Calculate the concentration of  $Fe^{2+}$  ions present in **FA 1**.

9	
10	

concentration of  $Fe^{2+} = \dots$ 

(iv) Hence, calculate the percentage by mass of  $Fe(NO_3)_2$  in the salt mixture.

[A<sub>r</sub>: Fe, 55.8; N, 14.0; O, 16.0]

percentage by mass of  $Fe(NO_3)_2 = \dots$  11

(d) A student repeated the experiment but used a sample of **FA 1** prepared in water instead of sulfuric acid.

Explain how this would affect the titre value.

- (e) The end-point of the titration is reached when the solution in the conical flask changes colour from yellow to orange.
  - (i) Account for the colour change with reference to the chemical species present.

(ii) Hydrogen peroxide is also able to oxidise the Fe<sup>2+</sup> ions in an acidic medium. However, it is not a suitable replacement for KMnO<sub>4</sub> in this experiment. Suggest a reason for this.

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(f) A student carried out the experiment and obtained an **FA 2** titre of 29.70 cm<sup>3</sup> for the end-point.

The absolute uncertainties associated with each apparatus are given below.

pipette	±0.06 cm <sup>3</sup>
burette	$\pm 0.05 \text{ cm}^3$
25.0 cm <sup>3</sup> measuring cylinder	$\pm 0.25$ cm <sup>3</sup>

(i) Use the given data to calculate the percentage uncertainty associated with each apparatus.

.....

.....

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(ii) Hence, identify the apparatus that gives rise to the highest percentage uncertainty in the student's titre value.

[Total: 16]

#### 2 Determination of the kinetics of the reaction between iron(III) ions and iodide ions

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.

In this series of experiments, the rate equation for the reaction can be simplified to rate =  $k' [I^-]^m$ , where **m** is the rate order with respect to  $[I^-]$  and k' is  $k[Fe^{3+}]$ .

The simplified rate equation can be further manipulated to derive the following relationship:

 $lg(rate) = m \times lg(volume of FA 6) + constant$ 

FA 5 is 0.0500 mol dm<sup>-3</sup> iron(III) chloride, FeC $l_3$ . FA 6 is 0.0500 mol dm<sup>-3</sup> potassium iodide, KI. FA 7 is 0.00500 mol dm<sup>-3</sup> sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>. FA 8 is starch indicator.

#### (a) Method

Prepare a table on page 7 for your results. You will need to include the volume of **FA 6**, volume of water, reaction time, lg(volume of **FA 6**) and lg(rate) for each of the four experiments. Record all calculated values to 3 significant figures.

#### **Experiment 1**

- 1. Use a 25.00 cm<sup>3</sup> measuring cylinder to place 20.00 cm<sup>3</sup> of **FA 6** in a 100 cm<sup>3</sup> beaker.
- 2. Use appropriate measuring cylinders to add the following to the same beaker.
  - 20.0 cm<sup>3</sup> of **FA 7**
  - 10.0 cm<sup>3</sup> of **FA 8**
- 3. Use an appropriate measuring cylinder to measure 10.0 cm<sup>3</sup> of **FA 5**.
- 4. Add this **FA 5** to the same 100 cm<sup>3</sup> beaker and start timing immediately.
- 5. Stir the mixture and place the beaker on a white tile.
- 6. Stop timing as soon as the solution turns blue-black.
- 7. Record this reaction time to the nearest 0.1 second.
- 8. Wash the beaker and dry it with a paper towel.

#### Experiment 2

- Use the same 25.00 cm<sup>3</sup> measuring cylinder to measure 10.00 cm<sup>3</sup> of FA 6 and make up the volume to 20.00 cm<sup>3</sup> using deionised water.
- 2. Place this solution in a 100 cm<sup>3</sup> beaker.
- 3. Use appropriate measuring cylinders to add the following to the same beaker.
  - 20.0 cm<sup>3</sup> of **FA 7**
  - 10.0 cm<sup>3</sup> of **FA 8**
- 4. Use an appropriate measuring cylinder to measure 10.0 cm<sup>3</sup> of **FA 5**.
- 5. Add this **FA 5** to the same 100 cm<sup>3</sup> beaker and start timing immediately.
- 6. Stir the mixture and place the beaker on a white tile.
- 7. Stop timing as soon as the solution turns blue-black.
- 8. Record this reaction time to the nearest 0.1 second.
- 9. Wash the beaker and dry it with a paper towel.

You have performed the fastest and the slowest experiments.

#### Experiments 3 and 4

Carry out two further experiments to investigate how the reaction time changes with different volumes of potassium iodide, **FA 6**.

The combined volume of **FA 6** and deionised water must always be 20.00 cm<sup>3</sup>.

#### Results

The rate of the reaction is defined as shown.

rate =  $\frac{1000}{\text{reaction time}}$ 

17	
18	
19	
20	
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(b) Plot the graph of  $lg(\frac{1000}{reaction time})$  (y-axis) against lg(volume of FA 6) (x-axis) on the grid. Draw a straight line of best fit through the points.





(c) (i) Calculate the gradient of the line to three significant figures, showing clearly how you did this. Hence deduce the rate order, *m*.

aradient =		
	25	

*m* = .....

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(ii) Using your graph, calculate the expected reaction time if 12.30 cm<sup>3</sup> of **FA 6** is used.

Show your working clearly.

(d) (i) To investigate the effect of concentration of iron(III) ions on the rate of this reaction, a student carried out another experiment, **Experiment 5**.

Suggest appropriate volumes of chemicals to be used in the procedure by completing Table 2.1 so that his results in **Experiment 5**, together with that from **Experiment 2**, could be used to determine the order of reaction with respect to [Fe<sup>3+</sup>].

	Та	ble	2.1
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expt	volume of <b>FA 5</b> /cm <sup>3</sup>	volume of <b>FA 6</b> /cm <sup>3</sup>	volume of <b>FA 7</b> /cm <sup>3</sup>	volume of water /cm <sup>3</sup>	reaction time /s
2	10	10	20	10	t <sub>2</sub>
5					t <sub>5</sub>

(ii) Taking the reaction time in **Experiments 2 and 5** to be  $t_2$  and  $t_5$  respectively, explain how the results of the two experiments can be used to confirm that this reaction is first order with respect to [Fe<sup>3+</sup>].

(iii) Hence, write the rate equation for the reaction between Fe<sup>3+</sup> and I<sup>-</sup>.

A student p	proposed the following mechanism for this re	eaction.
Step 1:	$Fe^{3+}(aq) + I^{-}(aq) = [FeI]^{2+}(aq)$	(fast)
Step 2:	$[FeI]^{2\text{+}}(aq) + \mathrm{I}^{\text{-}}(aq) \to Fe^{2\text{+}}(aq) + \mathrm{I}_2^{\text{-}}(aq)$	(slow)
Step 3:	$Fe^{3\text{+}}(aq) + \mathrm{I_2}^{\text{-}}(aq) \to Fe^{2\text{+}}(aq) + \mathrm{I_2}(aq)$	(fast)
(iv) With prop	the aid of the equilibrium constant express osed mechanism is consistent with the obse	ion for step 1, deduce if the erved kinetics data.
Another stu would be lo FA 7.	udent suggested that the time taken for the onger if a lower concentration of sodium thio	blue-black colour to appear sulfate was used in place of
Do you agr	ee with this student? Explain your answer.	

.... ..... ..... 31 .....

[Total: 15]

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(e)

#### 3 Qualitative Analysis

**FA 9** is an aqueous solution that contains two cations and one anion.

In addition to having access to the usual bench reagents, you are also provided with the following:

- FA 10,
- aqueous potassium thiocyanate, KSCN(aq).

You will investigate the reactions of the cations and anion in **FA 9** by carrying out the following tests. Record your observations in Table 3.1.

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

#### (a)

	Tests	Observations
1.	Test the <b>FA 9</b> solution using Universal Indicator paper.	
2.	To a 2 cm depth of <b>FA 9</b> in a test tube, add a 2 cm depth of <b>FA 10</b> and shake the mixture thoroughly. Observe the mixture until there is no further change.	
3.	To a 2 cm depth of <b>FA 9</b> in a boiling tube, add aqueous sodium hydroxide until there is no further change. Warm the mixture obtained.	

#### Table 3.1

4.	To a 2 cm depth of <b>FA 9</b> in a test tube, add aqueous sodium carbonate.	
5.	To a 2 cm depth of <b>FA 9</b> in a test tube, add aqueous potassium thiocyanate, KSCN(aq).	
6.	To a 2 cm depth of <b>FA 9</b> in a test tube, add aqueous barium nitrate. Leave the mixture to stand for 5 minutes and discard the liquid. To the remaining solid, add dilute nitric acid.	

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33	
34	
35	
36	

(b) Identify the metal cation responsible for the nature of FA 9 solution in test 1.Describe and explain the chemistry involved.

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(c) Identify the other cation and the anion in **FA 9**. Explain your answers with supporting evidence from your observations in Table 3.1.

Identity of ions	Supporting evidence

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39	

- (d) State the type of reaction that occurred in test 5.
- (e) A student suspects that **FA 10** is aqueous hydrogen peroxide.

With the aid of the data given in Table 3.2, describe how the student can confirm the presence of hydrogen peroxide in **FA 10** with a simple chemical test involving common laboratory bench reagents.

State and explain the expected observations, using relevant calculations.

Electrode reactions	E/V
$H_2O_2 + 2H^+ + 2e^- = 2H_2O$	+1.77
$O_2 + 2H^+ + 2e^- = H_2O_2$	+0.68
$MnO_4^- + 8H^+ + 5e^- = Mn^{2+} + 4H_2O$	+1.52
$Cl_2 + 2e^- = 2Cl^-$	+1.36
$I_2 + 2e^- = 2I^-$	+0.54

Table	3.2
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Test:

.....

.....

Observation and explanation:



### 4 Planning

The label of a bottle of an aqueous acid, represented by  $H_xA$ , has been damaged. The concentration of the acid is known to be 0.500 mol dm<sup>-3</sup>.

You are required to determine:

- 1. if the acid is monobasic or dibasic, and
- 2. if the acid is a strong acid or a weak acid.

You are provided with the following:

- 0.500 mol dm<sup>-3</sup> sodium hydroxide, **FA 11**
- 0.500 mol dm<sup>-3</sup> H<sub>x</sub>A, **FA 12**
- apparatus normally found in a school or college laboratory.
- (a) Write an equation to represent the standard enthalpy change of neutralisation between NaOH and H<sub>x</sub>A.

.....

(b) To determine the basicity of the acid, a thermometric titration can be conducted. A series of experiments can be carried out by mixing different volumes of FA 11 and FA 12 and measuring the temperature change,  $\Delta T$ , of each mixture. You should use a minimum of 10.0 cm<sup>3</sup> of FA 11 for the experiments, and keep the total volume of the mixture constant.

The data obtained can be used to plot a graph to show how  $\Delta T$  varies with the volume of one of the solutions added. Two best-fit straight lines can be drawn and the point of intersection corresponds to the equivalence point. The volume at equivalence point can then be used to determine the basicity of the acid.

Write a plan that include details of:

- the volumes of FA 11 and FA 12 used for the experiments;
- brief, but specific, details of the apparatus you would use, bearing in mind the levels of precision they offer;
- the procedure you would follow and the measurements you would take to obtain the data for graphical analysis, including how ΔT for each mixture can be obtained;
- a sketch of the graphs you would expect to obtain for (i) a monobasic acid, and (ii) a dibasic acid, on the same axes provided;
- the expected equivalence volumes for (i) a monobasic acid, and (ii) a dibasic acid;
- an explanation of the shape of the graph for a monobasic acid.



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(c) Explain how, if at all, the  $\Delta T$  for each experiment will vary if the volumes of FA 11 and FA 12 are doubled.

(d) The acid in **FA 12** is found to be monobasic (HA).

Comparison to the reaction between sodium hydroxide and hydrochloric acid allows for the determination of the strength of HA.

**One additional experiment** involving 0.500 mol dm<sup>-3</sup> hydrochloric acid can be carried out to determine the strength of HA. With reference to the procedure in (b), describe and explain how this additional experiment can be carried out to determine the strength of HA.

No details regarding use of specific glassware are required.

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(e) A student conducted a separate experiment involving 1.00 mol dm<sup>-3</sup> H<sub>2</sub>SO<sub>4</sub>(aq) and 1.00 mol dm<sup>-3</sup> NaOH(aq). The experimental results are as follows:

Volume of H <sub>2</sub> SO <sub>4</sub> (aq)/ cm <sup>3</sup>	25.0
Volume of NaOH(aq)/ cm <sup>3</sup>	25.0
Δ <i>T</i> / °C	6.8

Calculate the enthalpy change of neutralisation for the reaction between  $H_2SO_4$  and NaOH.

You may assume that specific heat capacity of the mixture is  $4.2 \text{ J cm}^{-3} \text{ K}^{-1}$ .

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[Total: 12]

- End of Paper -

# Qualitative Analysis Notes [ppt. = precipitate] 9

# 9(a) Reactions of aqueous cations

a a ti a m	reaction with		
cation	NaOH(aq)	NH₃(aq)	
aluminium, A <i>t</i> ³⁺(aq)	white ppt. soluble in excess	white ppt. insoluble in excess	
ammonium, NH₄⁺ (aq)	ammonia produced on heating	_	
barium, Ba <sup>2+</sup> (aq)	no ppt. (if reagents are pure)	no ppt.	
calcium, Ca <sup>2+</sup> (aq)	white. ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.	
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess	
copper(II), Cu <sup>2+</sup> (aq),	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution	
iron(II), Fe <sup>2+</sup> (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 <sup>3+</sup> (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess	
magnesium, Mg <sup>2⁺</sup> (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess	
manganese(II), Mn <sup>2+</sup> (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 <sup>2+</sup> (aq)	white ppt. soluble in excess	white ppt. soluble in excess	

# 9(b) Reactions of anions

anion	reaction
carbonate, CO <sub>3</sub> <sup>2-</sup>	CO <sub>2</sub> liberated by dilute acids
chloride, C <i>l</i> <sup>-</sup> (aq)	gives white ppt. with Ag <sup>+</sup> (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, NO₃ <sup>−</sup> (aq)	$NH_3$ liberated on heating with $OH^-(aq)$ and $Al$ foil
nitrite, NO <sub>2</sub> <sup>-</sup> (aq)	$NH_3$ liberated on heating with OH <sup>-</sup> (aq) and A <i>l</i> foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO <sub>2</sub> in air)
sulfate, SO <sub>4</sub> <sup>2−</sup> (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids)
sulfite, $SO_3^{2-}$ (aq)	SO <sub>2</sub> liberated with dilute acids; gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in dilute strong acids)

# 9(c) Tests for gases

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

#### 9(d) Colour of halogens

halogen	colour of element	colour in aqueous solution	colour in hexane
chlorine, Cl <sub>2</sub>	greenish yellow gas	pale yellow	pale yellow
bromine, Br <sub>2</sub>	reddish brown gas / liquid	orange	orange-red
iodine, $I_2$	black solid / purple gas	brown	purple