## JURONG PIONEER JUNIOR COLLEGE JC2 PRELIMINARY EXAMINATION 2021

## CHEMISTRY

Higher 2 Paper 4 Practical 9729/04

17 August 2021 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 exam 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, 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 17 and 18.

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 Examiner's Use		
1		
2		

3

Total

Shift

Laboratory

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

#### 1 Determination of the solubility product of calcium iodate

Calcium iodate,  $Ca(IO_3)_2$ , is a sparingly soluble salt and can dissociate in water according to the following equation.

equation 1 
$$Ca(IO_3)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2IO_3^{-}(aq)$$

In this experiment you will determine the solubility product of calcium iodate, Ca(IO<sub>3</sub>)<sub>2</sub>.

A saturated solution of calcium iodate was prepared, the concentration of iodate ions,  $IO_3^-$ , in this saturated solution can be determined by reacting  $IO_3^-$  ions with an excess of  $I^-$  ions to form iodine,  $I_2$ .

equation 2 
$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

The amount of iodine formed may be titrated against a standard solution of  $Na_2S_2O_3$  as shown in equation 3.

equation 3 
$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

- **FA 1** is a filtered saturated solution of calcium iodate, Ca(IO<sub>3</sub>)<sub>2</sub>.
- FA 2 is an aqueous strong acid

**FA 3** is 0.500 mol dm<sup>-3</sup> potassium iodide, KI.

**FA 4** is 0.150 mol dm<sup>-3</sup> sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>.

#### (a) (i) Titration of FA 1 against FA 4

- 1. Fill the burette with **FA 4**.
- 2. Use a pipette to transfer 25.0 cm<sup>3</sup> of **FA 1** into a 250 cm<sup>3</sup> conical flask.
- 3. Use a measuring cylinder to add 25 cm<sup>3</sup> of **FA 2** to the conical flask.
- 4. Use another measuring cylinder to add 10 cm<sup>3</sup> of **FA 3** to the conical flask. The solution will turn brown as iodine is produced.
- 5. Run **FA 4** from the burette into this flask. Near the end-point, when the yellow solution becomes pale, add about 1 cm<sup>3</sup> of starch indicator.
- 6. Continue adding **FA 4** slowly. The end-point is reached with the solution first becomes colourless.
- 7. Record your titration results, to an appropriate level of precision, in the space provided on page 3.
- 8. Repeat points 2 to 7 as necessary until consistent results are obtained.

	(ii)	From the titrations, obtain a suitable volume of <b>FA 4</b> , $V_{FA 4}$ , to be used in your calculations. Show clearly how you obtained this volume.	[3]
(b)	(i)	$V_{FA4}$ = Calculate the amount of IO <sub>3</sub> <sup>-</sup> ions present in 25.0 cm <sup>3</sup> of <b>FA 1</b> .	[3]
	(ii)	amount of $IO_3^-$ ions present in 25.0 cm <sup>3</sup> of <b>FA 1</b> =	[2]
	(11)	Calculate the concentration of IO <sub>3</sub> ions in <b>FA</b> 1.	

 (iii) Hence, determine the solubility product of calcium iodate, Ca(IO<sub>3</sub>)<sub>2</sub>.

		solubility product of calcium iodate, Ca(IO <sub>3</sub> ) <sub>2</sub> =	[1]
(c)	(i)	The literature value of the solubility product of $Ca(IO_3)_2$ is $6.47 \times 10^{-6} \text{ mol}^3 \text{ dm}^{-9}$ .	
		Calculate the experimental error in your experiment by expressing the difference between your calculated solubility product in <b>(b)(iii)</b> and the literature value as a percentage of the literature value.	
		experimental error =	[1]
	(ii)	Calculate the maximum percentage error in the volume of <b>FA 4</b> used in <b>1(a)(ii)</b> .	
		maximum percentage error in the volume of <b>FA 4</b> used =	[1]
	(iii)	A student was provided with an <b>FA 1</b> solution which was not filtered properly and contained traces of undissolved $Ca(IO_3)_2$ suspended in the solution.	
		Predict and explain how this would affect the titre obtained in her experiment.	
			[1]

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5

#### (d) Planning

A student suggested that the dissolution of calcium iodate,  $Ca(IO_3)_2$ , shown in equation **1**, is endothermic.

equation 1 
$$Ca(IO_3)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2IO_3^{-}(aq)$$

The actual value of the enthalpy change,  $\Delta H$ , and the entropy change,  $\Delta S$ , of the reaction can be determined from the following equation.

$$\ln K_{\rm sp} = -\frac{\Delta H}{RT} + \frac{\Delta S}{R}$$

T is the reaction temperature in Kelvin.

*R* is the molar gas constant.

The procedure you followed in **1(a)(i)** can be modified to investigate the effect of temperature, *T*, on the solubility product of Ca(IO<sub>3</sub>)<sub>2</sub>. Plotting In  $K_{sp}$  against  $\frac{1}{T}$  gives a straight line of best fit. The enthalpy change,  $\Delta H$ , and entropy change,  $\Delta S$ , of the reaction can then be graphically determined.

(i) Plan an investigation to determine the effect of temperature, T, on the solubility product,  $K_{sp}$ , of Ca(IO<sub>3</sub>)<sub>2</sub>.

You may assume that you are provided with

- solid calcium iodate, Ca(IO<sub>3</sub>)<sub>2</sub>.
- aqueous strong acid, FA 2.
- 0.500 mol dm<sup>-3</sup> potassium iodide, KI, **FA 3**.
- 0.150 mol dm<sup>-3</sup> sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>, **FA 4**.
- starch indicator
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of

- the reactants and conditions that you would use,
- how you would prepare a saturated solution,
- the procedure that you would follow and the measurements that you would take,
- how you would determine the  $K_{sp}$  of Ca(IO<sub>3</sub>)<sub>2</sub> for each experiment.

..... ..... ..... ..... ..... . . . . . ..... ..... .....

[7]

(ii) Sketch, on Fig. 2.1, the graph you would expect to obtain if the reaction is endothermic as suggested by the student.



(iii) Describe how you would use your graph to determine values for  $\Delta H$  and  $\Delta S$ , showing your working on the graph clearly.

 [3]

[Total: 24]

# 2 Determination of the enthalpy change of neutralisation, $\Delta H_{neu}$ , of an unknown strong acid by a strong base

When an aqueous strong acid is mixed with an aqueous strong base, the neutralisation reaction releases heat causing an increase in the temperature of the solution.

 $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ 

**FA 2** is 0.500 mol dm<sup>-3</sup> unknown aqueous strong acid.

**FA 5** is 1.00 mol dm<sup>-3</sup> sodium hydroxide, NaOH.

In this experiment you will mix different volumes of FA 2 and FA 5, keeping the total volume constant. For each mixture, the change in temperature,  $\Delta T$ , will be determined and used to plot a graph of  $\Delta T$  against volume of FA 5 used.

You will then use data from the graph to determine a value for the enthalpy change of neutralisation,  $\Delta H_{neu}$ , and the basicity of the strong acid used.

# (a) Determine the change in temperature for a series of reactions between FA 2 and FA 5

- 1. Fill the burette with **FA 5**.
- 2. Place the styrofoam cup in a 250 cm<sup>3</sup> beaker to prevent it from tipping over. Transfer 10.00 cm<sup>3</sup> of **FA 5** from the burette into the cup. Measure the temperature of the **FA 5** solution using the thermometer. Record the initial temperature of **FA 5** as  $T_{FA 5}$ .
- 3. Wash and dry the thermometer.
- 4. Use a measuring cylinder to measure 40.0 cm<sup>3</sup> of FA 2. Measure the temperature of the FA 2 solution and record the initial temperature of FA 2 as  $T_{FA 2}$ .
- 5. Add **FA 2** to **FA 5** in the styrofoam cup. Stir the mixture using the thermometer and record the maximum temperature, *T<sub>max</sub>*, reached.
- 6. Wash and shake dry the styrofoam cup.
- Repeat steps 2 to 6 using 15.00 cm<sup>3</sup>, 20.00 cm<sup>3</sup>, 30.00 cm<sup>3</sup>, 35.00 cm<sup>3</sup> and 40.00 cm<sup>3</sup> of FA 5 and appropriate volumes of FA 2 each time, such that the total volume of the reacting mixture is 50 cm<sup>3</sup>.

In an appropriate format in the space provided, record:

- All measurements of volumes used,
- All temperatures measured,
- $T_{weighted initial}$  and the change in temperature,  $\Delta T$  to 1 decimal place.

 $\Delta T$  should be calculated using the following formula:

 $\Delta T = T_{max} - T_{weighted initial}$ 

 $T_{weighted initial} = \frac{(volume of FA 5 \times T_{FA 5}) + (Volume of FA 2 \times T_{FA 2})}{(Volume of FA 2 \times T_{FA 2})}$ 

Volume of FA 5 + Volume of FA 2

#### Results

(b) On the grid provided, plot a graph of  $\Delta T$  (y-axis) against volume of **FA 5** (x-axis) using the data you obtained in (a).

The scale for  $\Delta T$  should extend at least 2°C above your greatest temperature rise.



(ii) Determine from your graph, the maximum change in temperature,  $\Delta T_{max}$ , and the volume,  $V_{max}$ , of **FA 5** required to obtain this value.

 $\Delta \boldsymbol{T}_{max} = \dots \qquad [1]$ 

Calculate the amount of H<sup>+</sup> that would react completely with the amount of (c) (i) NaOH contained in *V*<sub>max</sub> of **FA 5**. amount of H<sup>+</sup> that reacted with NaOH in  $V_{max}$  of **FA 5** = ..... [1] (ii) Using your answer in (c)(i), determine if FA 2 is monobasic, dibasic or tribasic. Basicity of **FA 2** = ..... [2] (iii) Calculate the heat change for the neutralisation reaction at  $\Delta T_{max}$ . You should assume that the specific heat capacity of the final solution is 4.18 Jg<sup>-1</sup>K<sup>-1</sup>, and the density of the final solution is 1.00 g cm<sup>-3</sup>. Heat change = ..... [1] Using your answers in (c)(iii), calculate a value for the enthalpy change of neutralisation,  $\Delta H_{neu.}$ 

 $\Delta H_{neu} = \dots$ 

[4]

(d) A student performed a similar experiment by mixing **FA 5** with 0.500 mol dm<sup>-3</sup> aqueous ethanoic acid.

Predict how the values of  $\Delta T_{max}$  and  $V_{max}$  will change for this experiment by ticking on the appropriate boxes provided.

	decrease	no change	increase	
$\Delta \pmb{T}_{\sf max}$				
V <sub>max</sub>				[1

[Total: 17]

#### 3 Investigation of the chemistry of some vanadium ions

**FA 6** is an acidic solution containing  $VO_2^+$  ions.

Vanadium, is able to exhibit variable oxidation states in its compounds. When **FA 6** is reacted with **FA 7**, a **series of colour changes occur**.

Table 3.1 gives some standard electrode potential values relevant to this question.

Electrode reaction	E <sup>θ</sup> / V
$V^{3+}(aq) + e^{-} \rightleftharpoons V^{2+}(aq)$	-0.26
$VO^{2+}(aq) + 2H^+ + e^- \Rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$VO_2^+(aq) + 2H^+ + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00
$\operatorname{Sn}^{2+}(\operatorname{aq}) + 2e^{-} \rightleftharpoons \operatorname{Sn}(s)$	-0.14

Table 3.1

Perform the tests described in Tables 3.2, 3.3 and 3.4, and record your observations in the table. 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**.

#### Table 3.2

	tests	observations
(a) (i)	To about 5 cm depth of <b>FA 6</b> in a test- tube, add a spatula measure of <b>FA 7</b> . Shake the mixture.	
	Leave the mixture for 5-15 minutes, observing the mixture occasionally. The reaction is complete when a violet solution is obtained.	
	Filter the reaction mixture into a test-tube. This is solution $X$ which contains V <sup>2+</sup> . Label this test-tube $X$ .	
(ii)	Wash a teat-pipette with solution <b>X</b> . Using this teat-pipette, transfer 20 drops of <b>X</b> into a test-tube.	
	Add aqueous potassium manganate(VII) dropwise with shaking, counting the number of drops needed to give the first permanent pink or orange colour.	

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(b) **FA 8** is an aqueous solution that has been made by reacting solid **FA 7** with dilute sulfuric acid.

	tests	observations	
(i)	To about 1 cm depth of <b>FA 8</b> in a test- tube, add aqueous sodium hydroxide until no further changes are observed.		
(ii)	To about 1 cm depth of <b>FA 8</b> in a test- tube, add aqueous ammonia until no further changes are observed.		[1]

Table 3.3

(iii) Identify FA 7.

#### FA 7 is .....

#### Table 3.4

		tests	observations
(c)	(i)	To about 3 cm depth of <b>FA 6</b> in a boiling tube, add a spatula measure of tin powder. Shake the mixture.	
		Gently warm the mixture. In order to view the colours clearly you may find it necessary, from time to time, to allow the tin to settle.	
		Warm the mixture until no further changes are seen.	
		The solution obtained is solution <b>Y</b> which contains another of the reduction products of the vanadium ion present in <b>FA 6</b> .	
			[1]

[1]

(c)	(ii)
$(\mathbf{v})$	··· <i>,</i>

Table 3.1

Electrode reaction	E <sup>θ</sup> / V
$V^{3+}(aq) + e^{-} \rightleftharpoons V^{2+}(aq)$	-0.26
$VO^{2+}(aq) + 2H^+ + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
$VO_2^+(aq) + 2H^+ + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00
$\operatorname{Sn}^{2+}(\operatorname{aq}) + 2e^{-} \rightleftharpoons \operatorname{Sn}(s)$	-0.14

Suggest which ion is responsible for the final colour observed in **3(c)(i)**. Explain your answer using data from Table 3.1.

lon: .....

Explanation:

		[3]
(iii)	Write an overall chemical equation to represent the reaction occurring in (c)(i).	
		[1]
(iv)	If the experiment in <b>3(a)(ii)</b> was repeated using solution <b>Y</b> , calculate the number of drops of aqueous potassium manganate(VII) that would be required to give the first permanent pink or orange colour. Explain your calculation in terms of the redox reactions involved.	
	Number of drops:	
	Explanation:	
		[2]
	[Total:	14]

## **Qualitative Analysis Notes**

## (a) Reactions of Aqueous Cations

	Reaction with		
cation	NaOH(aq) NH <sub>3</sub> (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 <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), Cu²⁺(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 <sup>3+</sup> (aq)	red–brown ppt. insoluble in excess	red–brown ppt. insoluble in excess	
magnesium, Mg²⁺(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess	
manganese(II), Mn²⁺(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	

Anion	Reaction		
carbonate, CO₃²⁻	CO <sub>2</sub> liberated by dilute acids		
choride, C <i>l</i> ⁻(aq)	gives white ppt. with Ag <sup>+</sup> (aq) (soluble in NH <sub>3</sub> (aq));		
bromide, Br⁻(aq)	gives pale cream ppt. with Ag <sup>+</sup> (aq) (partially soluble in NH <sub>3</sub> (aq));		
iodide, I⁻(aq)	gives yellow ppt. with Ag <sup>+</sup> (aq) (insoluble in NH <sub>3</sub> (aq));		
nitrate, NO₃⁻(aq)	NH <sub>3</sub> liberated on heating with OH⁻(aq) and A/ 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 <sub>2</sub> in air)		
sulfate, SO₄²⁻(aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids)		
sulfite, SO₃²⁻(aq)	SO <sub>2</sub> liberated on warming with dilute acids; gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in excess dilute strong acids)		

### (c) <u>Tests for Gases</u>

gas	Test and test results	
ammonia, NH₃	turns damp red litmus paper blue	
carbon dioxide, $CO_2$	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 acidified aqueous potassium manganate(VII) from purple to colourless	

## (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, I2	black solid/purple gas	brown	purple