## TEMASEK JUNIOR COLLEGE

#### 2024 JC2 PRELIMINARY EXAMINATION

#### Higher 2



2 hours 30 minutes

CANDIDATE NAME		CLASS	
CENTRE NUMBER	S	INDEX NUMBER	
Chemistry			9729/04
Paper 4 Practical			26 August 2024

Candidates answer on the Question Paper.

#### **READ THESE INSTRUCTIONS FIRST**

Shift

Laboratory

Write your Centre number, index number, name and class 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 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.

For Examiner's Use			
1	/ 16		
2	/ 16		
3	/ 13		
4	/ 10		
Total	/ 55		

This	document	consists of	18	printed	pages	and <b>2</b>	blank	pages.
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Answer all the questions in the spaces provided.

#### 1 Determination of the formula of hydrated sodium thiosulfate.

In this experiment, you will determine the value of x in the formula of hydrated sodium thiosulfate,  $Na_2S_2O_3 \cdot xH_2O$ , where x is an integer.

You will first react  $IO_3^-$  ions with an excess of iodide ions,  $I^-$ , to form iodine,  $I_2$ . The amount of iodine produced will then be determined by titration with thiosulfate ions,  $S_2O_3^{2-}$ .

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

**FA 1** is 27.3 g dm<sup>-3</sup> of hydrated sodium thiosulfate,  $Na_2S_2O_3 \cdot xH_2O$ .

FA 2 is 0.0150 mol dm<sup>-3</sup> potassium iodate(V), KIO<sub>3</sub>.

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

FA 4 is 2.20 mol dm<sup>-3</sup> hydrochloric acid, HCl.

Starch indicator

#### (a)(i) Procedure

- 1. Fill the burette with FA 1.
- 2. Pipette 25.0 cm<sup>3</sup> of FA 2 into a conical flask.
- 3. Use a measuring cylinder to add 10 cm<sup>3</sup> of **FA 3** to the conical flask.
- 4. Use another measuring cylinder to add 20 cm<sup>3</sup> of **FA 4** to the conical flask. The solution will turn brown.
- 5. Add **FA 1** from the burette until the solution in the conical flask turns pale yellow.
- 6. Add 10 drops of starch indicator to the conical flask. The solution will turn blue-black.
- 7. Continue to add more **FA 1** from the burette until the blue-black colour just disappears. This is the end point of the titration.
- 8. Repeat steps 2 to 7 until consistent results are obtained.

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

#### **Titration results**

(ii) From your titrations, obtain a suitable volume of **FA 1** to be used in your calculations. Show clearly how you obtained this volume.

Volume of **FA 1** = .....cm<sup>3</sup> [3]

(b) (i) The equation for this reaction between iodate(V) and iodide is shown.

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

Calculate the amount of iodine that forms when 25.0 cm<sup>3</sup> of FA 2 reacts with 10 cm<sup>3</sup> of FA 3.

Amount of  $I_2$  formed = ......[1]

(ii) Use your titration results and the equation on page 2 to calculate the concentration of  $Na_2S_2O_3$  in FA 1 in mol dm<sup>-3</sup>.

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(iii) Hence, determine the value of x in the formula of hydrated sodium thiosulfate,  $Na_2S_2O_3 \cdot xH_2O$ , used to prepare **FA 1**.

[A<sub>r</sub>: Na, 23.0; S, 32.1; O, 16.0; H, 1.0]

(c) (i) Calculate the maximum percentage error in the volume of FA 1 used.

Maximum percentage error = .....% [1]

(ii) A student suggested that a more accurate value of x could be obtained if a  $10.0 \text{ cm}^3$  pipette is used to measure **FA 3** rather than the measuring cylinder.

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

.....[1]

[Total: 16]

2 In this experiment you will use a thermometric method to determine the concentration of a sample of alkali. You will mix varying volumes of acid with a fixed volume of the alkali and measure the temperature rises that occur.

You will use your experimental data to calculate the enthalpy change for the neutralisation of the acid with alkali.

FA 4 is 2.20 mol dm<sup>-3</sup> hydrochloric acid, HCl.

FA 5 is aqueous sodium hydroxide, NaOH.

#### (a) Procedure

1. Use the thermometer to measure the initial temperature of FA 5.

initial temperature of FA 5 = ..... °C

- 2. Place a polystyrene cup inside a second polystyrene cup and place both cups in a 250 cm<sup>3</sup> beaker.
- 3. For **Experiment 1**, use a measuring cylinder to transfer 20 cm<sup>3</sup> of **FA 5** into the cup.
- 4. Using a second measuring cylinder, measure 18 cm<sup>3</sup> of water and add 2 cm<sup>3</sup> of **FA 4** to the same measuring cylinder.
- 5. Transfer the solution in the second measuring cylinder into the cup containing **FA 5**.
- 6. Stir the mixture in the cup gently with the thermometer. Read and record the maximum temperature obtained.
- 7. Empty, rinse and shake dry the cup ready for use in **Experiment 2**.
- 8. Repeat the procedure using 20 cm<sup>3</sup> of **FA 5** for each experiment and the volumes of water and **FA 4** shown in Table 2.1. In each case, measure and record the maximum temperature.

Experiment	Volume of water / cm <sup>3</sup>	Volume of <b>FA 4</b> / cm <sup>3</sup>	Maximum temperature / °C
1	18.0	2.0	
2	14.0	6.0	
3	10.0	10.0	
4	6.0	14.0	
5	2.0	18.0	

Table 2	2.1
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Carry out **one** further experiment which will enable you to determine more precisely the volume of **FA 4** that gives the highest maximum temperature.

Record your measurements for all experiments in Table 2.1.

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Draw two straight lines of best fit, taking into account the points when temperature of the mixture was rising and the points when temperature was falling. Each line should have a

Use your graph to determine the volume of FA 4 that reacts with 20.0 cm<sup>3</sup> of FA 5.

shape best suited to its plotted points.

Extrapolate (extend) both lines until they intersect.

The scale on the y-axis should allow for extrapolation above the highest maximum temperature recorded.



Plot a graph of the maximum temperature on y-axis and the volume of FA 4 used on *x*-axis.

(b)

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[Turn over

volume of **FA 4** = .....  $cm^{3}$  [4]

(c) (i) Calculate the amount of hydrochloric acid in the volume of FA 4 in (b).

If you were unable to determine an answer to **(b)** use 8.20 cm<sup>3</sup> as the volume of **FA 4**. This is **not** the correct value.

amount of HCl = ..... mol [1]

(ii) Use your answer to (c)(i) and the information on page 6 to calculate the concentration of sodium hydroxide in FA 5.

concentration of NaOH = ..... mol dm<sup>-3</sup>[1]

(iii) Calculate the energy released when the volume of **FA 4** in (b) is neutralised by sodium hydroxide. Show your working.

(Assume that 4.18 J of energy changes the temperature of 1.0  $\text{cm}^3$  of solution by 1.0 °C.)

energy released = ..... J [2]

(iv) Use your answers to (c)(i) and (c)(iii) to calculate the enthalpy change of neutralisation, in kJ mol<sup>-1</sup> for 1.0 mol of hydrochloric acid.

enthalpy change = ..... kJ mol<sup>-1</sup> [1]

(d) (i) The theoretical value of the enthalpy change of neutralisation is -57.6 kJ mol<sup>-1</sup>.
Calculate the percentage error in your value of the enthalpy change from (c)(iv).
Show your working.

(Assume that the conditions under which you carried out your experiment in **(a)** are identical to the conditions used to determine the theoretical value.)

#### percentage error = ..... % [1]

(ii) Predict whether the enthalpy change of neutralisation for the reaction between FA 4 and potassium hydrogencarbonate is more or less exothermic than -57.6 kJ mol<sup>-1</sup>.

Explain your answer.

......[2]

(iii) Suggest **one** modification to the procedure used in (a) that would give a more accurate value for the enthalpy change of neutralisation.

Do **not** suggest any modifications to apparatus in your answer.

......[1]

[Total: 16]

#### 3 Investigation of some inorganic reactions.

**FA 6** is an aqueous solution containing 1 cation and 1 anion.

**FA 7** is a solution containing a covalent compound.

You will perform tests to identify the cation and anion in **FA 6**. The volumes given are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

(a) (i) Perform the tests described in Table 3.1 and record your observations in the table.

	tests	observations
1	To a 1 cm depth of <b>FA 6</b> in a test-tube, add aqueous ammonia until there is no further change.	
2	To a 1 cm depth of <b>FA 6</b> in a test-tube, add a 1 cm depth of <b>FA 3</b> , KI(aq), then add starch indicator	
3	To a 1 cm depth of <b>FA 6</b> in a test-tube, add a 1 cm depth of <b>FA 1</b> , $Na_2S_2O_3(aq)$ . Leave to stand until there is no further change, then add aqueous sodium hydroxide.	

#### Table 3.1

[3]

(ii)	Identify the cation in <b>FA 6</b> . Use evidence from your observations in Table 3.1 to support your deduction.
	Cation:
	Evidence:
	[1]
(iii)	Write a balanced equation of the reaction that takes place in test 2 of (a)(i).
	[1]
(iv)	Explain your observations in test 3 of <b>(a)(i)</b> .
	[2]

- (b) The anion in **FA 6** is listed in the Qualitative Analysis Notes on page 19-20. The anion is not carbonate, nitrate or nitrite.
  - (i) Devise and perform a series of simple tests to identify the anion in **FA 6**. You should use only the bench reagents provided. Record your tests and observations in the space below.

[3]

#### (ii) Use your observations in (b)(i) to deduce the identity of the anion in FA 6.

......[1]

(c) Perform the tests described in Table 3.2 and record your observations in the table.

#### Table 3.2

	tests	observations
1	To a 1 cm depth of <b>FA 7</b> in a test-tube, add 1 cm depth of <b>FA 6</b> , followed by 1 cm depth of aqueous sodium hydroxide.	
2	To a 1 cm depth of <b>FA 7</b> in a test-tube, add a 1 cm depth of dilute sulfuric acid, followed by 1 cm depth of <b>FA 3</b> , KI(aq). Then add starch indicator	

[2]

#### 4 Planning

lodine and propanone react together in aqueous acidic solution according to the equation:

$$CH_{3}COCH_{3}(aq) \ + \ I_{2}(aq) \ \rightarrow \ CH_{3}COCH_{2}I(aq) \ + \ H^{+}(aq) \ + \ I^{-}(aq)$$

The reaction is catalysed by hydrogen ions and hence the rate equation can be expressed as

$$Rate = k [CH_3COCH_3]^a [H^+]^b [I_2]^c$$

where a, b and c are the orders with respect to the species shown in the rate equation.

If CH<sub>3</sub>COCH<sub>3</sub>(aq) and H<sup>+</sup>(aq) are used in large excess in the reaction, the rate equation becomes

rate =  $k' [I_2]^c$ 

where  $k' = k [CH_3COCH_3]^a [H^+]^b$ .

The order of reaction with respect to iodine can be determined experimentally using the continuous method, whereby the concentration of iodine is measured continuously at various time intervals by sampling, quenching, followed by titration with aqueous sodium thiosulfate.

(a) Aqueous sodium hydrogencarbonate is usually used as the quenching agent for the reaction above. Suggest why it is a suitable choice.

.....[1]

- (b) You may assume you are provided with
  - 50 cm<sup>3</sup> of 0.040 mol dm<sup>-3</sup> iodine
  - 1.00 mol dm<sup>-3</sup> propanone
  - 0.800 mol dm<sup>-3</sup> sulfuric acid
  - 1.00 mol dm<sup>-3</sup> sodium hydrogencarbonate
  - 0.010 mol dm<sup>-3</sup> sodium thiosulfate
  - starch
  - the equipment normally found in a school or college laboratory.
  - (i) 25.0 cm<sup>3</sup> each of propanone and sulfuric acid are separately measured and added to 50.0 cm<sup>3</sup> of iodine.

10.0 cm<sup>3</sup> of the reaction mixture is sampled at suitable time intervals. Calculate the minimum volume of sodium hydrogencarbonate required to quench each sample.

(ii) Plan an investigation to determine the order of reaction with respect to iodine using the continuous method.

In your plan you should include brief details of:

- the apparatus and procedure you would use to prepare a suitable volume of a standard solution of 1.00 mol dm<sup>-3</sup> CH<sub>3</sub>COCH<sub>3</sub>(aq) from liquid propanone, specifying the volume of liquid propanone to be used,
- the quantities of all reagents you would use,
- the apparatus and the procedure you would follow,
- the measurements you would take to allow for a suitable volume-time graph to be drawn from time t = 2 min to t = 20 min.

 $[M_r \text{ of } CH_3COCH_3 = 58.0; \text{ density of } CH_3COCH_3 = 0.7845 \text{ g cm}^{-3}]$ 

[5]

- (c) The order of reaction with respect to iodine is expected to be zero order.
  - (i) Sketch, on Fig. 4.1, the graph of volume of sodium thiosulfate against time you would expect to obtain.



[Total: 10]

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# Qualitative Analysis Notes [ppt. = precipitate]

#### (a) Reactions of aqueous cations

	reaction with			
cation	NaOH(aq)	NH₃(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, Ca²+(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), 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, Zn²+(aq)	white ppt. soluble in excess	white ppt. soluble in excess		

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# (b) Reactions of aqueous anions

anion	reaction		
carbonate, CO <sub>3</sub> ²-	CO <sub>2</sub> liberated by dilute acids		
chloride, 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 $NH_3(aq)$ )		
iodide, I⁻(aq)	gives yellow ppt. with Ag⁺(aq) (insoluble in NH₃(aq))		
nitrate, NO₃⁻(aq)	$NH_3$ liberated on heating with $OH^-(aq)$ and $AI$ foil		
nitrite, NO₂⁻(aq)	NH <sub>3</sub> 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, SO4 <sup>2–</sup> (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids)		
sulfite, SO <sub>3</sub> ²-(aq)	SO <sub>2</sub> liberated with dilute acids; gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in dilute strong acids)		

### (c) Test 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		

# (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 <i>I</i> purple gas	brown	purple