

CANDIDATE

CLASS

DATE

H2 CHEMISTRY

Higher 2

Paper 4 Practical Paper

Tuesday

9729/04

24 August 2021 2 hours 30 minutes

Candidates answer on question paper. No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

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

YISHUN INNOVA JUNIOR COLLEGE JC 2 PRELIMINARY EXAMINATION

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.





This document consists of **19** printed pages and **1** blank page.

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

1 To determine the enthalpy change of neutralisation, ΔH_n

The enthalpy change of neutralisation between an acid and an alkali can be determined using a type of experiment known as thermometric titration. One way of performing a thermometric titration involves using a fixed volume of alkali with progressive addition of small volumes of acid and monitoring the temperature of the reaction mixture during the process.

You are to determine the enthalpy change of neutralisation for the reaction given below.

 $HA(aq) + NaOH(aq) \rightarrow NaA(aq) + H_2O(I)$

FA 1 is 1.80 mol dm⁻³ HA **FA 2** is aqueous sodium hydroxide, NaOH

In this experiment, you will measure the temperature of the contents of a polystyrene cup. You will analyse your results graphically in order to determine an accurate value for the temperature change of the mixture, caused by the neutralisation of aqueous HA and NaOH.

You will use this value to calculate the heat change, q, for the experiment and hence determine a value for the enthalpy change of neutralisation for the reaction, ΔH_n .

(a) **Procedure**

- 1. Place one polystyrene cup in a 250 cm³ beaker.
- 2. Rinse and fill the burette with **FA 1**.
- 3. Use a measuring cylinder to transfer 25 cm³ of **FA 2** into the polystyrene cup.
- 4. Stir the solution in the cup with the thermometer. Read and record its temperature.
- 5. Run 5.00 cm³ of **FA 1** into the cup. Stir the solution with the thermometer. Record the new temperature and volume of **FA 1** added.
- 6. Run a second portion of 5.00 cm³ of **FA 1** into the cup. Stir and record the new temperature and the total volume of **FA 1** added.
- 7. Continue adding **FA 1** in 5.00 cm³ portions. Stir and record each new temperature and the total volume of **FA 1** until a total of 45.00 cm³ has been added.

Results

In an appropriate format in the space below, prepare a table to record the results of your experiment:

- all measurements of volume used
- all values of temperature, *T*, to an appropriate level of precision

Table of results

(b) Plot a graph of temperature, *T*, on the y-axis, against total volume of **FA 1** added, on the x-axis. The temperature axis should allow you to include a point at least 2 °C greater than the maximum temperature recorded.

Draw a best-fit straight line taking into account all of the points for the increase in temperature of the mixture. Draw another best-fit straight line taking into account all of the points for the cooling of the solution.

Extrapolate the two lines and determine the

- maximum temperature reached, T_{max},
- maximum temperature increase, ΔT_{max} ,
- corresponding volume of **FA 1** added.

T_{max} =

 ΔT_{max} =

Volume of **FA 1** added =

[4]

- (c) Explain the shape of the graphs before and after the maximum temperature is reached.

 before maximum temperature is reached

 after maximum temperature is reached

 [2]
- (d) (i) Calculate the number of moles of HA present in the volume of FA 1 recorded in (b).

number of moles of HA =[1]

(ii) Using your answers to (b), calculate the heat change, q, when **FA 1** has completely neutralised 25 cm³ of sodium hydroxide.

You should assume that the specific heat capacity of the solution is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$, and that the density of the solution is 1.00 g cm^{-3} .

(iii) Determine the enthalpy change of neutralisation, ΔH_n , for the reaction.

 $\Delta H_{\rm n} = \dots$ [1]

[1]

[1]

(e) The maximum error in a thermometer reading is ±0.1 °C.
 Calculate the maximum percentage error in the increase in temperature recorded.

maximum percentage error =

(f) Apart from using a thermometer with a greater level of precision, suggest one improvement that could be made to the method carried out in (a).

(g) A student decided to perform the same experiment in (a) but used aqueous ammonia instead of aqueous sodium hydroxide.
 Suggest what effect, if any, would replacing aqueous sodium hydroxide with aqueous ammonia have on the value of enthalpy change of neutralisation calculated in d(iii).
 effect
 explanation

.....

(h) Another student repeated the same experiment in (a) but used **FB 1** which is 0.9 mol dm⁻³ of HA instead of **FA 1**.

Suggest what effect, if any, would replacing FA 1 with FB 1 have on the maximum temperature increase, ΔT_{max} .

effect	
explanation	
	[2]

[Total:19]

2 Qualitative analysis

FA 3 contains one cation and two anions **FA 4** contains two cations

Carry out the following tests. Carefully record your observations in Table 2.1.

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured. Test and identify any gases evolved.

	Table 2.1			
		Test	Observations	
(a)	Place a spatula of FA 3 into a test tube, then add approximately 1 cm ³ of dilute nitric acid.			
(b)	Place a spatula of FA 3 into a boiling tube, then add about 15 cm³ of distilled water. Stopper and shake to mix the solution.Use a 1 cm depth of the FA 3 solution obtained in a test-tube for each of tests (i) to (iv).			
	(i)	Add aqueous sodium hydroxide slowly, with shaking, until no further change is seen.		
	(ii)	Add aqueous ammonia slowly, with shaking, until no further change is seen.		
	(iii)	Add 10 drops of aqueous barium chloride, then add dilute nitric acid, with shaking, until in excess.		
	(iv)	Add a few drops of aqueous silver nitrate. Decant, then add aqueous ammonia until in excess.		
			[3]	

 (e) **FA 4** contains two cations.

A student added aqueous ammonia to a sample of **FA 4** and observed the formation of a green precipitate that was insoluble in excess of the reagent. He concluded that iron(II) ions were present.

Next, he placed a spatula of **FA 4** in a boiling tube and heated the solid gently. The gas evolved turned moist red litmus blue. Upon cooling, a brown residue was obtained.

(i) Using **Table 2.2**, plan and carry out one other test that will enable you to identify the other cation in **FA 4**.

You should start by dissolving half a spatula of **FA 4** in approximately 10 cm³ of distilled water. Use this solution of **FA 4** in your test.

 Table 2.2

 Test

 Observations

Describe your test briefly and state your observations.

- [1]
- (ii) Identify the other cation in **FA 4** and write an ionic equation for the observation in **e(i)** that allows you to confirm its identity.

The other cation in **FA 4**:

Ionic equation:

[Total:7]

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3 Determination of the water of crystallisation in hydrated copper(II) sulfate

The addition of an excess of potassium iodide, KI, to a solution of Cu^{2+} ions produces iodine, I₂, and a stable precipitate of CuI. The I₂ turns the solution brown.

equation 1 $2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$

The iodine produced can be titrated with a standard solution of $Na_2S_2O_3$ as shown in equation 2.

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

FA 8 is an aqueous solution made by dissolving 32.5 g of CuSO₄.**x**H₂O in 1.00 dm³ of solution.

You are also provided with **FA 5**, 0.150 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃, **FA 6**, dilute sulfuric acid, H₂SO₄, **FA 7**, 1.00 mol dm⁻³ potassium iodide, KI, starch indicator.

In this experiment you will determine the value of x in the formula for hydrated copper(II) sulfate, CuSO₄.xH₂O. You will prepare a mixture containing FA 6, FA 7 and FA 8 and titrate the iodine produced against FA 5.

(a) (i) Titration of a mixture against FA 5

- 1. Fill a burette with **FA 5**.
- 2. Use a pipette to transfer 25.0 cm³ of **FA 8** into a 250 cm³ conical flask.
- 3. Use a measuring cylinder to add 10 cm^3 of **FA 6** to the conical flask from step 2.
- 4. Use a measuring cylinder to add 10 cm³ of **FA 7** to the same conical flask from step 3. A white precipitate forms in a brown solution.
- 5. Run **FA 5** from the burette into the flask. Near the end-point, when the brown solution becomes pale, add about 20 drops of the starch indicator.
- 6. Continue adding **FA 5** slowly. The end-point is reached when the **solution** first becomes colourless. The white precipitate remains.
- 7. Record your titration results, to an appropriate level of precision, in the space provided on Page 13.
- 8. Discard the contents of the conical flask **immediately** down the sink. Wash out the conical flask thoroughly with tap water.
- 9. Repeat points 2 to 8 until consistent results are obtained.

Titration results

(ii) From your titrations, obtain a suitable volume of **FA 5** to be used in your calculations. Show clearly how you obtained this volume.

Volume of **FA 5** =[1]

(b) (i) Calculate the amount of copper(II) ions, Cu^{2+} , in 25.0cm³ of **FA 8**.

amount of Cu²⁺ in **FA 8** =[1]

(ii) Calculate the concentration of copper(II) ions, $[Cu^{2+}]$, of **FA 8**.

concentration of Cu^{2+} in **FA 8** =[1]

*M*_r of hydrated copper(II) sulfate =

Hence, deduce the value of **x**. Show your working. [*A*_r: H, 1.0; O, 16.0; S, 32.1; Cu, 63.5]

		x =
		[5]
(c)	Ident	ify two different chemical processes that use iodide ions in this experiment.
		[1]
(d)	A student suggests that the experiment could be made more accurate if the volume of FA was measured using a burette.	
	(i)	Give a reason why the student might make this suggestion.
		[1]
	(ii)	Explain whether this change will improve the accuracy of the experiment.
		[1]

[Total: 17]

4 Planning

The method of initial rates is a commonly used technique for deriving rate laws. To determine the initial rate of a reaction, we can time how long it takes to reach an identifiable point early in the reaction.

In solution, iodide ions, I^- , are oxidised by peroxodisulfate ions, $S_2O_8^{2-}$.

 $S_2O_8^{2-}$ (aq) + 2I⁻ (aq) $\rightarrow 2SO_4^{2-}$ (aq) + I₂ (aq)

If sodium thiosulfate and starch are added to the reaction mixture, the blue-black colour of an iodinestarch complex appears suddenly after some time. This occurs when all of the thiosulfate ions, $S_2O_3^2$, present in the mixture have reacted with the iodine formed in the reaction above. This is the identifiable point in the reaction.

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

You are to plan an experiment to investigate how the rate of reaction between potassium peroxodisulfate and potassium iodide depends on the concentration of potassium peroxodisulfate based on a graphical analysis.

A preliminary experiment, using approximate volumes of solution, indicates that the time taken for the iodine-starch complex to form doubles when the potassium peroxodisulfate is diluted with an equal amount of water.

(a) Using the results of the preliminary experiment, predict the order of reaction with respect to potassium peroxodisulfate. Explain your answer. [2] (b) Explain why it is important that the iodine formed by oxidation reacts with the sodium thiosulfate and is converted back to iodide ions. [1] Explain why the volume of aqueous sodium thiosulfate should be measured precisely, using a (c) burette, in the experiment. [1] ©YIJC

(d) Consider the description of the experiment given in the previous page.

Write a plan for a series of experiments to investigate your prediction in (a).

You may assume that you are provided with:

- 0.60 mol dm⁻³ potassium iodide
 0.20 mol dm⁻³ potassium peroxodisulfate
- 0.01 mol dm⁻³ sodium thiosulfate
- distilled water
- starch indicator solution
- the equipment normally found in a school laboratory

A first experiment is carried out using the following quantities.

- 20 cm³ potassium iodide
- 40 cm³ potassium peroxodisulfate
- 20 cm³ sodium thiosulfate
- 0 cm³ distilled water •
- 10 cm³ starch indicator solution

Give a step-by-step description of the method you would use in further experiments.

Your plan should contain the following:

- the apparatus you would use, •
- a table to indicate the different quantities of reagents you would use,
- the procedure you would follow,
- the measurements you would make to allow a suitable graph to be drawn in order to investigate your prediction in (a).

.....

17

[6]

(e) Assuming that your prediction in (a) is correct, sketch on Fig. 4.1 the graph you would expect to obtain from your results. Label the axes.



Fig. 4.1

[2]

[Total: 12]

Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	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, Ba²⁺(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), Cu²⁺(aq),	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution	
iron(II), Fe ²⁺ (aq)	green ppt. insoluble in excess	green ppt. insoluble in excess	
iron(III), Fe ³⁺ (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. insoluble in excess	off-white ppt. insoluble in excess	
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess	

(b) Reactions of anions

ions	reaction	
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids	
chloride, C <i>l</i> ⁻(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, NO₃⁻(aq)	NH₃ liberated on heating with OH⁻(aq) and A <i>l</i> foil	
nitrite, NO₂⁻(aq)	NH ₃ liberated on heating with OH ⁻ (aq) and A <i>l</i> foil; NO liberated by dilute acids (colourless NO \rightarrow (pale) brown NO ₂ in air)	
sulfate, SO₄²⁻(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) Test for gases

ions	reaction	
ammonia, NH₃	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