TEMASEK
JUNIOR COLLEGE

2021 JC2 PRELIMINARY EXAMINATIONS
HIGHER 2

CANDIDATE NAME									
CIVICS GROUP			/						
CENTRE NO. / INDEX NO.					/				

CHEMISTRY **9729/04**

Paper 4 Practical **26 August 2021**

2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your Civics Group and name 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.

Shift
Laboratory

For Examiner's Use	
1	/ 12
2	/ 17
3	/ 14
4	/ 12
Total	/ 55

This document consists of 20 printed pages.

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

1 Determination of water of crystallisation in a hydrated iron(III) salt

A variety of hydrated iron(III) sulfates are known. Solutions of iron(III) sulfate are used in dyeing as a mordant, and as a coagulant for industrial wastes. **FA 1** is hydrated iron(III) sulfate with formula $Fe_2(SO_4)_3.nH_2O$. The addition of excess zinc to a solution of **FA 1** reduces the Fe^{3+} ions to Fe^{2+} ions.

The amount of Fe^{2+} ions can be determined quantitatively by titration against a standard solution of potassium manganate(VII), $KMnO_4$. The reaction is shown below.

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

In this experiment, you are to prepare a standard solution using **FA 1** and perform titrations to determine the value of *n*, the water of crystallisation in **FA 1**.

You are provided with

FA 2, dilute sulfuric acid,
FA 3, 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$,
zinc powder.

(a) Preparation of standard solution of hydrated iron(III) salt

1. Weigh accurately about 6.5 g of the **FA 1** provided using the weighing bottle. Transfer all the solid into a 250 cm^3 beaker. Determine the mass of solid **FA 1** used and record all your weighings, to an appropriate level of precision, in the space below.

[1]

2. Use a measuring cylinder to add about 100 cm^3 of **FA 2** to the beaker. Stir the mixture with a glass rod for 3 minutes. Ignore any cloudiness that remains.
3. Transfer the solution into a 250 cm^3 volumetric flask. Rinse the beaker with deionised water and pour the washings into the volumetric flask.
4. Make up to the 250 cm^3 mark with deionised water, stopper and mix thoroughly by inverting the flask a number of times.
5. Label this solution **FA 4**.

(b) **Preparation of Fe^{2+} solution from FA 4**

6. Use a measuring cylinder to transfer 100 cm^3 of **FA 4** into a 250 cm^3 beaker.
7. Add all the zinc powder into the beaker. Cover the beaker with a white tile.
8. Allow the reaction to take place for about 5 minutes, stirring the reaction mixture from time to time.
9. Filter the mixture into the **dry** conical flask provided using **dry** filter paper and filter funnel. Ignore any reaction that may still be taking place.
10. Label the filtrate as **FA 5**. Proceed to **1(c)** once you have collected sufficient filtrate.

(c) **(i) Titration of FA 5 against FA 3**

11. Fill a burette with **FA 3**.
12. Use a pipette to transfer 10.0 cm^3 of **FA 5** into a 250 cm^3 conical flask.
13. Use a measuring cylinder to add about 10 cm^3 of **FA 2** to this flask.
14. Titrate with **FA 3** from the burette until the appearance of the first permanent pale-pink colour.
15. Record your titration results, to an appropriate level of precision, in the space below.
16. Repeat steps 12 to 15 until consistent results are obtained.

Titration Results

[3]

(ii) From your titrations, obtain a suitable volume of **FA 3**, $V_{\text{FA 3}}$, to be used in your calculations. Show clearly how you obtained this volume.

$V_{\text{FA 3}}$ = …………………………………………….[3]

(d) **(i)** Calculate the amount of Fe^{2+} in 10.0 cm^3 of **FA 5**.

amount of Fe^{2+} in 10.0 cm^3 of **FA 5** = ………………………………………… [1]

(ii) In step 7, an excess of zinc was added to convert the Fe^{3+} to Fe^{2+}.

Calculate the amount of Fe^{3+} in 250 cm^3 of **FA 4**.

amount of Fe^{3+} in 250 cm^3 of **FA 4** = ………………………………………… [1]

(iii) Use your answer from **1(d)(ii)** to calculate the M_r of the hydrated iron(III) sulfate, $Fe_2(SO_4)_3.nH_2O$, in **FA 1**.

M_r of the hydrated iron(III) sulfate = ……………………………………

Hence, deduce the value of *n*, the water of crystallisation in the hydrated iron(III) sulfate.

[A_r: Fe, 55.8; S, 32.1; O, 16.0; H, 1.0]

n = ………………………………..

[2]

(e) In step 9, excess zinc was filtered off before titration of **FA 5** against **FA 3** to avoid any possible reaction between zinc and **FA 3**.

Suggest another reason why it was necessary to filter off the excess zinc metal, and what effect failing to do it would have on the titre values. [1]

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[Total: 12]

2 Determination of the enthalpy change of neutralisation by graphical analysis

The neutralisation reaction between sulfuric acid and sodium hydroxide is exothermic.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

FA 2 is sulfuric acid, H_2SO_4.
FA 6 is 1.50 mol dm^{-3} sodium hydroxide, NaOH.

In this question, you will add different volumes of **FA 6** to a fixed volume of **FA 2**. By measuring the temperature changes that occur, it is possible to determine the neutralisation point. This is the point at which just enough alkali has been added to react with all the acid present.

The aim of the investigation is to determine the enthalpy change of neutralisation for the reaction between sulfuric acid and sodium hydroxide.

Take care as aqueous solutions of sodium hydroxide are corrosive.

Read through the following instructions carefully before starting any practical work.

(a)

1. Fill the burette with **FA 6**.
2. Place a polystyrene cup inside a 250 cm^3 beaker to provide support for the cup.
3. Use a measuring cylinder to transfer 30.0 cm^3 of **FA 2** into the cup and record the steady temperature of **FA 2**, T_1, in the space below.

   T_1 = …………..°C

4. Add 5.00 cm^3 of **FA 6** from the burette to the cup, stir the mixture thoroughly with the thermometer and record the temperature of the solution.
5. Add a further 5.00 cm^3 of **FA 6** to the cup and again record the temperature.
6. Continue the addition of **FA 6**, in 5.00 cm^3 portions, until a total of 35.00 cm^3 of **FA 6** have been added from the burette. Measure the temperature after each addition.
7. Record the total volume of **FA 6** added, total volume of solution, V_T, and all temperatures, T_x, in Table 2.1 on page 8.

   Record V_T to 1 decimal place and the total volume of FA 6 and T_x to an appropriate level of precision.

Note: If you overshoot on an addition, record the <u>actual</u> volume of FA 6 added up to that point.

Table 2.1

Total volume of **FA 6** added / cm^3	Total volume of solution in cup, V_T / cm^3	Temperature, T_x / °C	ΔT / °C	V_T x ΔT / cm^3 °C

After each addition of **FA 6**, the temperature rise, ΔT, is given by,

$\Delta T = T_x - T_1$.

Complete Table 2.1 by calculating ΔT to 1 decimal place and (V_T x ΔT) for each measurement.

[4]

(b) Plot a graph of (V_T x ΔT) on the y-axis against the volume of **FA 6** added on the x-axis.

Draw two straight lines of best-fit through the plotted points to find the neutralisation point for the reaction.

[3]

(c) From your graph, determine the volume of **FA 6** and (V_T x ΔT) at the neutralisation point.

volume of **FA 6** = …..……………..…. cm^3

V_T x ΔT = ……………………cm^3 °C

[1]

(d) Calculate the enthalpy change of neutralisation for the reaction between sulfuric acid and sodium hydroxide.

You should assume that the:

- specific heat capacity of the mixture is 4.18 J g^{-1} K^{-1};
- density of the mixture is 1.00 g cm^{-3}.

enthalpy change of neutralisation = ……………………………….. [2]

(e) Fig. 2.1 was obtained when ΔT was plotted against the volume of **FA 6** added.

Explain the shape of the graph in Fig. 2.1 before the equivalence point and after the equivalence point.

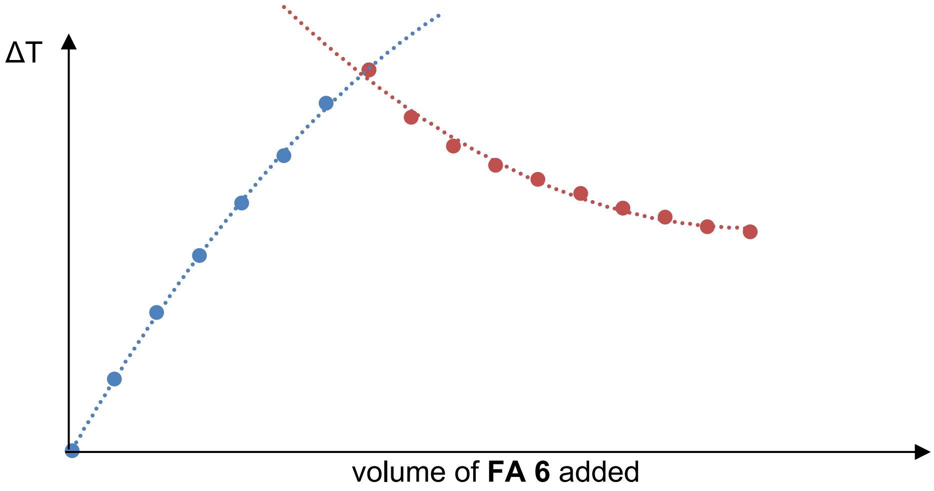

Fig. 2.1

[3]

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(f) In the experiment you have performed, determine whether using a measuring cylinder or a burette to measure each 5.00 cm^3 portion will be more accurate.

The errors (uncertainties) associated with each reading using a measuring cylinder and burette are ± 0.5 cm^3 and ± 0.05 cm^3 respectively.

Show calculations to justify your answer.

[4]

[Total: 17]

3 Qualitative Analysis

At each stage of any test, you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.

No additional tests for ions present should be attempted.

FA 7 is an aqueous solution that contains a mixture of salts with two cations and two anions listed in the Qualitative Analysis Notes.

Test	**Procedure**	**Observation**
(a)	Test the **FA 7** solution using Universal Indicator paper.	
(b)	To 2 cm depth of **FA 7**, add aqueous sodium hydroxide dropwise with shaking till 4 cm depth is added. Swirl and filter the mixture, collecting the filtrate in a test-tube. The filtrate is **FA 8** which should be put to one side for use in **(c)**. Wash the residue thoroughly with deionised water. Discard the washings. The residue is **FA 9**. Retain the residue for use in **(d)(i)**.	
(c)(i)	To 1 cm depth of **FA 8**, carefully add nitric acid dropwise until no further change is seen.	

[Turn over

Test	**Procedure**	**Observation**
(c)(ii)	To 1 cm depth of **FA 8**, heat gently. Add one piece of aluminium foil and heat gently.	
(c)(iii)	To 1 cm depth of **FA 8**, add 1 cm depth of nitric acid, followed by silver nitrate.	
(d)(i)	Transfer the residue, **FA 9**, into a clean test-tube. Carefully add **FA 2,** a few drops at a time with shaking, until all of the residue dissolved. This solution is **FA 10.** Use **FA 10** for **(d)(ii)**.	
(d)(ii)	To 1 cm depth of **FA 10**, add a few drops of KI. Leave to stand.	

[7]

(e) From your observations in **(c)(i)**, suggest the possible identity of the cations present in **FA 8**. [1]

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(f) Explain the observations when nitric acid was added to **FA 8** in **(c)(i).** [1]

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(g) Suggest the identity of the two anions present in **FA 7**, explain your reasoning. [3]

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(h) Identify the cation present in **FA 9**. [1]

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(i) Using your observation in **(d)(ii)**, suggest whether iodine is a stronger oxidising agent than the cation in **FA 9**. [1]

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[Total: 14]

[Turn over

4 Planning

(a) Calcium hydroxide, $Ca(OH)_2$, is a sparingly soluble salt.

A 25.0 cm^3 saturated solution containing $Ca(OH)_2$ dissolved in 0.020 mol dm^{-3} NaOH at 25 °C was titrated with HC*l*.

Determine a suitable concentration of hydrochloric acid needed for the titration. You are to assume that the solubility of $Ca(OH)_2$ in 0.020 mol dm^{-3} aqueous sodium hydroxide at 25 °C is approximately 5.00×10^{-3} mol dm^{-3}.

[3]

(b) Using the concentration of dilute hydrochloric acid, HC*l,* that you have determined in **(a)**, you are to plan an experiment to determine

- the solubility of $Ca(OH)_2$ in 0.020 mol dm^{-3} aqueous sodium hydroxide and
- the solubility product of $Ca(OH)_2$ at 25 °C.

Your plan should include the procedure you would follow with the appropriate choice of apparatus and the measurements to be made.

You may assume that you are provided with:

- solid calcium hydroxide, $Ca(OH)_2$,
- 0.020 mol dm^{-3} aqueous sodium hydroxide, NaOH,
- dilute hydrochloric acid, HC*l,* of concentration you determined in **(a)**
- methyl orange,
- the apparatus and equipment normally found in a school or college laboratory.

[6]

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(c) **(i)** Given that you obtain a titre value of 24.00 cm^3 HC*l* from your experiment in **(b)**, calculate the solubility of $Ca(OH)_2$ in 0.020 mol dm^{-3} sodium hydroxide solution.

[2]

(ii) Hence, calculate the solubility product of $Ca(OH)_2$.

[1]

[Total: 12]

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 Al foil
nitrite, $NO_2^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al 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	black solid / purple gas	brown	purple