NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CLASS		TUTOR'S NAME	

CHEMISTRY **9729/04**

Paper 4 Practical **August 2025**

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 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, 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	**/ 13**
2	**/ 15**
3	**/ 14**
4	**/ 13**
Total	**/ 55**

1 Determination of concentration of ethanedioic acid

FA 1 is 0.023 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 2 is aqueous ethanedioic acid, $H_2C_2O_4$, made by dissolving the hydrated salt, $H_2C_2O_4 \cdot 2H_2O$.

You are also provided with 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

In this experiment you are to determine the concentration, in g dm^{-3}, of hydrated ethanedioic acid, $H_2C_2O_4 \cdot 2H_2O$, in **FA 2**.

(a) Manganate(VII) ions, MnO_4^-, and ethanedioate ions, $C_2O_4^{2-}$, undergo redox reaction in an acidic solution.
Fill in the stoichiometric values for the reaction equation below.

.........MnO_4^- + ...H^+ + ...$C_2O_4^{2-}$ $\rightarrow$ ....Mn^{2+} + ...H_2O + ...CO_2 [1]

(b) Dilution of FA 2

1. Using a burette, measure between 42.50 cm^3 and 43.00 cm^3 of **FA 2** into a 250 cm^3 volumetric flask. Record the data in the space provided below.
2. Make the solution up to the mark with deionised water and shake well to mix.
3. Label this solution **FA 3**.

Results

Titration of FA 3 against FA 1

4. Fill a second burette with **FA 1**.
5. Use a pipette to transfer 25.0 cm^3 of **FA 3** into a 250 cm^3 conical flask.
6. Using a measuring cylinder, transfer 25.0 cm^3 of 1.0 mol dm^{-3} sulfuric acid and 40.0 cm^3 of deionised water into the same flask and place the flask on a tripod stand.
7. Put a thermometer into the conical flask and heat the solution using a Bunsen flame until the temperature of the solution is **just above 65 ºC**.
8. Carefully remove the thermometer and place the flask under the second burette containing **FA 1**. If the neck of the flask is too hot to hold safely, use a folded paper towel to hold the flask.
9. Run 1 cm^3 of **FA 1** and swirl the flask until the colour of the potassium manganate(VII) has disappeared then continue titrating with **FA 1**. The end-point is reached when a permanent pale pink colour is obtained.

   If a brown colour appears during the titration, reheat the flask to 65 ºC. The brown colour should disappear and the titration can be completed as above.
   If the brown colour does not disappear on reheating, discard the solution and start the titration again.

10. Record your titration results, to an appropriate level of precision, in the space provided below.
11. Repeat steps 4 to 10 until consistent results are obtained.

Titration results

[2]

(c) 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^3 [3]

(d) **(i)** Calculate the amount of MnO_4^- ions present in the volume of **FA 1** calculated in **(c)**.

amount of MnO_4^- ions = ... mol [1]

(ii) Calculate the amount of $C_2O_4^{2-}$ ions that reacted with MnO_4^- ions from the burette.

amount of $C_2O_4^{2-}$ ions = ... mol [1]

(iii) Determine the concentration, in mol dm^{-3}, of $C_2O_4^{2-}$ ions in **FA 3**.

concentration of $C_2O_4^{2-}$ ions in **FA 3** = ... mol dm^{-3} [1]

(iv) Calculate the concentration, in mol dm^{-3}, of $C_2O_4^{2-}$ ions in **FA 2**.

concentration of $C_2O_4^{2-}$ ions in **FA 2** = ... mol dm^{-3} [1]

(v) Hence calculate the concentration, in g dm^{-3}, of $H_2C_2O_4 \cdot 2H_2O$ in **FA 2**.
[A_r: H, 1.0; C, 12.0; O, 16.0]

concentration of $H_2C_2O_4 \cdot 2H_2O$ in **FA 2** = ... g dm^{-3} [1]

(e) Explain, in molecular terms, why

(i) the initial reaction in Step 9 is slow even though the conical flask was heated above 65 ºC before titration.

....

....

....[1]

(ii) the rate of reaction increases as the reaction progresses.

....

....

....[1]

[Total: 13]

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2 Determination of the enthalpy change of solution for potassium chloride

Solid FA 4 is anhydrous potassium chloride.

(a) In this experiment, you will measure the temperature of the contents of a polystyrene cup at timed intervals, both before and after **solid FA 4** is added. You will analyse your results graphically in order to determine an accurate value for the temperature change of the mixture, caused by dissolving **solid FA 4**.

You will use this value to calculate the heat change, *q,* for the experiment and hence determine a value for the enthalpy change of solution for **solid FA 4**, ΔH_{sol}.

In an appropriate format in the space provided on page 8, prepare tables in which to record results for your experiment in **(a)**:

- all weighings to an appropriate level of precision,
- all values of temperature, *T,* to an appropriate level of precision,
- all values of time, *t,* recorded to the nearest 0.5 min.

It is important that you measure each temperature at the specified time.

Procedure

1. Weigh the capped bottle containing **solid FA 4**.
2. Place a polystyrene cup in a 250 cm^3 beaker to prevent them from tipping over.
3. Use a 50 cm^3 measuring cylinder to transfer 50 cm^3 of deionised water into the polystyrene cup.
4. Stir the water in the cup with the thermometer. Read and record its temperature, *T* (time, t = 0.0 min).
5. Continue to stir the water. Read and record *T* every minute.
6. At **exactly** three minutes, transfer all the **solid FA 4** to the polystyrene cup. Stir the mixture but do not read *T.*
7. Continue to stir the mixture. Read and record *T* at t = 3.5 min.
8. Continue to stir the mixture. Read and record *T* at t = 4.0 min and every minute until t = 9.0 min.
9. Reweigh the empty bottle and its cap.

Results

[4]

(b) Plot a graph of temperature, *T*, on the y–axis, against time, *t*, on the x–axis on the grid in Fig. 2.1 on page 9.

Draw a best–fit straight line taking into account all of the points before t = 3.0min.

Draw another best–fit straight line taking into account all of the points after the temperature of the mixture has started to rise steadily.

Extrapolate (extend) both lines to t = 3.0 min.

Fig. 2.1

[4]

(c) From your graph, read the minimum temperature, T_{min}, and the maximum temperature, T_{max}, at t = 3.0 min. Record these values in the spaces provided.

Calculate the temperature change, ΔT, at t = 3.0 min

T_{min} = ... °C

T_{max} = ... °C

ΔT = ... °C

[1]

(d) Calculate the heat change, *q*, for your experiment using the value you calculated in **(c)**.

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

q = ...J [1]

(e) Determine the enthalpy change of solution, ΔH_{sol}, for **solid FA 4**. Include the sign of ΔH_{sol} in your answer.
[A_r: C*l*, 35.5; K, 39.1]

ΔH_{sol} = ...kJ mol^{-1} [3]

(f) Suggest how using 100 cm^3 of water rather than 50 cm^3 would affect your ΔT value. Hence, explain the impact it will have on the value of $\Delta H_{sol.}$

....

....

....

....

....

.... [2]

[Total: 15]

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3 Planning

Propanone, CH_3COCH_3, is an organic liquid which is soluble in water.
Aqueous propanone reacts with aqueous iodine. The reaction is catalysed by $H^+(aq)$ ions.

$$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + HI(aq)$$

The rate equation was found to be

$$\text{rate} = k\,[CH_3COCH_3]\,[H^+]$$

The order of reaction with respect to iodine can be determined experimentally and an experiment is carried out using the following solutions.

- 30.0 cm^3 of 1.00 mol dm^{-3} $CH_3COCH_3(aq)$
- 30.0 cm^3 of 1.00 mol dm^{-3} $H_2SO_4(aq)$
- 40.0 cm^3 of 0.200 mol dm^{-3} $I_2(aq)$

The solutions are mixed to start the reaction. 10 cm^3 portions are withdrawn at regular intervals and an excess of sodium hydrogencarbonate, $NaHCO_3(aq)$, is added. The concentration of unreacted $I_2(aq)$ in each sample of the mixture can then be determined by titration with aqueous sodium thiosulfate, $Na_2S_2O_3(aq)$.

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

(a) **(i)** Explain the purpose of adding $NaHCO_3(aq)$ to the 10.0 cm^3 portions of the mixture.

....

....[1]

(ii) Suggest a reason why $NaHCO_3(aq)$ is preferred to $NaOH(aq)$ as the reagent.

....

....

....[1]

(b) Plan an experiment to collect sufficient data to plot a graph of volume of $Na_2S_2O_3$ against time, to show that the order of reaction is zero with respect to iodine.

In your plan, you should use the solutions provided and assume that the concentrations of the reactants are chosen so that mixing the volume of solutions stated above gives a mixture with a suitable mole ratio for this method.

Your plan should include brief details of:

- the apparatus you would use
- the procedure you would follow
- the measurements you would take to allow a suitable graph to be plotted.

[6]

(c) Sketch on Fig. 3.1 the graph you would expect to obtain from your results.
Explain how you would determine the order of reaction with respect to the iodine concentration.

Fig. 3.1

....

....

....

.... [2]

(d) A student wants to confirm that the order of reaction with respect to CH_3COCH_3 is one. He carries out the same procedure in **(b)** but varies the volumes of the reactants.

Complete the following table to show the volumes of the reagents needed and give a sketch of the graph the student is expected to obtain on Fig 3.1. Label the sketch "*Experiment 2*".

Explain how the student can prove that the order of reaction with respect to CH_3COCH_3 is one from the graph.

experiment	aim	$V(I_2)$ / cm^3	$V(CH_3COCH_3)$ / cm^3	$V(H_2SO_4)$ / cm^3	V(water) / cm^3
1	determine order w.r.t. I_2	40	30	30	0
2	determine order w.r.t. CH_3COCH_3				

....

....

....

....

....

.... [4]

[Total: 14]

4 Investigation of inorganic and organic compounds

(a) (i) Identification of ions in an inorganic compound

FA 5 is a mixture containing two cations and two anions, one of the cations cannot be identified. You will perform tests to identify the ions present in **FA 5**.
Carry out the following tests. Carefully record your observations in Table 4.1.

The volumes given below are approximate and should be estimated rather than measured. Test and identify any gas evolved.
If there is no observable change, write **no observable change**.

Table 4.1

	tests	observations
1	To 3 cm depth of dilute nitric acid in a boiling tube, add half the amount of **FA 5** from the bottle. Use the resulting solution, labelled **FA 6**, for tests 2–6.	
2	To 1 cm depth of **FA 6**, add 1 cm depth of sodium chlorate(I). To the resulting solution, add aqueous sodium thiosulfate dropwise.	
3	To 1 cm depth of **FA 6**, add aqueous sodium hydroxide.	
4	To 1 cm depth of **FA 6**, add aqueous ammonia.	
5	To 1 cm depth of **FA 6**, add 1 cm depth of copper(II) sulfate. To the resulting solution, add aqueous sodium thiosulfate dropwise until no further change occurs.	
6	To 1 cm depth of **FA 6**, add a few drops of aqueous silver nitrate. To the resulting solution, add aqueous ammonia until no further change occurs.	

[6]

(ii) Using your observations above, identify the cation and 2 anions present in **FA 5**.

Ions present:.. [1]

(b) (i) Identification of organic compounds

FA 7, **FA 8** and **FA 9** are 3–carbon organic compounds having different functional groups.

You are to carry out tests to identify samples of **FA 7**, **FA 8** and **FA 9**. Some of the observations have been completed for you. There is no need to carry out those tests. Record your observation in Table 4.2.

Table 4.2

		Observations		
		FA 7	**FA 8**	**FA 9**
1	To 1 cm depth of **FA** solution into a test–tube add a few drops of 2,4–DNPH.			
2	To 1 cm depth of aqueous silver nitrate in a test–tube, add 1 drop of aqueous sodium hydroxide. Add aqueous ammonia dropwise with shaking until the brown solid just dissolve. Transfer 1 cm depth of the above mixture to a clean test–tube add 5 drops of **FA** solution. Place the test–tube in a hot water bath.			
3	To 1 cm depth of **FA** solution, add a little sodium carbonate powder.			

[3]

(ii) Identify **FA 7** to **FA 9**

FA 7: ....

FA 8: ....

FA 9: ....

[1]

(iii) Suggest another test to confirm the identity of **FA 7** and state what will be observed.

Reagents and conditions: ....

Observation: ....

[2]

[Total:13]

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 $\rightarrow$ (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_2	black solid / purple gas	brown	purple