H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
CLASS		TUTOR'S NAME	

CHEMISTRY **9729/04**

Paper 4 Practical **16 August 2023**

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

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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	**/ 14**
2	**/ 18**
3	**/ 10**
4	**/ 13**
Total	**/ 55**

[Turn Over

This document consists of **20** printed pages

1 Investigation of the reaction between phosphoric acid and sodium hydroxide

FA 1 is an aqueous solution of phosphoric acid, H_3PO_4.
FA 2 is 0.115 mol dm^{-3} sodium hydroxide, NaOH.

In this experiment you are to investigate the reaction between phosphoric acid and sodium hydroxide in order to determine the chemical equation.

Solution **I** is thymolphthalein indicator.

(a) (i) Procedure

Dilution of FA 1

1. Use the pipette to transfer 10.0 cm^3 of **FA 1** into a 250 cm^3 volumetric flask.

2. Make the solution up to the mark with deionised water and shake well to mix.

3. Label this solution **FA 3**.

Titration of FA 3 against FA 2

4. Fill the burette with **FA 2**.

5. Use the pipette to transfer 25.0 cm^3 of **FA 3** into a 250 cm^3 conical flask.

6. Add a few drops of solution **I** to the conical flask.

7. Run **FA 2** from the burette into the conical flask. The end-point is reached when the solution changes from colourless to a permanent **pale** blue colour.

8. Record your titration results, to an appropriate level of precision, in the space provided below.

9. Repeat points 5 to 8 until consistent results are obtained.

Results

[4]

(ii) From your titrations, obtain a suitable volume of **FA 2** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 2** = ______________ cm^3 [1]

(b) **(i)** Calculate the amount of sodium hydroxide present in the volume of **FA 2** calculated in **(a)(ii)**.

amount of NaOH = ______________ mol [1]

(ii) The density of the aqueous solution of phosphoric acid, **FA 1**, is 1.75 g cm^{-3} and **FA 1** contained 8.40 % by mass of H_3PO_4.

Show that the concentration of H_3PO_4 in **FA 1** is 1.50 mol dm^{-3}.
[A_r: H, 1.0; O, 16.0; P, 31.0]

[2]

(iii) Hence, calculate the amount of H_3PO_4 present in 25.0 cm^3 of **FA 3**.

amount of H_3PO_4 = ________________ mol [2]

(iv) When NaOH reacts with H_3PO_4, the salt formed could be NaH_2PO_4, Na_2HPO_4 or Na_3PO_4.

Use your answer to **(b)(i)** and **(b)(iii)** to deduce which one of these three salts was the major product formed during the titration.
Write the equation for the reaction of NaOH with H_3PO_4 to produce this salt.

[2]

(c) The individual error in any burette reading is ±0.05 cm^3.
Two students, A and B, record identical burette readings.

final burette reading	25.60 cm^3
initial burette reading	1.35 cm^3
volume added	24.25 cm^3

By considering the individual error in each burette reading, explain the following.

- The initial burette reading made by student A was 0.05 cm^3 greater than the true value but the volume added was exactly 24.25 cm^3.

  ____

  ____

- The initial burette reading made by student B was 0.05 cm^3 less than the true value and the actual volume added was exactly 24.15 cm^3.

  ____

  ____

[2]

[Total: 14]

2 Determination of the enthalpy change of solution for ammonium chloride

FA 4 is solid ammonium chloride, $NH_4Cl(s)$.

When an exothermic reaction takes place in a container such as a beaker, some of the evolved heat energy is absorbed by the beaker.

When an endothermic reaction takes place some of the required heat energy is supplied by the beaker.

The amount of heat energy evolved or supplied for a 1 °C change in temperature is known as the heat capacity of the beaker.

In preparation for your experiment to determine the enthalpy change of solution for **FA 4**, you will first need to determine the heat capacity of the 250 cm^3 beaker labelled **A**.

When samples of hot and cold water are mixed in beaker **A**, some heat is lost to the beaker in raising its temperature. To determine the approximate heat capacity of beaker **A**, you will determine the maximum temperature rise when a sample of hot water is added to cold water in the beaker.

(a) (i) Determination of the heat capacity of beaker A

1. Use a 50 cm^3 measuring cylinder to transfer 50 cm^3 of cold water into beaker **A.**

2. Use the 50 cm^3 measuring cylinder to transfer 50 cm^3 of cold water into the other 250 cm^3 beaker. Note the temperature of the water in this 250 cm^3 beaker and heat it **carefully and gently** until the temperature of the water in it has increased by 45–50 °C then stop heating, *e.g. if the water is at 30.0 °C you should warm it to 75–80 °C*.

3. Stir the cold water in beaker **A** with the thermometer.

4. Record the temperature of the cold water (this is the temperature at t = 0.0 min).

5. Record the temperature each minute for 3 minutes.

6. After you have taken the reading at t = 3.0 min, use the thermometer to stir the hot water in the 250 cm^3 beaker.

7. At t = 4.0 min, measure the temperature of the hot water and record this value in the box below.

The temperature, T_1, of the hot water at t = 4.0 min is ____________ °C.

8. **Immediately** add the hot water from the 250 cm^3 beaker to the cold water in beaker **A**. Stir with the thermometer but do **not** record the temperature.

9. Continue to stir the water in beaker **A** throughout the experiment.

10. Record the temperature at *t* = 5.0 min, and then every **0.5 minute** until *t* = 8.0 min.

11. Empty and rinse beaker **A**. Dry it using a paper towel.

12. Record all measurements of time and temperature obtained. Do **not** include the temperature, T_1, of the hot water at *t* = 4.0 min measured in point 7.

Results

[3]

(ii) Plot a graph of the temperature of the water in beaker **A**, on the *y*-axis, against time, on the *x*-axis, on the grid in Fig. 2.1.

Draw a best-fit straight line taking into account all of the points before *t* = 4.0 min.

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

Extrapolate (extend) both lines to *t* = 4.0 min.

Do **not** plot the temperature, T_1, of the hot water at *t* = 4.0 min.

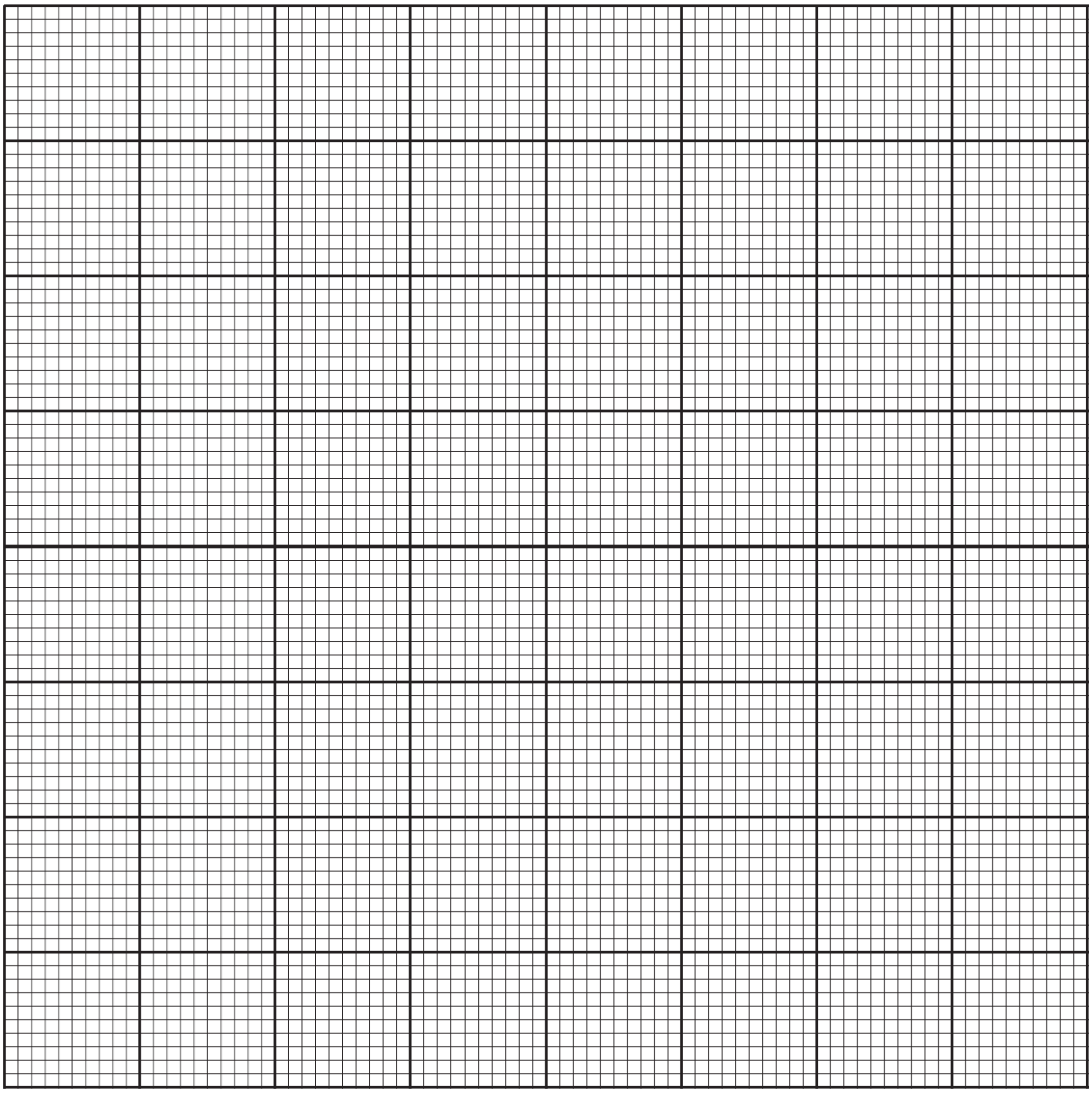

Fig. 2.1

[4]

(iii) From the extrapolated lines, read the minimum and the maximum temperatures at t = 4.0 min and determine the values for the two temperature changes.

Minimum temperature, T_2, at t = 4.0 min is ______________ °C.

Maximum temperature, T_3, at t = 4.0 min is ______________ °C.

Temperature rise for 50 cm^3 of cold water, ($T_3 - T_2$) is ______________ °C.

Temperature fall for 50 cm^3 of hot water, ($T_1 - T_3$) is ______________ °C.

[1]

(iv) An approximate value for the total heat energy absorbed by beaker **A** during the experiment can be determined from the heat energy gained by the 50 cm^3 of cold water in beaker **A** and the heat energy lost by the 50 cm^3 of hot water from the other 250 cm^3 beaker.

Use your answer in **(a)(iii)** to determine the heat energy absorbed by beaker **A** during the experiment.

You may assume that the specific heat capacity of water is 4.18 $J\ cm^{-3}\ K^{-1}$.

heat energy absorbed by beaker **A** = ________________ J [1]

(v) The heat capacity of the beaker is the amount of heat energy absorbed for a 1 °C change in temperature.

Use your answer to **(a)(iv)** and the temperature rise from **(a)(iii)** to calculate the approximate heat capacity of beaker **A**. Include the units.

heat capacity of beaker **A** = ______________________ [1]

(b) (i) Determination of the enthalpy change of solution for ammonium chloride

1. Weigh a clean and dry boiling tube.

2. Weigh between 9.8 g and 10.2 g of **FA 4** into the boiling tube.

3. Use the 50 cm^3 measuring cylinder to transfer 100 cm^3 of cold water into the rinsed and dried beaker **A** used in **(a)**.

4. Stir the water in the beaker with the thermometer and record the temperature.

5. Add the solid from the boiling tube to the water.

6. Stir the mixture constantly with the thermometer.

7. Record the minimum temperature obtained in the solution.

8. Reweigh the boiling tube and any residual ammonium chloride.

9. Record your results in Table 2.1.

Results

Table 2.1

mass of boiling tube + **FA 4** / g	
mass of empty boiling tube / g	
mass of boiling tube + residual **FA 4** / g	
mass of **FA 4** added / g	
initial temperature of water / °C	
minimum temperature obtained / °C	
temperature fall, ΔT / °C	

[1]

3 Planning

When solutions of peroxodisulfate anions, $S_2O_8^{2-}$, and iodide ions, I^-, are mixed in a beaker, the iodide ions are oxidised to produce iodine, I_2, according to the following equation.

$$S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq) \qquad \text{reaction 1}$$

The reaction takes place slowly and the amount of iodine produced in the beaker of solution increases with time. The overall order for reaction 1 is second order and the rate equation is shown.

$$\text{rate} = k[S_2O_8^{2-}][I^-]$$

where k is the rate constant.

When a large excess of peroxodisulfate is used, the equation becomes a pseudo first order reaction with respect to iodide ion concentration.

$$\text{rate} = k'[I^-]$$

(a) You are to plan a procedure to verify the order of reaction with respect to iodide ion concentration is first order using graphical method and hence determine the relative initial rate of reaction 1.

Your procedure will need to:

- extract fixed volumes of solution from a reaction mixture containing $S_2O_8^{2-}$ and I^- ions,
- quench the reaction in the extracted volumes at timed intervals,
- determine the amount of iodine present in each extracted volume.

The amount of iodine produced in each extracted volume can be determined by titrating against a solution of sodium thiosulfate, $Na_2S_2O_3$, according to the equation shown.

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

Since the volume of $S_2O_3^{2-}$ used for titration is proportional to the amount of iodine present at the time when the extracted volume is quenched, a graph of volume of $S_2O_3^{2-}$ against time can be used to verify the order of reaction with respect to iodide ion concentration and determine the relative rate of the reaction.

You should plan to make a reaction mixture using the following:

- 75 cm^3 of potassium peroxodisulfate, $K_2S_2O_8$
- 75 cm^3 of 0.800 mol dm^{-3} potassium iodide, KI

You may assume potassium peroxodisulfate is present in large excess.

You are provided with the following:

- 0.200 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$,
- starch solution,
- deionised water,

- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of:

- the apparatus you would use,
- the procedure you would follow,
- the measurements you would make.

____ [5]

(b) Determine the largest possible volume of sodium thiosulfate solution required to react with the iodine produced in the extracted volume.

[2]

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

Fig. 3.1

[1]

(d) Explain why reaction 1 takes place slowly.

[1]

(e) Explain, in terms of Collision Theory, how quenching the reaction in the extracted volumes will improve the reliability of the titration results.

[1]

[Total: 10]

4 Investigation of an inorganic and an organic compound

(a) Identification of one cation and two anions

Solution **FA 5** contains a cation and two anions. You will perform tests to identify the ions present in **FA 5**.

(i) Carry out the following test. 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 1 cm depth of the **FA 5** solution in a test-tube, add aqueous sodium hydroxide, with shaking, until no further change is seen.	
2	To 1 cm depth of the **FA 5** solution in a test-tube, add aqueous ammonia, with shaking, until no further change is seen.	

Identity of cation in **FA 5**: _______________

[3]

(ii) You are to devise and perform a series of simple tests to identify the anions present in **FA 5**. Your tests should be based on the Qualitative Analysis Notes on pages 19–20 and should use only the bench reagents provided. Record your tests and observations in the space below. Draw a line across after each test.

FA 5 does not contain sulfite ions, SO_3^{2-}, or any nitrogen.

If there is no observable change, write **no observable change**.

Any test requiring heating MUST be performed in a boiling tube.

tests	observations

Identities of anions in **FA 5**: ______________

[6]

(b) Identification of an organic compound

In this question, you will deduce the identity of an organic compound **FA 6**, with molecular formula $C_8H_{10}O$.

(i) Perform the tests described in Table 4.2.

Table 4.2

tests		observations
1	To 1 cm depth of **FA 6**, add 1 cm depth of dilute sulfuric acid followed by 3 drops of aqueous potassium manganate(VII). Warm the test-tube in a hot water bath.	
2	To 1 cm depth of **FA 6**, add 5 drops of 2,4-dinitrophenylhydrazine and warm.	
3	To 6 drops of **FA 6**, add 1 cm depth of aqueous iodine. Add aqueous sodium hydroxide slowly with shaking, until an orange solution is obtained. Warm the mixture in a beaker of hot water for 1 minute. Cool the mixture.	

[3]

(ii) Based on the molecular formula and the observations in Table 4.2, suggest the structure of **FA 6**.

[1]

[Total: 13]

Qualitative Analysis Notes

[ppt. = precipitate]

(a)

ca
alu A*l*
an NH

ba Ba
ca Ca
ch , C
co Cu
iro Fe
iro Fe
ma Mg
ma , M
zir Zr

(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_2	black solid / purple gas	brown	purple