Candidate Name: _____

Class	Adm No

H

millennia institute

2025 Preliminary Examination
Pre-University 3

H2 CHEMISTRY **9729/04**

Paper 4 Practical **28 Aug 2025**

2 hours 30 minutes

Candidates answer on the Question paper.

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so.

Write your name, class and admission number 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 16 and 17.

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.

Question	1	2	3	4	Total
Marks	/8	/28	/11	/8	/55

Shift
Laboratory

1 Identification of anions

FA 1 is an aqueous solution containing two anions.

You will perform tests to identify the two anions in **FA 1**.
You are **not** expected to identify the cations.

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

(a) Carry out the following tests. Carefully record your observations in Table 1.1.

Table 1.1

tests		observations
1	Test **FA 1** solution using Universal Indicator paper.	
2	To a 1 cm depth of **FA 1** in a clean test-tube, add 1 cm depth of aqueous silver nitrate. Add excess aqueous ammonia.	
3	To a 1 cm depth of **FA 1** in a clean boiling tube, add a small piece of aluminium foil into the boiling tube, then heat gently over a Bunsen flame.	
4	To a 1 cm depth of **FA 1** in a clean test-tube, add 2 cm depth of dilute hydrochloric acid.	No effervescence observed

[4]

(b) Identify the two anions in **FA 1** and state the evidence for each anion by completing Table 1.2. The evidence given must be sufficiently conclusive in identifying the anions.

Table 1.2

anion	evidence

[4]

[Total: 8]

2 Investigation on a solution of oxalic acid

Oxalic acid is a common organic acid containing the carboxylic acid functional group.

You will perform two separate experiments to investigate its properties.

(a) Determination of concentration and enthalpy change of neutralisation by thermometric titration

Oxalic acid is an organic acid that occurs naturally in many foods, such as quinoa and rhubarb leaves. It is known to be a dibasic acid, potentially donating two H^+ ions per molecule of oxalic acid.

FA 2 is aqueous oxalic acid of unknown concentration.
FA 3 is 2.2 mol dm^{-3} sodium hydroxide, NaOH.

Prepare a table in the space provided on **page 6** and record, to the appropriate level of precision:

- all volumes of **FA 3** added, *V*
- the maximum temperature, *T*, after each addition of **FA 3**

It is important that the volume of **FA 3** recorded is the total volume you have added up to the point when the temperature reading was made.

Procedure

1. Place a polystyrene cup inside a second polystyrene cup and place both cups in a glass beaker.

2. Use a pipette to transfer 10.0 cm^3 of **FA 2** into the polystyrene cup.

3. Fill the burette with **FA 3**.

4. Stir the **FA 2** in the cup gently with the thermometer. Read and record its temperature, tilting the cup to ensure that the bulb of thermometer is fully submerged in the solution.

5. Use the burette to add 2.00 cm^3 of **FA 3** to the cup and stir the mixture gently with the thermometer. Read and record both the maximum temperature and the actual total volume of **FA 3** added.

6. Repeat step 5 until a total of 30.00 cm^3 of **FA 3** has been added. For each addition of **FA 3**, read and record both the maximum temperature, *T*, and the actual total volume of **FA 3** added up to that point, *V*.

Note: If you overshoot on an addition, record the actual total volume of **FA 3** added up to that point.

BLANK PAGE

Results

[3]

(i) Plot a graph of temperature, *T,* on the *y*-axis, against total volume of **FA 3**, *V*, on the *x*-axis on the grid in Fig. 2.1. Your scale on the *y*-axis should allow for extrapolation above the highest temperature recorded.

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

Extrapolate both lines until they intersect.

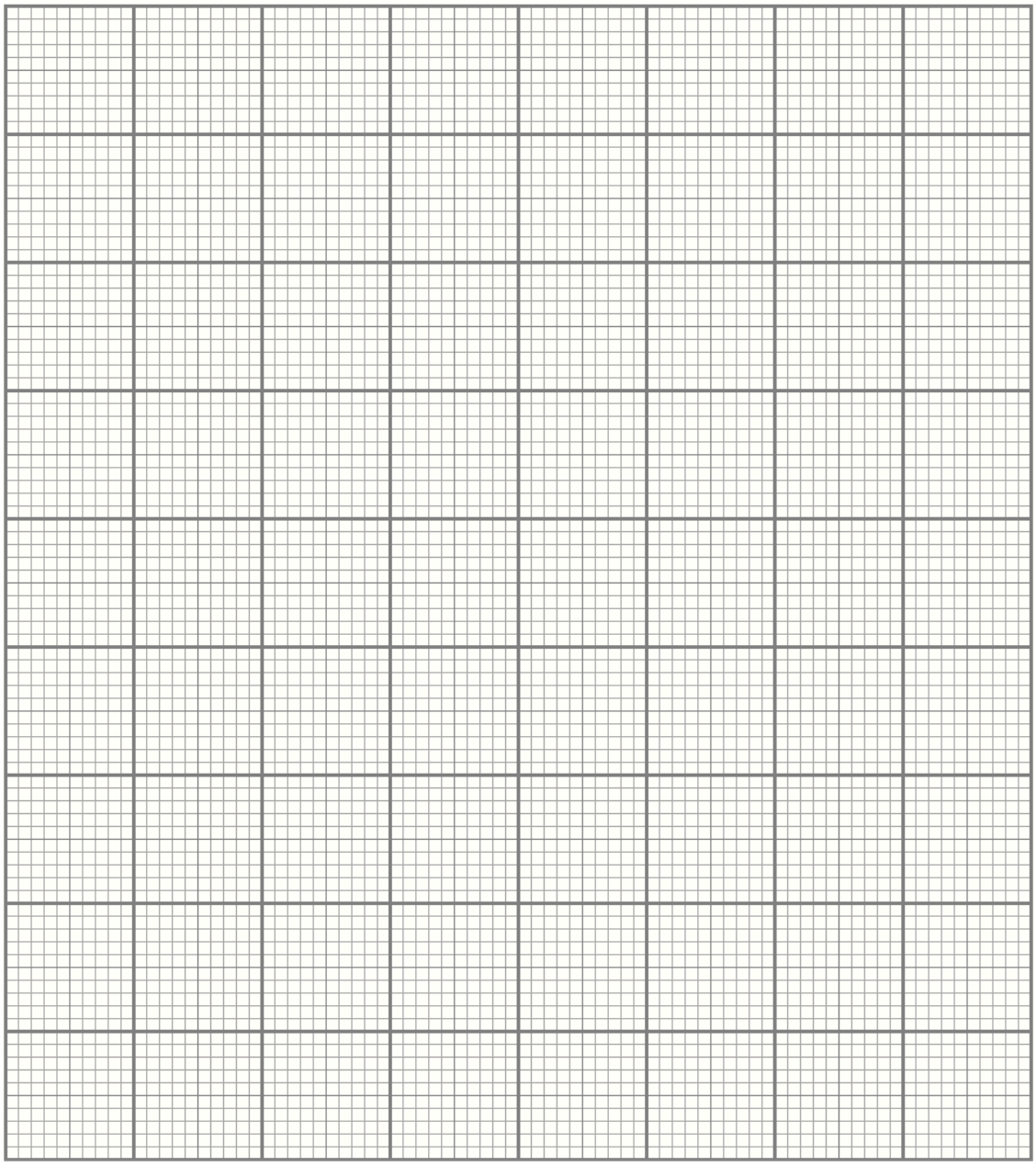


Fig 2.1

[3]

(ii) Explain the shape of your line of best-fit drawn in **(a)(i)**, when the temperature is falling.

……

……

……

……[2]

(iii) Hence, from your graph, identify the total volume of **FA 3** added at the point of neutralisation, V_{neut}.

V_{neut} = ……

Using the initial temperature of **FA 2**, $T_{initial}$, and the maximum temperature of the mixture from the graph, T_{max}, calculate the change in temperature, ΔT.

$T_{initial}$ = ……

T_{max} = ……

ΔT = ……

[4]

(iv) Determine the concentration of oxalic acid in **FA 2**.

concentration of oxalic acid in **FA 2** = ……... [2]

(v) Calculate the heat change, q, at the point of neutralisation in your experiment.

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 1.0 g cm^{-3}.

q = ... [1]

(vi) Calculate the enthalpy change of neutralisation, ΔH_{neut}, for the reaction between oxalic acid and sodium hydroxide.

ΔH_{neut} = ... [3]

(vii) The enthalpy change of neutralisation for hydrochloric acid reacting with sodium hydroxide is −57.3 kJ mol^{-1}.

Comment on your value of ΔH_{neut} obtained in **(a)(vi)**.

.....

.....

.....

..... [2]

(b) Determination of concentration by acid-base titration

The concentration of oxalic acid can also be determined via a simple acid-base titration.

Procedure

1. Fill the burette with **FA 3**.
2. Use a pipette to transfer 10.0 cm^3 of **FA 2** into a 250 cm^3 conical flask.
3. Add 2-3 drops of thymol blue indicator.
4. Titrate **FA 2** against **FA 3**. The end-point is reached when the mixture first turns blue.
5. Record your titration results, to an appropriate level of precision, in the space provided below.
6. Repeat steps 2 to 5 until consistent results are obtained.

Results

[4]

(i) From your titrations, obtain a suitable volume of **FA 3** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 3** = ... cm^3 [1]

(ii) Calculate the concentration of oxalic acid in **FA 2**.

concentration of oxalic acid in **FA 2** = ……... mol dm^{-3} [2]

(iii) Consider the two different methods used to determine the concentration of oxalic acid in **FA 2**, **(a)** thermometric titration, and **(b)** acid-base titration.

Suggest, with explanation, which method is likely to give a more accurate result.

……

……

……[1]

[Total: 28]

3 Qualitative analysis of salicylic acid

Salicylic acid is a common ingredient used in acne treatments due to its ability to exfoliate the skin, unclog pores, and reduce inflammation. Like oxalic acid, it is also an organic acid containing the carboxylic acid functional group.

FA 4 is aqueous salicylic acid.

You will perform tests to deduce the structure of salicylic acid.

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured. **Discard all waste into the container labelled "waste".**

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

(a) Carry out the following tests using the **FA 4** provided. Carefully record your observations and corresponding deductions of functional groups in Table 3.1.

Table 3.1

tests		observations and deductions of functional groups
1	To a 1 cm depth of **FA 4** in a test-tube, add 8 drops of aqueous sodium hydroxide followed by aqueous iodine dropwise, until a permanent yellow/orange colour is present. Warm the mixture in a beaker of hot water for 5 minutes. Add aqueous sodium hydroxide until no further change is seen.	
2	To a test-tube containing 1 cm depth of **FA 4**, add 2 cm depth Br_2(aq).	
3	To a test-tube containing 1 cm depth of **FA 4**, add 1 cm depth neutral $FeCl_3$.	
4	To a test-tube, mix 5 drops of Fehling's solution A and 5 drops of Fehling's solution B. Add 1 cm depth of **FA 4** and warm the solution in a beaker of hot water for 5 minutes.	

[8]

(b) Salicylic acid is known to have an M_r between 130.0 to 140.0.

It also exhibits a lower than expected melting point.

Using your deductions from **(a)** as well as all other information provided, deduce the structure of salicylic acid.

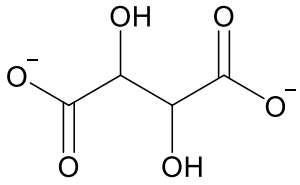
[A_r: C, 12.0; H, 1.0; O, 16.0; N, 14.0]

[2]

(c) In test 4, Fehling's reagent is prepared by mixing Fehling's solution A and B. The identities of the solutions are as follows.

Fehling's solution A: aqueous copper(II) sulfate

Fehling's solution B: sodium hydroxide and tartrate ions



tartrate ion

By considering the reaction between copper(II) and hydroxide ions, as well as relevant observations of test 4, suggest the role of tartrate ions.

……

……

……

……[1]

[Total: 11]

4 Planning

Oxalic acid is oxidised readily by MnO_4^- in the presence of excess H^+.

The rate equation for this redox reaction can be expressed as

$$\text{rate} = k[\text{oxalic acid}]^{\mathbf{a}}[MnO_4^-]$$

where **a** represents the order of reaction with respect to oxalic acid.

Oxalic acid can be found in sufficiently high concentrations in the stalks of the rhubarb plant. It can be extracted by heating thin slices of rhubarb stalk gently in water for 5 minutes.

The rate of reaction between oxalic acid and MnO_4^- can then be studied by measuring the time taken for a fixed concentration of MnO_4^- to decolourise into Mn^{2+}.

You are to plan experiment(s) to:

1) prepare a standard solution of oxalic acid from rhubarb stalks, then use it to
2) determine the order of reaction with respect to oxalic acid, **a**.

You may assume that you are provided with

- whole rhubarb stalks,
- a kitchen knife,
- 0.1 mol dm^{-3} $KMnO_4$ solution,
- 1 mol dm^{-3} sulfuric acid,
- 250 cm^3 volumetric flask,
- filter funnel and filter paper,
- stopwatch,
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of

- the reactants and conditions that you would use,
- the apparatus that you would use,
- the procedure that you would follow,
- the measurements that you would take,
- how you would determine the order of reaction with respect to oxalic acid, **a**.

……

……

……

……

……

……

……

……

[8]

[Total: 8]

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) Test 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

BLANK PAGE