Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 CHEMISTRY 9729/04

Paper 4 Practical

25 August 2025

2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
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	26
2	18
3	11
Total	55

This question paper consists of **20** printed pages.

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

1 Determination of the concentrations of two solutions by graphical analysis

Sulfuric acid is a strong acid which neutralises sodium hydroxide in an exothermic reaction as shown in equation 1.

equation 1 $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

In this question, you will prepare six mixtures, each containing the same total volume of solution but with different volumes of sulfuric acid and sodium hydroxide added. For each mixture, you will measure the temperature change.

Graphical analysis of your results will enable you to determine the concentrations of the sulfuric acid and of the sodium hydroxide used.

FA 1 is aqueous sodium hydroxide, NaOH.
FA 2 is aqueous sulfuric acid, H_2SO_4.

(a) Prepare a table in the space provided on page 4 in which to record, to an appropriate degree of precision:
- the volumes of **FA 1** ($V_{FA\,1}$) and **FA 2** ($V_{FA\,2}$) used
- all values of temperature $T_{FA\,1}$, $T_{FA\,2}$, T_{ave}, T_{max} and ΔT_{max}

Experiment 1

1. Using a measuring cylinder, transfer 10.0 cm^3 of **FA 1** into a Styrofoam cup. Place this cup inside a second Styrofoam cup, which is placed in a 250 cm^3 glass beaker.
2. Place the thermometer into the **FA 1** in the cup. Tilt the cup if necessary to ensure the bulb of the thermometer is fully covered. Record the temperature of **FA 1**, $T_{FA\,1}$.
3. Using another measuring cylinder, measure 60.0 cm^3 of **FA 2**.
4. Rinse and dry the thermometer. Measure and record the temperature of **FA 2**, $T_{FA\,2}$.
5. Add the **FA 2** from the measuring cylinder to the **FA 1** in the Styrofoam cup.
6. Using the thermometer, stir the mixture continuously until it reaches its maximum temperature. Record this temperature, T_{max}.
7. Rinse and dry the thermometer. Wash out the Styrofoam cup thoroughly with tap water and then with deionised water. Stand the cup upside down on a paper towel to drain.

Experiments 2 to 6

Repeat experiment 1 five times, adding 20.0 cm^3, 30.0 cm^3, 40.0 cm^3, 50.0 cm^3 and 60.0 cm^3 of **FA 1** respectively in step 1.

In each experiment, you should adjust the volume of **FA 2** in step 3 to ensure the same total volume of solution is used.

You should alternate the use of the two Styrofoam cups.

Calculate the following values for each experiment

- T_{ave}, the average of $T_{FA\,1}$ and $T_{FA\,2}$
- ΔT_{max}, where $\Delta T_{max} = T_{max} - T_{ave}$

Record all volumes and temperatures in your table on page 4.

Results

[4]

(b) **(i)** Plot a graph of ΔT_{max} on the y–axis against $V_{FA\ 1}$ on the x–axis on the grid in Fig. 1.1. Your scale on the y–axis should allow for extrapolation above the highest temperature recorded.

Draw two straight 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.

Extrapolate (extend) both lines until they intersect.

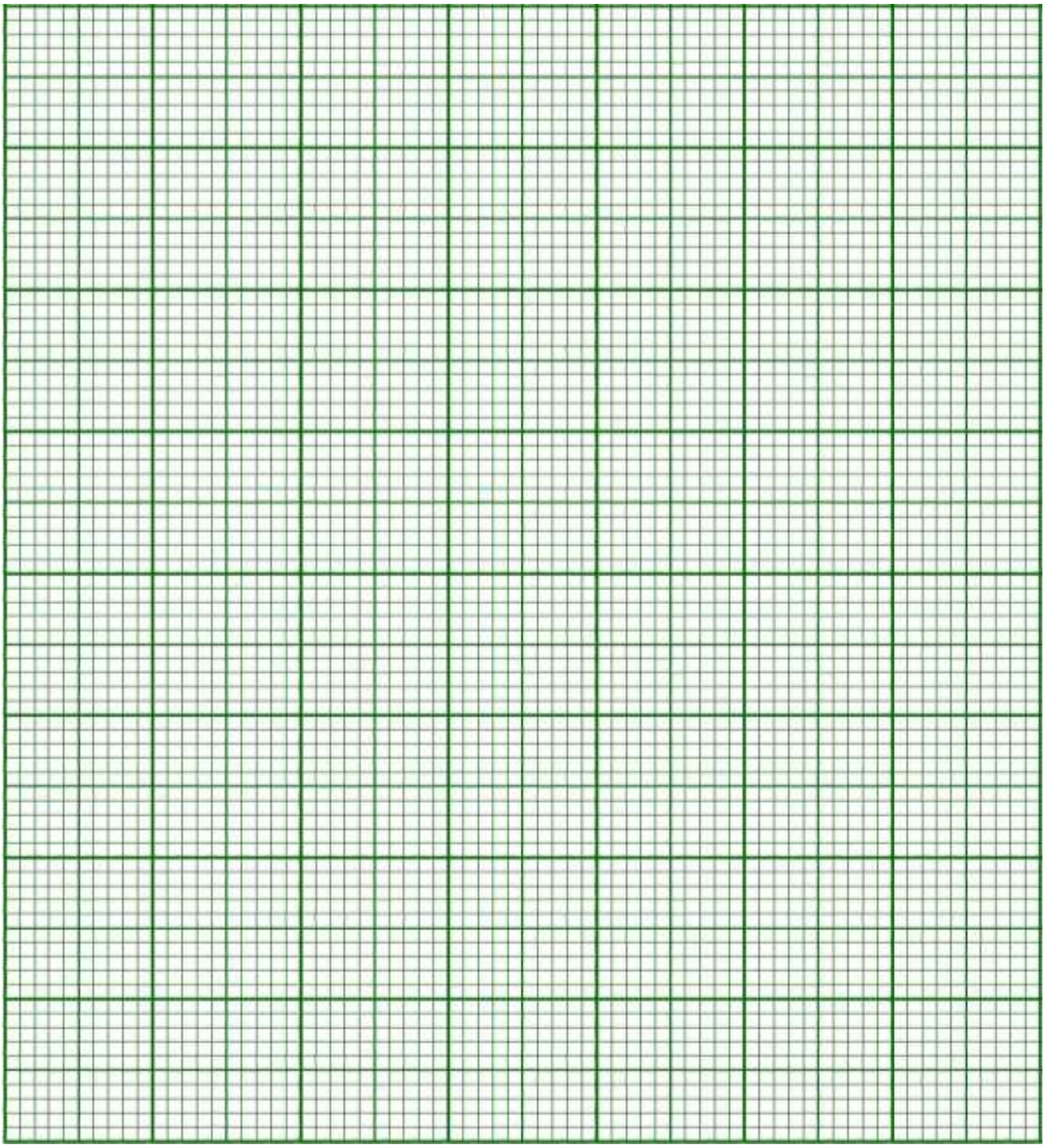

Fig. 1.1

[3]

(ii) From your graph, read $V_{FA\ 1}$ and ΔT_{max} of the intersection point.
Record these values in the spaces provided.

$V_{FA\ 1}$ = …………………… cm^3

ΔT_{max} = ………………………°C

[3]

(iii) Calculate the heat change, *q*, at the point of neutralisation in your experiment, using your answer in **(b)(ii)**.

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 = ………………………… [2]

(iv) The literature value for the enthalpy change of neutralisation of a strong alkali by a strong acid is −57.0 kJ mol^{-1}.

Calculate the amount of water formed at the point of neutralisation in your experiment using your answer in **(b)(iii)**.

Hence, determine the concentrations of the sulfuric acid and of the sodium hydroxide used.

amount of water formed = ………………………… mol

[NaOH] in **FA 1** = ………………………… mol dm^{-3}

[H_2SO_4] in **FA 2** = ………………………… mol dm^{-3}

[4]

(v) The actual concentration of the sodium hydroxide used is 2.40 mol dm^{-3}.
Calculate the percentage error in your value of concentration.

[1]

(c) **(i)** The calculated values of the concentrations of the sulfuric acid and of the sodium hydroxide in **(b)(iv)** are expected to be lower than the actual values. Explain why.

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(ii) Suggest **two** improvements to the method that would give more accurate values for the concentrations of the sulfuric acid and of the sodium hydroxide.

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(d) Planning

The enthalpy change of neutralisation when sodium hydroxide reacts with sulfuric acid, ΔH_{neut}, can be determined using a thermometric titration. This involves adding portions of aqueous sulfuric acid progressively to a fixed volume of aqueous sodium hydroxide in a Styrofoam cup. The temperature of the resulting solution is then measured after each addition. A suitable graph can be plotted to find ΔT at equivalence point and hence ΔH_{neut}.

You may assume that you are provided with:

- 50 cm^3 of 2.03 mol dm^{-3} aqueous sodium hydroxide, **FB 1**
- 50 cm^3 of 1.00 mol dm^{-3} aqueous sulfuric acid, **FB 2**

(i) Determine a suitable volume of **FB 1** to be used for the thermometric titration.
Explain your reasoning, showing any relevant calculations.

volume of **FB 1** = ……………………… cm^3 [2]

(ii) Suggest a suitable graph to be plotted to determine ΔT at equivalence point.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………... [1]

(iii) Plan a procedure to determine ΔH_{neut} using thermometric titration.

You may assume you are provided with:

- 50 cm^3 of 2.03 mol dm^{-3} aqueous sodium hydroxide, **FB 1**
- 50 cm^3 of 1.00 mol dm^{-3} aqueous sulfuric acid, **FB 2**
- 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 volumes of **FB 1** and **FB 2** you would use
- the procedure you would follow
- the measurements you would make to allow the suitable graph identified in **(d)(ii)** to be drawn.

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.... [4]

[Total: 26]

2 Determination of concentrations of sodium hydroxide, and of sodium carbonate in a mixture

FA 3 is a solution containing sodium hydroxide, NaOH, and sodium carbonate, Na_2CO_3.
FA 4 is 0.150 mol dm^{-3} hydrochloric acid, HC*l*.

Sodium hydroxide reacts with hydrochloric acid according to the equation below:

Reaction 1 $NaOH + HCl \rightarrow NaCl + H_2O$

Sodium carbonate reacts with hydrochloric acid in two separate stages. The reactions that occur are:

Reaction 2 $Na_2CO_3 + HCl \rightarrow NaCl + NaHCO_3$
Reaction 3 $NaHCO_3 + HCl \rightarrow NaCl + CO_2 + H_2O$

You are required to find the concentrations of sodium hydroxide, and of sodium carbonate, in **FA 3**, by means of a *double–indicator* titration.

In a *double–indicator* titration, **two different** indicators are used, separately, in the **same** titration. In this experiment, thymol blue indicator, followed by methyl orange indicator, will be used.

Thymol blue indicates the end–point when **Reaction 1** and **2** are complete, while methyl orange indicates the end–point when **Reaction 3** is complete.

(a) Titration of FA 3 against FA 4

1. Fill a burette with **FA 4**.

2. Pipette 25.0 cm^3 of **FA 3** into a conical flask.

   Replace the cap over the FA 3 bottle to prevent absorption of carbon dioxide from the atmosphere.

3. Add a few drops of thymol blue indicator and titrate **FA 3** with **FA 4**.

4. The first end–point is reached when the solution turns pale yellow/colourless. Ignore any cloudiness that you may observe in the conical flask. **Do not discard this solution**.

5. Record your titration results in Table 2.1 on page 11.
   The volume of **FA 4** used to reach the first end–point **need not be consistent**.

6. To the solution in Step 4, add a few drops of methyl orange indicator and **continue** to titrate it with **FA 4** until the colour changes from yellow to orange. This is the second end–point.

7. Record your titration results in Table 2.1 on page 11.

8. Perform sufficient titrations to obtain accurate results for the **second end–point**, which refers to the **total** volume of **FA 4** required for the whole titration.

Table 2.1

initial burette reading / cm^3			
final burette reading at first end–point / cm^3			
final burette reading at second end–point / cm^3			
volume of **FA 4** used to reach first end–point / cm^3			
total volume of **FA 4** used to reach second end–point / cm^3			

[2]

(b) **(i)** From your titrations in **(a)**, obtain a suitable volume of **FA 4** used to reach the first end–point. Show clearly how you obtained this volume.

volume of **FA 4** for first end–point = …………..……………..….. [1]

(ii) From your titrations in **(a)**, obtain a suitable **total** volume of **FA 4** used to reach the second end–point. Show clearly how you obtained this volume.

total volume of **FA 4** for second end–point = …………..……………..….. [3]

(c) **(i)** Calculate the volume of **FA 4** that reacted with $NaHCO_3$ formed in 25.0 cm^3 of **FA 3**.

volume of **FA 4** reacted with $NaHCO_3$ = …………..……………..….. [1]

(ii) Calculate the amount of sodium carbonate, Na_2CO_3, present in 25.0 cm^3 of **FA 3**.

amount of Na_2CO_3 in 25.0 cm^3 of **FA 3** = …………..……………..….. [1]

(iii) Calculate the amount of sodium hydroxide, NaOH, present in 25.0 cm^3 of **FA 3**.

amount of NaOH in 25.0 cm^3 of **FA 3** = …………..……………..….. [2]

(iv) Using your answers from **(c)(ii)** and **(c)(iii)**, calculate the concentrations, in mol dm^{-3}, of Na_2CO_3 and NaOH in **FA 3**.

$[Na_2CO_3]$ in **FA 3** = …...……....……………..…..

[NaOH] in **FA 3** = ..…………...…………….….…..
[2]

(d) The error (uncertainty) associated with each burette reading is ±0.05 cm^3.

Calculate the percentage error in the total volume of **FA 4** for second end–point obtained in **(b)**.

[1]

(e) **Planning**

FA 4 is made by diluting **FA 5**, which is 0.75 mol dm^{-3} hydrochloric acid, HCl.

Outline a description of how you would prepare a diluted solution of **FA 4** from **FA 5**.

Your plan should include brief details of:

- the quantities you would use
- the apparatus you would use
- the procedure you would follow.

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(f) The reaction in the titration produces carbon dioxide. Some carbon dioxide dissolves in the solution. Dissolved carbon dioxide is acidic.

Methyl orange indicator changes colour over a pH range of 3.1 to 4.4.

Explain why the dissolved carbon dioxide does not decrease the end–point of the titration.

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.... [1]

(g) A student suggested doing the titration in **(a)** differently – **FA 4** is placed in the conical flask and **FA 3** in the burette, using methyl orange indicator followed by thymol blue indicator.

Explain why this method will **not** allow you to determine the concentrations of NaOH and Na_2CO_3 in **FA 3**.

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.... [1]

[Total: 18]

Turn Over for Question 3.

3 Inorganic Qualitative Analysis

FA 6 is an aqueous solution containing two cations and one anion from the ions listed in the *Qualitative Analysis Notes*.

(a) You will carry out the tests in Table 3.1, which will allow you to identify the cations present in **FA 6**. Record your observations in Table 3.1.

Test and identify any gases evolved.

Table 3.1

	test	observations
(i)	Test solution **FA 6** with Universal Indicator (UI) paper. Using the colour chart provided, record the pH of the solution and colour of the UI paper.	
(ii)	To 2 cm depth of **FA 6** in a test–tube, add an equal depth of aqueous sodium hydroxide. Stir and filter the mixture. The filtrate is **FA 7,** for use in test **(a)(iii)**. The residue is **FA 8**, for use in test **(a)(iv)**.	
(iii)	To 2 cm depth of **FA 7** in a test–tube, carefully add nitric acid dropwise until no further change is seen.	
(iv)	Place the filter funnel containing **FA 8** into a clean test–tube. Carefully add sulfuric acid to the filter funnel so that it covers the precipitate. Collect 3 cm depth of filtrate in the test–tube. Add one piece of granulated zinc to the filtrate and warm gently. Leave the mixture to stand for a few minutes. Decant 2 cm depth of the solution into another clean test–tube. Add 1 drop of potassium manganate(VII). **Discard the mixture containing granulated zinc in the waste bottle.**	

(v)	To 1 cm depth of **FA 6** in a test–tube, add 1 cm depth of potassium iodide. To the resulting solution, add 5 drops of starch solution.	

[5]

(b) **(i)** Identify the two cations present in **FA 6**. Use evidence from your observations in Table 3.1 to support your deduction.

cation 1………………..

evidence………………………………………………………………………………..……

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cation 2………………..

evidence……………………………………………………………………………….……

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(ii) With the aid of a balanced equation, explain your observation in test **(a)(i)** of Table 3.1.

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………………………………………………………………………………………………. [1]

(c) **(i)** Only one anion is present in **FA 6**. The anion is not carbonate, sulfite or nitrite and **FA 6** does not contain any halides.

Describe and carry out a series of tests that will allow you to identify the anion.

[2]

(ii) Hence, identify the anion present in **FA 6**.

………………………………………………………………………………………………. [1]

[Total: 11]

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

ion	*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 A*l* foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and A*l* 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

