HWA CHONG INSTITUTION
C2 Preliminary Examination
Higher 2

CANDIDATE NAME						**CT GROUP**	2	4	S
CENTRE NUMBER	S					**INDEX NUMBER**			

CHEMISTRY

9729/04

Paper 4 Practical

26 August 2025

2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your **name**, **CT group, centre number** and **index 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.

DO **NOT** WRITE ON ANY BARCODES.

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 17 and 18.

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	
2	
3	
Total	

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

1 Qualitative Analysis

(a) **FA 1** is an aqueous solution of a sodium salt containing two anions.

(i) You will devise and perform a series of simple tests to identify the anions present in **FA 1.** Your tests should be based on the Qualitative Analysis Notes on pages 17 – 18 and should use only the bench reagents provided. Record your tests and observations in the space below.

FA 1 does not contain SO_3^{2-}, NO_3^- and NO_2^-.

[4]

(ii) Use your observations in **(a)(i)** to deduce the identity of the two anions in **FA 1**.

anions: …… and …… [2]

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Question 1 continues on the next page.

(b) **FA 2** is ZO_2, an oxide of an unknown metal, Z.
FA 3 is dilute sulfuric acid, H_2SO_4.
FA 4 is a solid sample of potassium ethanedioate, $K_2C_2O_4$.

Perform the tests described in Table 1.1 and record your observations in the table.
Test and identify any gases produced.

Table 1.1

	test	observations
(i)	Transfer all of the solid sample of **FA 4** into a boiling tube. Add all of **FA 3** to this boiling tube. Gently warm the boiling tube. Turn off the Bunsen flame.	
	Handle the hot boiling tube with care. Add **FA 2** to the mixture in three separate portions using a spatula, shaking after each separate addition. Add all the remaining **FA 2** to the mixture. Using the ***glass filter funnel***, filter the mixture into a test tube and leave the filtrate to stand. Retain this filtrate for use in **(b)(ii)**.	

[3]

(ii) **FA 5** is an aqueous solution of a cation of Z, which is also present in the filtrate from **(b)(i)**.

In this part, you are to investigate the effect of the addition of aqueous ammonia to separate portions of **FA 5** and the filtrate from **(b)(i).**

Table 1.2

test	**FA 5**	filtrate from **(b)(i)**
To 1 cm depth of **FA 5** in a test tube, add aqueous ammonia dropwise, until in excess. Repeat using the filtrate from **(b)(i)**.		

[3]

(iii) Identify the cation in **FA 5**. Explain with reference to your observations in Table 1.2.

ion present is ……..

explanation ……

…… [1]

(iv) The filtrate from **(b)(i)** contains another cation of Z.

Using your observations in Table 1.2, deduce the identity of this ion and suggest how it was formed from test **(b)(i)**.

……..

……..

…….. [1]

(c) **FA 6** is an organic compound with a molecular formula of $C_4H_8O_2$. It contains two functional groups.

(i) Carry out the following tests. Carefully record your observations in Table 1.3.

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

Table 1.3

	test	observations
1	Add 2 cm depth of aqueous silver nitrate to a clean boiling tube. Add 1 cm depth of aqueous sodium hydroxide slowly to the same boiling tube.	
	Add aqueous ammonia slowly, with shaking, until the precipitate just dissolves. You may use a clean glass rod to help dissolve the precipitate.	
	Add 2 cm depth of **FA 6** to this mixture and shake the boiling tube. Place the boiling tube in the test-tube rack and leave it for 3 minutes.	
	Important: After about 3 minutes, pour the mixture down the sink and wash out the boiling tube several times with tap water.	
2	Add about 1 cm depth of **FA 6** in a test-tube. To this test-tube, add 8 drops of sodium hydroxide solution followed by iodine solution, dropwise until no further change is seen.	

[3]

(ii) State and explain the chemical change the **reagent** undergoes during the reaction in **test 1**.

……

……[1]

(iii) Using your observations in Table 1.3, suggest the structure of **FA 6**.

[1]

[Total: 19]

2 Determination of the order of reaction with respect to the concentration of iodine in the iodination of propanone

FA 7 is 1.00 mol dm^{-3} propanone, CH_3COCH_3.
FA 8 is an aqueous solution of iodine, I_2.
FA 9 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4.
FA 10 is 0.50 mol dm^{-3} sodium hydrogencarbonate, $NaHCO_3$.
FA 11 is 0.0100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.

Note: **FA 9** is also used in **Question 3**.

You are also provided with a starch indicator.

The iodination of propanone, to form iodopropanone, proceeds as shown in the equation below.

$$CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+} CH_3COCH_2I(aq) + HI(aq) \qquad \textbf{reaction 1}$$

This reaction is first order with respect to the concentration of CH_3COCH_3 and of H^+ ions.

You are to determine the order of reaction with respect to $[I_2]$. To do this, you will prepare a reaction mixture containing **FA 7**, **FA 8** and **FA 9**. At different chosen times you will remove aliquots (fixed volumes) of this reaction mixture, add an excess of **FA 10**, and titrate the resulting solutions with **FA 11**. The titration reaction is given below.

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

Each titration can only be performed **once**, so you must work very carefully.

Your titre values will indicate the amount of iodine present in the reaction mixture at different times. The required order of reaction will be obtained by graphical analysis of your results.

The first aliquot should be removed approximately **4** minutes after the reagents were mixed. You will then remove four further aliquots, at time intervals of your choice, up to a maximum time of **20** minutes.

Once you have started the stopwatch, allow it to continue running for the duration of the experiment. You must not stop the stopwatch until you have finished this experiment.

In an appropriate format in the space provided on the next page, prepare a table in which to record for each aliquot

- the actual time, in minutes and seconds,
- the decimal time, ***t***, in minutes, to 1 decimal place, for example, an actual time of 4 min 33 s would give ***t*** = 4 min + 33/60 = 4.6 min,
- the burette readings and the volume of **FA 11** added.

(a) Preparation and titration of the reaction mixture

Safety: Propanone is volatile and flammable. Iodine is volatile.
Transfer your titrated solutions to the **waste** bottle for later disposal.
Keep the **FA 7** bottle, **FA 8** bottle and **waste** bottle capped when not in use.
Keep the conical flask (**reaction mixture**) stoppered except when removing aliquots.

1. Fill a burette with **FA 11**.

2. Using the 25 cm^3 measuring cylinder, add 25.0 cm^3 of **FA 7** and 25.0 cm^3 of **FA 9** to the conical flask labelled **reaction mixture**.

3. Using the 50 cm^3 measuring cylinder, measure 50.0 cm^3 of **FA 8**. Pour the contents of this measuring cylinder into the above conical flask. Start the stopwatch, **insert the stopper** and swirl the mixture thoroughly.

4. Using the 10 cm^3 measuring cylinder, measure about 10 cm^3 of **FA 10**.

5. Before 4 minutes, use a 10 cm^3 pipette to remove a 10.0 cm^3 aliquot of the reaction mixture. Transfer this aliquot to a second conical flask. At approximately 4 minutes, add the 10 cm^3 **FA 10** to the aliquot, noting the actual time, and swirl the mixture. Replace the stopper in the conical flask labelled **reaction mixture**.

6. Titrate the contents of the second conical flask with **FA 11**. When the colour of the solution turns pale yellow, add about 1 cm^3 of starch indicator. The solution will turn dark blue/black. The end-point is reached when the dark blue/black colour just disappears. Record your results.

7. Empty the contents of the second conical flask to the waste bottle. Wash this conical flask thoroughly with water.

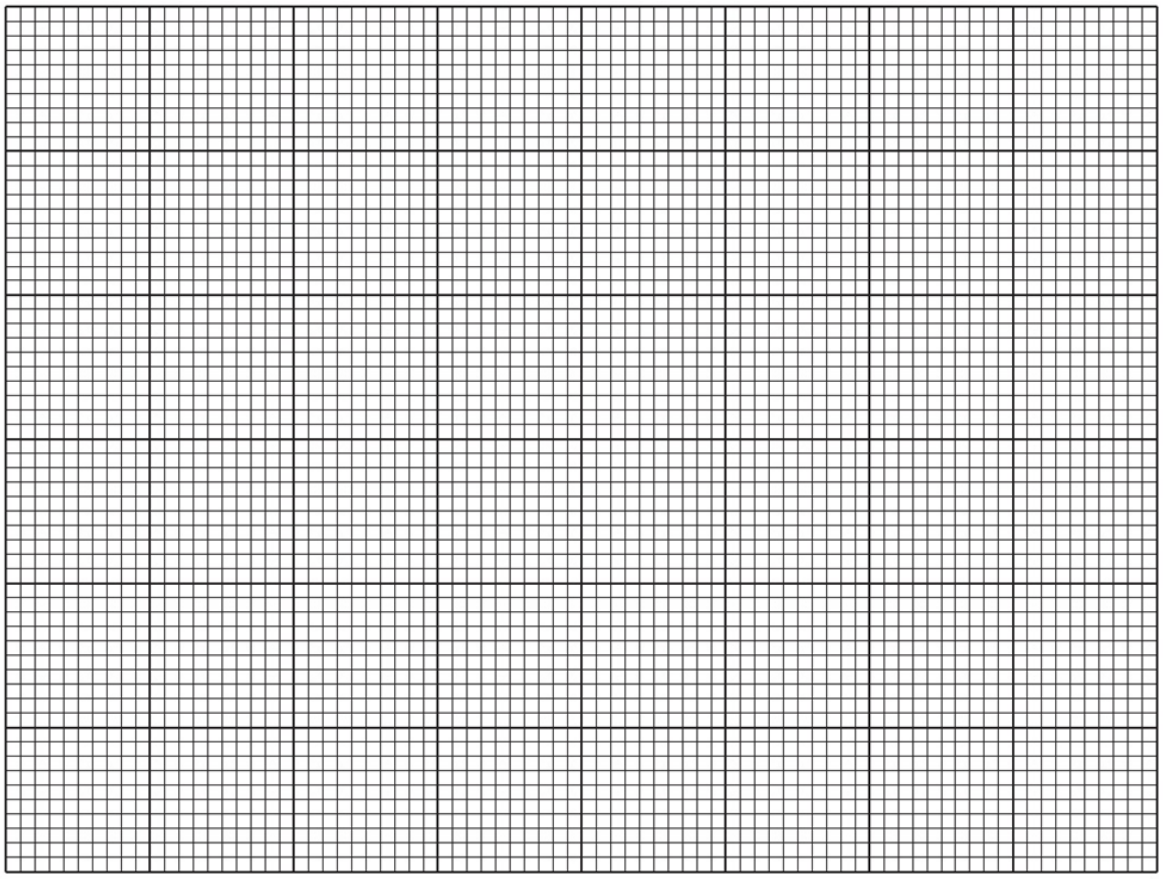
8. At each of your chosen times, repeat steps **4** to **7** until a total of **five** aliquots have been titrated and their results recorded.

Results

[4]

(b) **(i)** Plot a graph of **volume of sodium thiosulfate**, **FA 11**, on the *y*-axis, against **time, *t***, on the *x*-axis. Start the *x*-axis at ***t*** = 0. For the *y*-axis, choose a scale such that its maximum is about 20 cm^3.

Draw the most appropriate best-fit line taking into account all of your plotted points.



[4]

(ii) Deduce the order of reaction with respect to $[I_2]$ in **reaction 1**. Explain your answer.

order .....

explanation .....

..... [1]

(iii) Calculate the gradient of the line, showing clearly how you did this.

gradient = ... $cm^3\ min^{-1}$ [1]

(iv) Extrapolate (extend) your graph line until it intercepts the *y*-axis.

Read and record the volume, V_{max} of sodium thiosulfate **FA 11** at this intercept point. Use this value to calculate the concentration of iodine in **FA 8**.

intercept volume, V_{max} = ... cm^3

concentration of iodine in **FA 8** = ... $mol\ dm^{-3}$ [4]

(v) Use your answer to part **(b)(iii)** together with your value for V_{max} in **(b)(iv)** to estimate the time t_{max} at which all the iodine in your reaction mixture would have reacted completely.

t_{max} = ... min [1]

(c) Write the rate equation for **reaction 1**.

..... [1]

(d) Explain why it is important in this experiment that the concentration of iodine in **FA 8** is very much lower than the concentration of propanone in **FA 7** and that of H^+ ions in **FA 9**.

.....

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.....

..... [1]

(e) Step **5** requires you to mix each aliquot with an excess of sodium hydrogencarbonate solution, $NaHCO_3$ (**FA 10**). Suggest an explanation for this requirement.

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…… [1]

(f) A student repeated the experiment in **(a)** using sodium carbonate, Na_2CO_3, instead of $NaHCO_3$ in step **5**. He observed that the titre values were significantly lower and a pale yellow precipitate was produced in the aliquot.

Suggest the identity of the pale yellow precipitate and the type of reaction that propanone had undergone.

……

…… [1]

[Total: 19]

3 Analysis of sulfuric acid content in industrial wastewater

Sulfuric acid can be found in pre-treated industrial wastewater. Sodium carbonate, a weak base, is added as a pH regulator during the treatment of industrial wastewater. It reacts with sulfuric acid according to the equation shown for **reaction 3**.

reaction 3 $Na_2CO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + CO_2(g) + H_2O(l)$ ΔH_r

In this question, you will perform an experiment to determine a value for ΔH_r.

You are provided with:

- **FA 9**, 1.00 mol dm^{-3} sulfuric acid, H_2SO_4.
- **FA 12**, solid sodium carbonate, Na_2CO_3.

Note: FA 9 is also used in **Question 2**.

You will measure the initial temperature of sulfuric acid in a polystyrene cup and the maximum temperature reached after sodium carbonate is added. The temperature change, ΔT, will be calculated.

You will use this value to calculate the heat change, q, for the experiment and hence determine a value for the molar enthalpy change of **reaction 3**, ΔH_r.

In Tables 3.1 and 3.2 on **page 13**, record the temperature and mass values to an appropriate level of precision.

(a) 1 Weigh the capped container containing solid **FA 12**. Record the mass in Table 3.1.

2 Place one polystyrene cup inside another polystyrene cup and place both in a 250 cm^3 glass beaker.

3 Use the 25 cm^3 measuring cylinder to transfer 20 cm^3 of **FA 9** into the polystyrene cup.

4 Insert the thermometer through the lid and place it over the polystyrene cup.

5 Carefully stir the **FA 9** in the polystyrene cup with the thermometer. Read and record its temperature, $T_{initial}$, in Table 3.2.

6 Transfer all the solid **FA 12** to the polystyrene cup. Quickly put the lid back over the polystyrene cup.

7 Stir the mixture with the thermometer. Read and record the maximum temperature reached, T_{max}, in Table 3.2.

8 Reweigh the empty capped container. Record this mass in Table 3.1.

Results

Table 3.1

mass of capped container and **FA 12** / g	
mass of capped container and residual **FA 12** / g	
mass of **FA 12** used / g	

Table 3.2

	temperature / °C
$T_{initial}$	
T_{max}	

[2]

(b) (i) Calculate the temperature change, $\triangle T$, produced by the reaction.

$\triangle T$ = ... [1]

(ii) Calculate the heat change, q, for your experiment in **(a)** using the value calculated in **(b)(i)**.

Assume that the specific heat capacity of the solution is 4.2 J g^{-1} K^{-1}, and that the density of the solution is 1.00 g cm^{-3}.

q = ... [1]

(iii) Hence, determine the molar enthalpy change of **reaction 3**, $\triangle H_r$.

[A_r: H 1.0, C 12.0, O 16.0, Na 23.0, S 32.1]

ΔH_r = ... [3]

(c) (i) The concentration of sulfuric acid in a sample of pre-treated industrial wastewater can be found via *thermometric titration* with sodium hydroxide.

Thermometric titration involves determining the equivalence point of a neutralisation reaction by monitoring the temperature of the reaction mixture before and after the equivalence point.

Portions of sodium hydroxide, a strong base, will be progressively added into the wastewater sample containing sulfuric acid until the equivalence point is reached and passed. This reaction between an acid and base is exothermic. The temperature is monitored throughout the experiment. The best fit lines before and after the equivalence point are extrapolated until they intersect.

The graph of temperature against volume of sodium hydroxide obtained is shown in Fig 3.1.

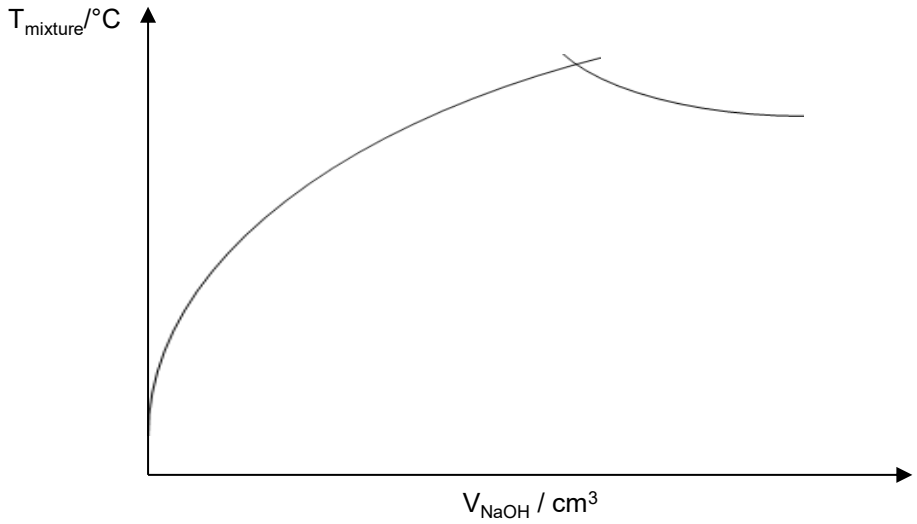

Fig 3.1

Plan an investigation to determine the exact concentration of sulfuric acid in a sample of industrial wastewater via thermometric titration.

You may assume the following:

- sulfuric acid is the only compound that reacts with sodium hydroxide in the wastewater
- original solutions provided are at room temperature

You are provided with the following:

- 50 cm^3 of pre-treated wastewater sample containing approximately 1.5 mol dm^{-3} H_2SO_4(aq)
- 1.5 mol dm^{-3} NaOH(aq)
- equipment normally found in a school or college laboratory

In your plan you should include brief details of:

- the apparatus you would use
- the quantities you would use
- the procedure you would follow
- the measurements you would take

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……..

……..

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……..

…… [6]

(ii) Explain how the graph in Fig 3.1 would be used to determine the concentration of sulfuric acid in the wastewater sample.

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……..

……..

……..

……..

……..[2]

(iii) The shape of the two best fit lines in Fig 3.1 are described below. Explain the shape of each best fit line.

- Before the equivalence point, each addition of NaOH increases the temperature of the mixture, but each rise is smaller than the previous.

……..

……..

……..

……..

…… [1]

- After the equivalence point, each addition of NaOH decreases the temperature of the mixture, but each fall is smaller than the previous.

……..

……..

…… [1]

[Total: 17]

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