HWA CHONG INSTITUTION
C2 Preliminary Examination
Higher 1

CANDIDATE NAME		CT GROUP	24S

CHEMISTRY

8873/02

Paper 2 Structured Questions

18 September 2025

2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and CT group in the space provided at the top of this page.
Write in dark blue or black pen.
You may use a 2B pencil for any diagrams or graphs.
Do not use staples, paper clips, glue, correction fluid or tapes.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINERS' USE ONLY

Paper 2	**Section A**	**1**	**/ 11**
		2	**/ 8**
		3	**/ 14**
		4	**/ 12**
		5	**/ 15**
	Section B	**6 or 7**	**/ 20**
			/ 80
Paper 1			**/ 30**
TOTAL			**/ 100**

This document consists of **21** printed pages and **1** blank page.

Section A

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

1 (a) Table 1.1 lists the number of protons, neutrons and electrons in seven different particles. Each particle may be an atom, an anion or a cation.

Table 1.1

particle	number of protons	number of neutrons	number of electrons
A	18	22	18
B	18	22	17
C	20	20	20
D	20	20	18
E	17	20	18
F	17	18	17
G	17	20	16

(i) Explain why particle **E** and particle **F** are a pair of isotopes of the same element.

……

…… [1]

(ii) State the number of electron pairs in particle **G**.

…… [1]

(iii) Identify the pair of atoms of different elements with the same nucleon number.

…… [1]

(iv) Explain why particle **C** is larger than particle **D**.

……

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……

……

…… [2]

(v) Deduce how the behaviour of beams of particles **B**, **E** and **G**, differ in an electric field.

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…… [2]

(b) **(i)** Explain how the electronegativity of the elements in Period 3 influences the bonding in the chlorides.

……

……

…… [1]

(ii) Write equations to show what happens when water is added to a mixture of sodium chloride and phosphorus pentachloride.

Suggest the expected pH of the resulting mixture.

……

……

…… [3]

[Total: 11]

2 (a) State *Le Chatelier's* Principle.

……

……

…… [1]

(b) A mixture of gaseous reactants and products was allowed to reach equilibrium.

The effects on the equilibrium yield of the products caused by changes in the pressure and in the temperature of the gaseous mixture are shown in Fig. 2.1.

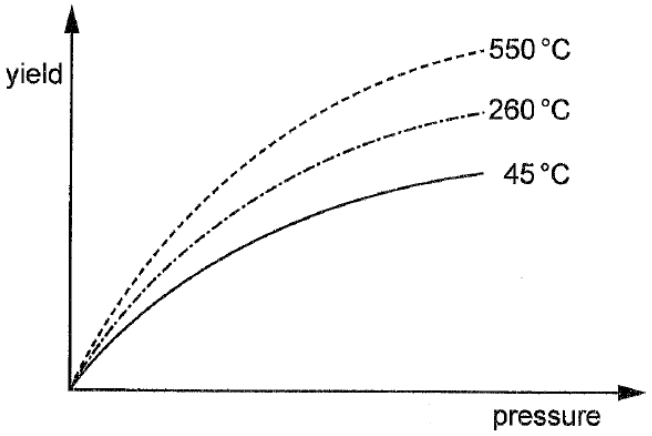

Fig. 2.1

(i) Deduce whether the forward reaction is exothermic or endothermic.

Explain your answer using references to Fig. 2.1 and to the equilibrium position.

……

……

……

…… [2]

.

(ii) Deduce whether the forward reaction involves an increase or decrease in the total number of molecules in the gaseous mixture.

Explain your answer using references to Fig. 2.1 and to the equilibrium position.

……

……

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…… [2]

(c) When steam is passed over white hot coke, hydrogen and carbon monoxide are produced.

$$H_2O(g) + C(s) \rightleftharpoons H_2(g) + CO(g)$$

2.0 moles of $H_2O(g)$ and 3.0 moles of C(s) are placed in a 1 dm^3 container and the mixture was allowed to reach equilibrium under certain conditions.

The equilibrium mixture contains 0.30 moles of $H_2(g)$.

(i) Write the expression for the equilibrium constant, K_c, for this equilibrium.

[1]

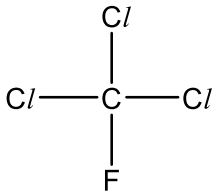
(ii) Calculate the value of K_c under these conditions.

[2]

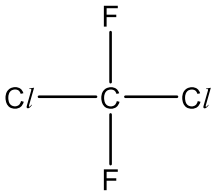
[Total: 8]

3 Chlorofluorocarbons (CFCs) were widely used as refrigerants, aerosol propellants and industrial solvents until the mid-1980s. They are now banned in most countries because they lead to the depletion of the ozone layer.

Two CFCs have the trade names Freon-11 and Freon-12.



Freon-11



Freon-12

(a) **(i)** Give the IUPAC name of Freon-11.

……..……..……. [1]

(ii) Another Freon has the formula CF_4.

Suggest the trade name of this Freon.

……..……..……. [1]

(b) The shapes of the molecules of Freon-11 and Freon-12 are the same.

Use VSEPR theory to describe and explain the shape of Freon-11.

……..….....

……..….....

……..….....

……..….....

…….…….....… [2]

(c) State whether Freon-12 is a polar or non-polar molecule.

Explain your answer.

……..….....

……..….....

…….…….....… [1]

(d) In the stratosphere, CFCs are broken down by ultraviolet radiation, releasing chlorine atoms. Equation 1 shows how chlorine atoms are produced from Freon-12.

equation 1 $CF_2Cl_2 \rightarrow CF_2Cl + Cl$

These chlorine atoms catalyse the breakdown of ozone in a two-step reaction.

equation 2 $Cl + O_3 \rightarrow ClO + O_2$

equation 3 $ClO + O_3 \rightarrow 2O_2 + Cl$

(i) Draw the 'dot-and-cross' diagram for a molecule of ozone, O_3.

[1]

(ii) Use data from the *Data Booklet* to suggest why the ozone layer contains many more chlorine atoms than fluorine atoms.

……...……...……...

……...……...……...

……...……. [1]

(iii) Use equations 2 and 3 to write the overall equation for the breakdown of ozone.

……...……. [1]

(iv) Explain, with the aid of a labelled Boltzmann distribution diagram, how chlorine atoms catalyse the breakdown of ozone.

……...……...……...

……...……...……...

……...……...……...

……...……...……...

……...……. [2]

(e) Researchers have converted Freon-11 into 3-dimensional graphene using molten magnesium at around 800 °C.

Graphene is a single layer of carbon atoms.

3-dimensional graphene consists of layers of graphene stacked into a 3-dimensional network. It has high electrical conductivity and has potential for applications like supercapacitors.

(i) Draw a diagram to represent part of a graphene layer which contains a total of 18 carbon atoms with at least two complete carbon rings.

[1]

(ii) Explain why 3-dimensional graphene is a good electrical conductor.

……...……...……...

……...……...……...

……...……. [1]

(iii) Whilst producing 3-dimensional graphene, MgF_2 and $MgCl_2$ are also formed.

Explain which compound, MgF_2 or $MgCl_2$, has a higher melting point.

……...……...……...

……...……...……...

……...……...……...

……...……...……...

……...……. [2]

[Total: 14]

4 **(a)** Methylamine, CH_3NH_2, is a weak Brønsted-Lowry base.

Define the term weak Brønsted-Lowry base.

…… [1]

(b) Fig. 4.1 shows the change in pH when 25.0 cm^3 of $CH_3NH_2(aq)$ is titrated with 0.10 mol dm^{-3} HC*l*(aq).

$$CH_3NH_2(aq) + HCl(aq) \rightarrow CH_3NH_3^+(aq) + Cl^-(aq)$$

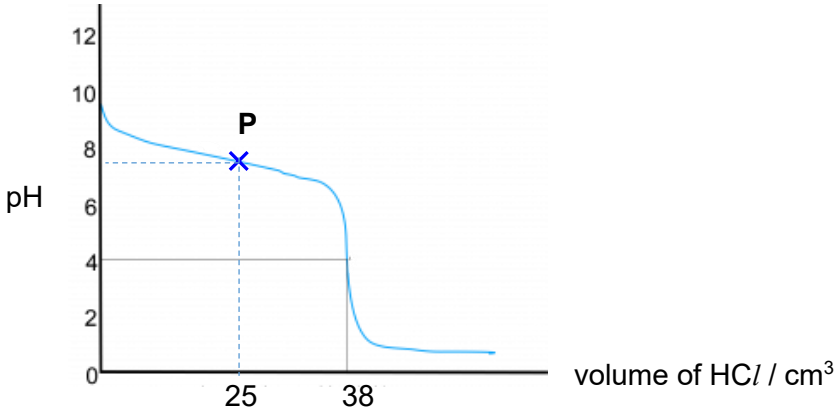


Fig. 4.1

(i) Calculate the concentration of CH_3NH_2 in the solution used in the titration.

[1]

(ii) Identify the two major organic species present in the solution at point **P**.

…… [1]

(iii) Suggest why the slope of the graph only changes gradually in the region around point **P**.

Explain your answer with reference to the equilibrium position.

……

……

……

…… [2]

(iv) Write an equation to show what happens when a small amount of aqueous sodium hydroxide is added to the solution at point **P**.

…… [1]

(c) Methylamine, CH_3NH_2, reacts with ethanoic acid in the presence of dicyclohexylcarbodiimide, DCC.

(i) State the type of reaction which occurs.

……..……..……. [1]

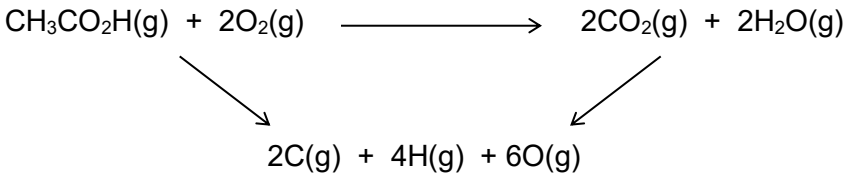
(ii) Draw the displayed formula of the product formed.

[1]

(d) The equation for the complete combustion of ethanoic acid is shown.

$$CH_3CO_2H(l) + 2O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l) \qquad \Delta H_c = -874 \text{ kJ mol}^{-1}$$

(i) Calculate the enthalpy change of combustion of ethanoic acid using bond energy values from the *Data Booklet* and the energy cycle shown.



[3]

(ii) Some bond energy values in the *Data Booklet* are average values. Using them in calculations can result in discrepancies when compared to actual enthalpy change values.

Suggest another reason why the value of ΔH_c calculated in **(d)(i)** is different from the –874 kJ mol^{-1} value quoted.

……..……..……...

……..……..……. [1]

[Total: 12]

5 (a) Both high density poly(ethene), HDPE, and low density poly(ethene), LDPE, are polymers of ethene.

Table 5.1 lists some properties of HDPE and LDPE.

Table 5.1

polymer	**HDPE**	**LDPE**
density / g cm^{-3}	0.95	0.92
melting point / °C	120 - 130	105 - 115
property	hard and stiff	soft and flexible

HDPE is used in milk bottles and detergent bottles, while LDPE is used in plastic bags.

(i) Explain why HDPE has a higher density than LDPE in terms of its structure and bonding.

……...……...

……...……...

……..……..……. [1]

(ii) Explain why LDPE has a lower melting point than HDPE in terms of its structure and bonding.

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……...……...

……...……...

……..……..……. [2]

(iii) Suggest why both HDPE and LDPE are not biodegradable.

……...……...

……...……...

……..……..……. [1]

(iv) HDPE is more commonly recycled than LDPE as it is easier to reprocess the polymer into new products.

At the recycling facility, HDPE bottles are sorted, cleaned and shredded into flakes. The flakes are then melted in an oven and reformed into pellets before being made into new products like benches or tables.

Use the information in Table 5.1 to suggest why the above method is not suitable for recycling LDPE.

……..……..……. [1]

(v) A 2-litre milk bottle made of HDPE weighs 70 grams.

Use the information in Table 5.1 to calculate the number of milk bottles needed to make a pellet with dimensions 50 cm x 40 cm x 2 cm.

Assume that the density of the HDPE remains unchanged by the recycling process.

[2]

Poly(vinyl chloride), PVC, is used in raincoats while poly(vinyl alcohol), PVA, is used in eye drops.

(b) (i) State the property of PVC that makes it suitable for making raincoats.

…… [1]

One way to dispose of PVC is to react it with oxygen at high temperature. This is called incineration.

(ii) Using the repeat unit $-CH_2CHCl-$, write an equation for the incineration of PVC to produce carbon dioxide, water and hydrogen chloride.

…… [1]

(iii) Chemists have reduced the environmental impact of this incineration by removing the hydrogen chloride from the waste gases.

Suggest a reactant that could be used to remove the hydrogen chloride.

…… [1]

(c) Besides eye drops, PVA is also used as the outer casing of laundry capsules.

(i) Draw a labelled diagram to show the interaction of one repeat unit of PVA with a water molecule, and explain why PVA is suitable for making laundry capsules.

……..……...

……..……...

……..……. [3]

(ii) Laundry capsule packaging often states "Keep in a dry place" and "Do not touch with wet hands".

Suggest a reason for these instructions.

……..……...

……..……. [1]

(iii) Suggest one environmental advantage of using PVA in laundry capsules compared to using bottles made with HDPE to store the detergents.

……..……...

……..……. [1]

[Total: 15]

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Section B

Answer **one** question from this section in the spaces provided.

6 (a) Group 1 metals react vigorously with water.

$$2M + 2H_2O \rightarrow 2MOH + H_2 \qquad \text{where M is a group 1 metal}$$

(i) State which metal, sodium or potassium, has a greater reactivity when added to water. Explain your reasoning in terms of the role of the metal in these reactions.

……

……

……

…… [2]

1.0 g of metal **M** was added to 100 cm^3 of water. When all the metal has reacted, the pH of the resulting solution of **M**OH was found to be 13.6 at 25.0 °C.

(ii) State another observation the student makes that confirms the reaction is complete.

…… [1]

(iii) Calculate the concentration of **M**OH in the resulting solution.

[1]

(iv) Hence, calculate the relative atomic mass of metal **M** and suggest the identity of metal **M**.

[2]

(b) (i) Define the standard enthalpy change of neutralisation.

……..……..……...

……..…… [1]

A student uses two different methods to determine the enthalpy change of neutralisation for the reaction between hydrochloric acid and potassium hydroxide.

$$HCl + KOH \rightarrow KCl + H_2O$$

He reacts 50 cm^3 of 1.0 mol dm^{-3} potassium hydroxide solution with 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid in a polystyrene cup.

(ii) Table 6.1 shows the results of method **1**.

Table 6.1

initial temperature of KOH(aq)	27.0 °C
initial temperature of HCl(aq)	27.0 °C
highest temperature of mixture	33.5 °C
maximum temperature change, ΔT_{max}	

Complete Table **6.1**.

Use the results of method **1** to calculate the enthalpy change of neutralisation, in kJ mol^{-1}, for the reaction between hydrochloric acid and potassium hydroxide.

Assume density of the reaction mixture is 1.00 g cm^{-3}, and that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1}.

[3]

In method **2**, the student measures the temperature of KOH(aq) at 0.5 min intervals. At 2.0 min, he adds the HC*l*(aq) to the KOH(aq) in the polystyrene cup, and measures the temperature of the mixture from 2.5 min to 7.0 min.

Fig 6.1 shows the results of method **2**.

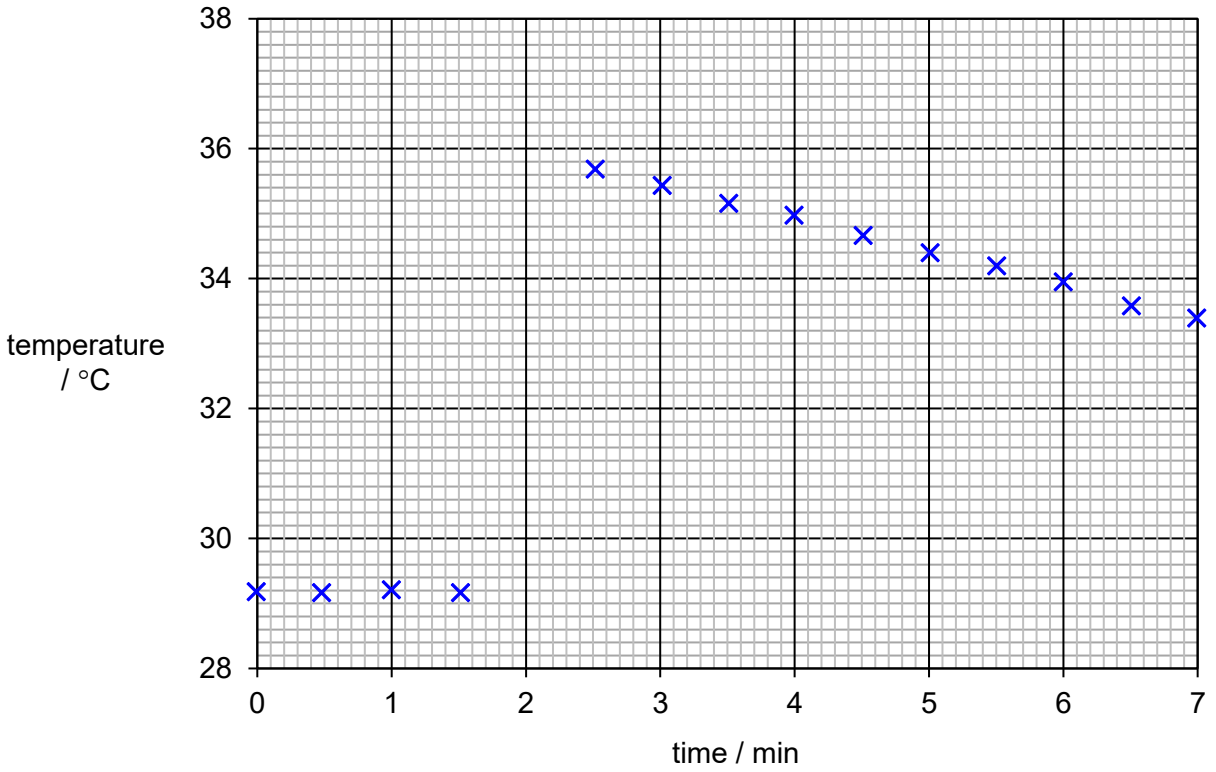

Fig. 6.1

(iii) On Fig. 6.1, draw two separate straight lines of best fit.

The first line should take into account the temperatures of KOH(aq) before the addition of HC*l*(aq).

The second line should take into account the temperatures of the reaction mixture after the addition of HC*l*(aq).

Extend these lines to t = 2.0 min and determine the maximum temperature change, ΔT_{max}, of the experiment.

Show your working.

ΔT_{max} = ……°C
[2]

(iv) The maximum temperature change, ΔT_{max}, obtained in method **2** is closer to the theoretical value than the ΔT_{max} obtained in method **1**.

Suggest **one** reason for this difference. Do not include errors in measurement.

……

…… [1]

(c) There are four isomeric alcohols with the formula $C_4H_{10}O$.

(i) Draw the structures of a primary alcohol and a tertiary alcohol with the formula $C_4H_{10}O$.

[2]

(ii) Describe a simple chemical test to distinguish between the two alcohols in **(c)(i)**. Write the equation for the reaction which occurred.

test:……..……..……...

observations:……..……..……...

……..……..……...

equation:……..……..……. [3]

Alcohols can undergo elimination reactions to form alkenes.

(iii) State the reagents and conditions needed for the reaction.

……..……..……. [1]

(iv) Draw the skeletal structure of the alcohol with the formula $C_4H_{10}O$ which forms an alkene that exhibits cis-trans isomerism.

[1]

[Total: 20]

7 **(a)** The halogens Br_2 and I_2 both react with H_2S in similar reactions. The reaction of Br_2 with H_2S is shown in equation 4.

equation 4 $Br_2 + H_2S \rightarrow 2HBr + S$

(i) Deduce, by reference to equation 4, the role of the halogen in the reaction with H_2S. Include oxidation numbers in your answer.

……

……

…… [1]

(ii) Explain which halogen, Br_2 or I_2, has a greater reactivity when added to H_2S.

……

……

……

…… [2]

(b) Table 7.1 lists the melting points of some Group 17 halogens and of IC*l*.

Table 7.1

substance	melting point / °C
Cl_2	–101
Br_2	–7
I_2	114
IC*l*	27

(i) Explain the trend in melting point of the halogens down Group 17.

……

……

……

……

…… [2]

(ii) Deduce all the types of intermolecular forces in separate samples of Br_2 and of IC*l*. Compare and explain the relative strength of these intermolecular forces.

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…… [3]

(c) (i) Define the term order of reaction.

……

……

…… [1]

The 'clock method' can be used to investigate the reaction between hydrogen peroxide and acidified potassium iodide.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2 \qquad \text{reaction 1}$$

When a small and constant amount of sodium thiosulfate is added to the reaction mixture, the iodine being produced will immediately react with the thiosulfate.

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

As a result, the mixture remains colourless until all the thiosulfate is used up. At that point, if starch is present in the mixture, the iodine produced reacts with the starch, and the mixture turns dark blue.

The time taken for the sudden appearance of the dark blue colour is used as a measure of the rate of reaction.

Table 7.1 shows the results of a series of experiments done using different volumes of H_2O_2(aq), KI(aq) and HC*l*(aq). The mixture was made up to 100 cm^3 each time by adding 2 cm^3 of sodium thiosulfate, 2 cm^3 of starch and deionised water.

Table 7.1

experiment	volume of H_2O_2 /cm^3	volume of KI /cm^3	volume of HC*l* /cm^3	relative rate / s^{-1}
1	15	10	5	3
2	5	10	10	1
3	5	15	10	1.5
4	10	10	10	2

(ii) Use the results in Table 7.1 to deduce the order of reaction with respect to each of the three reactants.

[3]

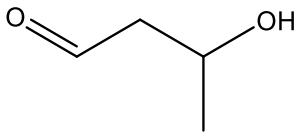
(iii) Hence, deduce the units for the rate constant, *k*, for reaction 1.

[1]

(iv) Suggest the colour change observed when all the thiosulfate is used up if starch is **not** present in the mixture.

…… [1]

(d) Compound **X** is an aldol.



X

(i) Name the two functional groups in **X**.

…… [1]

(ii) Deduce the number of σ and π bonds in **X**.

…… [1]

(iii) Compounds **Y** and **Z** are constitutional isomers of **X**. Both compounds contain only one functional group.

Y reacts with both sodium hydroxide and sodium carbonate.

Z reacts with hot sodium hydroxide but does not react with sodium carbonate.

Draw the structure of compounds **Y** and **Z**.

Explain your answer with reference to the reactions and the functional groups present in the compounds.

……

……

……

……[4]

[Total: 20]