HWA CHONG INSTITUTION
C1 Promotional Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	**22S**

CHEMISTRY **9729/02**

Paper 2 Structured Questions **28 September 2022**

1 h 5 min

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and CT group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for diagrams and graphs only.
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.

A Data Booklet is provided.

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

FOR EXAMINERS' USE ONLY

Q1	/ 11
Q2	/ 18
Q3	/ 11
	/ 40

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1 Iron is the fourth most abundant element on Earth. It is essential to all living things and has widespread industrial application.

(a) Describe the bonding in iron with the aid of a labelled diagram.

....

....

....

.... [2]

(b) Iron, copper and zinc can be found in Period 4 of the Periodic Table.

(i) Complete the electronic configurations of Cu^+ and Zn^+.

Cu^+: $1s^2\ 2s^2\ 2p^6$ ....

Zn^+: $1s^2\ 2s^2\ 2p^6$ .... [2]

(ii) With reference to your answer in **(b)(i)**, suggest why the second ionisation energy of copper is higher than that of zinc.

....

....

....

....

....

....

....

.... [2]

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(c) Finely divided iron is used industrially as a catalyst in the Haber process to manufacture ammonia from nitrogen gas and hydrogen gas. The Haber process is typically carried out at 450 °C and 200 atm.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H_r = -92.0 \text{ kJ mol}^{-1}$$

(i) By considering the rate of reaction and position of equilibrium, explain why a moderately high temperature of 450 °C is used for the Haber process.

……

……

……

……

…… [2]

Ammonia is one of the most highly produced inorganic chemicals. For the process, nitrogen gas is obtained from the air which contains 78.08% nitrogen gas by volume.

(ii) The current global output of ammonia is 3300 tonnes of ammonia per day. Calculate the volume of nitrogen gas required for the reaction per day, given that the yield of the reaction is 15%.

Assume all gases are measured at room temperature and pressure. (1 tonne = 1000 kg)

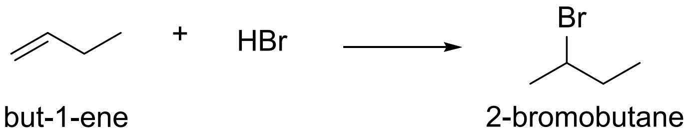
[2]

(iii) Hence, calculate the volume of air consumed for the reaction daily.

[1]

[Total: 11]

2 (a) (i) But-1-ene reacts with hydrogen bromide to form 2-bromobutane.



Describe the mechanism of the reaction of but-1-ene with HBr to form 2-bromobutane, showing curly arrows, charges, dipoles and any relevant lone pairs.

[3]

(ii) Explain what is meant by the term *bond energy*.

....

.... [1]

(iii) Use appropriate bond energy data from the *Data Booklet* to calculate a value for the standard enthalpy change of the reaction in **(a)(i)**.

ΔH = ...

[2]

(iv) Explain what is meant by the term *activation energy*.

....

.... [1]

(v) On the axes in Fig 2.1, construct an energy profile diagram for the reaction of but-1-ene with HBr to form 2-bromobutane.

Label clearly the axes, the carbocation intermediate, the activation energies and the ΔH you calculated in **(a)(iii)**.

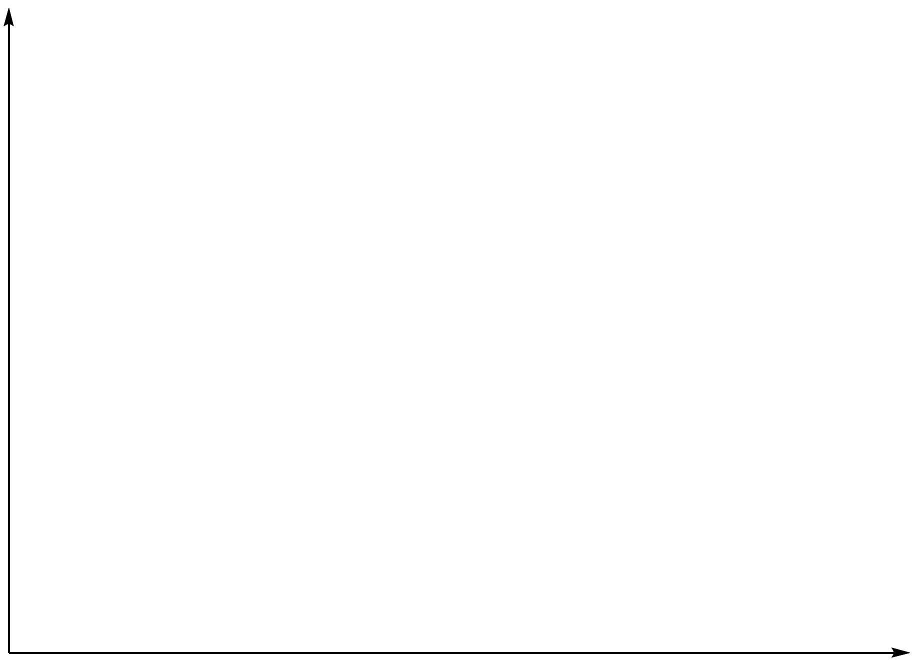
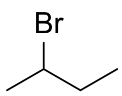


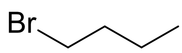
Fig. 2.1

[2]

(vi) The reaction between but-1-ene and hydrogen bromide produces 2-bromobutane rather than 1-bromobutane.



2-bromobutane



1-bromobutane

Explain why 2-bromobutane is the product formed rather than 1-bromobutane.

....

....

....

.... [2]

(b) Butadiene also reacts with hydrogen bromide. When they react in a 1:1 mole ratio, a mixture of products, **A** and **B**, are formed, as shown in Fig 2.2.

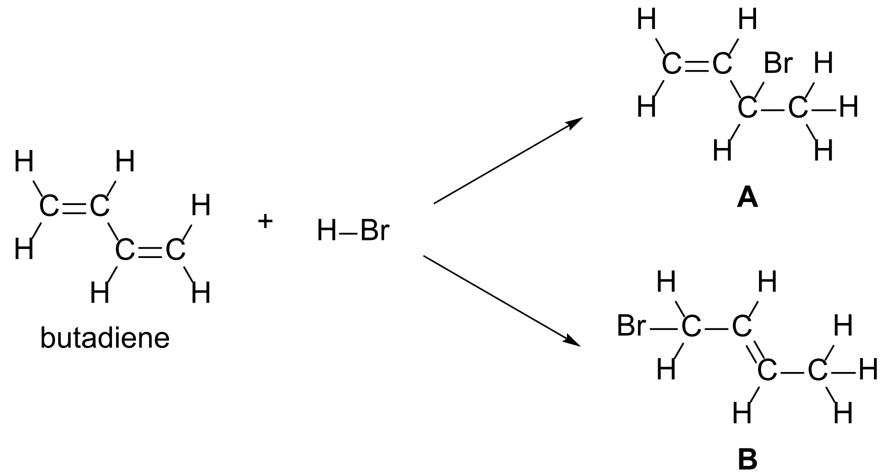
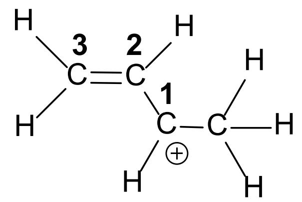


Fig. 2.2

(i) Both products **A** and **B** are formed via the same carbocation intermediate, **C**.



carbocation **C**

The bromide anion, Br^-, can either attack carbon-1 or carbon-3 on carbocation **C** to give **A** or **B**, respectively. This is because the positive charge on carbocation **C** is delocalised across carbon-1, carbon-2 and carbon-3.

Carbon-1, carbon-2 and carbon-3 are sp^2 hybridised. Explain why delocalisation is possible across these three carbon atoms.

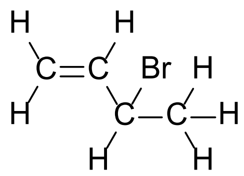
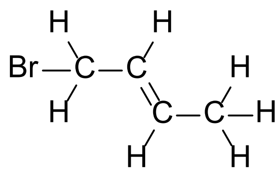
……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

(ii) For each product **A** and **B** respectively, state the number of each type of carbon-carbon σ bonds present in Table 2.1.

Table 2.1

carbon-carbon σ bonds	product **A** 	product **B** 
number of sp^2–sp^2 bonds		
number of sp^2–sp^3 bonds		
number of sp^3–sp^3 bonds		

[1]

(iii) The strengths of the carbon-carbon σ bonds in Table 2.1 increase in the following order.

$$sp^3\text{–}sp^3 < sp^2\text{–}sp^3 < sp^2\text{–}sp^2$$

Explain why.

....

....

.... [1]

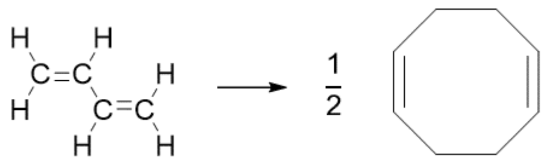
(iv) Alkenes which have stronger covalent bonds are more stable.

Using your answers in **(b)(ii)** and **(b)(iii)**, explain whether **A** or **B** is more stable.

....

.... [1]

(c) When heated at a high temperature, butadiene forms 1,5-cyclooctadiene.



butadiene 1,5-cyclooctadiene

The concentration of butadiene is monitored at fixed time intervals in an experiment and the results are shown in Fig. 2.3.

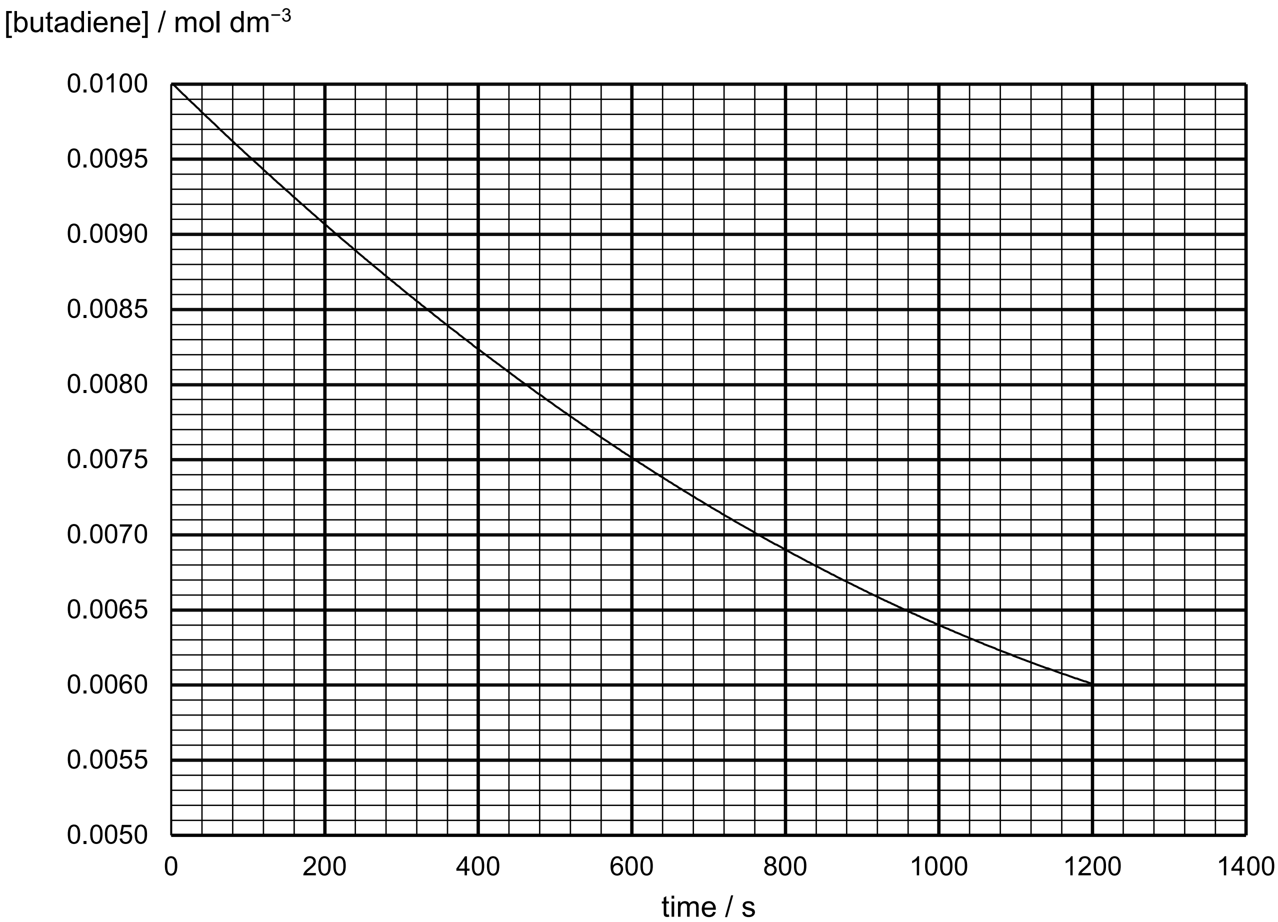


Fig. 2.3

(i) Using Fig. 2.3, determine the initial rate of reaction, in mol dm^{-3} s^{-1}, for this experiment. Show your working clearly.

initial rate = ………………………………………… mol dm^{-3} s^{-1}

[1]

(ii) The rate equation of the reaction was found to be: rate = k[butadiene]^2.

Use your answer in **(c)(i)** to calculate the value of the rate constant, stating its units.

k = ………………………………………

units = ………………………………………

[2]

[Total: 18]

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3 Refrigerants are fluids that commonly undergo repeated liquid-gas phase transitions in the refrigerator. Heat from the food contents causes the refrigerant fluid to vaporise, then condenses in the coils behind the refrigerator as heat is dissipated.

Chlorofluorocarbons (CFCs) were widely used as refrigerants in the 1970s. They were initially considered good refrigerants due to their low toxicity and non-flammability, but were later banned due to their destructive effect on the ozone layer. Since then, chemists have sought to prepare new compounds as replacements, such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). In modern refrigerators, the most common refrigerants are ammonia, and hydrocarbons (HCs) such as propane.

The properties of some common refrigerants are summarised in Table 3.1. Ozone depletion potential is a measure of how much damage a substance can cause to the ozone layer.

Table 3.1

type	compound	boiling point / °C	ozone depletion potential
CFC	CCl_3F	24	1.00
HCFC	$CHClF_2$	−41	0.055
HFC	CH_2F_2	−52	0
HC	$CH_3CH_2CH_3$	−42	0
natural	NH_3	−33	0

(a) Suggest why the condensation of refrigerant vapour is exothermic.

....

.... [1]

(b) Other than their low toxicity and non-flammability, suggest **one** reason why CFCs were originally used as refrigerants.

....

.... [1]

(c) In the presence of ultraviolet light, CFCs such as CCl_3F will produce chlorine radicals which react with ozone, O_3, causing its decomposition to O_2 gas.

The equation for the decomposition is:

$$2O_3(g) \downarrow 3O_2(g)$$

(i) In the reaction, a chlorine radical, $Cl\bullet$, is formed from a molecule of CCl_3F in the presence of ultraviolet light.

In Fig. 3.1, draw curly arrows to show the formation of the chlorine radical and the other species obtained. State the type of bond breaking involved.

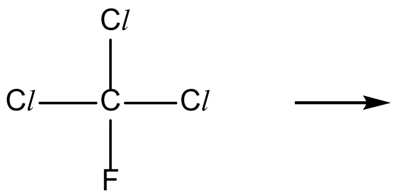

Fig. 3.1

Type of bond breaking: .... [2]

(ii) The propagation steps of the mechanism are proposed as described below.

In step 1, the chlorine radical reacts with an ozone molecule to form a radical $ClO\bullet$.

In step 2, $ClO\bullet$ reacts with another ozone molecule to regenerate the chlorine radical.

Suggest the mechanism for the decomposition of ozone. There is no need to show curly arrows in your equations.

step 1: ....

step 2: .... [2]

(iii) Trace amounts of other products, besides O_2, may be obtained in the reaction. Suggest one possible trace product.

.... [1]

(iv) Suggest why HFCs like CH_2F_2 has no ozone depletion potential as compared to other CFCs and HCFCs as shown in Table 3.1.

....

.... [1]

(d) Some thermodynamic data of a hydrocarbon refrigerant, propane, $CH_3CH_2CH_3$, are given in Table 3.2.

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Table 3.2

enthalpy change of vaporisation, ΔH_{vap}	$+24.5$ kJ mol^{-1}
specific heat capacity of liquid propane, c_{liq}, $CH_3CH_2CH_3(l)$	2.24 J g^{-1} K^{-1}

700 g of liquid propane, $CH_3CH_2CH_3(l)$, at −50 °C absorbed heat from its surroundings to reach a temperature of 25 °C.

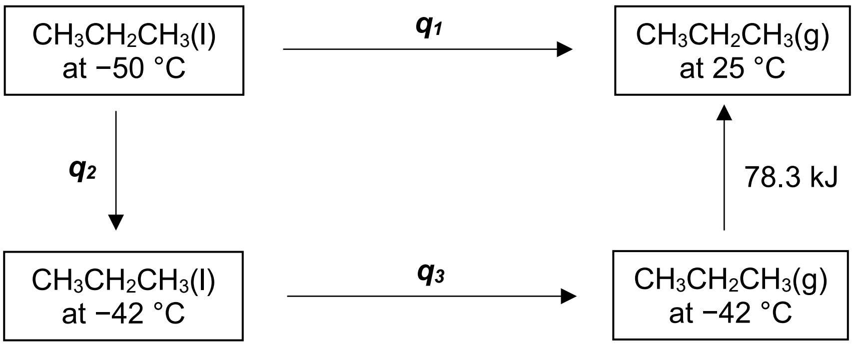

Fig 3.2

9With reference to Fig. 3.2, calculate

- $\boldsymbol{q_2}$, the heat absorbed by 700 g of liquid propane at −50 °C to raise its temperature to −42 °C,
- $\boldsymbol{q_3}$, the heat absorbed by liquid propane at its boiling point of −42 °C to be converted entirely to vapour,
- hence $\boldsymbol{q_1}$, the total heat absorbed by 700 g of liquid propane at –50 °C to reach 25 °C.

[M_r of propane = 44.0]

[3]

[Total: 11]