HWA CHONG INSTITUTION
C1 Promotional Examination
Higher 2

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

CHEMISTRY

9729/03

Paper 3 Free Response

28 September 2022

55 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 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. If additional space is required, you should use the pages at the end of this booklet. The question number and part must be clearly shown.

Section A
Question 1 is a compulsory question.

Section B
Answer only **one** question from this section.

A Data Booklet is provided.
The use of an approved scientific calculator is expected, where appropriate.

You are reminded of the need for good English and clear presentation in your answers.

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.

FOR EXAMINER'S USE

Question No.	**Marks obtained**
1	/ 20
^Circle the question attempted below.	
^ 2 / 3	/ 15
Total Marks	**35**

Section A

Question 1 is a **compulsory** question. All candidates should answer this question.

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1 (a) Volcanology is the scientific study of volcanoes. At the Earth's core, there is a molten mixture of rock, gases and crystals called magma. During a volcanic eruption, magma makes its way to the surface and flows out as lava.

The most abundant elements in magma are oxygen and silicon.

(i) State the electronic configuration of an atom of silicon. [1]

(ii) Describe one similarity and one difference between a 3s orbital and a 3p orbital. [2]

(iii) Describe one difference between a 2p orbital and a 3p orbital. [1]

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(b) Silica, SiO_2, is a major component of lava. At the high temperatures during eruptions, silica in the lava can react with other metals present to form a variety of salts, such as basalt.

Analysis of a sample of basalt produced the following composition:

element	mass percentage (%)
Ca	18.51
Mg	11.22
Si	25.95
O	44.32

(i) Use the information provided above to determine the empirical formula of basalt. [2]

(ii) Basalt can be thought of as a mixture of a salt of calcium and a salt of magnesium, both containing the same anion. Based on your answer to **(b)(i)**, state the formula of this anion. [1]

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(c) Hydrocarbon reservoirs can often be found in volcanic zones.

Pentenes, one of the byproducts of thermal cracking of hydrocarbons, are alkenes with the formula C_5H_{10}. Pentenes are generally very volatile and boil just above room temperature.

(i) **D**, **E**, and **F** are three straight-chain pentenes with different structures. **E** and **F** are a pair of stereoisomers.

Draw the structures of **D**, **E** and **F**, and name each of them. [3]

(ii) Explain how the isomerism between **E** and **F** arises. [2]

Hydrogenation is a useful way to convert unsaturated hydrocarbons, such as pentenes, into saturated hydrocarbons.

$$C_5H_{10}(g) + H_2(g) \rightarrow C_5H_{12}(g)$$

This conversion is usually conducted in the presence of a finely divided metal catalyst. Without the catalyst, pentenes do not react readily with hydrogen gas.

(iii) Explain, with the aid of a labelled Maxwell-Boltzmann distribution diagram, the effect on a rate constant of adding a catalyst. [3]

(iv) At very low pressures, the reaction rate is directly proportional to the partial pressure of each reactant, while at higher pressures, the reaction rate appears to be independent of the partial pressure of each reactant. Suggest an explanation for this observation. [2]

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(d) **G** is an alkene with the formula C_6H_{12}. An isolated sample of **G** is able to rotate plane-polarised light. Draw a possible structure for hydrocarbon **G**. [1]

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(e) **J** is a hydrocarbon with the formula C_xH_y. **J** is a liquid at room temperature, but a gas at 150 °C.

10 cm^3 of hydrocarbon **J** was exploded in exactly 95 cm^3 of oxygen and a mixture of carbon dioxide and steam were formed. Both **J** and the oxygen were completely used up. These volumes were measured at 150 °C and 1.0 atm.

The complete combustion of **J** is shown below.

$$C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

When the gaseous product mixture was cooled down at 1.0 atm from 150 °C to 20 °C, 48.5 cm^3 of gas was left after discarding the liquid water.

(i) Calculate the volume of CO_2 at 150 °C. [1]

(ii) Hence, deduce the molecular formula of **J**, showing your working clearly. [1]

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[Total: 20]

Section B

Answer **one** question from this section.

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2 (a) 2.10 g of a Group 1 metallic salt (M_r < 500) containing the $I_xCl_y^-$ anion decomposed when heated to form iodine vapour and the metallic chloride as the residue.

The iodine evolved was bubbled into excess potassium iodide solution. The iodine required 25.56 cm^3 of 0.500 mol dm^{-3} aqueous sodium thiosulfate for complete reaction. The ionic equation for the reaction between iodine and thiosulfate is shown below:

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

0.92 g of solid AgC*l* was obtained when the metallic chloride residue was added to an excess of aqueous silver nitrate.

(i) Calculate the amount in moles of I atoms present in the sample of metallic salt. [1]

(ii) Calculate the amount in moles of C*l* atoms present in the sample of metallic salt. [1]

(iii) Hence, determine the formula of the $I_xCl_y^-$ anion and deduce the identity of the Group 1 metal present in the metallic salt. [2]

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(b) I_2 molecules and I^- ions react to form tri-iodide ions, I_3^-. A *dynamic equilibrium* is set up as shown in equilibrium 1.

equilibrium 1 $\quad I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq) \quad \Delta H < 0$

(i) Explain what is meant by *dynamic equilibrium*. [1]

(ii) The shape of I_3^- is linear. Draw a dot-and-cross diagram for I_3^-. [1]

(iii) Although molecular iodine is not very soluble in water, it is freely soluble when added to KI(aq). With reference to the shift in position of equilibrium 1 and forces of attraction between particles, explain why molecular iodine is soluble when added to KI(aq). [2]

Some solid I_2 is dissolved in 100 cm^3 of KI(aq) and the reaction mixture is allowed to reach equilibrium at 25 °C, according to equilibrium 1. The resulting concentrations of $I_2(aq)$, $I^-(aq)$ and $I_3^-(aq)$ are 0.040 mol dm^{-3}, 0.040 mol dm^{-3} and 0.850 mol dm^{-3} respectively.

(iv) Calculate a value of K_c for equilibrium 1. [1]

(v) Explain the significance of the magnitude of your answer in **(b)(iv)**. [1]

When more solid I_2 is added to the equilibrium mixture at 25 °C, the amount of I_3^- increases to 0.086 mol at the new equilibrium.

(vi) Use your value of K_c to calculate the amount in moles of I_2 added and hence the new equilibrium concentration of $I_2(aq)$. [3]

(vii) Predict and explain the sign of ΔS with respect to equilibrium 1. Hence, deduce and explain the effect on the spontaneity of the forward reaction when temperature increases. [2]

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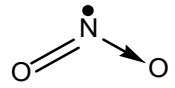
3 Nitrogen dioxide, NO_2, is an oxide of nitrogen that is an air pollutant.



nitrogen dioxide

(a) (i) Two molecules of NO_2 can dimerise to form another oxide of nitrogen, N_2O_4. Draw the structure of N_2O_4 and state the shape about each N atom. [2]

(ii) The bond angle in the NO_2 molecule is 134°, much larger than 120°. Explain why. [1]

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(b) The dimerisation of NO_2 is a reversible reaction.

equilibrium 2 $\quad 2NO_2(g) \rightleftharpoons N_2O_4(g)$

(i) Write the K_p expression for equilibrium 2. [1]

(ii) x kPa of NO_2 was introduced into an evacuated vessel of fixed volume and allowed to equilibrate at a constant temperature of 25 °C. The total pressure inside the vessel decreased by 100 kPa when equilibrium was reached.

Determine the partial pressure of N_2O_4 at equilibrium. [1]

(iii) The K_p of equilibrium 2 is 6.25×10^{-2} kPa^{-1} at 25 °C.

Use your answers in **(b)(i)** and **(b)(ii)** to determine the value of x. [1]

(iv) Deduce the effect on the position of equilibrium 2 when the volume of the vessel used is decreased. Explain your reasoning. [2]

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(c) **(i)** Sketch a graph of pV vs p for a fixed mass of an ideal gas at constant temperature, where p is the pressure and V is the volume of the gas. [1]

(ii) When real gas molecules collide, the kinetic energy during collision is not necessarily conserved.

State **two** other properties of real gas molecules which could lead to the product pV for a fixed mass of real gas at constant temperature being different from that for an ideal gas. [2]

The plotted points in Fig. 3.1 are experimental values of the product pV for a mass m of a gas **A** at a constant temperature of T.

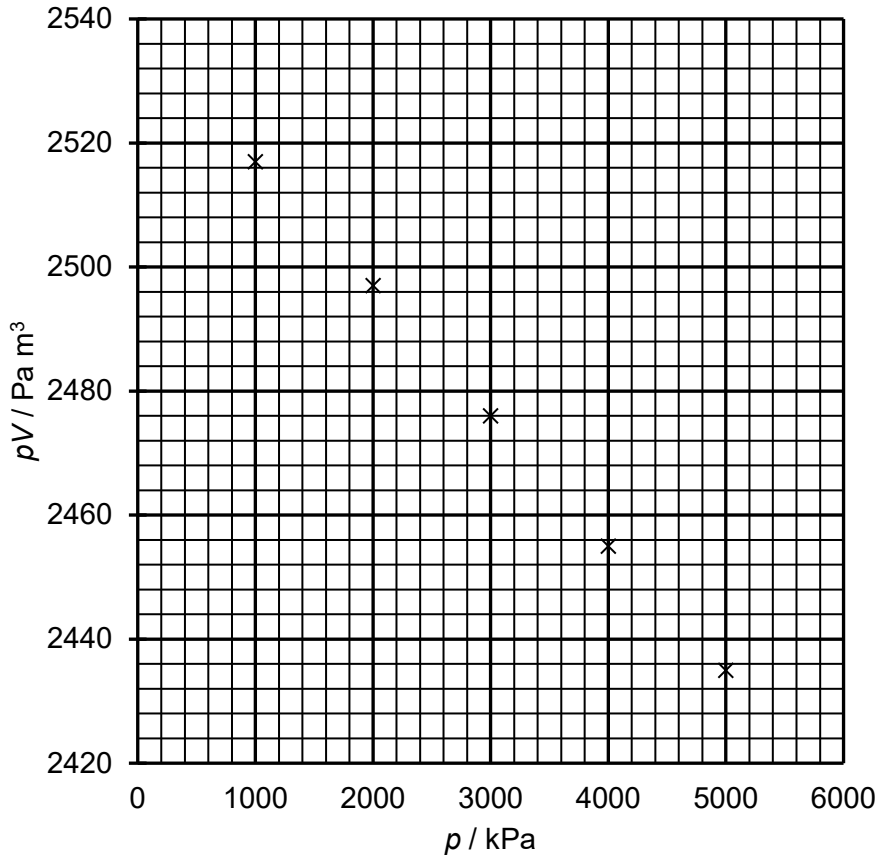

Fig. 3.1

(iii) In Fig. 3.1, pV of gas **A** decreases as p increases, which differs from your sketch in **(c)(i)** for an ideal gas. Which one of the properties that you have stated in **(c)(ii)** results in the decrease in pV as p increases? Explain your answer briefly. [1]

(iv) A real gas can approach ideal behavior under certain conditions, such as high temperature. State another condition under which a real gas behaves more ideally. [1]

(v) Use the graph in Fig. 3.1 and your answer in **(c)(iv)** to estimate the pV value for an ideal gas. [1]

(vi) Hence, use the ideal gas equation to determine the relative molecular mass of gas **A** to 1 decimal place, given that the experimental results in Fig. 3.1 were obtained with a sample of 56 g of gas **A** at 150 K. [1]

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[Total: 15]

Additional answer space

If you use this page to complete the answer to any question, the **question number must be clearly shown**.

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