YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CG

INDEX NO

CHEMISTRY

9729/02

Paper 2 Structured Questions

28 August 2023

2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, CG and Index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

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.

You are advised to show all working in calculations.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use		
1	/ 9	
2	/ 8	
3	/ 8	
4	/ 8	
5	/ 12	
6	/ 20	
7	/ 10	
Penalty	units	significant figures
Overall	/ 75	

This document consists of **23** printed pages and **3** blank pages.

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

1 Semiconductors are made from a variety of raw materials. Through a complex process, semiconductor grade silicon of high purity can be produced by refining the raw materials.

(a) An unknown element **R** was studied for its semiconductor properties.

The table below shows the ionisation energies of element **R**.

Table 1.1

	1st	2nd	3rd	4th	5th	6th	7th
Ionisation Energy/kJ mol^{-1}	945	2026	2987	4144	6593	7880	14 990

The principal quantum number of Element **R** is ***n***.

Predict, with explanation, the Group where element **R** will be found in and complete its electronic configuration.

Group: **……..**

Electronic configuration: **…….**

……..…….....

……..…….....

……..……..... [2]

(b) Silicon is commonly used in semiconductors.

One important raw material for semiconductors is silane (SiH_4), which is a key precursor in the production of semiconductor-grade silicon.

(i) Draw the dot-and-cross diagram of silane.

State the molecular shape about the central Si atom in silane.

[2]

(ii) Is silane molecule polar or non polar? Give a reason for your answer.

.....

..... [1]

(c) The chlorides of silicon share similar properties as the chlorides of aluminium and phosphorus when they are dissolved in water.

With the aid of equations, explain how chlorides of aluminium, silicon, and phosphorus exhibit acidic properties when dissolved in water.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

[Total: 9]

2 (a) The pK_b value of three bases at 25 °C are shown in Table 2.1.

Table 2.1

base	formula	pK_b
diethylamine	$(CH_3CH_2)_2NH$	2.9
ethylamine	$CH_3CH_2NH_2$	3.3
phenylamine	$C_6H_5NH_2$	9.4

(i) State the relationship between pK_b and the strength of a base.

……..…. [1]

(ii) Explain the relative magnitudes of the pK_b values in Table 2.1.

……..…

……..…

……..…

……..…

……..…

……..…

……..…

……..…

……..…

……..…

……..…

……..…. [4]

BLANK PAGE

(b) Preparation of N-phenylethanamide can be carried out by acylation reaction of phenylamine with ethanoic anhydride.

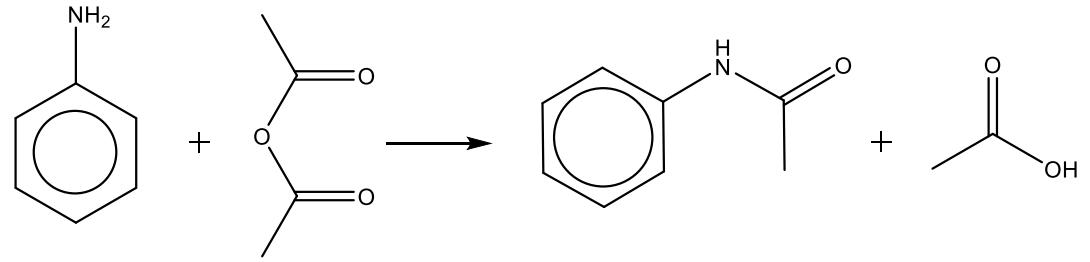
The reaction is performed in two stages

I. An excess of sodium ethanoate is heated with 1.5 g of phenylammonium chloride forming phenylamine, ethanoic acid and sodium chloride.

$$C_6H_5NH_3Cl + CH_3COONa \longrightarrow C_6H_5NH_2 + CH_3COOH + NaCl$$

M_r: 129.5 *M_r: 93.0*

II. Phenylamine then reacts with excess of ethanoic anhydride to form 1.12 g of N-phenylethanamide (as a white solid), together with ethanoic acid.



phenylamine
M_r: 93.0

ethanoic anhydride

N-phenylethanamide
M_r: 135.0

ethanoic acid

(i) Calculate the percentage yield of N-phenylethanamide.

[1]

(ii) Student A wanted to use sodium hydroxide instead of sodium ethanoate in stage I to produce phenylamine.

Suggest an equation for the reaction between phenylammonium chloride and sodium hydroxide to form phenylamine.

…… [1]

(iii) Student B claimed that the percentage yield of N-phenylethanmide will be affected by using sodium hydroxide instead of sodium ethanoate in stage I.

Suggest and explain if Student B's claim is correct.

.....

.....

..... [1]

[Total: 8]

3 Transesterification involves the conversion of one ester into another through the exchange of an – OR group, forming a new ester. A general reaction scheme is shown in F.g. 3.1.

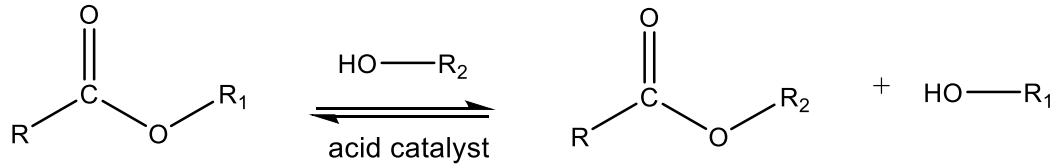


Fig. 3.1

Non-edible oils such as castor oil contain components such as triricinolein that can undergo transesterification with methanol to produce methyl esters and glycerol, in Fig. 3.2.

The values k_1 and k_2 refer to the relative rate constants for the forward and reverse reactions respectively.

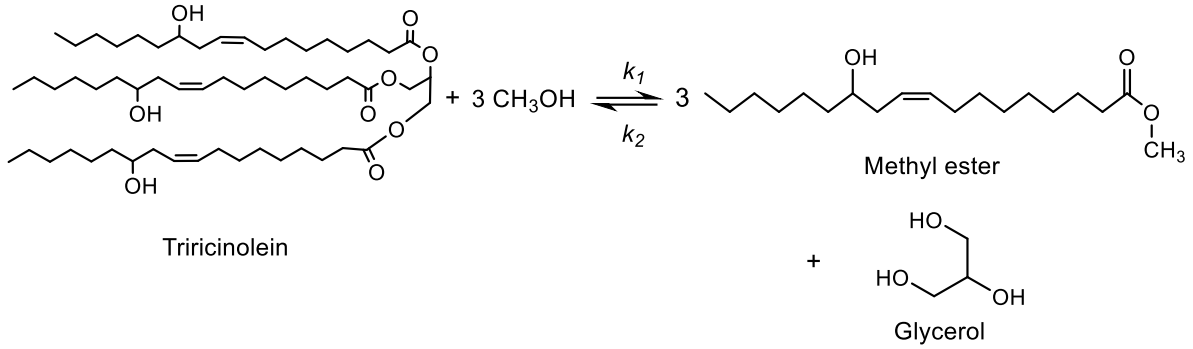


Fig. 3.2

(a) **(i)** The reaction shown in Fig 3.2 is at dynamic equilibrium. Explain what is meant by dynamic equilibrium in terms of k_1 and k_2.

……

……

…… [1]

(ii) The equilibrium constant, K_c, is related to the ratio of k_1 and k_2.

Prove that $K_c = \frac{k_1}{k_2}$

[1]

Some data regarding the reversible reaction is provided in Table 3.3

Table 3.3

Temperature/ K	k_1	k_2
308.15	7.10×10^{-4}	7.98×10^{-2}
318.15	1.02×10^{-3}	3.14×10^{-2}
328.15	1.65×10^{-3}	1.48×10^{-2}
338.15	2.06×10^{-3}	1.61×10^{-2}

(iii) Calculate the K_c values and explain whether transesterification is endothermic or exothermic.

[2]

(b) The intermediates for the stepwise mechanism of transesterification of the acid-catalysed transesterification are shown in Fig 3.4.

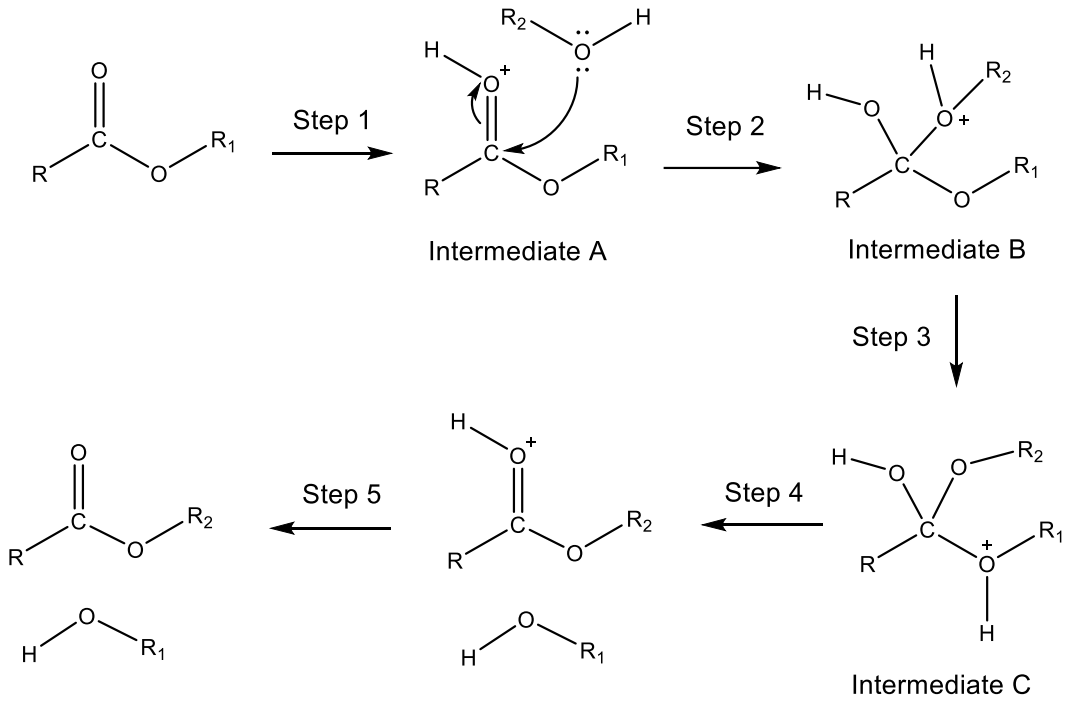


Fig. 3.4

(i) State the types of reaction in Steps 1 and 2.

Step 1: .....

Step 2: ..... [2]

(ii) In the presence of a base such as sodium hydride, transesterification can proceed with the generation of a strong nucleophile.

$$R_2OH + NaH \rightarrow R_2O^- Na^+ + H_2$$

State the role of R_2OH.

..... [1]

Explain why this step is significant.

..... [1]

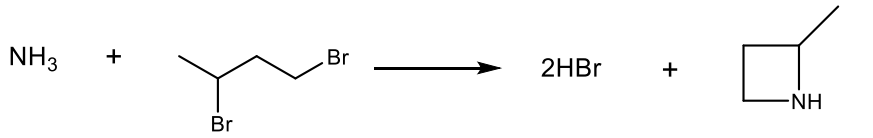
[Total: 8]

BLANK PAGE

4 2-methylazetidine is a chemical compound that is used as a building block in the synthesis of polypeptides and other nitrogen-containing compounds with potential biological properties. It is also a precursor to the drug avapritinib, which is used to treat cancer.

In addition to its use in the pharmaceutical industry, 2-methylazetidine has also been studied for its potential applications in other areas, such as pesticides in agriculture, a fragrance ingredient in cosmetics and a flavouring agent in food additives.

(a) 2-methylazetidine can be synthesised by reacting ammonia with a dibromo compound, 1,3-dibromobutane.



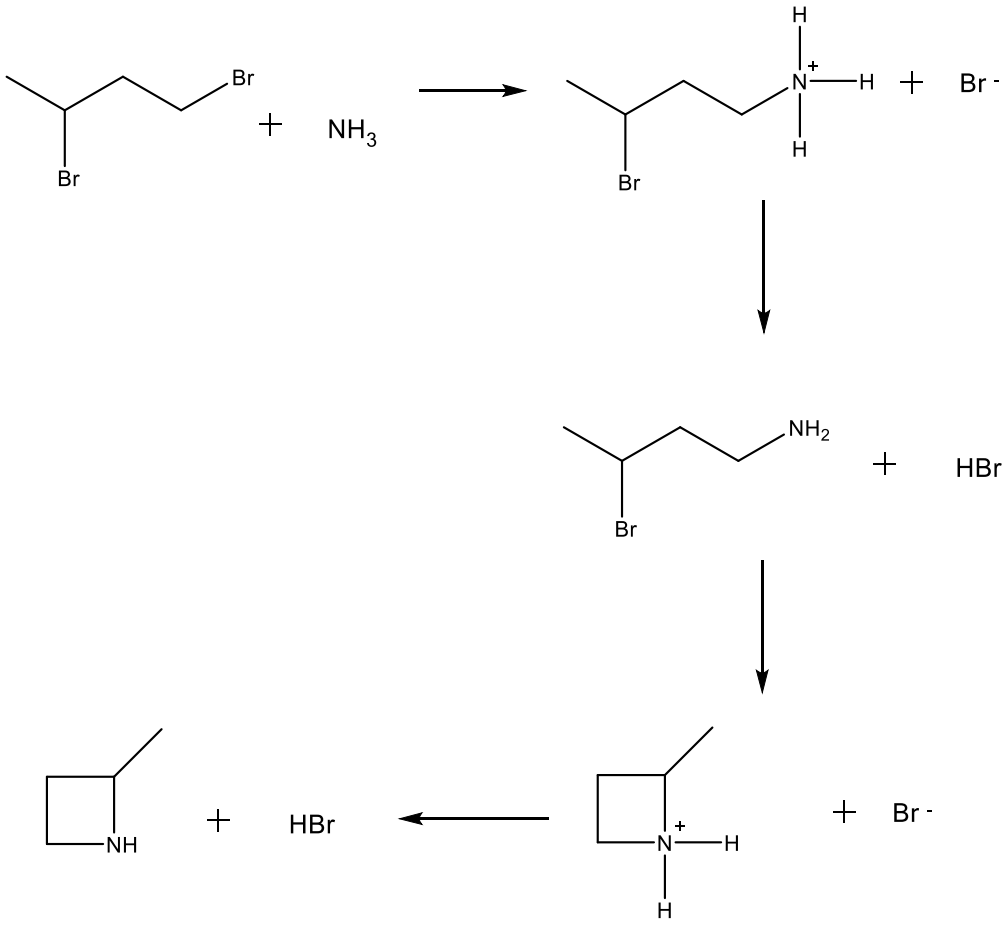
2-methylazetidine

(i) Suggest the type of reaction occurring in the reaction above

..... [1]

(ii) Ammonia reacts with 1,3-dibromobutane in a four step process.

Complete the diagram to suggest a mechanism to show how 2-methylazetidine is formed. Show all relevant lone pairs and dipoles, and use curly arrows to indicate movement of electron pairs.



[3]

(iii) Describe a chemical test, with appropriate observations, which would distinguish 2-methylazetidine from 1,3-dibromobutane.

……

……

……

…… [2]

(b) Calculate the enthalpy change for the reaction using relevant bond energies from the *Data Booklet*.

[2]

[Total: 8]

5 **(a)** During the corrosion of iron in the presence of oxygen and water, Fe is oxidised to Fe^{2+} while O_2 is reduced to OH^-.

(i) Using appropriate data from the *Data Booklet*, draw a fully labelled diagram of a cell set-up to measure the cell potential between the $Fe^{2+}(aq)/Fe(s)$ half-cell and $O_2(g)/OH^-(aq)$ half-cell.

On your diagram, indicate the direction of electron flow.

[2]

(ii) Calculate the cell potential of the overall reaction.

[1]

(iii) Write an equation, including state symbols, for the overall cell reaction.

..... [1]

(b) Iron forms many complexes with a range of colours as shown in Table 5.1:

Table 5.1

complex	colour
$[Fe(H_2O)_6]^{3+}$	yellow
$[Fe(CN)_6]^{3-}$	red
$[Fe(H_2O)_6]^{2+}$	green

(i) Explain why most iron complexes are coloured.

.....

.....

.....

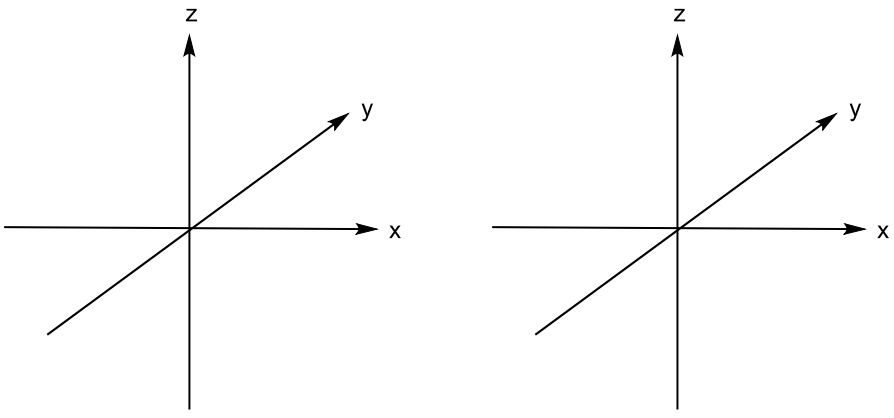
.....

.....

.....[3]

(ii) Draw **fully labelled** diagrams of the following:

- One of the d-orbitals at the lower energy level in $[Fe(H_2O)_6]^{2+}$.
- One of the d-orbitals at the upper energy level in $[Fe(H_2O)_6]^{2+}$.



Lower Upper

[2]

(c) Fe^{2+} is commonly used to catalyse the reaction between $S_2O_8^{2-}$ and I^-. In another similar reaction, peroxodisulfate, $S_2O_8^{2-}$, reacts with tartrate ion, $[CH(OH)CO_2]_2^{2-}$, to give carbon dioxide and methanoate as shown in the following equation.

$$[CH(OH)CO_2]_2^{2-} + 3S_2O_8^{2-} + 2H_2O \rightarrow 2CO_2 + 2HCO_2^- + 6H^+ + 6SO_4^{2-}$$

The reaction is very slow, even when heated, hence a catalyst is used to speed up the reaction.

(i) Given that the standard electrode potential for the following half-equation is

$$2CO_2 + 2HCO_2^- + 6H^+ + 6e^- \rightleftharpoons [CH(OH)CO_2]_2^{2-} + 2H_2O \qquad E^\theta = +0.56\ V$$

Use relevant standard redox potentials from the *Data Booklet* and suitable equations, calculate relevant $E^\ominus_{cell}$ values and explain why Mn^{2+} is a suitable catalyst for this reaction.

[2]

(ii) Explain why manganese can function as a homogenous catalyst in this reaction.

……

……

……

…… [1]

[Total: 12]

6 Fig. 6.1 is a simplified illustration of a car fuel-exhaust system.

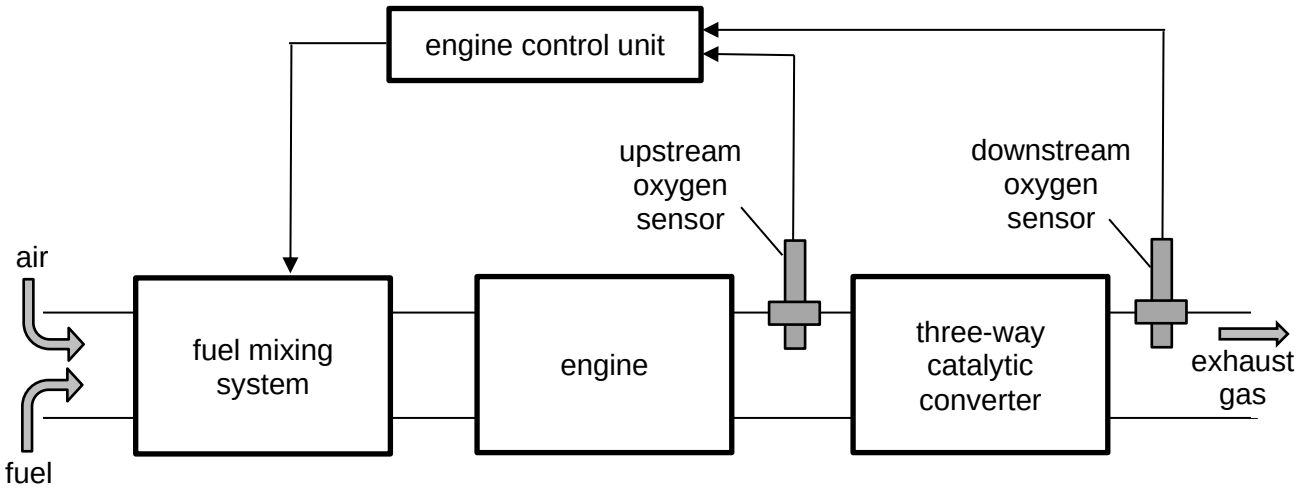


Fig. 6.1

Air and fuel are injected into the fuel mixing system, and subsequently supplied to the engine for combustion. The resultant gaseous mixture is then processed in the three-way catalytic converter via a series of chemical reactions to eliminate harmful exhaust pollutants. The purified exhaust gas is discharged from the car.

(a) In the fuel mixing system, the air-fuel ratio (AFR) is regulated by the engine control unit to ensure optimum power generation.

The air-fuel ratio (AFR) is defined as the ratio between the mass of air, m_a and mass of fuel, m_f used by the engine.

$$\text{AFR} = \frac{m_a}{m_f}$$

The stoichiometric AFR is the stoichiometric ratio of air and fuel of a mixture prepared for complete combustion.

Table 6.1 shows the approximate stoichiometric AFR for some fossil fuels.

Table 6.1

fuel	molecular formula	Stoichiometric AFR
hydrogen	H_2	34.3 : 1
methane	CH_4	17.19 : 1
propane	C_3H_8	x : 1
gasoline	-	14.7 : 1
diesel	-	14.5 : 1

(i) Write an equation for the complete combustion of propane.

..... [1]

(ii) The value of x can be determined by reacting 44g of propane with a sample of air which is made up of 160g of oxygen gas.

Assuming that air contains 23.2% by mass of oxygen gas, calculate the value of x.

[2]

(iii) Suggest the purpose of the upstream oxygen sensor in the car-fuel exhaust system.

.....

.....

..... [1]

(b) The resultant gaseous mixture produced from the engine contains pollutants such as carbon monoxide (CO), oxides of nitrogen (NO_x) and unburnt hydrocarbons (C_xH_y) which are chemically modified when they passed through the three-way catalytic converter.

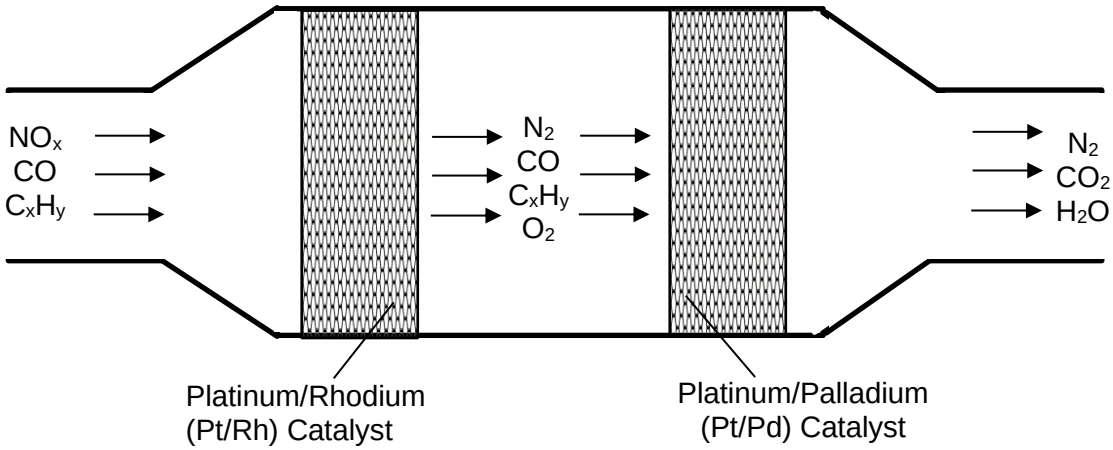


Fig. 6.2

The three-way catalytic converter consist of two honeycomb-like monoliths covered with a thin layer of Pt/Rh (first monolith) and Pt/Pd (second). The Pt/Rh catalyst reduces NO_x whereas the Pt/Pd catalyst oxidises CO and C_xH_y.

(i) Suggest why honeycomb structures are used in the catalytic converter.

.....

.....

..... [1]

(ii) State the type of catalysis and with reference to Fig. 6.2, explain the mode of action of the Pt/Rh catalyst.

.....

.....

.....

.....

.....

..... [3]

In two-way catalytic converters, NO_x is not eliminated and is released into the atmosphere. Nitrogen monoxide and nitrogen dioxide are two common NO_x present in these exhaust gas.

(c) In the lower atmosphere, nitrogen monoxide is responsible for the formation of ozone, O_3, in a series of chemical reactions shown below.

Step 1 :	$NO(g) + ½\ O_2(g) \rightarrow NO_2(g)$
Step 2 :	$NO_2(g) \rightarrow NO(g) + O(g)$
Step 3 :	$O_2(g) + O(g) \rightarrow O_3(g)$

(i) State the role of NO and NO_2 in the formation of ozone.

NO : .....

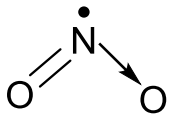
NO_2 : .....

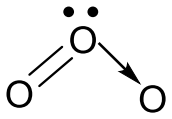
[1]

(ii) Write the overall equation for the formation of ozone due to nitrogen monoxide.

..... [1]

The structures of NO_2 and O_3 are given below.





(iii) State the bond angle in O_3.

bond angle: ..... [1]

(iv) Using Valence Shell Electron Pair Repulsion (VSEPR) Theory, suggest why the bond angle in NO_2 is larger than that of O_3.

.....

.....

..... [1]

(v) Suggest why the N-O bond in NO_2 is stronger than O-O bond in O_3.

.....

.....

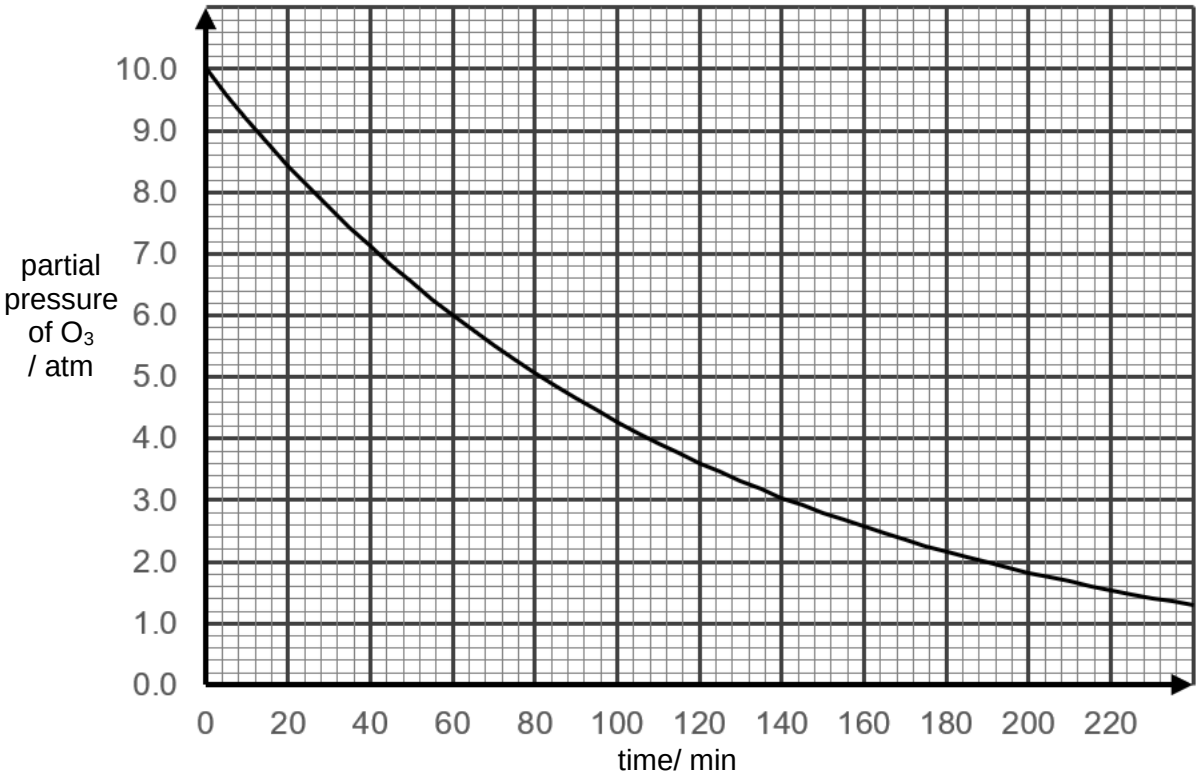
..... [1]

(d) Ozone formed in the lower atmosphere can react with ethene to produce methanal, which contributes to low-level smog. The equation is shown below.

$$O_3(g) + C_2H_4(g) \rightarrow 2CH_2O(g) + \tfrac{1}{2}O_2(g)$$

To determine the order of reaction with respect to the partial pressure of O_3, an investigation was carried out at constant temperature and with a large excess of ethene.

The graph of partial pressure of O_3 against time is obtained as shown.



Use evidence from your graph to show that the reaction is first order with respect to partial pressure of O_3.

[2]

(e) When nitrogen monoxide is present in the upper atmosphere, it is involved in the depletion of O_3. The overall equation for the reaction is shown below.

$$O_3(g) + O(g) \rightarrow 2O_2(g)$$

(i) Given that NO_2 is formed as an intermediate, deduce a possible two-step mechanism for this reaction.

first step:	
second step:	

[2]

The rate equation for the reaction is given below.

$$\text{rate} = k[NO][O_3]$$

(ii) Explain if your mechanism proposed in **(i)** is consistent with the rate equation, given that the first step of the mechanism is the slow step.

.....

.....

.....

..... [1]

(iii) Freon-11, $CFCl_3$ is a chloroflurocarbon which is also responsible for the depletion of O_3 in the upper atmosphere. The depletion occurs via a series of chain reaction.

Fig. 6.3 shows part of the chain reaction for the depletion of O_3. Use curly arrows to show the movement of electrons in step I and draw the structure of the missing product formed in step II.

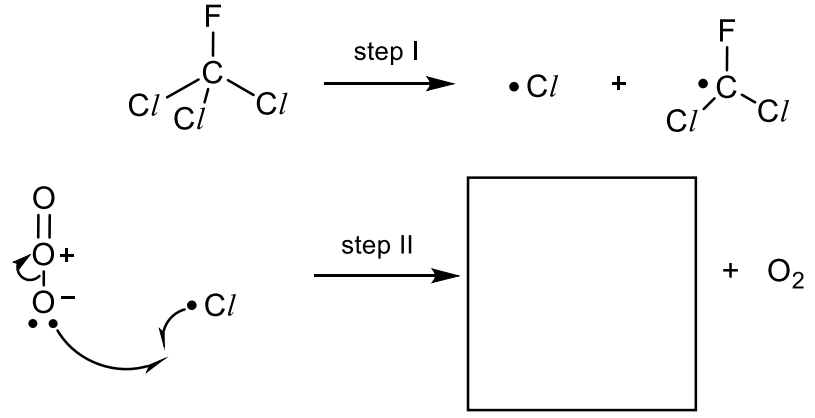


Fig. 6.3

[2]

[Total:20]

7 (a) A 1.00dm^3 gas cylinder is used to store 15.0g of methane gas (CH_4) at 25^{o}C. The gas cylinder is fitted with a safety valve that will rupture when there is a significant difference between the internal pressure and the atmospheric pressure. The gas cylinder is equipped with a burst disc capable of withstanding a pressure difference of 2500 kPa.

(i) Calculate the pressure exerted by CH_4 at 25^o C in kPa.

[2]

(ii) Assuming the atmospheric pressure is 101kPa, calculate the maximum internal pressure of the gas cylinder that can be safely stored.

[1]

(iii) Hence, determine the maximum temperature that this gas cylinder can be exposed to before the burst disc ruptures.

[1]

(b) Compound **E**, $C_{10}H_{12}O_2$, was heated for several hours with a slight excess of an aqueous solution of sodium hydroxide and the solution was partly distilled. The distillate contained a neutral aromatic compound **F**, $C_8H_{10}O$ which rotate plane polarised light and sodium ethanoate. Compound **F** reacts with acidified potassium dichromate(VI) with immediate distillation to give compound **G**, C_8H_8O. **G** gave a positive test when treated with 2,4-dinitrophenylhydrazine.

(i) State the type of reaction occurring compound **E** is heated for several hours with a slight excess of an aqueous solution of sodium hydroxide and hence the functional group present in compound **E**.

Type of reaction: **……**.

Functional group in compound **E**: **……**

[1]

(ii) State the type of reaction occurring when Compound **F** reacts with acidified potassium dichromate(VI) with immediate distillation to give compound **G**, and hence the functional group present in compound **G**.

Type of reaction **……**

Functional group in compound **G**: **……**

[2]

(iii) Draw the structures of compound **E**, **F** and **G**.

E	**F**	**G**

[3]

[Total: 10]

BLANK PAGE