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 and class 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.

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 xx printed pages and x 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 ionization energies of element **R**.

Table 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. [2]

Group: . . . . . .

Electronic configuration: . . . . . .

Group 16
R: **ns^{2}np^6**

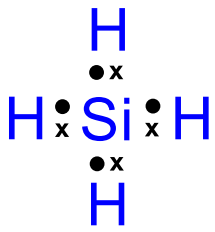
Largest energy difference: 14900 – 7880 = 7110 kJ mol^{-1}
Based on the I.E data, the **largest difference in energy is between the 6th and the 7th I.E**. This means that the 7th electron to be removed is found in the inner shell, and thus element **R** has **6 valence electrons**

(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]



Tetrahedral

(ii) Deduce the polarity in silane, giving a reason for your answer. [1]

Silane is non-polar, as the dipole moments caused by all Si – H bonds in a tetrahedral arrangement cancel each other out, resulting in net zero dipole moment.
OR

SiH_4 has a symmetrical tetrahedral shape. The dipole moments of the polar Si – H bonds cancel each other out, resulting in a non-polar molecule.

(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]

For aluminium:
$AlCl_3$ (s) + 6 H_2O (*l*) → $[Al(H_2O)_6]^{3+}$ (aq) + Cl^-(aq)
$[Al(H_2O)_6]^{3+}$ (aq) + H_2O (*l*) ⇌ $[Al(H_2O)_5(OH^-)]^{2+}$(aq) + H_3O^+(aq)

$AlCl_3$ reacts with water to form hydrated ions. Since Al^{3+} ions have a high charge density, it has a high polarizing power to polarize the electron cloud from the (datively bonded water molecules), weakening the O – H bond, producing H_3O^+ ions in water, thereby forming an acidic solution of around pH 3.

For $SiCl_4$ and PCl_3,

$SiCl_4$ (*l*) + $4H_2O$(*l*) → $SiO_2.2H_2O$(s) + 4HCl (aq) or
$SiCl_4$ (*l*) + $2H_2O$(*l*) → SiO_2 (s) + 4HCl (aq)

PCl_3 (s) + $4H_2O(l)$ → H_3PO_4(aq) + 5HCl(aq)

Both chlorides hydrolyse completely in water due to (energetically accessible vacant 3d orbitals) which can accommodate the lone pairs of electrons from water to form very acidic solutions of around pH 2.

[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]

Inverse relationship. The larger the pK_b, the weaker the base.

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

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..... [4]

Diethylamine, with a pK_b value of 2.9, has the lowest pK_b among the three compounds. This is due to the presence of two electron donating ethyl groups (-CH_2CH_3) attached to the nitrogen atom which increase the electron density on the nitrogen atom. Hence the lone pair of electron on nitrogen atom is more available to accept a proton.

Ethylamine, with a pK_b value of 3.3, has a slightly higher pK_b compared to diethylamine. In ethylamine, there is only one ethyl group attached to the nitrogen atom, which leads to lower electron density on the nitrogen compared to diethylamine. As a result, lone pair of electron on nitrogen atom is less available to accept a proton compared to diethylamine.

Phenylamine has the highest pK_b value of 9.4, the lone pair of electrons on the nitrogen atoms is delocalised into the benzene ring. Hence lone pair of electron on nitrogen atom is least available to accept a proton.

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

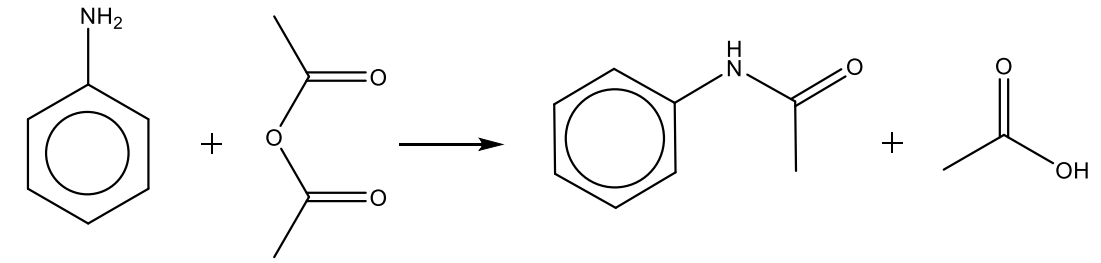
The reaction is performed in two stages

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]

Amount of phenylamine = phenylammonium chloride = 1.5 / 129.5 = 0.01158 mol

Theoretical yield of N-phenylethanmide= amount of N-phenylethanmide x molar mass

= 0.01158 x 135.0 = 1.563 g

Percentage yield = 1.12 /1.563 x 100% = 71.6 %

.....

(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]

$C_6H_5NH_3Cl + NaOH \longrightarrow C_6H_5NH_2 + H_2O + NaCl$

(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]

If the stages are done without purifying the products of stage 1:
Student B is correct, NaOH is a strong base which can undergo hydrolysis with the product N-phenylethamide and yield obtained will be affected.

OR
If the stages are done with purification of the products of stage 1 to obtain phenylamine:

Student B is incorrect, NaOH is used in excess. Hence, the phenylamine formed is unchanged and yield obtained will not be affected.

[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.

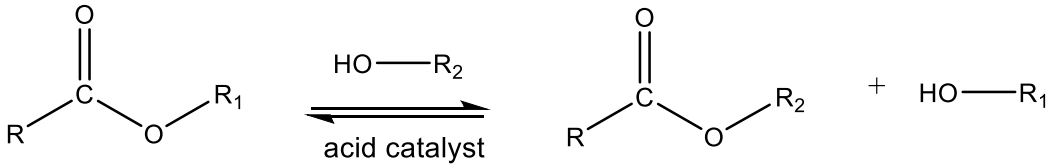


Fig. 3.1

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.

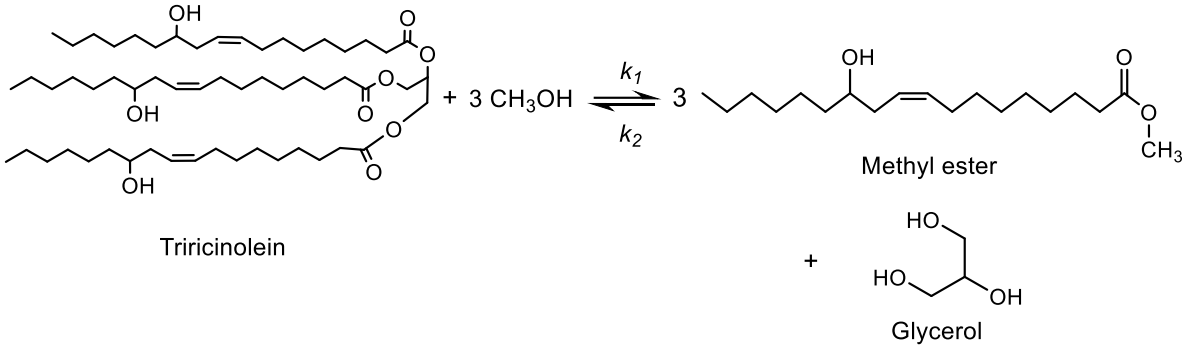


Fig. 3.2

(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]

At dynamic equilibrium, it refers to the forward and backward reactions are occurring at the same rate, where $k_1 [Triricinolein][CH_3OH]^3 = k_2[Methyl\ ester][Glycerol]^3$.

(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]

Rate of forward reaction = k_1 [triricinolein] $[CH_3OH]^3$
Rate of backward reaction = k_2 [methyl ester]^3 [glycerol]

At dynamic equilibrium, rate of forward reaction = rate of backward reaction.
Hence,
Since $K_c = \frac{[\text{methyl ester}]^3\ [\text{glycerol}]}{[\text{triricinolein}][CH_3OH]^3}$,
and k_1 [triricinolein] $[CH_3OH]^3 = k_2$ [methyl ester]^3 [glycerol]
k_1 [triricinolein] $[CH_3OH]^3 = k_2$ [methyl ester]^3 [glycerol]

$\frac{k_1}{k_2} = \frac{[\text{methyl ester}]^3\ [\text{glycerol}]}{[\text{triricinolein}][CH_3OH]^3} = K_C$ (proven)

(ii) 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]

Temperature/K	K_c
308.15	0.00890
318.15	0.0325
328.15	0.111
338.15	0.128

From calculations, K_c increases when temperature increases.
By Le Chatelier's Principle, this shows that the forward reaction is favoured as more products are formed to counteract the increase in heat energy [√] in the system.
Thus, the forward reaction which is transesterification is endothermic.

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

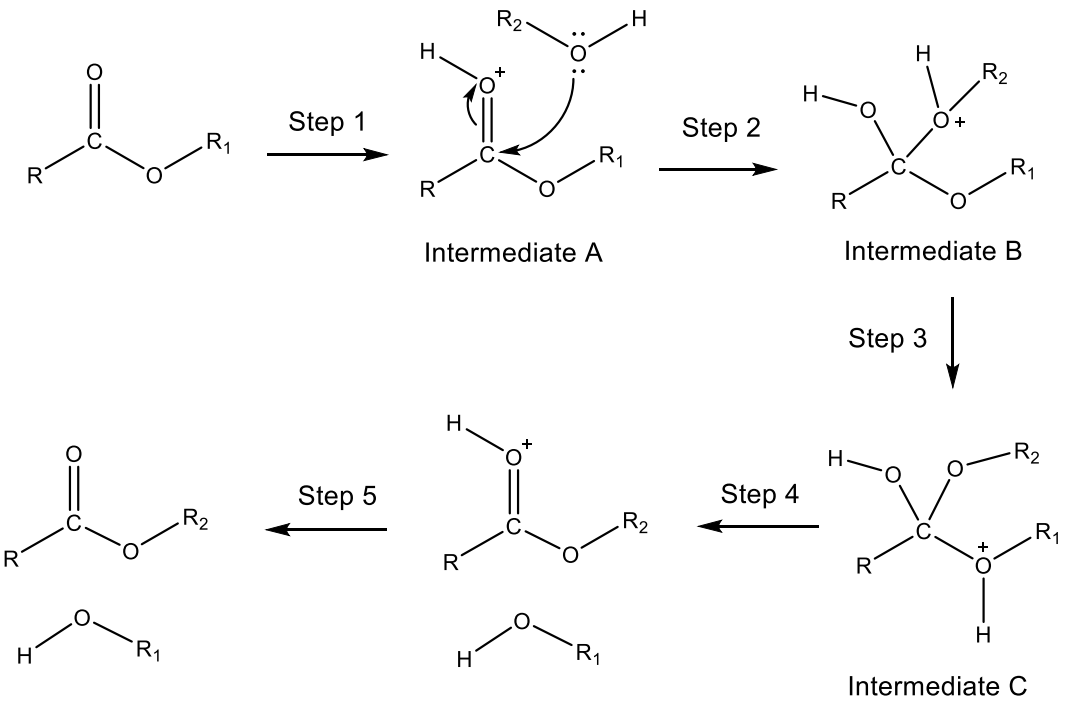


Fig. 3.4

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

Step 1: _____

Step 2: _____

1. Acid-base reaction
2. Nucleophilic addition

(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]

_____

It acts as a Brønsted–Lowry acid/ proton donor.

Explain why this step is significant. [1]

_____

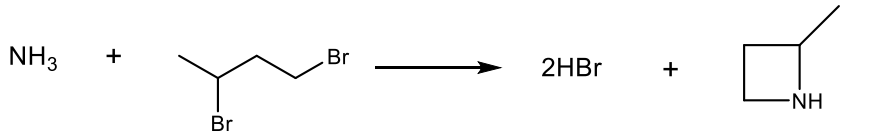
The alkoxide (R_2O^-) carries a negative charge and is more nucleophilic. Hence, the partial positive carbon on the reactant ester is more susceptible to the nucleophilic attack from the alkoxide ion.

[Total: 8]

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

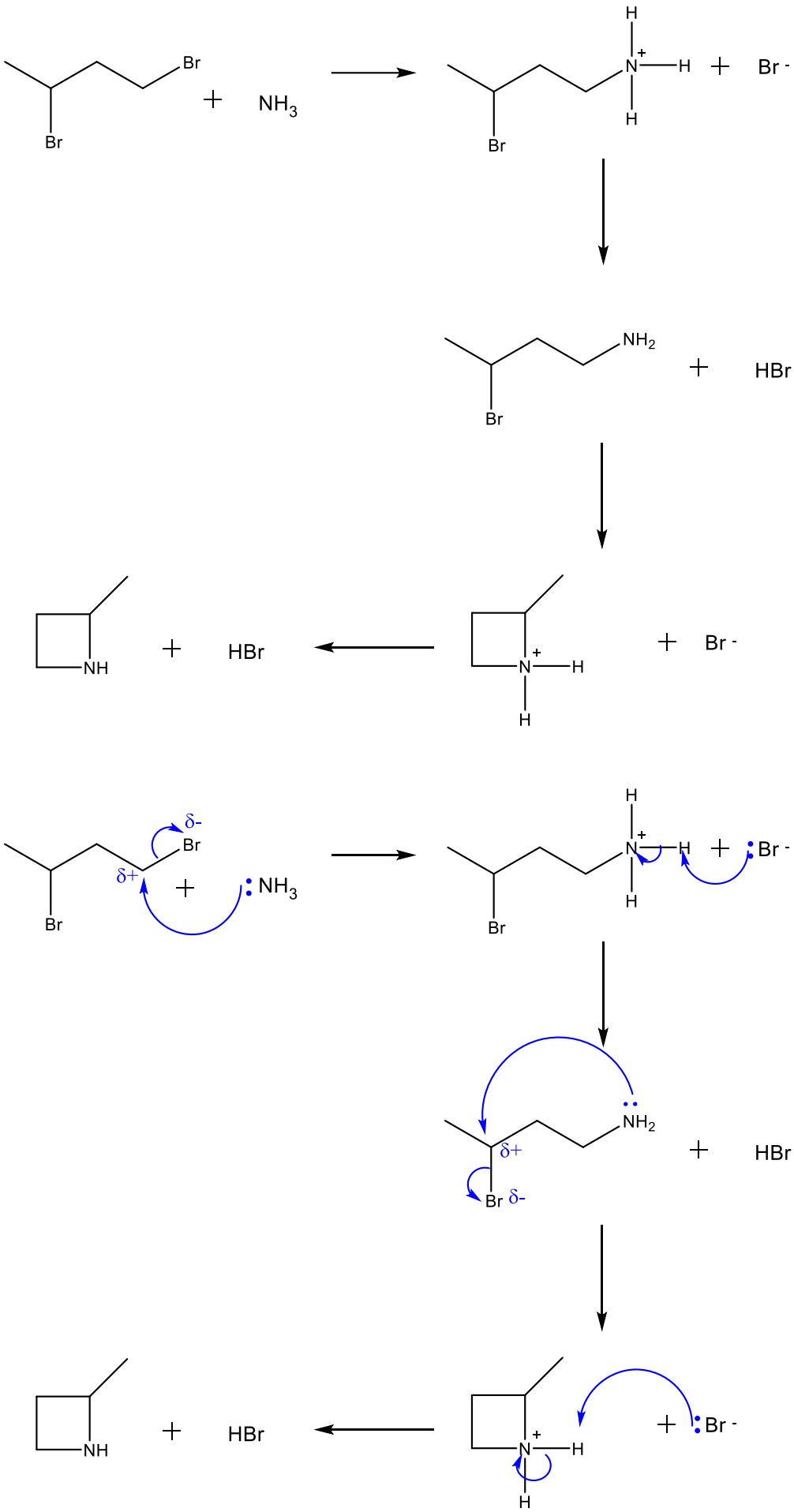
(i) Suggest the type of reaction occurring in the reaction above

……[1]
Nucleophilic Substitution

(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]


Br
Br
NH3
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Br -
Br
NH2
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Br
NH
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Br -

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

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……

……[2]

Heat with NaOH(aq), cool, and add excess dilute HNO_3 followed by $AgNO_3$(aq). 1,3-dibromobutane will produce a cream precipitate whereas 2-methylazetidine will not produce any precipitate.

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

[2]

Bonds broken		Bonds formed	
N-H X 2	390 X 2	H-Br X 2	366 X 2
C-Br X 2	280 X 2	C-N X 2	305 X 2
	Total: 1340		Total: 1952

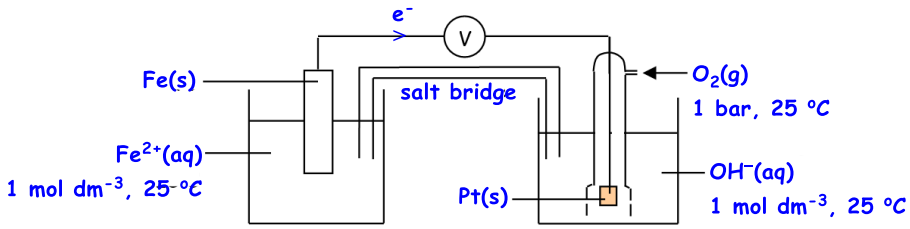
$\Delta H = 1340 - 1342 = -2$ kJ mol^{-1}

[Total: 8 marks]

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, state the direction of electron flow. [2]



(ii) Calculate the cell potential of the overall reaction. [1]

E^{θ}_{cell} = +0.40 – (-0.44) = +0.84 V

Give zero if the sign is omitted.

(iii) Write an equation, including state symbols, for the overall cell reaction. [1]

……

$2Fe(s) + O_2(g) + 2H_2O(l) \rightarrow 2Fe^{2+}(aq) + 4OH^-(aq)$

(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]

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……

……[3]

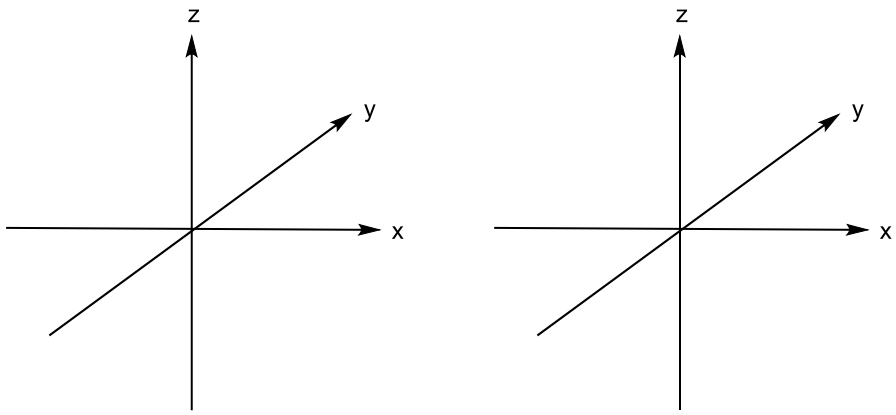
The iron ion has partially filled 3d orbitals and in the presence of ligands, they are split into two groups with small energy gap

A wavelength of light energy from the visible region is used to excite an electron from a 3d orbital of lower energy into the unfilled/ partially filled 3d orbital of higher energy. (d-d electron transitions).

Colour seen is complementary of the colours absorbed in the visible region of the spectrum.

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

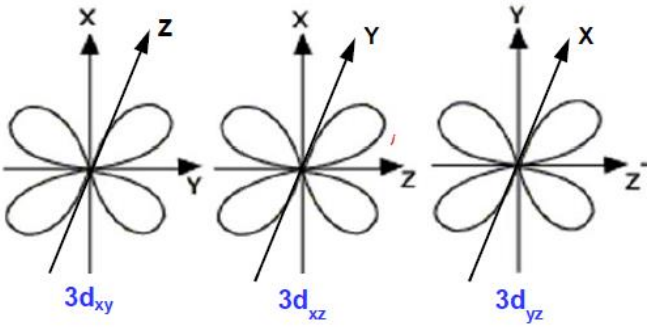
- One of the d-orbitals at the lower energy level in $[Fe(H_2O)_6]^{2+}$.
- One of the d-orbitals at the upper energy level in $[Fe(H_2O)_6]^{2+}$.



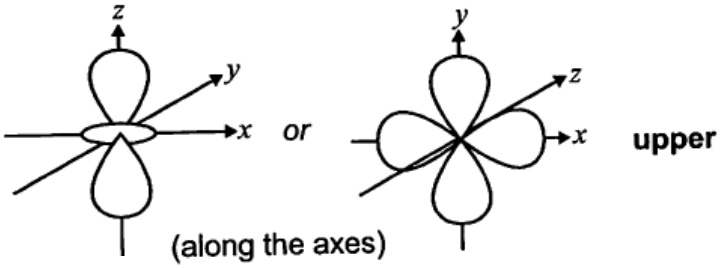
Lower Upper

[2]

Lower: any



Upper: either



$3dz^2$ $3dx^2 – y^2$

(c) *Use of the Data Booklet is relevant to this question.*

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

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

Using suitable equations, and by calculating relevant $E^\ominus_{cell}$ values, explain why Mn^{2+} is a suitable catalyst for this reaction. [2]

$S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-}$ $\quad E^\theta = +2.01\ V$

$Mn^{3+} + e^- \rightleftharpoons Mn^{2+}$ $\quad E^\theta = +1.54\ V$

(Catalysed reaction using Mn^{2+})

$2Mn^{2+} + S_2O_8^{2-} \rightarrow 2Mn^{3+} + 2SO_4^{2-}$

$E^\theta_{cell} = 2.01 - (1.54) = +0.47\ V$

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

$E^\theta_{cell} = 1.54 - 0.56 = +0.98\ V$

Alternative answer:

$S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-}$ $\quad E^\theta = +2.01\ V$

$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$ $\quad E^\theta = +1.52\ V$

$5S_2O_8^{2-} + 2Mn^{2+} + 8H_2O \rightarrow 10SO_4^{2-} + 2MnO_4^- + 16H^+$

$E^\theta_{cell} = 2.01 - (1.52) = +0.49\ V$

$6MnO_4^- + 18H^+ + 5[CH(OH)CO_2]_2^{2-} \rightarrow 6Mn^{2+} + 14H_2O + 10CO_2 + 10HCO_2^-$

$E^\theta_{cell} = 1.52 - 0.56 = +0.96\ V$

(ii) Explain why manganese can function as a homogenous catalyst in this reaction. [1]

……

……

……

……[1]

Manganese can exhibit a variety of oxidation states due to the similar energy of the 3d and 4s orbitals and hence both 3d and 4s electrons are able to be shared or lost or be used in bond formation.

[Total: 12 marks]

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

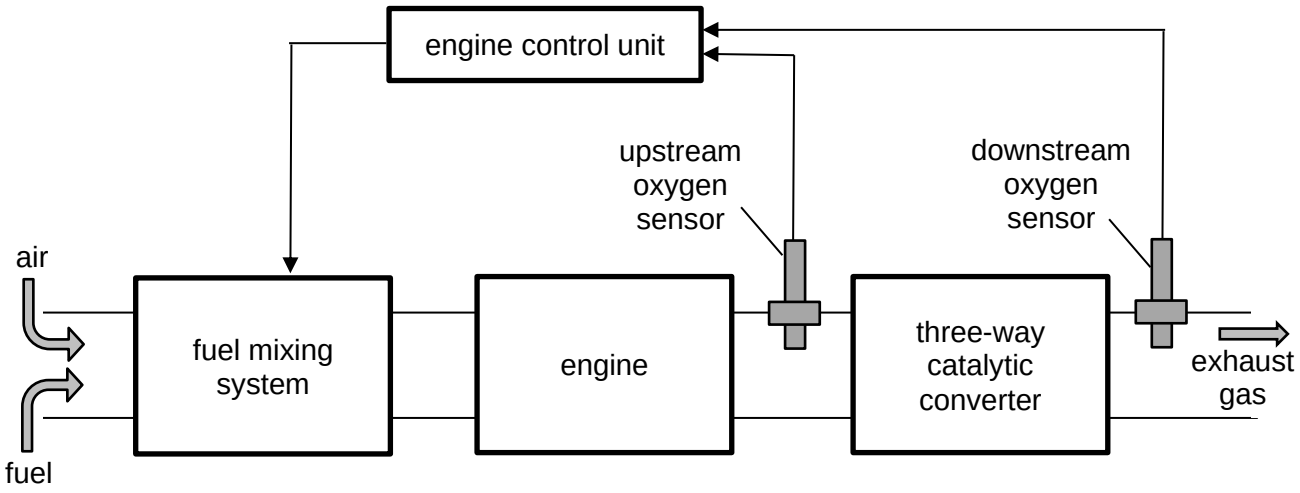


Fig. 6.1

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]

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

(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.

Mass of air = $\frac{100}{23.2}$ x 160 = 689.66g

AFR, x = $\frac{689.66}{44}$ = 15.7

[2]

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

To detect the amount of oxygen after combustion in the engine so as to regulate the air-fuel ratio (AFR) for optimum power generation.

.....

..... [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.

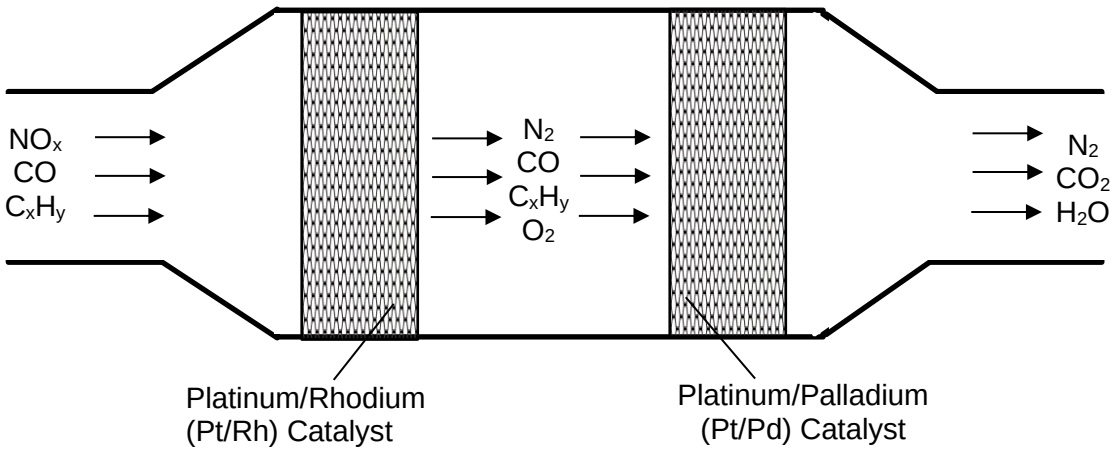


Fig. 6.2

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.

To increase surface area to volume ratio for reaction so as to speed up the rate of reaction

[1]

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

Heterogeneous catalysis

- NO_x become adsorbed onto the active sites of the catalyst surface by means of attractive forces.
    - This increases the surface concentration of NO_x
    - This weakens the N-O covalent bonds in the molecules resulting in lower activation energy than the uncatalysed reaction
- Adjacent reactant molecules react to form N_2 and O_2.
- Once formed, N_2 and O_2 molecules can easily desorb from the Fe surface so that the active sites are exposed for further reaction and the vacant active sites are now available for adsorbing other NO_x molecules.

[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 : catalyst

NO_2 : intermediate

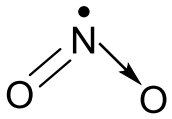
[1]

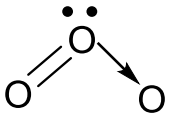
(ii) Write the overall equation for the formation of ozone due to nitrogen monoxide.

$\frac{1}{2} O_2(g) + O_2(g) \rightarrow O_3(g)$

..... [1]

The structures of NO_2 and O_3 are given below.





(iii) State the bond angle in O_3.

bond angle: 117º (accept 110 – 119) ..... [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.

The lone pair-bond pair repulsion in O_3 is greater than the lone electron-bond pair repulsion in NO_2. Hence, bond angle in NO_2 is compressed to a smaller extent, giving rise to a larger bond angle.

OR

The lone electron-bond pair repulsion in NO_2 is weaker than its bond pair-bond pair repulsion. Hence, the bond angle in NO_2 is larger.

.....

.....

..... [1]

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

The N-O bond in NO_2 is polar, giving rise to a stronger N-O bond.

.....

.....

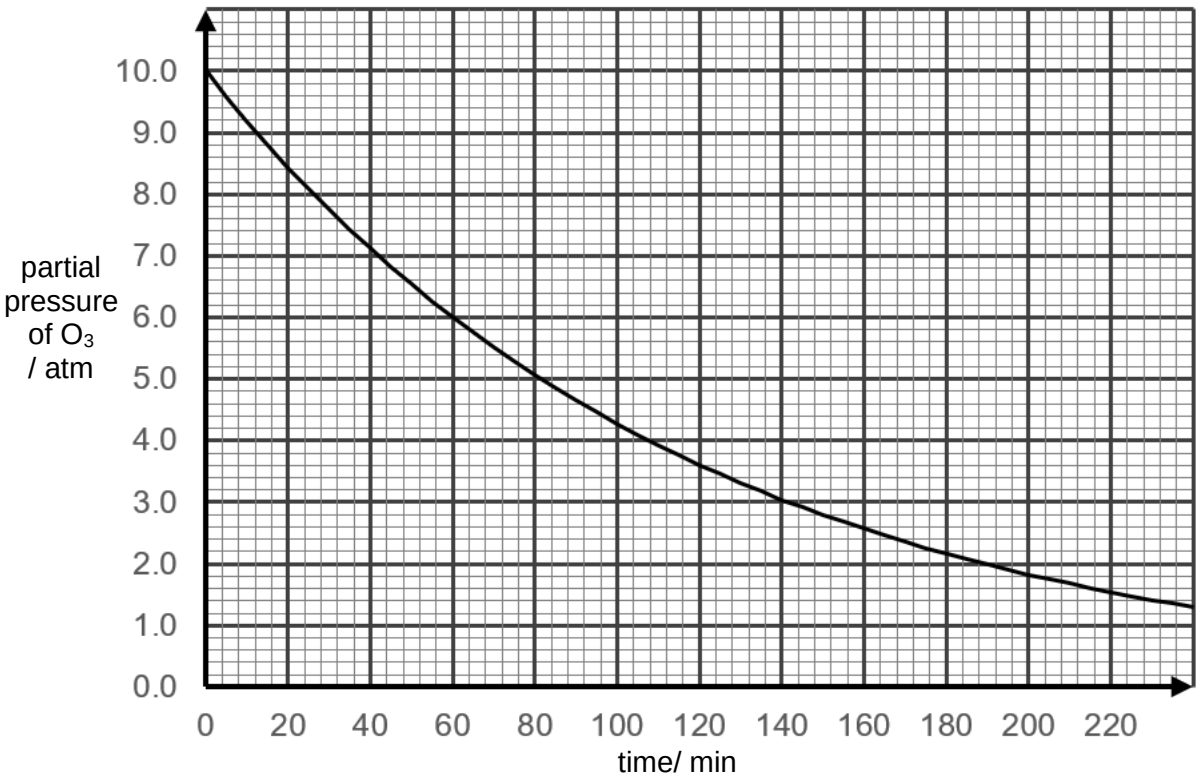
..... [1]

(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.

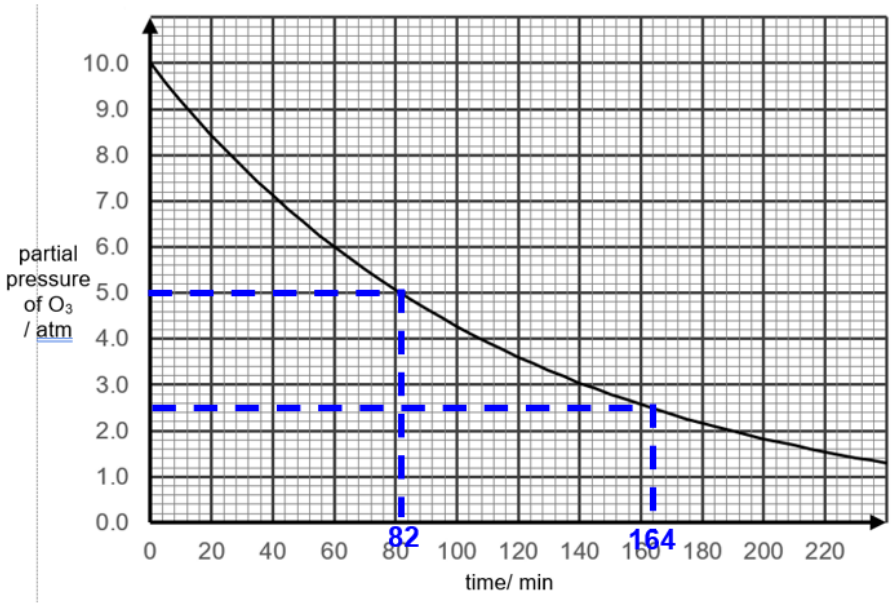
$$O_3(g) + C_2H_4(g) \rightarrow 2CH_2O(g) + \frac{1}{2} O_2(g)$$

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]



Since first $t_{½}$ = second $t_{½}$ = 82min

Since $t_{½}$ is constant, reaction is first order with respect to partial pressure of O_3.

(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:	$NO + O_3 \rightarrow NO_2 + O_2$
second step:	$NO_2 + O \rightarrow NO + O_2$

[2]

OR
First step: $NO + O \rightarrow NO_2$
Second step: $NO_2 + O_3 \rightarrow NO + 2O_2$

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.
Yes. The first step consists of one NO and one O_3 reacting. Hence, it is consistent with the rate equation.

OR (if answer for (i) is alternative mechanism)

No, the rate equation would be rate = k [NO][O] or rate equation would include O or O_3 is not involved in the first 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.

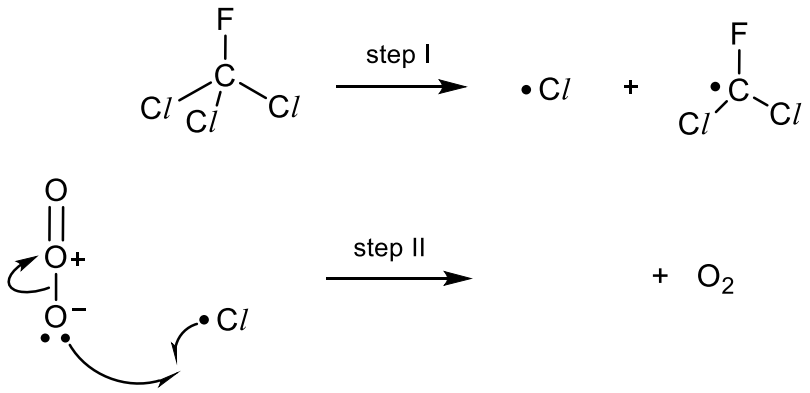
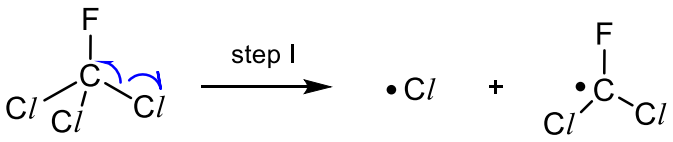
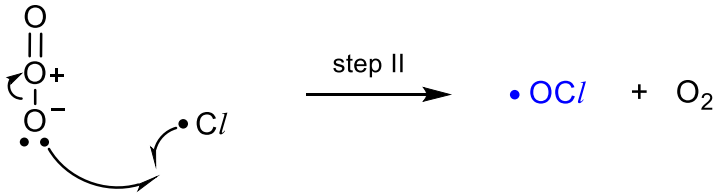


Fig. 6.3

[2]





[Total: 20]

7 **(a)** A 1.00dm^3 gas cylinder is used to store 15.0g of methane gas (CH_4) at 25ºC. 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 2500kPa.

(i) Calculate the pressure exerted by CH_4 at 25ºC in kPa. [2]

$$pV = \frac{m}{M_r}RT$$

$$p = \frac{nRT}{V}$$

$$= \frac{\frac{15.0}{16.0} \times 8.31 \times 298}{1.00 \times 10^{-3}}$$

$$= 2322 \text{ kPa} = 2320 \text{ kPa (3 sf)}$$

(ii) Assuming the atmospheric pressure is 101 kPa, calculate the maximum internal pressure of the gas cylinder that can be safely stored. [1]

pressure difference = internal pressure – atmospheric pressure
2500 = internal pressure – 101
Internal pressure: 2601 kPa = 2600 kPa (3 sf)

(iii) Hence, determine the maximum temperature that this gas cylinder can be exposed to before the burst disc ruptures. [1]

$$pV = nRT$$

$$T = \frac{pV}{nR}$$

$$= \frac{2601 \times 10^3 \times 1.00 \times 10^{-3}}{8.31 \times \frac{15.0}{16.0}}$$

$$= 334 \text{ K (3sf)}$$

(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**. [1]

Type of reaction:……...

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

(Alkaline) hydrolysis, E: ester.

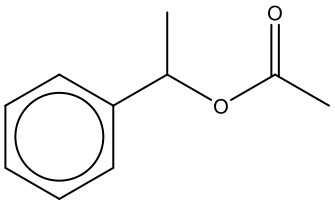
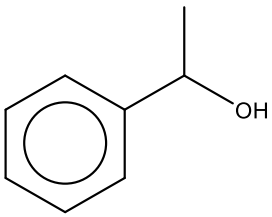
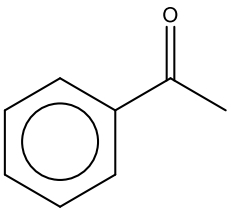
(ii) State the type of reaction occurring when Compound **F** reacts with acidified potassium dichromate(VI) with immediate distillation to give compound **G**, and hence the functional group present in compound **G**. [2]

Type of reaction:……...

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

1m each, oxidation, G: ketone.

(iii) Draw the structures of compound **E**, **F** and **G**. [3]

E	**F**	**G**
		

[Total: 10]