JJC Chemistry H1 P2 Answers

1. (a) (i) Amount of Cl_2 in 1 cylinder $= \frac{170000000}{71.0} / 5730$ = **4.18 x 10^2 mol** [1]

(ii) Conc. of Cl_2 in g dm^{-3} $= 1000 \times \frac{1\ mg}{dm^3} \times \frac{1\ g}{1000\ mg}$ = 1

Conc. of Cl_2 in mol dm^{-3} $= \frac{1}{71.0}$ = **0.0141 mol dm^{-3}** [1]

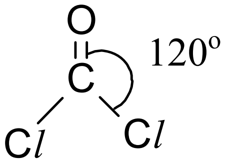
(a) (iii) Volume of factory room = $25\ m^3 \times \frac{1\ dm^3}{1 \times 10^{-3}\ m^3}$ = 25 000 dm^3 [2]

Conc. of Cl_2 in the factory $= \frac{4.18 \times 10^2}{25000}$

= **0.0167 mol dm^{-3}**

0.0167 mol dm^{-3} **> 0.0141 mol dm^{-3} / lethal conc**

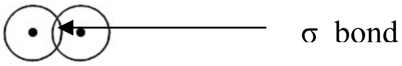
(b) (i) [1]



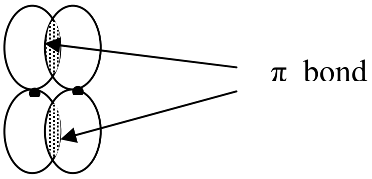
(ii) sp^2 [1]

(iii) Phosgene contains both *σ bonds* and *π bonds.* Explain the terms in italics, drawing diagrams to show these bonds clearly. State the number of *σ bonds* and *π bonds* in phosgene.

A sigma bond (σ bond) is formed by head-on overlap of orbitals.



A pi bond (π bond) is formed by side-way overlap of orbitals.



Phosgene has 3 σ bonds and 1 π bond.

(iv) Both phosgene and chlorine have **simple covalent / molecular structure**

Higher amount of energy is required to overcome the **stronger permanent dipole – permanent dipole attraction / van der Waals' forces of attraction/ intermolecular forces between phosgene molecules** than **weaker** in **induced dipole – induced dipole attraction / van der Waals' forces of attraction/ intermolecular**

forces between chlorine molecules.

OR

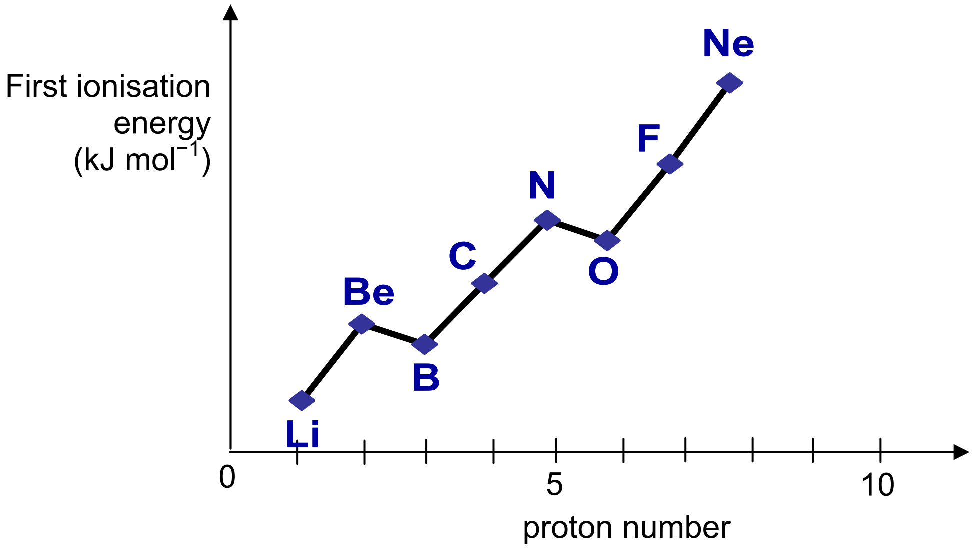
Phosgene has a **larger size of electron cloud / no. of electrons than chlorine**. Higher amount of energy is **stronger permanent dipole – permanent dipole attraction / van der Waals' forces of attraction/ intermolecular forces between phosgene molecules** than **weaker** in **induced dipole – induced dipole attraction / van der Waals' forces of attraction/ intermolecular forces between chlorine molecules**.

Thus **phosgene has a higher boiling point than chlorine**. [2]

[Total: 11]

2. **(a)** The 1st IE of an element E is the **energy required to remove one mole of electrons from one mole of gaseous E atoms.** [1]

(b)



[1]

(c) Explain the difference between the first ionisation energy of

(i) carbon and nitrogen

$_6$C: $1s^2\ 2s^2\ \mathbf{2p^2}$

$_7$N: $1s^2\ 2s^2\ \mathbf{2p^3}$

N has a smaller atomic radius than C and **N has a larger nuclear charge** than C while shielding effect by the inner shell electrons is relatively constant for both elements. Hence 1st IE of N is higher than that of C. [1]

(ii) nitrogen and oxygen

N: $1s^2\ 2s^2\ \mathbf{2p^3}$

O: $1s^2\ 2s^2\ \mathbf{2p^4}$

Mutual repulsion between the **paired 2p electrons in O** makes it easier to remove one of the paired electrons compared to removing the **unpaired 2p electron of P** which does not experience such repulsion. Hence 1st IE of O is lower than that of N. [1]

[Total: 4]

3. (a) (i) [1]

$$[\text{acetylsalicylic acid}] = \frac{\frac{20}{1000}\times 0.200}{\frac{25.0}{1000}} = \mathbf{0.160\ mol\ dm^{-3}}$$

(ii) $\mathbf{[H^+] = 10^{-2.8} = 1.58 \times 10^{-3}\ mol\ dm^{-3}}$

$\mathbf{[H^+] \ll}$ **or** $\mathbf{\neq}$ **[acetylsalicylic acid]**

OR

Degree of acid dissociation = $\frac{1.58\times 10^{-3}}{0.160}$ = $\mathbf{9.88 \times 10^{-3}}$

$\therefore$ acetylsalicylic acid is a *weak* acid as it only **dissociates/ionises partially** in water.

[2]

(iii) $K_a = \frac{[C_8H_7CO_2^-][H^+]}{[C_8H_7O_2CO_2H]}$ OR $K_a = \frac{[RCOO^-][H^+]}{[RCOOH]}$

$$= \frac{(1.58\times 10^{-3})^2}{0.160} = \mathbf{1.56 \times 10^{-5}\ mol\ dm^{-3}}$$

OR

$$= \frac{(1.58\times 10^{-3})^2}{0.160 - 1.58\times 10^{-3}} = \mathbf{1.59 \times 10^{-5}\ mol\ dm^{-3}}$$

[2]

3. (b) (i) K_a **increases increasing number of C*l* substituents**

Both **$CH_2ClCOOH$ and $CHCl_2COOH$** has **electron-withdrawing C*l*** atom which **disperse the negative charge on O** atom on the $RCOO^-$/ carboxylate anion, making **CH_2ClCOO^- and $CHCl_2COO^-$ more stable** than CH_3COO^-.

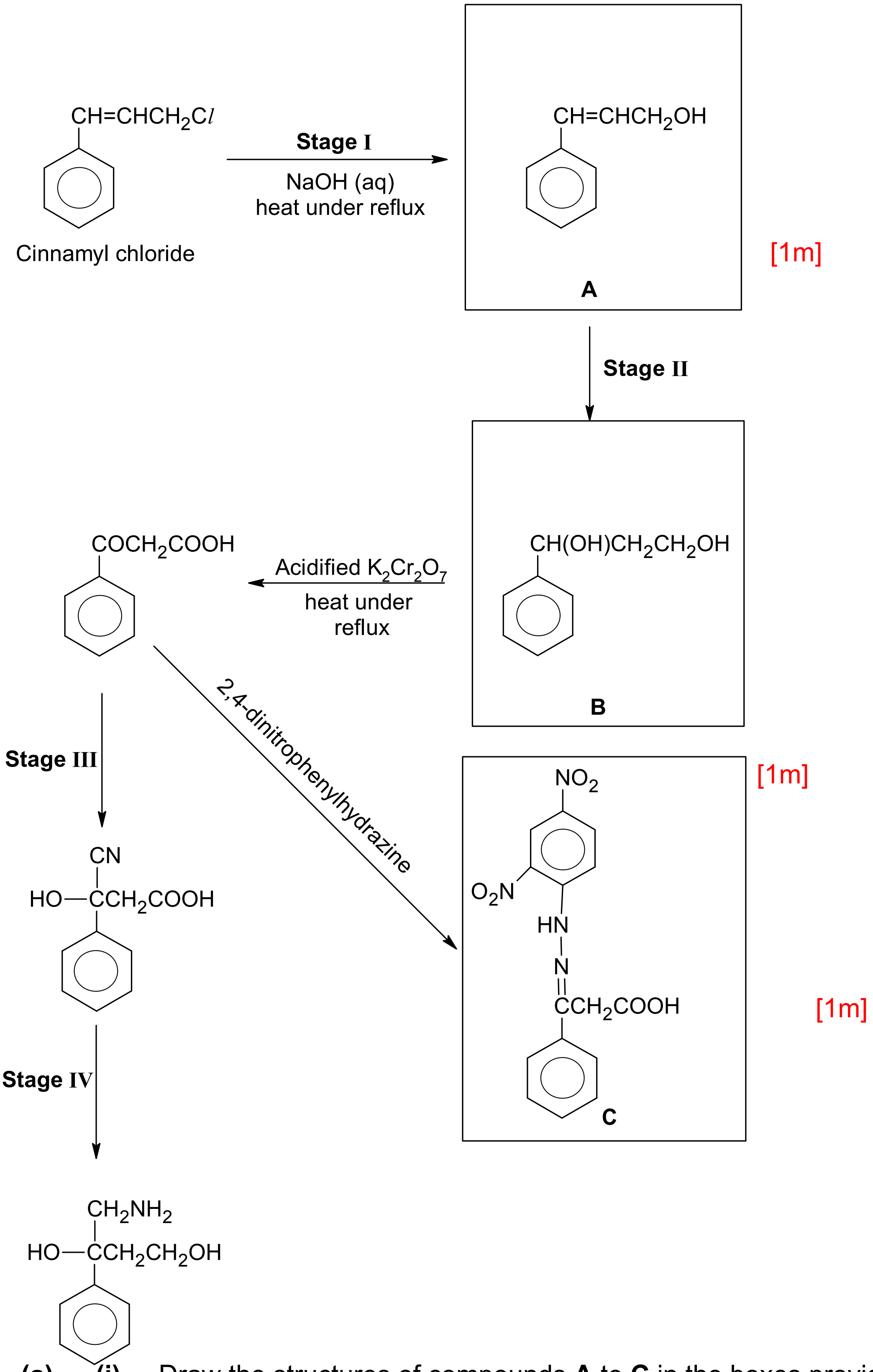
$CHCl_2COOH$ has **one more electron-withdrawing C*l*** atom than **$CH_2ClCOOH$**, **dispersing the negative charge on O** atom **to a larger extend / more**, making **$CHCl_2COO^-$ more stable** than **CH_2ClCOO** [2]

(ii) Benzoic acid is **more acidic** than ethanoic acid

The **negative charge on the COO^-** group of the benzoic acid **can be delocalised into the π** system of the **benzene ring / benzene ring**, **dispersing the negative charge on the COO^-** anion, making the **benzoate** anion **more stable** than CH_3COO^-. [2]

[Total: 9]

4.



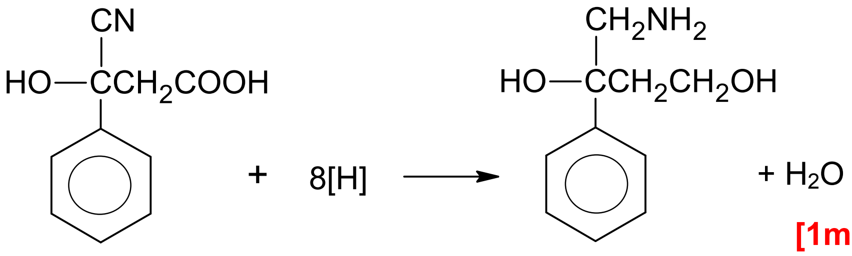
4. **(a)** **(i)** Draw the structures of compounds **A** to **C** in the boxes provided.

(ii) State the type of reaction and reagents and conditions required for **Stages II** to **IV.**

Stage	**Reagents and conditions**	**Type of Reaction**
II	**H_2O (g) / steam** **H_3PO_4 cat. , 300°C , 65 atm**	**Addition /Hydration**
III	**HCN,** **trace amt of NaCN/KCN/base**	**Addition**
IV	**$LiAlH_4$, dry ether**	**Reduction**

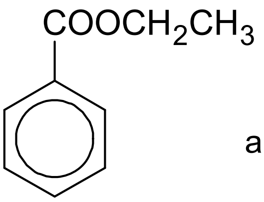
[1m] each [6]

(iii) Write a balanced equation for the reaction in **Stage IV**.



[1m] [10]

4. **(b)** **(i)**



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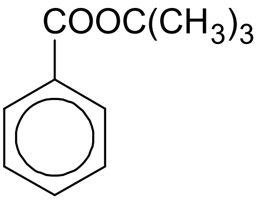
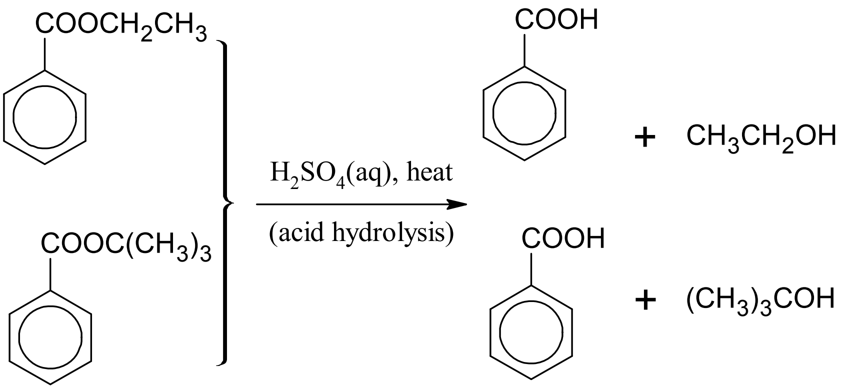


W **X**



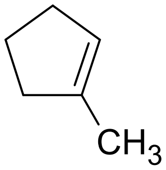
Cannot be oxidised

Test :
Add **<u>H_2SO_4(aq)</u>** to each of the samples and **<u>heat</u>**.

To the resulting hot mixture, add a few drops of **<u>acidified $KMnO_4$(aq) / $K_2Cr_2O_7$</u>** and heat.

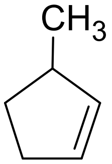
Observations: **<u>W</u>** will **<u>decolourise purple $KMnO_4$ / orange $K_2Cr_2O_7$ turns green</u>** but **<u>X will not</u>**. [3]

(ii)

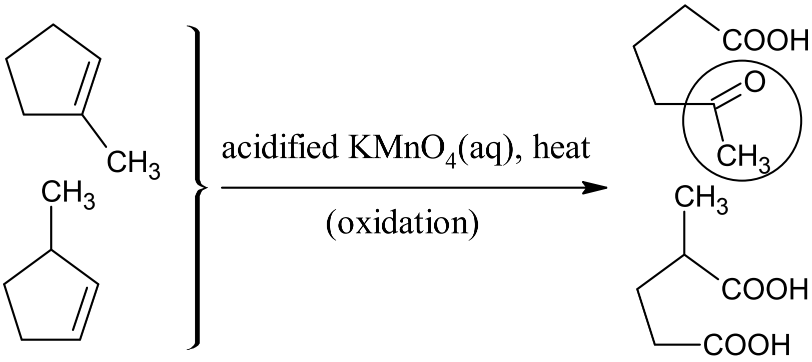


Y

and



Z



can undergo condensation reaction with 2,4-DNPH

Test:

Add **acidified $KMnO_4$(aq)** to each of the samples and **heat**.

To the resulting mixture, add **Brady's reagent /2,4-dinitrophenylhydrazine**.

Observations:

Y will **decolourise purple $KMnO_4$** and give an **orange ppt** with the Brady's reagent. **Z** will also **decolourise purple $KMnO_4$** but **will not form** an **orange ppt** with Brady's reagent.

[3]

[Total : 16]

SECTION B (40 MARKS)

Answer **two** of the **three** questions in this section on separate paper.

5. **(a)** **(i)** Standard enthalpy change of combustion of a substance is the **enthalpy change/ energy change** when **one mole of substance** is **completely burnt** in oxygen under **standard conditions**.

$$CH_3CH_3\,(g) + \frac{7}{2}\,O_2\,(g) \rightarrow 2CO_2\,(g) + 3\,H_2O\,(l)$$ [2]

(ii) Heat evolved = m c ΔT = 500 x 4.2 x 40

= **84000J** = **84 kJ**

$\Delta H_{c\ (ethane)} = -84 \,/\, \frac{2.5}{30.0} = \mathbf{-1008\ kJ\ mol^{-1}}$ [2]

(iii) Heat loss to the surroundings [1]

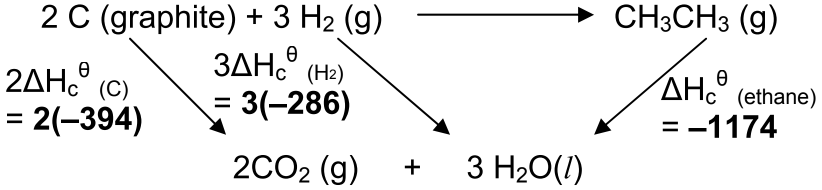
(b) **(i)** $\Delta H_c{}^{\theta}{}_{(\text{ethane})} = \sum BE(reactants) - \sum BE(products)$

$= \Sigma[BE(C\text{—}C) + 6BE(C\text{—}H) + \frac{7}{2}BE(O{=}O)] - \Sigma[4BE(C{=}O) + 6\,BE(O\text{—}H)]$

$= [(350 + 6(410) + \frac{7}{2}(496)] - [4(740)+6(460)]$

$= \underline{\mathbf{-1174\ kJ\ mol^{-1}}}$ [2]

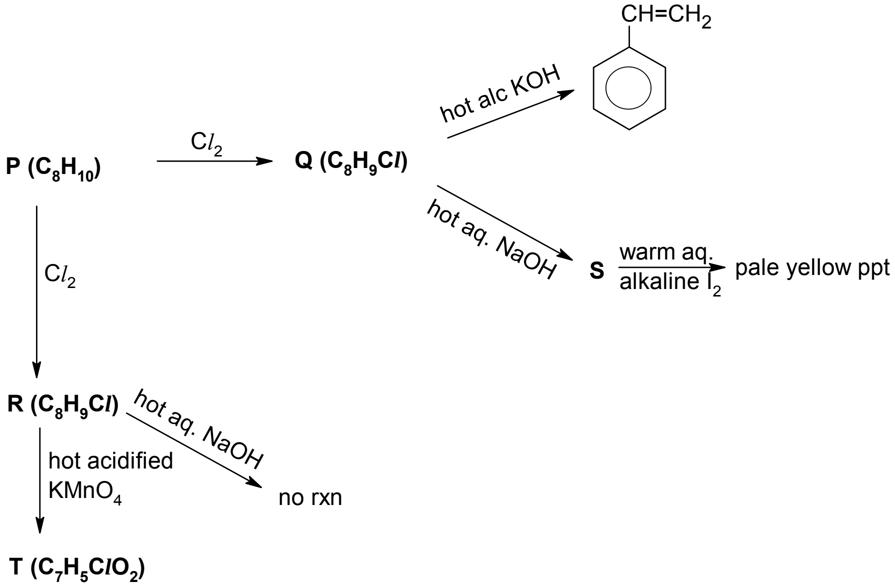
(ii)



$\Delta H_f{}^{\theta}{}_{(\text{ethane})} = 2(-394) + 3(-286) - (-1174)$

$= \underline{\mathbf{-472\ kJ\ mol^{-1}}}$ [2]

(c) **(i)** Deduce the identities of compounds **P** to **T**, explaining the chemistry of the reactions wherever possible.

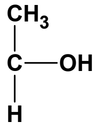


- M.F $\mathbf{C_8H_{10}}$: C/H ratio $\approx$ 1 → **P** has a **benzene ring**
- **Q** reacts with hot alcoholic KOH : **Elimination**

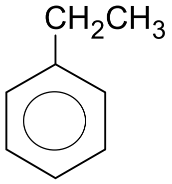
  Q contains **halogenoalkane/ alkylhalide** group
- **Q** reacts with hot aq. NaOH : **Substitution**

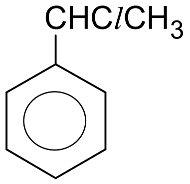
  Q contains **halogenoalkane/ alkylhalide** group

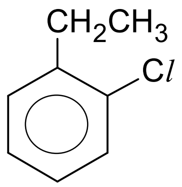
  S : contains **–OH group / hydroxyl** group
- **S** reacts with warm aq. I_2 : **oxidation / positive iodoform test / positive tri-iodomethane test**

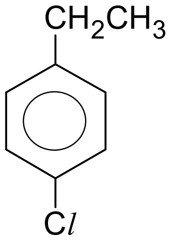
  Q contains  $\overset{CH_3}{|}\underset{|\atop H}{C}—OH$ structural unit
- **R** does not contains halogenoalkane/ alkylhalide group
- **R** with $KMnO_4$: **oxidation**

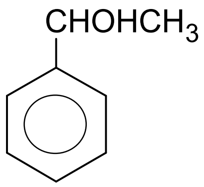
  R has an **carboxylic acid** group

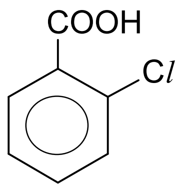
P : 

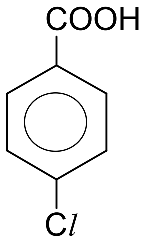
Q : 

R: 

OR 

S: 

T: 

OR 

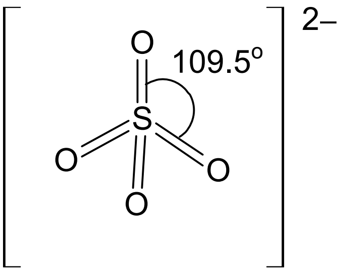
(ii) Suggest the conditions needed and state the type of reaction undergone to obtain **R** from **P**. [2]

Type of reaction : **Substitution**

Reagent and conditions: $\mathbf{Cl_2}$ **,** $\mathbf{FeCl_3}$ **/** $\mathbf{AlCl_3}$

[Total: 20]

6. (a)



[2]

(b) (i) $K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$ $mol^{-1}dm^3$ [1]

(ii) $2SO_2(g) + O_2(g) = 2SO_3(g)$

	$2SO_2(g)$	$O_2(g)$	$2SO_3(g)$
Initial amt/mol	2.0	1.0	-
	− 0.84	− 0.42	
Eqm amt/mol	**1.16**	**0.58**	0.84

$$K_c = \frac{(\frac{0.84}{2})^2}{(\frac{1.16}{2})^2(\frac{0.58}{2})} = \mathbf{1.81\ mol^{-1}dm^3}$$

[3]

(iii) When temperature increase, the **equilibrium** position will **shift** to the **left** /the system will **favour the backward reaction** [1m] **to favour endothermic reaction / so as to absorb some heat to reduce the temperature**. [1m]

When the pressure is increased, the **equilibrium** position will **shift to the right**/ the system will **favour the forward reaction** [1m] to **form/ favour less no. of gaseous molecules** [1m] so as to reduce the pressure.

(iv) When a catalyst is added, the **rate of the forward and the backward reaction will increase by the same extent.** [1m] Therefore, the **Kc value** and the **yield of the product would remain unchanged**. [1m]

[3]

(c) (i) (high melting points of Na_2O and Al_2O_3)

- **giant ionic** structure
- **strong electrostatic attraction/ionic bond**(ing) between **oppositely charged ions** in Na_2O and Al_2O_3 or between Na^+ ions and O^{2-} ions in Na_2O AND between Al^{3+} ions and O^{2-} ions in Al_2O_3

(low melting point of SO_2)

- **simple covalent/molecular** structure
- **weak intermolecular forces**
  OR
  weak van der Waals' forces/ weak permanent dipole-permanent dipole interactions between molecules

(Al_2O_3 has higher melting point than Na_2O)

- **<u>stronger</u> ionic bond**/electrostatic attraction
- **Al^{3+} has higher charge density/ higher (ionic) charge AND smaller size (or radius)**

(ii) (Na_2O)

- **reacts vigorously with water**
- solution with pH = **13/ 14**
- **$Na_2O + H_2O \rightarrow 2NaOH$**

(Al_2O_3)

- **does not dissolve/ insoluble in water** or does not react with water

(SO_2)

- **reacts with water**
- solution with **pH = 1/ 2 / 3**
- **$SO_2 + H_2O \rightarrow H_2SO_3$**

[3]

[Total: 20]

7. **(a)** Consider an experimentally determined rate equation, Rate = $k[A]^m[B]^n$. [2]

The order of reaction (or overall order of reaction) is the ***<u>sum of the orders of reaction</u> <u>with respect to /w.r.t the reactants</u>***.

For the above rate equation, overall order of reaction = m+n.

Half-life is the **<u>time taken</u>** for the **<u>concentration/ amount</u>** of the **<u>reactant</u>** to **<u>reduce to half of its original concentration/or amount</u>**.

(b) **(i)** **RBr** (aq) + **NaOH** (aq)→ **ROH** (aq) + **NaBr** (aq) **[1]**

(ii)

- From Expt 1 & 2, when **<u>$[OH^-]$ ↑ by 3/2</u>** times, **<u>rate ↑</u>** by approximately **<u>3/2</u>** times, i.e. **<u>Rate ∝ $[OH^-]^1$ / Rate is first order with respect to OH^-</u>**. **[1m]**
- From Expt 2 & 3, when **<u>[RBr] ↑ by 2</u>** times, **<u>rate ↑</u>** by **<u>2</u>** times, i.e. **<u>Rate ∝ $[RBr]^1$/ Rate is first order with respect to RBr.</u>** **[1m]**

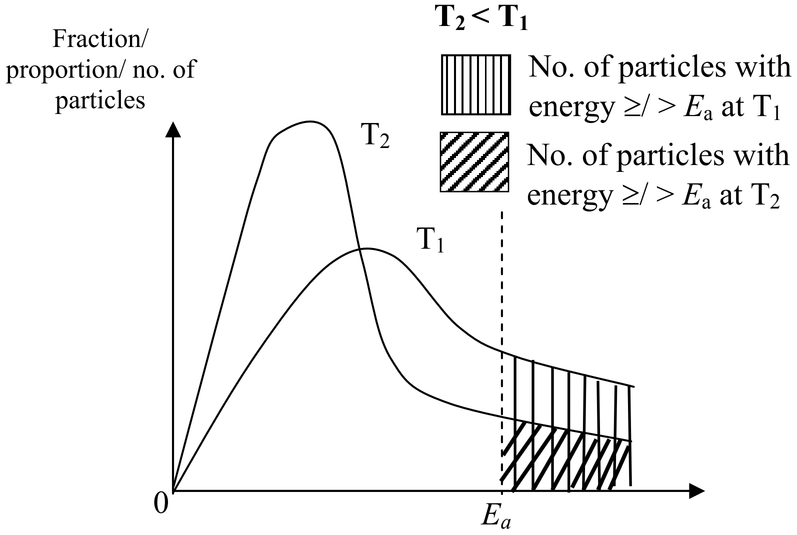
(iii) **<u>Rate = k [RBr] $[OH^-]$</u>**

Using Expt 1

k = Rate/(<u>[RBr] $[OH^-]$</u>)

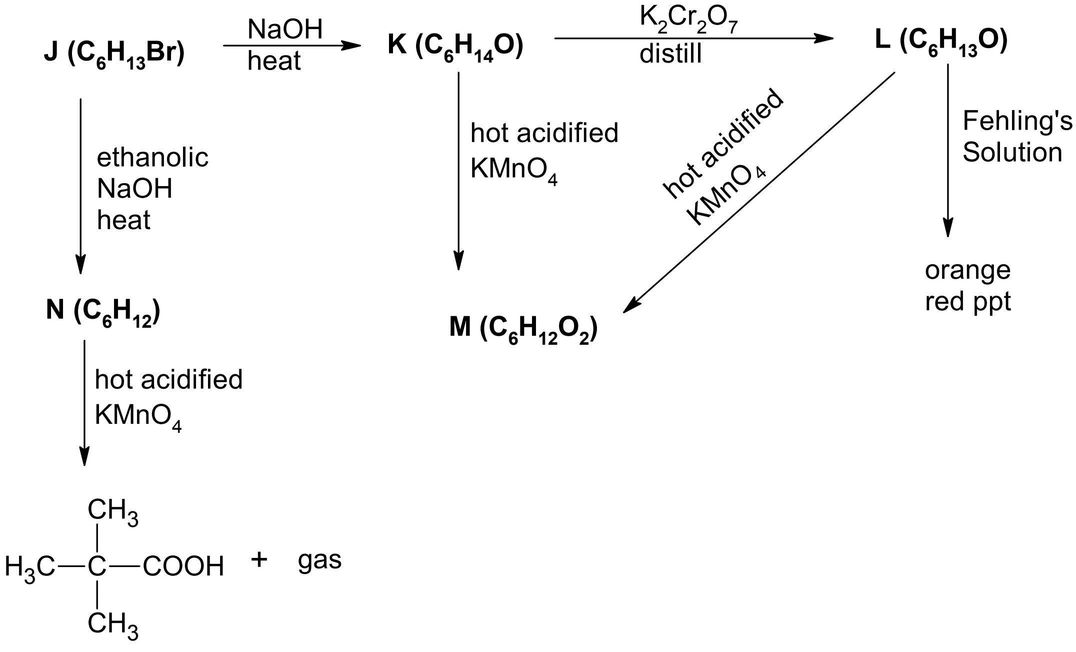
<u>= 6.16×10^{-5} / (0.0100 x 0.200) = 0.0308 $mol^{-1}dm^3s^{-1}$</u>

(iv) When **temperature decreases** from T_1 to T_2, the **number of molecules with energy greater than** or equal to **the activation energy / E_a decreases**.

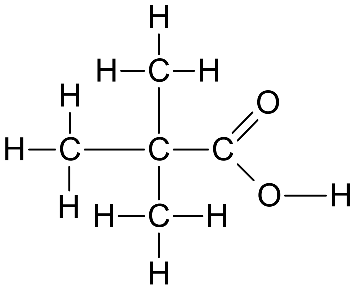


Hence **frequency of effective collisions** between molecules with energy greater than or equal to activation energy **decreases** and **rate** of hydrolysis reaction **decreases**.

(c)



Draw the displayed formula of 2,2-dimethylpropanoic acid.



[1m]

(ii) Deduce the identities of compounds **J** to **N**, explaining the chemistry of the reactions wherever possible.

- **J** reacts with hot aq. NaOH : **Substitution**

  J contains **halogenoalkane/ alkylhalide** group

  K : contains **–OH group / hydroxyl** group

- **K** reacts with $K_2Cr_2O_7$, distill : **oxidation**

  K has a **–primary alcohol** group

- **L** reacts with Fehling's solution : **oxidation**

  L contains aliphatic **aldehyde** group

- **K and L** reacts with hot acidified $KMnO_4$: **oxidation**

  M has an **carboxylic acid** group

- **J** reacts with hot alcoholic KOH : **Elimination**

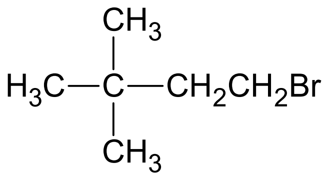
  J contains **halogenoalkane/ alkylhalide** group

  N contains **alkene/ C=C** group

- **N** with $KMnO_4$: **oxidation** with **cleavage of C=C**

- Colourless gas is **CO_2**

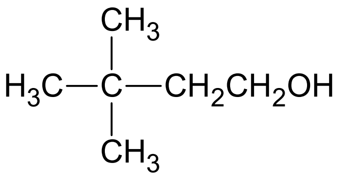
J :



$H_3C-\overset{CH_3}{\underset{CH_3}{C}}-CH_2CH_2Br$

[1m]

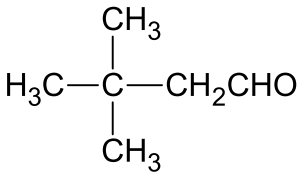
K :



$H_3C-\overset{CH_3}{\underset{CH_3}{C}}-CH_2CH_2OH$

[1m]

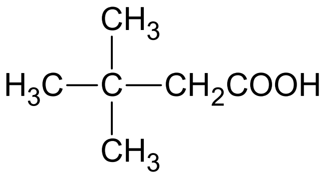
L:



$H_3C-\overset{CH_3}{\underset{CH_3}{C}}-CH_2CHO$

[1m]

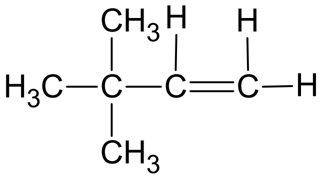
M:



$H_3C-\overset{CH_3}{\underset{CH_3}{C}}-CH_2COOH$

[1m]

N :



$H_3C-\overset{CH_3}{\underset{CH_3}{C}}-\overset{H}{C}=\overset{H}{C}-H$

[1m]