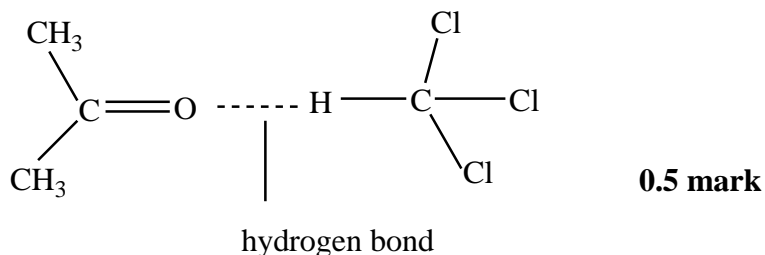**CHEMISTRY 2 MARKING SCHEME**

1. (a) i.   Due to greater intermolecular forces of attraction in the solution than the attraction between the pure liquids molecules. Hence, few molecules escape leading to low vapour pressure.   **(2 marks)**

ii.   In a solution containing acetone and chloroform, the two molecules form hydrogen bond between them as shown below: **(1 mark)**

0.5 mark

hydrogen bond

This hydrogen bonding lowers the escaping tendency of both the molecules, and as a result, the vapour pressure of the solution is less than that expected from Raoult's law.

(0.5 mark)

iii.   In pure ethanol, the molecules are bonded by hydrogen bonds. In pure cyclohexane, the molecular interactions are very weak. When cyclohexane is added into ethanol, the cyclohexane molecules get in between the molecules of ethanol, i.e, cyclohexane breaks the hydrogen bonds between ethanol molecules. This reduces the ethanol-ethanol intermolecular attractions considerably. As a result, the vapour pressure of such solutions show positive deviations.   **(2 marks)**

(b) Data;

$P^0_{ethanol}$ = 44.5 mmHg

$P^0_{methanol}$ = 88.7 mmHg

Mass of ethanol = 60 g

Mass of methanol = 40 g

Molar mass of ethanol (C_2H_5OH) = (12×2+1×6+16) = 46 g/mol

Molar mass of methanol (CH_3OH) = (12+1×4+16) = 32 g/mol

i.   Required total vapour pressure of the solution, $P_{solution}$ = ?

From $number\ of\ moles\ of\ ethanol = \dfrac{mass\ of\ ethanol}{molar\ mass\ of\ ethanol} = \dfrac{60g}{46\frac{g}{mol}}$

$= 1.3043\ mol$ **(0.5 mark)**

$number\ of\ moles\ of\ methanol = \dfrac{mass\ of\ methanol}{molar\ mass\ of\ methanol}$

$= \dfrac{40g}{32\frac{g}{mol}}$

$$= 1.25 \, mol \qquad \textbf{(0.5 mark)}$$

So, $Mole \; fraction \; of \; ethanol, X_{ethanol} = \dfrac{n \; of \; ethanol}{n \; of \; ethanol + n \; of \; methanol}$ **(0.5 mark)**

$$X_{ethanol} = \frac{1.3043 \, mol}{(1.3043 + 1.25)mol} = 0.5106$$

$$Mole \; fraction \; of \; methanol, X_{methanol} = 1 - X_{ethanol}$$

$$= 1 - 0.5106 \quad = 0.4894 \qquad \textbf{(0.5 mark)}$$

The partial pressures are given by;

$P_{ethanol} = X_{ethanol} \times P^0_{ethanol} = 0.5106 \times 44.5 \, mmHg = 22.72 \, mmHg$

$P_{methanol} = X_{methanol} \times P^0_{methanol} = 0.4894 \times 88.7 \, mmHg = 43.41 \, mmHg$

(1 mark)

So,

total vapour pressure of the solution, $P_{solution} = P_{ethanol} + P_{methanol}$ **(0.5 mark)**

$$= 22.72 mmHg + 43.41 mmHg$$

$$= 66.13 \; mmHg$$

Therefore, the total vapour pressure of the solution = 66.13 mmHg **(0.5 mark)**

ii. $mole \; fraction \; of \; methanol \; in \; vapour, C_{methanol} = \dfrac{P(methanol)}{P(solution)}$ **(1 mark)**

$$= \frac{43.41 mmHg}{66.13 \; mmHg} \quad \textbf{(0.5 mark)}$$

$$= 0.6564 \text{ or } 65.64\%$$

Therefore the $mole \; fraction \; of \; methanol \; in \; vapour = 0.6564$ or 65.64%

(0.5 mark)

(c)   Data given;

Total vapour pressure = 760 mmHg

Vapour pressure of water, $P_{water} = 733$ mmHg

Molecular mass of nitrobenzene, $M_{nitrobenzene} = 123$ g/mol

Molecular mass of water, $m_{water} = 18$ g/mol

Mass of nitrobenzene, $m_{nitrobenzene} = ?$

Mass of water, $M_{water} = ?$

From, Dalton's law:

Total vapour pressure = Vapour pressure of water + Vapour pressure of nitrobenzene

Vapour pressure of nitrobenzene, $P_{nitrobenzene}$ = Total vapour pressure - Vapour pressure of nitrobenzene

= (760-733) mmHg = 27 mmHg   **(1 mark)**

From;

$$\frac{m_{nitrobenzene}}{m_{water}} = \frac{P_{nitrobenzene} \times M_{nitrobenzene}}{P_{water} \times M_{water}}$$ **(1 mark)**

$$= \frac{27mmHg \times 123g/mol}{733mmHg \times 18g/mol}$$ **(1 mark)**

$$= 0.2517 \approx 0.25 = 1/4$$

Therefore, the proportion of water and nitrobenzene in distillate is 4:1   **(1 mark)**

(d) i. Because greater amount of the will be extracted (removed) for multiple extraction unlike single step extraction which extracts less amount of the solute   **(1 mark)**

ii. The principle of solvent extraction.

Solvent extraction is the method of removing (extracting) a solute from a certain solvent by introducing the second solvent (extractive solvent) which is immiscible to the first one and then allowing the solute to distribute itself in the two solvents. **(1 mark)** The layer of extractive solvent is then removed with significant amount of the solute, **(1 mark)** and on successive extractions which are done by introducing a fresh extractive solvent again and again, the solute is finally completely removed from the first solvent or very small amount will remain in the first solvent. **(1 mark)**

2. (a) i. Corrosion of a metal is the wearing (or deterioration) of the metal by an electrochemical process occurring on its surface. Example rust on iron and tarnish on silver   **(1 mark)**

ii. Corrosion of iron is a redox reaction which takes place on the surface of the metal whereby one region of the same metal (Iron) acts as the cathode and the other as the anode. **(0.5 mark)**

In the presence of air and moisture, iron serves as the anode and therefore undergoes oxidation to iron (II).   **(0.5 mark)**

$Fe(s) \rightarrow Fe^{2+}(aq) + 2\bar{e}$ **(1 mark)**
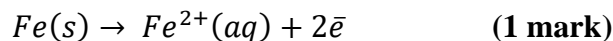
The electrons that are released move through the iron and reduce atmospheric oxygen at the cathode, which is another region of the same metal surface.

$O_2(g) + 2H_2O(l) + 4\bar{e} \rightarrow 4OH^-(aq)$ **(1 mark)**
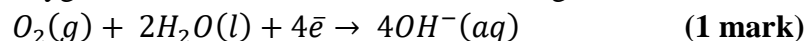
The overall process is represented by the overall redox reaction:

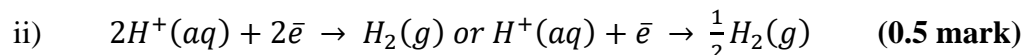$Fe(s) + O_2(g) + (4 + 2x)H_2O(l) \rightarrow 2Fe_2O_3.xH_2O\ (s) + 8H^+(aq)$
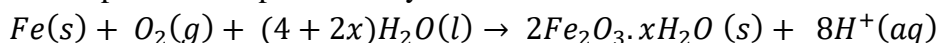
The hydrated form of iron (III) oxide ($2Fe_2O_3.xH_2O\ (s)$) is what is known as rust.   **(1 mark)**

(b)   Half-cell reactions will be:
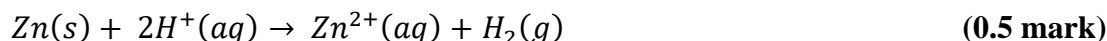
Oxidation half cell reaction (at anode):

      i) $Zn(s) \rightarrow Zn^{2+}(aq) + 2\bar{e}$ **(0.5 mark)**

Reduction half-cell reaction (at cathode):

      ii) $2H^+(aq) + 2\bar{e} \rightarrow H_2(g)$ or $H^+(aq) + \bar{e} \rightarrow \frac{1}{2}H_2(g)$ **(0.5 mark)**

Required P^H

Overall cell reaction (taking eqn i plus eqn ii)

$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$ **(0.5 mark)**

From Nernst equation at 25°C

$$E_{cell} = E^{\theta}_{cell} - \frac{0.0591}{n} \log \frac{[Zn^{2+}(aq)].P(H_2(g))}{[H^+(aq)]^2}$$ **(1 mark)**

But $E_{cell} = 0.28V$ and number of electrons transferred, n = 2

$E^{\theta}_{cell} = E^{\theta}_{cathode} - E^{\theta}_{anode} = E^{\theta}(H^+/H_2) - E^{\theta}(Zn^{2+}/Zn)$ **(1 mark)**

$E^{\theta}_{cell} = 0 - (-0.76V) = +0.76V$ **(0.5 mark)**

But, $[Zn^{2+}(aq)] = 0.1M$

$$0.28V = 0.76V - \frac{0.0591}{2} \log \frac{(0.1) \times 1}{[H^+(aq)]^2}$$ **(1 mark)**

$$\frac{0.0591}{2} \log \frac{0.1}{[H^+(aq)]^2} = 0.48\text{V}$$

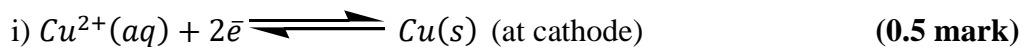$$\log \frac{0.1}{[H^+(aq)]^2} = \frac{2 \times 0.48}{0.0591}$$

$$\log 0.1 + 2(-\log[H^+(aq)]) = \frac{2 \times 0.48}{0.0591}$$

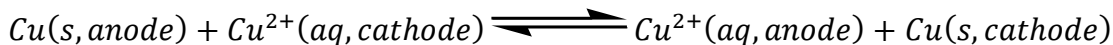But $-\log[H^+(aq)] = P^H$ then $\log 0.1 + 2P^H = \frac{2 \times 0.48}{0.0591}$

Then $P^H = 8.62$

Therefore P^H of the solution = 8.62.   **(1 mark)**

(c)   Electrode reactions occurring:

i) $Cu^{2+}(aq) + 2\bar{e} \rightleftharpoons Cu(s)$ (at cathode)   **(0.5 mark)**

ii) $Cu(s) \rightleftharpoons Cu^{2+}(aq) + 2\bar{e}$ (at anode)   **(0.5 mark)**

Overall reaction,eqn i plus eqn ii

$Cu(s, anode) + Cu^{2+}(aq, cathode) \rightleftharpoons Cu^{2+}(aq, anode) + Cu(s, cathode)$

From Nernst equation at 25°C

$$E_{cell} = E_{cell}^{\theta} - \frac{0.0591}{n} log \frac{[Cu^{2+}(aq)]_{anode}}{[Cu^{2+}(aq)]_{cathode}}$$ **(0.5 mark)**

But number of electrons transferred, n = 2   **(0.5 mark)**

$E_{cell}^{\theta} = E_{cathode}^{\theta} - E_{anode}^{\theta} = E^{\theta}(Cu^{2+}/Cu) - E^{\theta}(Cu^{2+}/Cu)$ **(0.5 mark)**

$E_{cell}^{\theta} = 0.34V - 0.34V = 0\ V$ **(0.5 mark)**

$$E_{cell} = 0V - \frac{0.0591}{n} log \frac{[Cu^{2+}(aq)]_{anode}}{[Cu^{2+}(aq)]_{cathode}}$$

Therefore, for concentration cell at 25°C,

$$E_{cell} = \frac{0.0591}{n} log \frac{[Cu^{2+}(aq)]_{cathode}}{[Cu^{2+}(aq)]_{anode}}$$ **(1 mark)**

$$E_{cell} = \frac{0.0591}{2} log \left(\frac{1}{0.01}\right)$$ **(1 mark)**

$E_{cell} = 0.0591V$

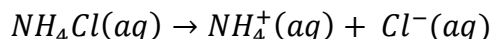Hence, the emf of the cell = 0.059V.   **(1 mark)**

(d) i.   Kohlrausch's law of independent migration of ions states that "the molar conductivity of an electrolyte at infinite dilution is equal to the sum of the molar conductivities of its cations and anions"   **(1 mark)**

ii.   Applications of Kohlrausch's law of independent migration of ions

➢ Calculation of molar conductance at infinite dilution for a weak electrolyte
➢ Calculation of degree of dissociation of weak electrolyte
➢ Calculation of dissociation constant for weak electrolytes
➢ Calculation of solubility of sparingly soluble salts

(4 points @ 0.5 mark = **2 marks**)

3. (a) Aqueous NH_4Cl is acidic in nature because it is a salt of weak base NH_4OH, and strong acid, HCl, and it gets completely ionized in water as;
$$NH_4Cl(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$$
Since $Cl^-(aq)$ ion is anion of strong acid, it remains as such in a solution, however $NH_4^+(aq)$ ions undergo hydrolysis in water (cationic hydrolysis) to form $NH_4OH(aq)$ and $H^+(aq)$ ions.

$NH_4^+(aq) + H_2O(l) \rightleftharpoons$ $NH_4OH(aq) + H^+(aq)$ **(1 mark)**

$NH_4OH(aq)$ formed is a weak base and hence remains mainly unionized in the solution, this results to the increase in $H^+(aq)$ ions concentration in the solution making the solution acidic.

(0.5 mark)

The hydrolysis reaction of NH_4Cl in water can also be written as

$NH4Cl(aq) + H_2O(l) \rightleftharpoons$ $NH_4OH(aq) + H^+(aq) + Cl^-(aq)$

While

Sodium acetate solution contains anions from weak acid, $CH_3COO^-(aq)$ ions and cations from strong base, $Na^+(aq)$ ions so, $CH_3COONa(aq)$ undergo anionic hydrolysis yielding basic solution. $CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$ **(1 mark)**

$CH_3COOH(aq)$ formed is a weak acid and hence remains mainly unionized in the solution, this results to the increase in $OH^-(aq)$ ions concentration in the solution making the solution basic. **(0.5 mark)**
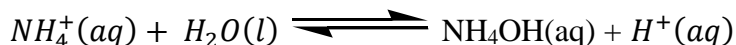
The hydrolysis reaction of $CH_3COOH(aq)$ in water can also be written as:

$CH_3COONa(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + Na^+(aq) + OH^-(aq)$
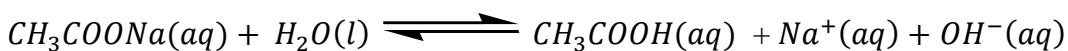
(b) i. $NH4Cl(aq)$ undergoes cationic hydrolysis as per equation

	$NH_4^+(aq) + H_2O(l) \rightleftharpoons$	$NH_4OH(aq) +$	$H^+(aq)$
Initial conc. (M)	C	0	0
Conc. at equilibrium (M)	C(1-h)	Ch	Ch

Then,

$$[H^+(aq)] = Ch \qquad \text{(1 mark)}$$

But, $P^H = -log[H^+(aq)]$

$$[H^+(aq)] = 10^{-P^H} = 10^{-5.127} = 7.46 \times 10^{-6}M \qquad \text{(0.5 mark)}$$

$$h = \frac{[H^+(aq)]}{C} = \frac{7.46 \times 10^{-6}M}{0.1M} \qquad \text{(0.5 mark)}$$

$$h = 7.46 \times 10^{-5}$$

The degree of hydrolysis, h $= 7.46 \times 10^{-5}$ **(0.5 mark)**

ii.   Hydrolysis constant, $K_h = \frac{[NH_4OH(aq)][H^+(aq)]}{[NH_4^+(aq)]}$

$K_h = \frac{Ch \times Ch}{C(1-h)} \approx Ch^2$ **(0.5 mark)**

       Since h is very small , 1-h $\approx h$

$K_h = 0.1 \times (7.46 \times 10^{-5})^2$ **(0.5 mark)**

$$K_h = 5.563 \times 10^{-10}$$

Therefore, the hydrolysis constant , $K_h = 5.563 \times 10^{-10}$ **(1 mark)**

ii.   From Hydrolysis constant, $K_h = \frac{K_w}{K_b}$ **(0.5 mark)**

$K_b = \frac{K_w}{K_h} = \frac{1 \times 10^{-14}}{5.563 \times 10^{-10}}$ **(0.5 mark)**

$$K_b = 1.797 \times 10^{-5}$$

Therefore, the dissociation constant of the base, $K_b = 1.797 \times 10^{-5}$ **(0.5 mark)**
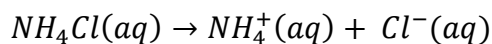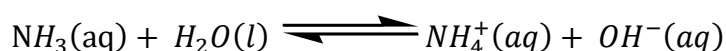
(c) i.   Conc. of base, $[NH_3(aq)] = 0.25M$

       Conc. of salt, $[NH_4Cl(aq)] = 0.40M$

       $K_b = 1.8 \times 10^{-5}$

       Required P^H = ?

       This is a basic buffer solution; the reactions occurring are:

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

$$NH_4Cl(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$$

          0.40M   0.40M

From Henderson Hasselbalch equation

$P^{OH} = P^{K_b} + log\frac{[NH_4^+(aq)]}{[NH_3(aq)]}$

But the mole ratio between $NH_4Cl(aq)$ and $NH_4^+(aq)$ is 1:1, then

$[NH_4^+(aq)] = [NH_4Cl(aq)]$

$P^{OH} = P^{K_b} + log\frac{[NH_4Cl(aq)]}{[NH_3(aq)]}$ **(0.5 mark)**
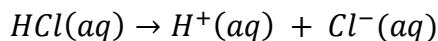
$$P^{K_b} = -logK_b = -log\ (1.8 \times 10^{-5}\ ) = 4.7447$$

$$P^{OH} = 4.7447 + log\left(\frac{0.4}{0.25}\right) = 4.95 \qquad \textbf{(0.5 mark)}$$

But $P^H = 14 - P^{OH} = 14 - 4.95 = 9.05$ **(0.5 mark)**

Therefore the $P^H = 9.05$ **(0.5 mark)**

(ii) When HCl is added, it dissociates completely in the solution as per equation:

$$HCl(aq) \rightarrow H^+(aq)\ +\ Cl^-(aq)$$

0.1mol   0.1mol

Since the mole ratio of HCl to $H^+(aq)$ is 1:1

Then number of moles of HCl = number of moles of $H^+(aq) = 0.1mol$ **(0.5 mark)**

Original number of moles present:

For NH_3(aq)

number of moles of NH_3(aq) $= Molarity\ \times Volume = \frac{0.25mol}{l} \times 1l = 0.25mol$

For $NH_4Cl(aq)$

number of moles of $NH_4Cl(aq) = Molarity\ \times Volume = \frac{0.4mol}{l} \times 1l = 0.4mol$ **(0.5 mark)**

The addition of HCl causes NH_3(aq) to dissociate more and form more $NH_4^+(aq)$ ions, hence the conc. of NH_3(aq) decreases and the conc. of $NH_4^+(aq)$ increases hence increasing $NH_4Cl(aq)$ conc. increases as well.

i.e,

New number of moles of NH_3(aq) $= (0.25 - 0.1)mol = 0.15mol$ **(0.5 mark)**

New number of moles of $NH_4^+(aq)$ (and hence $NH_4Cl(aq)$) $= (0.40 + 0.1)mol$

$$= 0.50mol \qquad \textbf{(0.5 mark)}$$

$$new\ [NH_4Cl(aq)] = \frac{number\ of\ moles}{Volume\ of\ solution} = \frac{0.15mol}{1l} = 0.15mol/l$$

$$new\ [NH_3(aq)] = \frac{number\ of\ moles}{Volume\ of\ solution} = \frac{0.5mol}{1l} = 0.50mol/l$$

Then from,

$$P^{OH} = P^{K_b} + log \frac{[NH_4Cl(aq)]}{[NH_3(aq)]}$$

$$P^{OH} = 4.7447 + log\left(\frac{0.5}{0.15}\right) = 5.27 \qquad \textbf{(0.5 mark)}$$

But $P^H = 14 - P^{OH} = 14 - 5.27 = 8.73$ **(0.5 mark)**

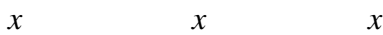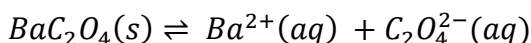Therefore the $P^H = 8.73$ **(0.5 mark)**

(d) Required K_{sp} of $BaC_2O_4(s) = ?$

$$The\ molarity\ of\ BaC_2O_4(s) = \frac{solubility\ in\ g/dm^3}{Molar\ mass\ of\ BaC_2O_4}$$

$$Molar\ mass\ of\ BaC_2O_4(s) = (137 + 12 \times 2 + 16 \times 4)gmol^{-1} = 225gmol^{-1}$$

$$[BaC_2O_4(aq)] = \frac{0.09gdm^{-3}}{225gmol^{-1}} = 4 \times 10^{-4}moldm^{-3} \textbf{ (0.5 mark)}$$

Let x be the solubility of $BaC_2O_4(s)$ in aqueous solution

From the equilibrium for dissolution of $BaC_2O_4(s)$

$$BaC_2O_4(s) \rightleftharpoons Ba^{2+}(aq) + C_2O_4^{2-}(aq)$$

$$x \qquad\qquad x \qquad\qquad x$$

$$[Ba^{2+}(aq)] = [C_2O_4^{2-}(aq)] = 4 \times 10^{-4}moldm^{-3}$$

Solubility product, $K_{sp} = [Ba^{2+}(aq)][C_2O_4^{2-}(aq)]$ **(0.5 mark)**

$K_{sp} = x.x = x^2 = (4 \times 10^{-4}moldm^{-3})^2$ **(0.5 mark)**

$$K_{sp} = 1.6 \times 10^{-7}mol^2dm^{-6}$$

Therefore the solubility product, $K_{sp} = 1.6 \times 10^{-7}mol^2dm^{-6}$. **(0.5 mark)**

(ii) Required mass of $BaC_2O_4(s)$ precipitated:

$$The\ conc. of\ Na_2C_2O_4(aq)\ added = \frac{conc.\ in\ g/dm^3}{Molar\ mass\ of\ Na_2C_2O_4(aq)}$$

$$Molar\ mass\ of\ Na_2C_2O_4(aq) = 134gmol^{-1}$$

$$[Na_2C_2O_4(aq)] = \frac{2.68gdm^{-3}}{134gmol^{-1}} = 0.02\ moldm^{-3} \qquad \textbf{(0.5 mark)}$$

$$Na_2C_2O_4(aq) \rightarrow 2Na^+(aq) + C_2O_4^{2-}(aq)$$

$$0.02M \qquad\qquad\qquad\qquad 0.02M$$

Since; $Na_2C_2O_4(aq): C_2O_4^{2-}(aq) = 1:1$

Then, $[Na_2C_2O_4(aq)] = [C_2O_4^{2-}(aq)] = 0.02M$

The extra $C_2O_4^{2-}(aq)$ ions added causes common ion effect which lowers the solubility of $BaC_2O_4(s)$

Let y be the solubility of $BaC_2O_4(s)$ after common ion effect

From the equilibrium for dissolution of $BaC_2O_4(s)$

$$BaC_2O_4(s) \rightleftharpoons Ba^{2+}(aq) + C_2O_4^{2-}(aq)$$

$\qquad$ y $\qquad\qquad$ y $\qquad\qquad$ y $\qquad\qquad\qquad\qquad$ **(0.5 mark)**

$$Na_2C_2O_4(aq) \rightarrow 2Na^+(aq) + C_2O_4^{2-}(aq)$$

$\qquad$ 0.02M $\qquad\qquad\qquad\qquad$ 0.02M

$[Ba^{2+}(aq)] = y$

$[C_2O_4^{2-}(aq)] = (y + 0.02)moldm^{-3} \approx 0.02moldm^{-3}$ (since y is very small) **(0.5 mark)**

Solubility product, $K_{sp} = [Ba^{2+}(aq)][C_2O_4^{2-}(aq)]$

$1.6 \times 10^{-7}mol^2dm^{-6} = y(0.02moldm^{-3})$

$y = 8 \times 10^{-6}moldm^{-3}$ $\qquad\qquad\qquad\qquad\qquad\qquad$ **(0.5 mark)**

Solubility of $BaC_2O_4(s) = [Ba^{2+}(aq)]_{remaining\ soluble} = 8 \times 10^{-6}moldm^{-3}$

$[Ba^{2+}(aq)]_{forming\ precipitate} = [Ba^{2+}(aq)]_{initially\ soluble} - [Ba^{2+}(aq)]_{remaining\ soluble}$

$= 4 \times 10^{-4}moldm^{-3} - 8 \times 10^{-6}moldm^{-3} = 3.92 \times 10^{-4}moldm^{-3}$ $\qquad$ **(0.5 mark)**

Net ionic equation for precipitation of $BaC_2O_4(s)$

$$Ba^{2+}(aq) \qquad + \qquad C_2O_4^{2-}(aq) \qquad \rightarrow \qquad BaC_2O_4(s)$$

$3.92 \times 10^{-4}moldm^{-3}$ $\qquad\qquad\qquad\qquad\qquad$ $3.92 \times 10^{-4}moldm^{-3}$

Since the mole ratio of $Ba^{2+}(aq)$ to $BaC_2O_4(s) = 1:1$

Then $[Ba^{2+}(aq)]_{forming\ precipitate} = [BaC_2O_4(s)]\ ppt\ formed = 3.92 \times 10^{-4}moldm^{-3}$

Mass of $BaC_2O_4(s)\ precipitated = molarity \times volume\ of\ solution\ in\ dm^3 \times molar\ mass$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ **(0.5 mark)**

$= 3.92 \times 10^{-4}moldm^{-3} \times 1dm^3 \times 225gmol^{-1} = 0.0882g$

$Therefore,$ Mass of $BaC_2O_4(s)\ precipitated = 0.0882g.$ $\qquad\qquad$ **(0.5 mark)**

4. (a) Fluorine atom is smaller in size than iodine atom and therefore, bond dissociation enthalpy of H-F is very high as compared to that of H-I bond. Consequently H-I bond breaks more easily than H-F bond and hence HI is stronger acid than HF.   (**02**)
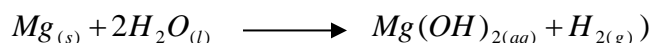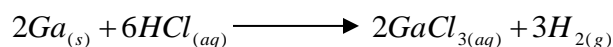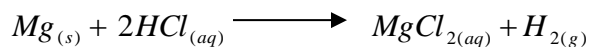
(b) Characteristics of p-block elements are;

i.   The p-block elements include metals, non-metals and metalloids. That is certain elements in p-block are metals, some non-metals, while some others are metalloids. In group, the metallic character increases in going from top to the bottom. In a period, the metallic character decreases in going from left to right

ii. The general outer electronic configuration of p-block elements is ns^2 and np^{1-6}.

iii. The p-block elements enter into chemical combination by losing, gaining or sharing the valence electrons. The noble gas elements do not show any reactivity. This is because the outermost shell in these elements are completely filled (ns^2 np^6)

iv. The p-block elements mostly form covalent compounds. The halogens, however, form ionic compounds with alkali and alkaline earth metals.

(4 pts@**01** = (**04 marks**))

(c) Beryllium and aluminium are diagonally related because they have similar chemical properties such as polarizing power. The following are diagonal relationships between Be and Al. (Student should give any 4 points @ **01** = **04**)

(i)   Both Be and Al do not easily react with acids and water, because these elements react with Oxygen to form a thin oxide layer which is inert, this makes Be and Al elements impervious to further attack.   (**01**)
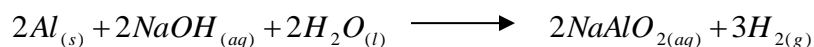
(But their corresponding elements of group IIA and group IIIA metals react with acids and water as follows:

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$$

$$2Ga_{(s)} + 6HCl_{(aq)} \longrightarrow 2GaCl_{3(aq)} + 3H_{2(g)}$$

$$Mg_{(s)} + 2H_2O_{(l)} \longrightarrow Mg(OH)_{2(aq)} + H_{2(g)})$$

(ii)   Both Be and Al dissolve in excess alkalis to give beryllate and aluminate ions, respectively and liberate hydrogen gas.   (**00^1/$_2$**)

$$Be_{(s)} + 2NaOH_{(aq)} \longrightarrow Na_2BeO_{2(aq)} + H_{2(g)}$$

Sodium beryllate

$$2Al_{(s)} + 2NaOH_{(aq)} + 2H_2O_{(l)} \longrightarrow 2NaAlO_{2(aq)} + 3H_{2(g)}$$
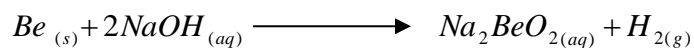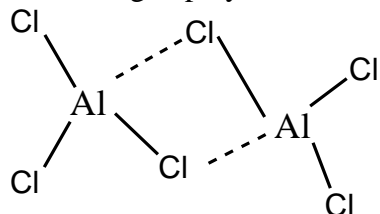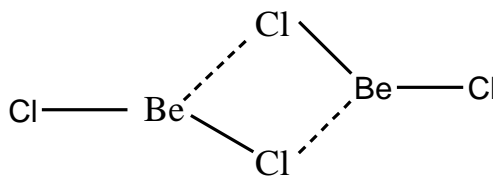
Sodium aluminate   (**00^1/$_2$**)

Other elements group IIA and IIIA do not react with alkalis.

(iii) Both Be and Al posses strong tendencies of forming covalent compounds, while other elements in groups IIA and IIIA form ionic compounds.   (**01**)

(iv) The chlorides of beryllium (Be$_2$Cl$_4$) and aluminium (Al$_2$Cl$_6$) are covalent and have bridged polymeric structures. **(00^1/$_2$)**

$$Al_2Cl_6 \qquad\qquad\qquad\qquad Be_2Cl_4$$

(0.5 mark)

(v) Both Be^{2+} and Al^{3+} ions have strong tendencies of forming complexes due to their similar charge to radius ratios. **(00^1/$_2$)**
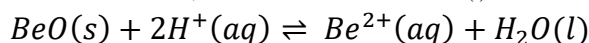
The following are example of complexes of Be and Al:

- $BeF_4^{2-}(aq)$ and $AlF_6^{2-}(aq)$
- $[Be(C_2O_4)_2]_{(aq)}^{2-}$ $[Al(C_2O_4)_3]_{(aq)}^{3-}$

(any pair of correct complexes of Be and Al = **00^1/$_2$**)

(vi) Both salts of Be and Al hydrolyse in water and precipitate when boiled in hydroxides. The hydroxides and oxides of both Be and Al are amphoteric. **(00^1/$_2$)**

BeO as a base, forms Be^{2+} and H$_2$O$_{(l)}$

$BeO(s) + 2H^+(aq) \rightleftharpoons Be^{2+}(aq) + H_2O(l)$

BeO as an acid, forms beryllate ion.

$BeO(s) + 3H_2O(l) \rightleftharpoons [Be(OH)_4]_{(aq)}^{2-} + H_2(g)$
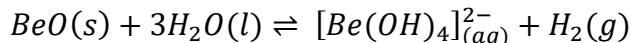
Al_2O_3 as a base, neutralises the HCl to form salt and water.

$Al_2O_3(s) + 6HCl(g) \rightarrow 2AlCl_3(g) + 3H_2O(l)$
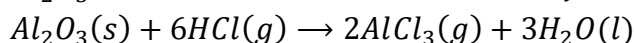
Al_2O_3 as an acid, reacts with strong alkalis to form aluminate.

$Al_2O_3(s) + 2NaOH(aq) \rightarrow 2NaAlO_2(aq) + H_2O(l)$ **(00^1/$_2$)**
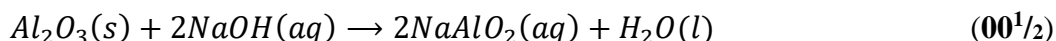
(d) (i) The melting point of Mg is higher than that of Na because Mg is smaller than Na and has higher metallic bond since it contributes two electrons in the electron cloud unlike Na which contributes only one electron in electron cloud (or delocalized sea of electrons) of metallic bond hence weak metallic bond. **(2 marks)**

(ii) Melting point of Al is close to that of Mg because although Al ionizes by losing three electrons, due to its high total ionization energies (1st I.E, 2nd I.E, 3rd I.E), it contributes only two electrons during formation of metallic crystal (metallic bond formation), hence this accounts for the close melting point to that of Mg which also contributes two electrons in the metallic crystal. **(2 marks)**

(iii) Silicon which is metalloid that possess both non-metallic and metallic properties, has a strong covalent bonding where by each silicon is bonded to four other silicon atoms forming a

three-dimensional giant molecule. Therefore, silicon has very high melting point because of the strong covalent bonds that need a large amount of energy to be broken. **(2 marks)**

(iv) Sulphur has a higher melting point than phosphorous due to large molecular weight of sulphur molecules. Sulphur exists as S_8 molecules, while phosphorous exists as P_4 molecules; Since Van der Waals forces existing between the molecules increase with increasing molecular weight, then sulphur tends to have higher Van der Waals forces than phosphorous thus higher melting point than phosphorous. **(2 marks)**

(v) Melting point of chlorine is very low because it is diatomic and a gas at room temperature so has very weak Van der Waals forces of attraction, hence low melting point. **(2 marks)**

5. (a) i. The monomers must be bifunctional ie. Contain two functional groups (or the monomers must be polyfunctional) **(1 mark)**

     ii.   Homopolymer is a polymer formed from only one type of monomers example PVC, polyethene etc (any 1 example)

<center>While</center>

Copolymer is a polymer formed from two or more different kinds of monomers for mean nylon-66, terylene/dacron (any 1 example)

<div align="right">(@meaning 0.5 mark, @eg 0.5 mark = 2 marks)</div>

     iii.   Acrylonitrile ($H_2C=CH-C\equiv N$) contains an electron withdrawing $(-C \equiv N)\ group$ which can stabilize the carbanion intermediate by negative mesomeric effect. Since in anionic polymerization, carbanion intermediates are produced, therefore, polymerization of acrylonitrile must be carried out under anionic conditions. **(2 marks)**

     iv.   Sulphur makes the rubber more elastic, more ductile, less plastic ie more elastic and non-sticky. **(2 marks)**

(b)   On the basis of molecular forces present between the chains of various polymers, polymers are classified as:- **(note: give 0.5 mark to only one correct example given)**

    (i)   Elastomers   **(0.5 mark)**
            Elastomers are polymers in which the intermolecular forces of attraction between the polymer chains are weakest and have elastic character like rubber. Due to presence of weak forces, the polymers can easily be stretched by applying small stress and regains their original shape when the stress is removed. **(0.5 mark)**
            Example: natural rubber, Buna-S, Buna-N. **(0.5 mark)**

(ii)   Fibres **(0.5 mark)**
       These are polymers which have strong intermolecular forces between the chains.
       These forces are either hydrogen bonds or dipole-dipole interactions. **(0.5 mark)**
       Example; nylon-66, terylene (Dacron), silk etc. **(0.5 mark)**
(iii) Thermoplastics   **(0.5 mark)**
       These are polymers which can be easily softened repeatedly when heated, and
       hardened when cooled with little change in their properties. The intermolecular
       forces in these polymers are intermediate between those of elastomers and fibres.
                                                                         (0.5 mark)
       Examples are polythene, polystyrene, PVC, Teflon etc   **(0.5 mark)**
(iv)   Thermosetting polymers   **(0.5 mark)**
       These are the polymers which undergo permanent change on heating. **(0.5 mark)**
       Example Bakelite, melamine formaldehyde resin.   **(0.5 mark)**

(c) i. It is obtained by the addition polymerization of methylmethacrylate.
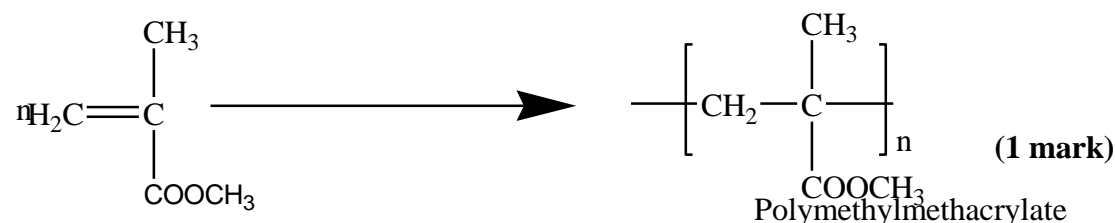
(1 mark)

ii.   Teflon is a polymer of tetrafluoroethene ($CF_2=CF_2$) by addition polymerization.
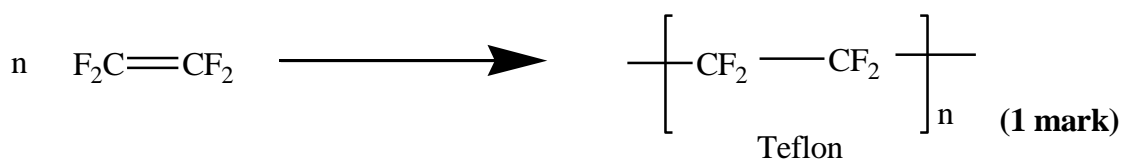
(1 mark)

iii.   Dacron is a condensation polymer of ethylene glycol and terephthalic acid
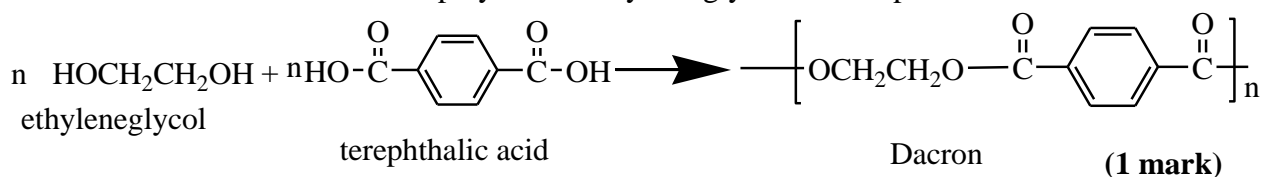
(1 mark)

(c) i.   The monomers are:

$HOCH_2CH_2CH_2CH_2OH$ **(1 mark)**   and

1,4-butanediol

terephthalic acid   Dimethylterephthalate   **(1 mark)**
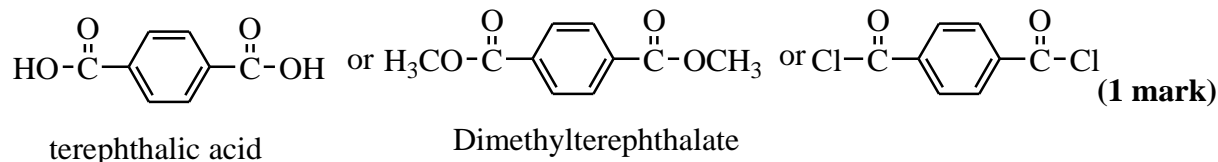
ii.   It is a polyester **(0.5 mark)**
iii.   Condensation polymer **(0.5 mark)**
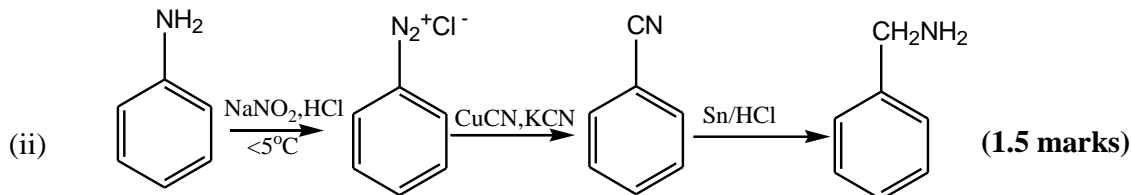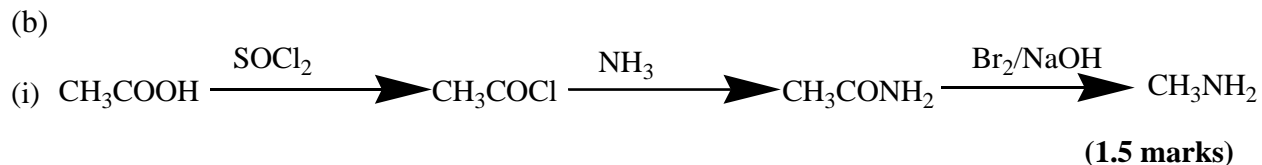iv.

(1 mark)
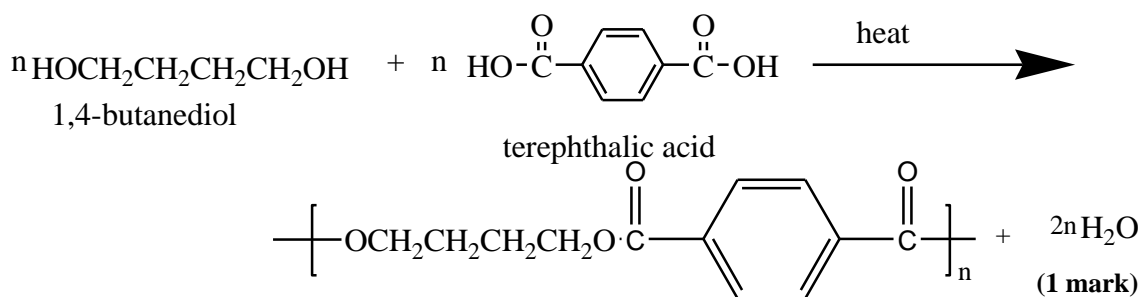
6. (a) i. Chloroacetic acid is a stronger acid than acetic acid and has higher value of dissociation constant, K_a than that of acetic acid. We know that pK_a = -log K_a, it means that chloroacetic acid having higher value of K_a will have lower value of pK_a. Chloroacetic acid is stronger acid than acetic acid because Cl group withdraws electrons by negative inductive effect thus decreasing the electron density in the -O-H bond and weaken it more hence making it easy to break and release H^+ proton, and chloroacetate ion is more stabilized than acetate ion (methyl group is electron releasing).   **(1.5 mark)**

ii.   Carboxylic group (-COOH) is electron withdrawing group by negative mesomeric effect i.e. deactivating the benzene ring and thus electron density becomes very less at ortho and para position in comparison to meta position. Electrophiles (+vely charged species) find it easier to attack at meta position as there is higher electron density thus -COOH group is meta directing.   **(1 mark)**
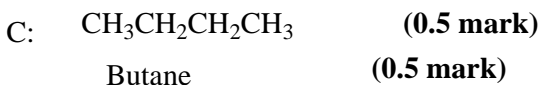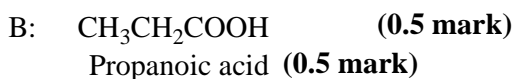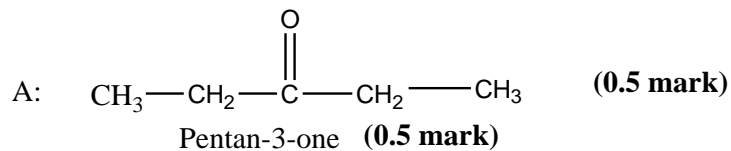
iii.   Because carboxylic group, -COOH in acids is highly polar and generally, exists as dimers containing two hydrogen bonds each as shown below: **(0.5 mark)**
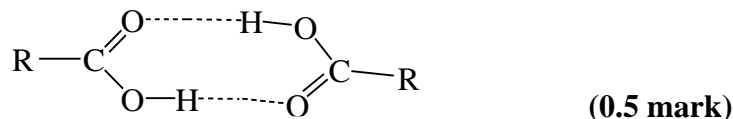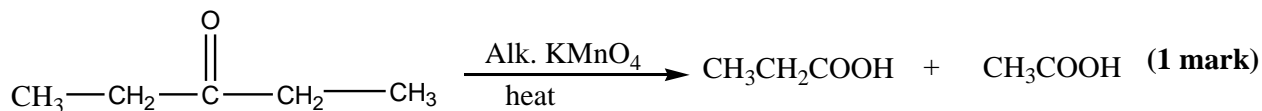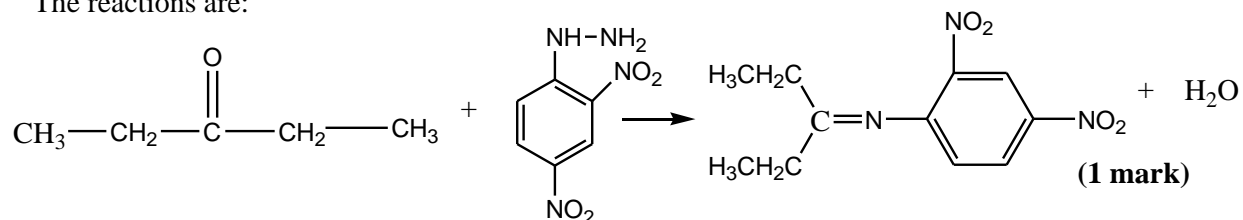

(0.5 mark)

These hydrogen bonds in carbocylic acids are stronger than those in alcohols. Thus carboxylic acids possess higher boiling point than alcohols of similar molecular masses. **(0.5 mark)**

(b)

(i) $CH_3COOH \xrightarrow{SOCl_2} CH_3COCl \xrightarrow{NH_3} CH_3CONH_2 \xrightarrow{Br_2/NaOH} CH_3NH_2$
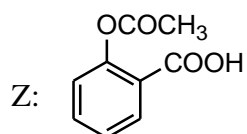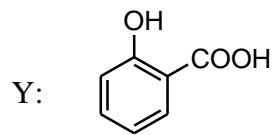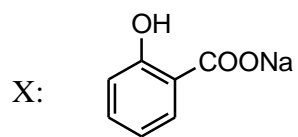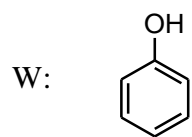
(1.5 marks)

(ii)

(1.5 marks)

(c) As compound A gives -ve Tollen's test but positive 2,4-dinitrophenylhydrazine test, it is a ketone and not an aldehyde. It is further confirmed by the fact that it gives a carboxylic acid with lesser number of carbon atoms on vigorous oxidation. The sodium salt of acid B on electrolytic reduction gives a hydrocarbon. Thus,

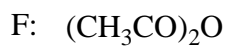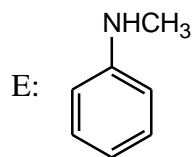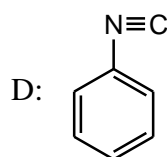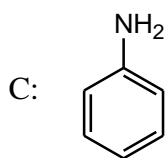A: $CH_3\!-\!CH_2\!-\!\overset{\overset{\displaystyle O}{\|}}{C}\!-\!CH_2\!-\!CH_3$ **(0.5 mark)**

   Pentan-3-one **(0.5 mark)**

B: CH_3CH_2COOH **(0.5 mark)**

   Propanoic acid **(0.5 mark)**

C: $CH_3CH_2CH_2CH_3$ **(0.5 mark)**

   Butane **(0.5 mark)**

The reactions are:

(1 mark)

$CH_3\!-\!CH_2\!-\!\overset{\overset{\displaystyle O}{\|}}{C}\!-\!CH_2\!-\!CH_3 \xrightarrow[\text{heat}]{\text{Alk. KMnO}_4} CH_3CH_2COOH + CH_3COOH$ **(1 mark)**

$CH_3CH_2COOK \xrightarrow{\text{Kolbe electrolysis}} CH_3CH_2CH_2CH_3 + 2CO_2 + 2KOH + H_2$ **(1 mark)**

(d)

W: (phenol, OH on benzene ring)

X: (benzene ring with OH and COONa)

Y: (benzene ring with OH and COOH)

Z: (benzene ring with OCOCH₃ and COOH)

(@**1 mark = 4 marks**)

(e)

A: (benzene ring)

B: (benzene ring with NO₂)

C: (benzene ring with NH₂)

D: (benzene ring with N≡C)

E: (benzene ring with NHCH₃)

F: (CH₃CO)₂O

(@**0.5 mark = 3 marks**)