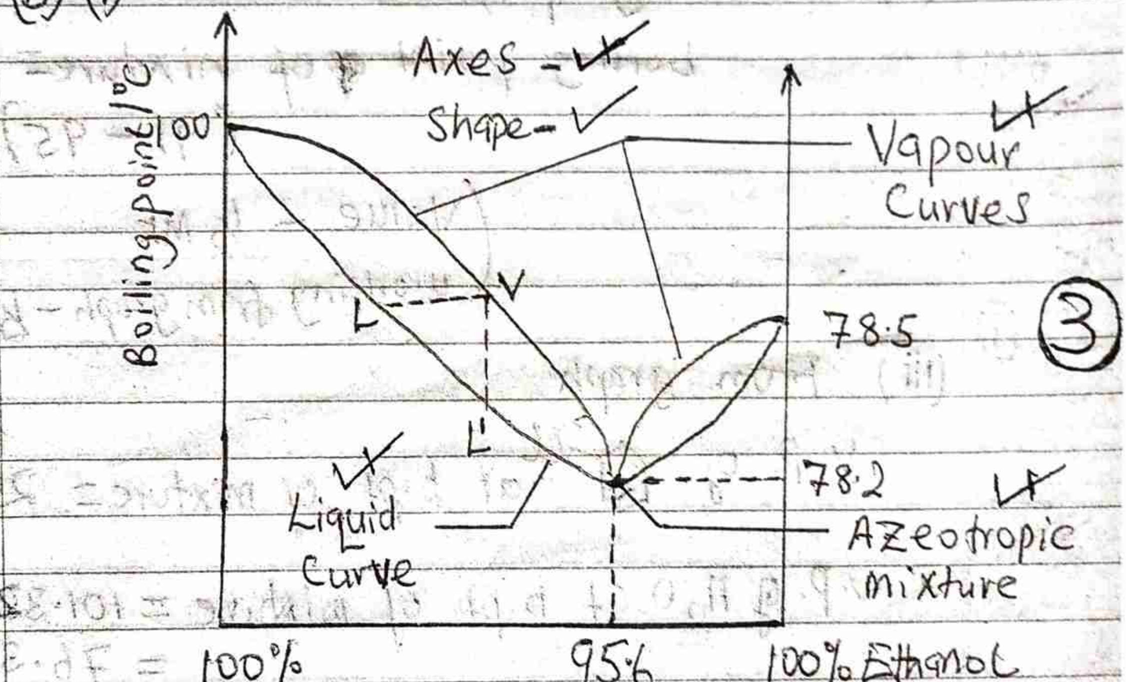
Question 1

(a) (i) It is a liquid mixture which gives off a vapour having a composition which is the same as that of the liquid and the mixtures boil at a constant temperature at a given pressure. ①

(ii) It is the separation of a volatile component which is immiscible with water from a mixture of non-volatile impurities by bubbling steam through the heated mixture ①

(b) (i)



③

(ii) The mixture exhibits positive deviation from Raoult's law.

Cause of the deviation:

The forces of attraction between

techtnique

than those between water – water and ethanol – ethanol. As a result there is a higher tendency for liquid in the mixture the vapourise – thus leading to a higher vapour pressure than that predicted by Raoult's law.

3

(C) (i)

Temperature / °C	70	80	90	100	110
V. P. of mixture	38	60	90	134	190

for all.

Refer to Graph.

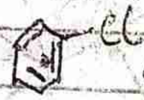
1

(ii) From graph,

boiling point of mixture = 93°C
(91 – 95).

(Value – ½ MK
working from graph – ½ MK)

(iii) From graph

V.P. of  at b.pt. of mixture = $25 kNm^{-2}$

V.P. of H_2O at b.pt. of mixture = 101.325 – 25
= $76.325 kNm^{-2}$
(75 – 78).

R.M.M. of 
= (12 × 6) + 5 + 35.5
= 112.5

R.M.M of H_2O = (1 × 2) + 16 = 18.

- Let Percentage of chlorobenzene in distillate be y.

- Percentage of water in distillate $= (100-y)$.

But $\frac{m_c}{m_w} = \frac{M_c P_c^o}{M_w P_w^o}$ ✓✓

(3)

$\therefore \frac{y}{100-y} = \frac{11.2 \times 25}{18 \times 76.325}$ ✓✓

$1,373.85y = 281250 - 2,812.5y$

$4,186.35y = 281250$

$y = \underline{67.18\ \%}$ ✓✓

(NB)

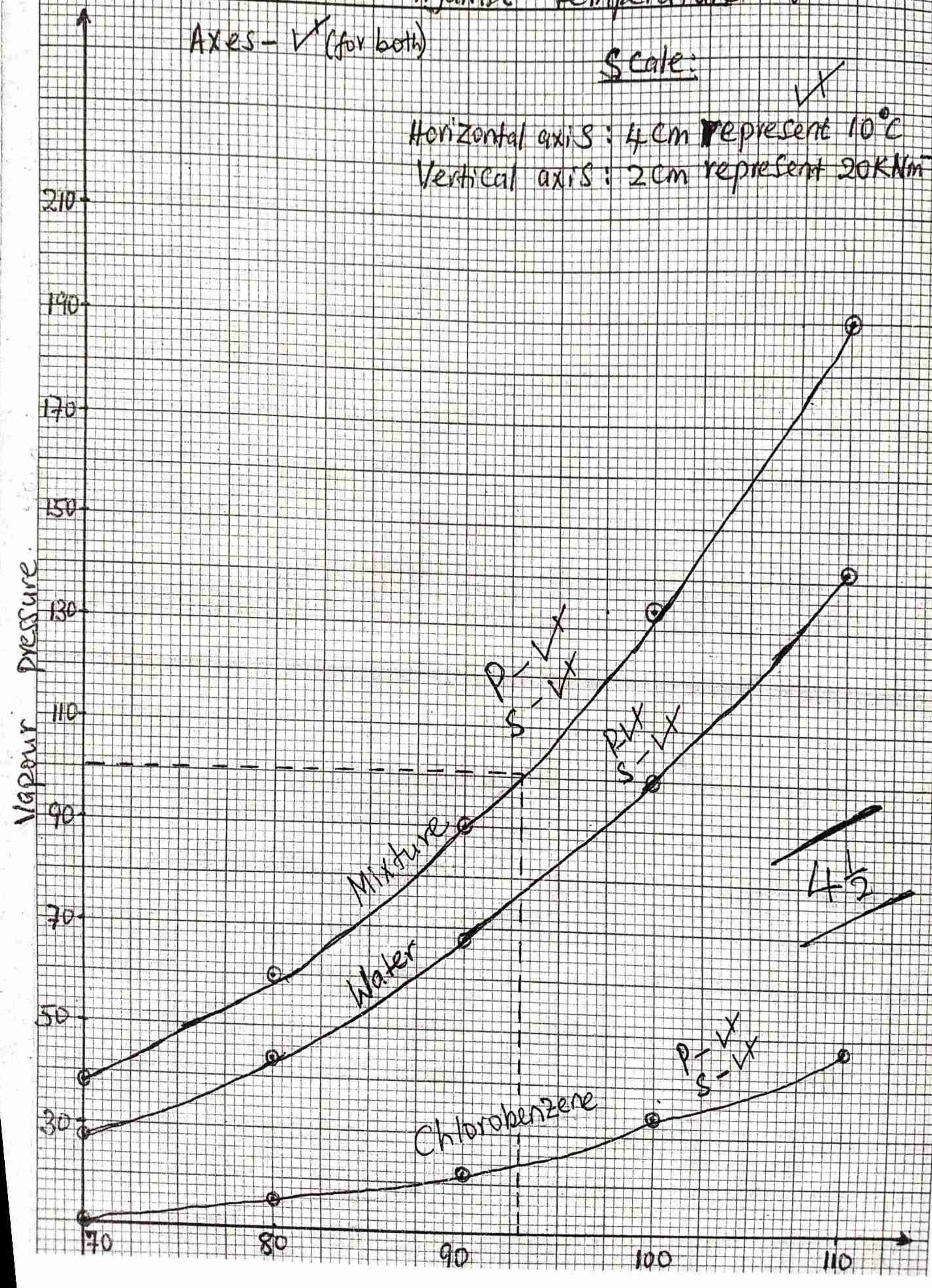
b(iii) When a liquid mixture, L (40% ethanol) is heated it gives off a vapour, V which is richer in ethanol ✓. Hence the liquid left in the flask becomes richer in water instead. When V is condensed it ✓ forms a liquid L', with the same composition as the vapour.

Repeated heating and condensing finally forms an azeotropic mixture ✓✓ and as distillate and water as residue. ✓✓

(3)

$\boxed{\text{Total} = 20 \text{ mks.}}$

Graph of Vapour pressure of Chlorobenzene, Water and Mixture Against Temperature.



Question 2

2 (a) Mass of carbon $= \frac{12}{22.4} \times 1.68$

$= 0.9g$ ✓

Mass of hydrogen $= \frac{2}{18} \times 1.35$

$= 0.15g$ ✓

Mass of oxygen $= 2.25 - (0.9 + 0.15)$

$= 1.2g$ ✓

$3\frac{1}{2}$

	C	H	O
Masses	0.9	0.15	1.2
Moles	$\frac{0.9}{12}$	$\frac{0.15}{1}$	$\frac{1.2}{16}$ ✓
	0.075	0.15	0.075
Mole ratio	$\frac{0.075}{0.075}$	$\frac{0.15}{0.075}$	$\frac{0.075}{0.075}$ ✓
	1 :	2 :	1 ✓

Empirical formula is CH_2O. ✓

(b) $PV = \frac{m}{M_r} \times RT$.

✓

$93.5 \times 1000 \times 55 \times 10^{-6} = \frac{0.102}{M_r} \times 8314 \times 546$

$M_r = 90.$ ✓

$(CH_2O)_n = 90$

Molecular formula is $C_3H_6O_3$.

$1\frac{1}{2}$

(C) $CH_3\underset{|}{\overset{}{C}}H\,COOH$ with OH on the middle carbon: $CH_3CH(OH)COOH$

01

$HO-CH_2CH_2COOH$

(any two).

CH_3OCH_2COOH.

(d) (i) $CH_3CH(OH)COOH$

$0\frac{1}{2}$

(ii) $CH_3CH(OH)COOH \xrightarrow{I_{2(aq)}/NaOH_{(aq)}} CHI_{3(s)} + Na_2C_2O_{4(aq)}$

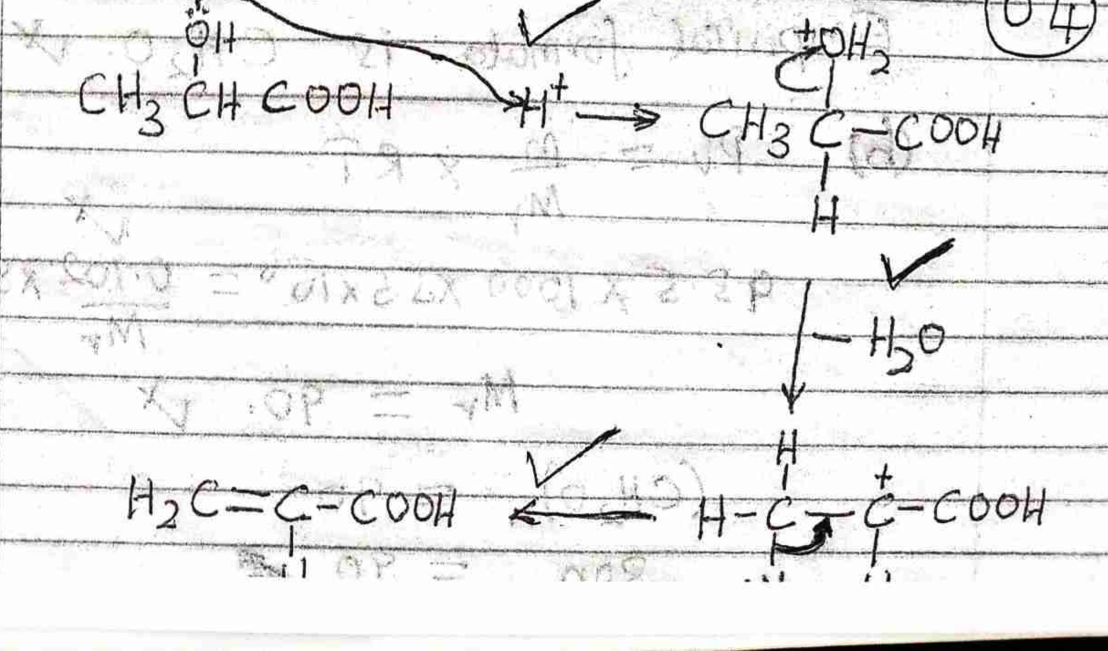
1

(e) (i)

$CH_3CH(OH)COOH \xrightarrow[170°C]{Conc.\,H_2SO_4} H_2C=CHCOOH.$

Mechanism

04



(II) $CH_3CH(OH)COOH \xrightarrow[\text{heat}]{CH_3OH/\text{conc}\,H_2SO_4} CH_3CH(OH)COOCH_3$

Mechanism:

$H_2SO_4 \rightleftharpoons H^+ + {}^-OSO_3H.$

$CH_3CH(OH)C(=O)OH + H^+ \longrightarrow CH_3CH(OH)C(=\overset{+}{O}H)OH$

$CH_3CH(OH)C(=\overset{+}{O}H)OH + CH_3\ddot{O}H \longrightarrow CH_3CH(OH)C(OH)(OH)-\overset{+}{O}(H)CH_3$

$\Big\Downarrow H^+$ Shift.

$CH_3CH(OH)C(\ddot{O}H)(OCH_3)-\overset{+}{O}H_2 \xrightarrow{-H_2O} CH_3CH(OH)C(=\overset{+}{O}H)-OCH_3$

$\Big\downarrow -H^+$

$CH_3CH(OH)C(=O)-O-CH_3.$

4½

f) (i) $CH_3CH(OH)COOH \xrightarrow[\text{heat}]{NaOH_{(s)}/CaO} CH_3CH_2OH$

$\Big\downarrow Cr_2O_7^{2-}/H^+$

$CH_3COOH.$

02

(ii) $CH_3C(=O)-H \xrightarrow[<20^\circ C]{KCN/\text{dil}\,H_2SO_4} CH_3C(OH)(H)-CN$

02

$\Big\downarrow H_2O/H^+$

Question 3

(a) (i)

Given: $PH = 2.39$

$\therefore \log_{10}\left(\frac{1}{[H^+]}\right) = 2.39$

$\frac{1}{[H^+]} = 10^{2.39}$

$[H^+] = \frac{1}{10^{2.39}} = 4.0738 \times 10^{-3}$ M.

$HCOOH_{(aq)} \rightleftharpoons HCOO^-_{(aq)} + H^+_{(aq)}$

$K_a = \frac{[HCOO^-][H^+]}{[HCOOH]}$

Assuming: $[HCOO^-] = [H^-]$ and

$[HCOOH] = 0.1M$

$\therefore K_a = \frac{[H^+]^2}{0.1}$

$= \frac{(4.0738 \times 10^{-3})^2}{0.1}$

$= \underline{1.6596 \times 10^{-4} M.}$ 3

OR

$H^+ = 4.0738 \times 10^{-3}$

$[H^+] = \alpha C$

4.0738×10^{-3}

$\alpha = 4.0738 \times 10^{-2}$

$K_a = \dfrac{\alpha^2 C}{1-\alpha}$

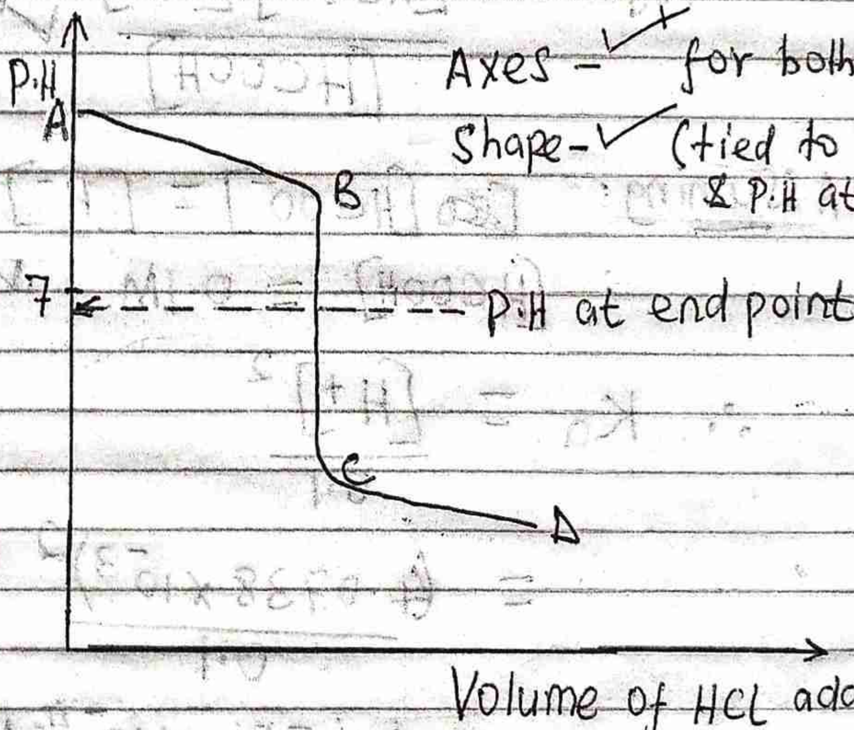
$= \dfrac{(4.0738 \times 10^{-2})^2 \times 0.1}{1 - 4.0738 \times 10^{-2}}$

$= \underline{1.7301 \times 10^{-2}\,M}$

(ii) The K_a Value in a(i) is higher than that of propanoic acid. This is because methanoic acid is a stronger acid than propanoic acid

1

(b) (i)



Axes – for both

Shape – (tied to PH of 7 & P.H at end point.)

$1\frac{1}{2}$

(ii) Initially at A, PH is not very high. This is because ammonia is a weak base and thus slightly ionised, resulting into a low concentration of hydroxide ions.

neutralised by the added hydrochloric acid - thus concentration of hydroxide ions is decreasing
i.e.

$$NH_{3(aq)} + HCl_{(aq)} \longrightarrow NH_4Cl_{(aq)}$$

The decrease in P.H. is gradual because ammonia is still in excess and also the ammonium chloride formed together with ammonia constitute a buffer - which resists a change in PH.

At B ammonia is completely neutralized. Along BC PH decreases sharply. This is due to the excess drop of hydrochloric acid - which has a high concentration of hydrogen ions.

PH at the end point is less than seven. This is because ammonium chloride undergoes hydrolysis releasing hydrogen ions - which make the solution acidic.
i.e.

$$NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_{3(aq)} + H_3O^+_{(aq)}$$

Along CD PH decreases gradually. This is due to the increasing concentration of hydrogen ions from the excess acid added.

$5\frac{1}{2}$

(iii) At half-way neutralisation,

$$POH = pK_b$$
$$= -\log_{10}(1.8 \times 10^{-5})$$
$$= 4.74.$$

$1\frac{1}{2}$

$$\therefore PH = 14 - 4.74$$

(C) (i) RFM of $NH_4Cl = 14 + (1 \times 4) + 35.5 = 53.5$

$\therefore [Salt] = \frac{1.07}{53.5} = 0.02M$, $[Base] = 0.1M$.

$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH^+_{4(aq)} + \bar{O}H_{(aq)}$

$K_b = \frac{[NH_4^+][\bar{O}H]}{[NH_3]}$

Assuming: $[NH_4^+] = 0.02M$

and $[NH_3] = 0.1M$.

$\therefore 1.8 \times 10^{-5} = \frac{0.02 \times [\bar{O}H]}{0.1}$

$[\bar{O}H] = \frac{1.8 \times 10^{-5} \times 0.1}{0.02}$

$= 9.0 \times 10^{-5} M.$

$[H^+] = \frac{K_W}{[\bar{O}H]}$

$= \frac{1.0 \times 10^{-14}}{9.0 \times 10^{-5}}$

$= 1.1111 \times 10^{-10} M.$

$PH = -\log_{10}[H^+]$

$= -\log_{10}(1.1111 \times 10^{-10})$

$= 9.95$

5

(ii) PH does not change

Reason:

Ammonium ions (from the completely dissociated ammonium chloride) react with the incoming hydroxide ions forming ammonia molecules — thus preventing a PH rise.

ie. $NH^+_{4(aq)} + \bar{O}H_{(aq)} \longrightarrow NH_{3(aq)} + H_2O_{(l)}$.

$\boxed{\text{Total = 20 MKS.}}$

Question 4.

(a) It is prepared by adding concentrated sulphuric acid to solid sodium chloride at room temperature.

ie.

$$H_2SO_{4(l)} + NaCl_{(s)} \longrightarrow HCl_{(g)} + NaHSO_{4(s)}.$$

2

(b) (i) Fluorine reacts with water producing hydrogen fluoride gas and oxygen.

$$2F_{2(g)} + 2H_2O_{(l)} \longrightarrow 4HF_{(g)} + 1O_{2(g)}.$$

Chlorine react with water forming hydrochloric acid and chloric (I) acid. (hypochlorous acid).

$$Cl_{2(g)} + H_2O_{(l)} \longrightarrow HCl_{(aq)} + HClO_{(aq)}$$

(for both)

4

(ii) Cold, dilute sodium hydroxide.

Fluorine reacts with cold, dilute sodium hydroxide solution forming sodium fluoride, oxygen difluoride and water.

i.e

$$2F_{2(g)} + 2\bar{O}H_{(aq)} \longrightarrow 2F^-_{(aq)} + F_2O_{(g)} + H_2O_{(l)}.$$

Chlorine react with cold, dilute sodium hydroxide solution forming sodium chloride, sodium chlorate(I) and water.

i.e.

$$Cl_{2(g)} + 2\bar{O}H_{(aq)} \longrightarrow Cl^-_{(aq)} + ClO^-_{(aq)} + H_2O_{(l)}$$

(for both).

Hot, concentrated sodium hydroxide.

oxygen and water.

i.e.

$2F_{2(g)} + 4\bar{O}H_{(aq)} \longrightarrow 4F^-_{(aq)} + O_{2(g)} + 2H_2O_{(l)}$

Chlorine reacts with hot, concentrated sodium-hydroxide solution forming sodium chloride, sodium chlorate (V) and water.

i.e.

$3Cl_{2(g)} + 6\bar{O}H_{(aq)} \longrightarrow 5Cl^-_{(aq)} + ClO^-_{3(aq)} + 3H_2O_{(l)}$

7

(c) (i) Aluminium ion has a high charge density making it to have a high polarising power. In aluminium fluoride, the fluoride ion has a small ionic radius and therefore not easily polarised - thus compound remains ionic.

In aluminium chloride, the chloride ion has a large ionic radius and therefore easily polarised by the aluminium ion - thus leading to electron-sharing.

$3\frac{1}{2}$

(ii) The atomic radius of fluorine is smaller than that of chlorine. Hence, in a fluorine molecule, the lone pairs of electrons on the two electrons are closer and thus repel themselves more strongly, making the bond between the two atoms weaker and thus easier to break.

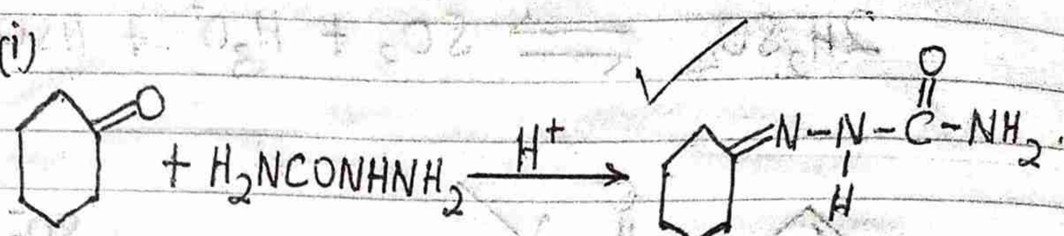
$3\frac{1}{2}$

Total = 20 Mks.

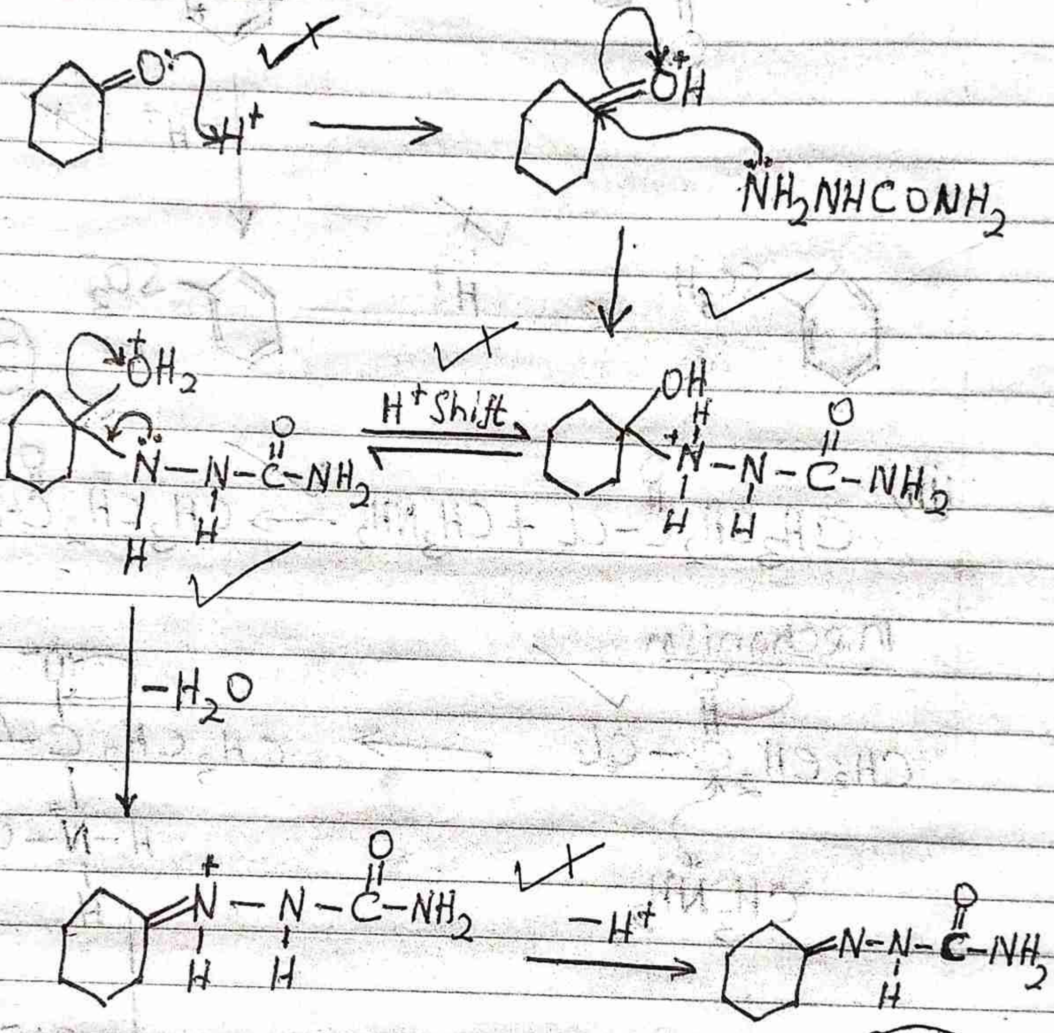
Question 5

(a)

(i)

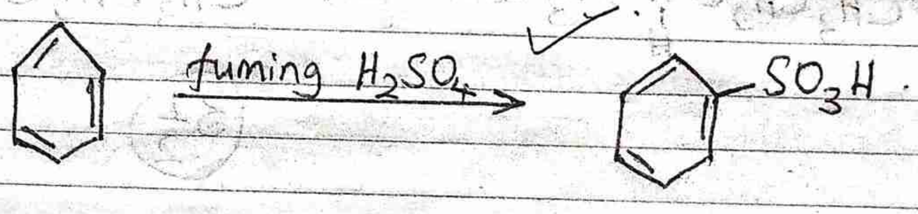


Mechanism:



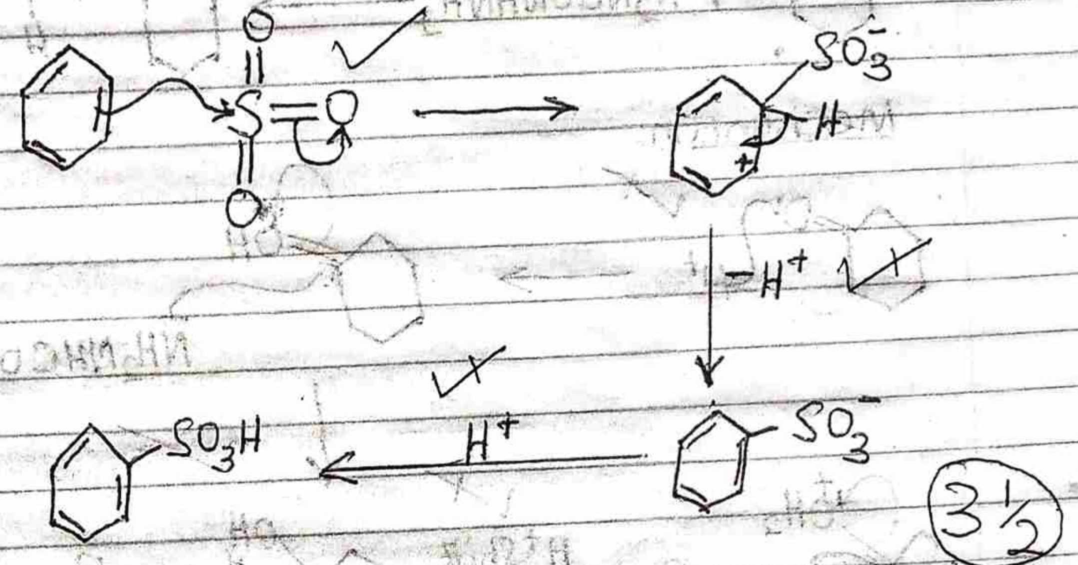
4 1/2

(ii)



Mechanism:

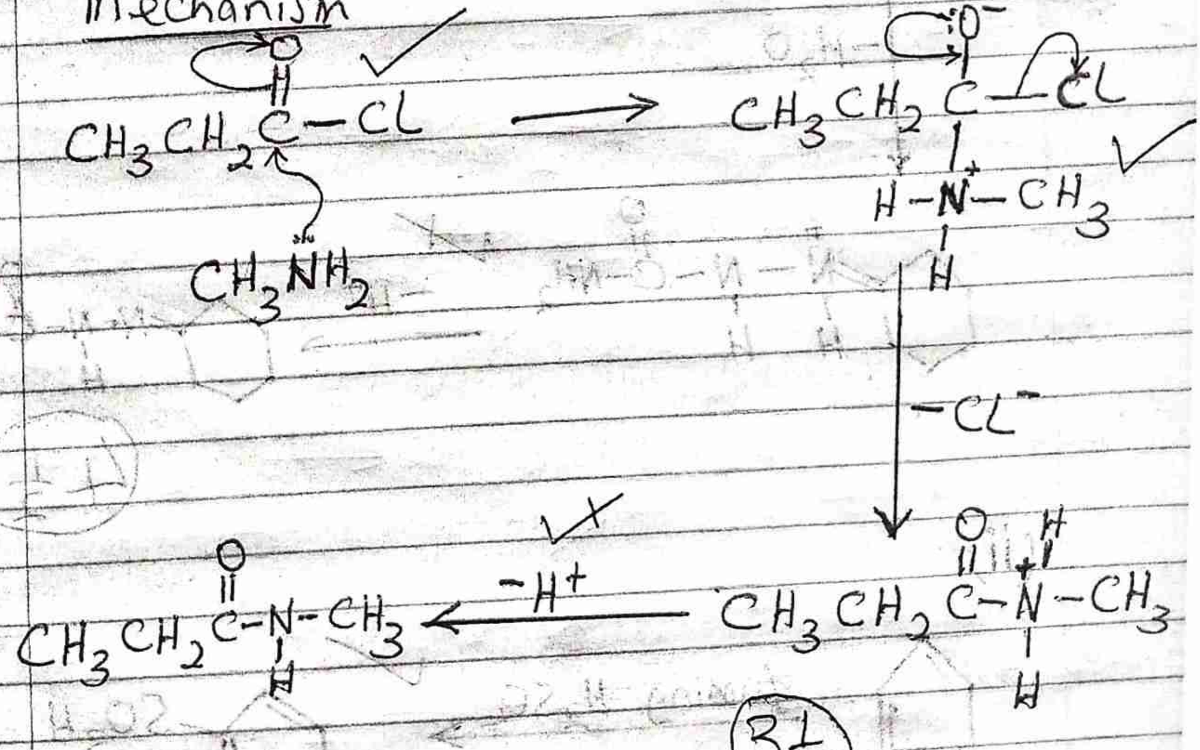
$$2H_2SO_4 \rightleftharpoons SO_3 + H_3O^+ + HSO_4^-$$



3 1/2

(iii) $CH_3CH_2\overset{O}{\overset{\|}{C}}-Cl + CH_3NH_2 \longrightarrow CH_3CH_2\overset{O}{\overset{\|}{C}}-NHCH_3$

Mechanism



3 1/2

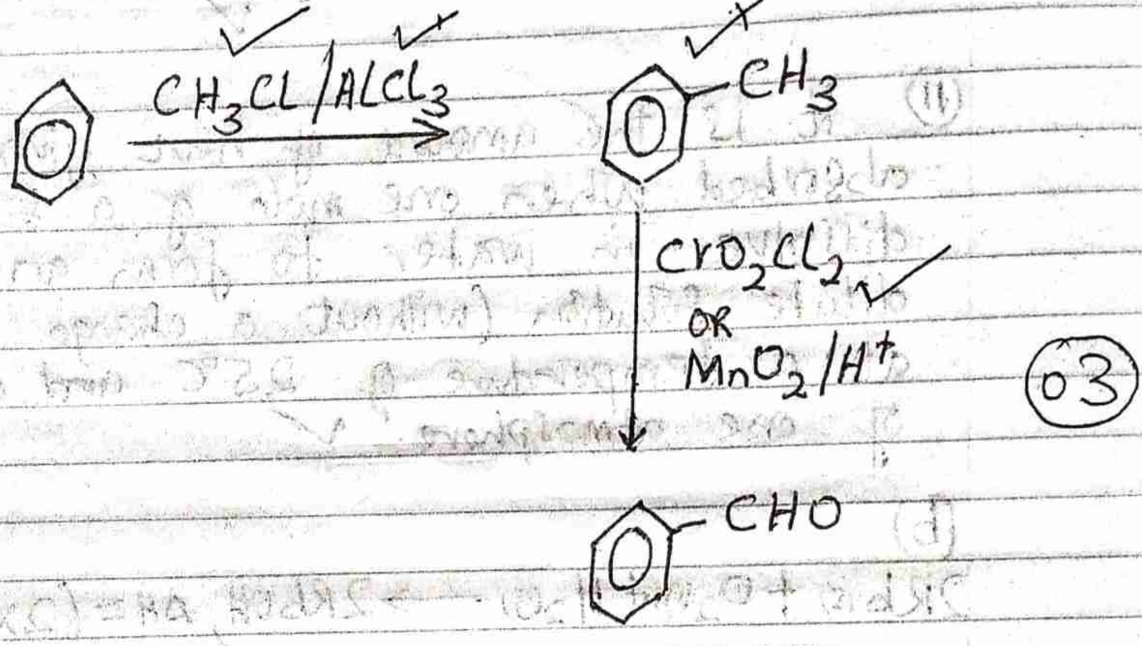
(b)

(i) $CH_3CH_2CH_2Br \xrightarrow[heat]{NaOH_{(aq)}} CH_3CH_2CH_2OH$

$$CH_3CH_2CH_2OH \xrightarrow[heat]{Cr_2O_7^{2-}/H^+} CH_3CH_2COOH.$$

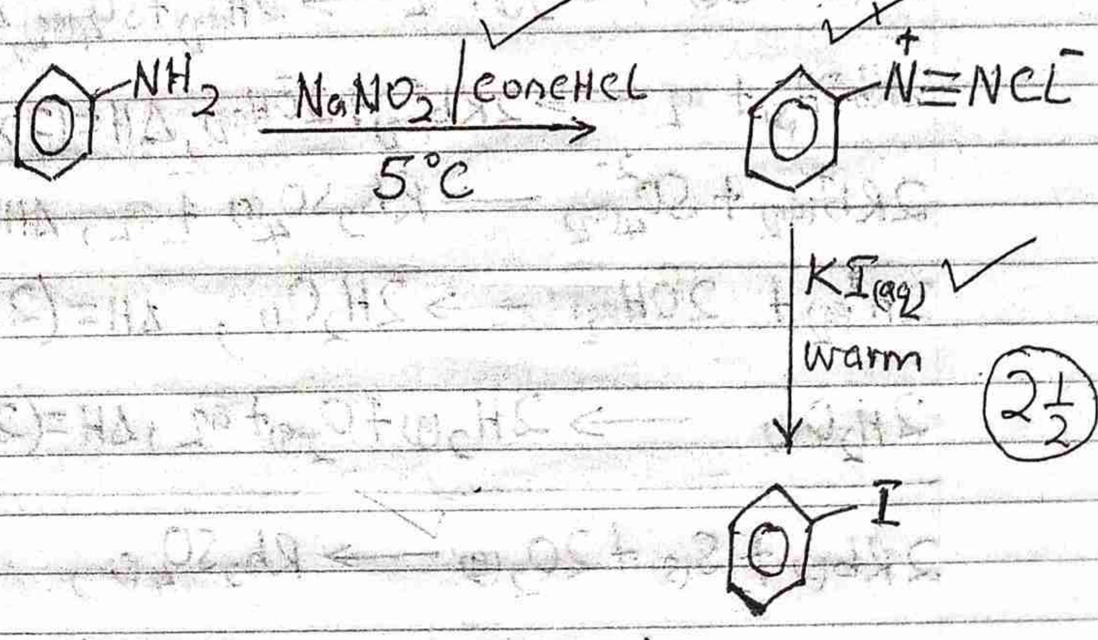
03

(ii)



03

(iii)



$2\frac{1}{2}$

$\boxed{\text{Total = 20 Mks.}}$

Question 6.

(a)

(i) It is the amount of heat given out or absorbed when one mole of a substance in its standard state is formed from its elements in their standard states at a temperature of 25°C and a pressure of one atmosphere.

①

(ii) It is the amount of heat given out or absorbed when one mole of a substance dissolves in water to form an infinitely dilute solution (without a change in PH) at a temperature of 25°C and a pressure of one atmosphere.

①

(b)

$2Rb_{(s)} + O_{2(g)} + H_{2(g)} \longrightarrow 2RbOH, \Delta H = (2 \times {}^{-}414)$ KJ.

$H_{2(g)} + S_{(s)} + 2O_{2(g)} + aq \longrightarrow 2H^{+}_{(aq)} + SO^{2-}_{4(aq)}, \Delta H = {}^{-}907.5$ KJ

$2RbOH_{(s)} + aq \longrightarrow 2Rb^{+}_{(aq)} + 2\bar{O}H_{(aq)}, \Delta H = (2 \times {}^{-}62.8)$ KJ

$2Rb^{+}_{(aq)} + SO^{2-}_{4(aq)} \longrightarrow Rb_2SO_{4(s)} + aq, \Delta H = {}^{-}24.3$ KJ

$2H^{+}_{(aq)} + 2\bar{O}H_{(aq)} \longrightarrow 2H_2O_{(l)}, \Delta H = (2 \times {}^{-}57.3)$ KJ.

$2H_2O_{(l)} \longrightarrow 2H_{2(g)} + O_{2(g)} + aq, \Delta H = (2 \times {}^{+}285.0)$ KJ.

$2Rb_{(s)} + S_{(s)} + 2O_{2(g)} \longrightarrow Rb_2SO_{4(s)},$

$\Delta H = {}^{-}828 + {}^{-}907.5 + {}^{-}125.6 + {}^{-}24.3$

$+ {}^{-}114.6 + 570$

$= {}^{-}1,430$ KJmol^{-1}

(C)

(i) A known volume ($V\ cm^3$) of water is put in a plastic beaker, a thermometer inserted in the water and its temperature ($\theta_1 °C$) noted.

A known mass (m g) of rubidium sulphate is introduced into the water. The mixture is stirred using a thermometer and the lowest (minimum) temperature ($\theta_2 °C$) attained noted.

Treatment of Results.

Assuming:

specific heat capacity of solution = specific heat capacity of water

$= 4.2\ Jg^{-1}K^{-1}$.

Temperature drop, $\theta = (\theta_1 - \theta_2)°C$.

Mass of solution $= (m+V)g$.

Heat absorbed by dissolving salt $= [(m+V) \times 4.2 \times \theta]\ J$.

Let RFM of Rb_2SO_4 be M

moles of $Rb_2SO_4 = \frac{m}{M}$

$\frac{m}{M}$ moles of Rb_2SO_4 absorb $[(m+V) \times 4.2 \times \theta]\ J$.

1 mole of Rb_2SO_4 absorbs $\left[\frac{(m+V) \times 4.2 \times \theta \times M}{m}\right] J$

$= \left[\frac{(m+V) \times 4.2 \times \theta \times M}{1000m}\right] KJ$

$\therefore$ Heat of Solution $= +\left[\dfrac{(m+V) \times 4.2 \times \theta \times M}{1000m}\right] KJmol^{-1}$

6

(ii) $\Delta H_{Hyd.}(Rb_2SO_4) = (2 \times {}^-301) + {}^-560$

$= {}^-602 - 560$

$= {}^-1162\ KJmol^{-1}.$

$\Delta H_{soln} = \Delta H_{lat.} + \Delta H_{Hyd.}$	OR $\Delta H_{soln} = {}^-\Delta H_{lat.} + \Delta H_{Hyd.}$
$\therefore 24.3 = \Delta H_{lat.} + {}^-1,162$	$\therefore 24.3 = {}^-\Delta H_{lat.} + {}^-1,162$
$\Delta H_{lat.} = 24.3 + 1,162$	$\Delta H_{lat.} = {}^-1,162 - 24.3$
$= {}^+\underline{1,186.3\ KJmol^{-1}}.$	$= \underline{{}^-1,186.3\ KJmol^{-1}}.$

4

(d)
$$\begin{tikzcd}[column sep=small]
2C_{(s)} + 3H_{2(g)} + O_{2(g)} \arrow[rr, "\Delta H_f"] \arrow[dr, "O_{2(g)}\ \Delta H_1"', "3/2O_{2(g)}\ \Delta H_2"] & & CH_3CH_2OH \arrow[dl, "3/2O_{2(g)}\ \Delta H_3"] \\
& 2CO_{2(g)} + 3H_2O_{(l)} &
\end{tikzcd}$$

$\Delta H_f + \Delta H_3 = \Delta H_1 + \Delta H_2$

$\Delta H_f + {}^-1371 = (2 \times {}^-394) + (3 \times {}^-285.8)$

$= {}^-788 + {}^-857.4$

4

$= {}^-1645.4 + 1371$

$= \underline{{}^-274.4\ KJmol^{-1}.}$

Question 7

(a) Aminobenzene and water are immiscible When this mixture is agitated, each component exerts its own vapour pressure independent of the other.

Hence each component contributes its vapour pressure to that of the other-thus increasing the vapour pressure of the component. Hence each component requires less heat energy to increase it's now higher vapour pressure and make it equal to atmospheric pressure

4

(b) chloroethanoic acid is a stronger acid than ethanoic acid.

In chloroethanoic acid, the chlorine atom has a higher electronegativity than that of Carbon. Thus the chlorine atom draws bonding electrons towards itself.

This effect of electron-pull in the direction of the chlorine atom is transmitted to the carboxyl group, resulting into making the oxygen-hydrogen bond more polar, weaker and easier to break to release a proton.

In ethanoic acid, CH_3COOH, the methyl group has a positive inductive effect. This group pushes electrons in the direction of the carboxyl group, reducing polarity of the oxygen-hydrogen bond and making it stronger and harder to break to release a proton.

$4\frac{1}{2}$

(c) Both lithium and sodium ions have the same ionic charge but lithium ion has a smaller ionic radius.
This makes lithium ion to have a higher charge density and thus attracts a larger shell of water molecules to itself which makes it heavier and slower during conduction of electric current.

3½

(d) The chromium (III) ion, Cr^{3+} has a high charge density and thus undergoes hydrolysis forming the insoluble chromium (III) hydroxide and releasing hydrogen ions.

ie
$$Cr^{3+}_{(aq)} + 3H_2O_{(l)} \rightleftharpoons Cr(OH)_{3(s)} + 3H^+_{(aq)}$$

The hydrogen ions react with sodium hydrogencarbonate liberating carbondioxide gas.

ie. $H^+_{(aq)} + HCO_{3(aq)}^- \longrightarrow CO_{2(g)} + H_2O_{(l)}$.

4½

(e) Methanoic acid, $H-\overset{O}{\overset{\|}{C}}-OH$ contains an aldehyde group, ($H-\overset{O}{\overset{\|}{C}}-$) which enables the acid to reduce the purple manganate (VII) ion to colourless manganese(II) ion.

ie.
$$5H\overset{O}{\overset{\|}{C}}-OH_{(aq)} + 2MnO_4^-{}_{(aq)} + 6H^+_{(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + 5CO_{2(g)} + 8H_2$$

3½

Total = 20 Mks

Question 8

(a) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ ✓ ①

(ii) $CuFeS_2$ ✓, Copper pyrites ✓ ①

(b) Copper pyrites are crushed ✓ and agitated with water containing a frothing agent. ✓
Air is blown ✓ through the mixture forming a froth. ✓
The ore rises ✓ to the surface in the froth. Earthy materials are wetted by water and they sink ✓ to the bottom. ✓
The froth is skimmed off. ✓ An acid is added to the froth to break it down.
The froth is filtered and the ore dried. ✓
The ore is roasted in air ✓ to obtain Iron (II) oxide, ✓ Copper (I) sulphide ✓ and sulphur dioxide. ✓

$$2CuFeS_{2(s)} + 4O_{2(g)} \longrightarrow Cu_2S_{(s)} + 2FeO_{(s)} + 3SO_{2(g)}$$ ✓

The ore is heated with Silicon (IV) oxide ✓ in the absence ✓ of air to form Iron (II) Silicate ✓ liquid, which is poured away.

$$FeO_{(s)} + SiO_{2(s)} \longrightarrow FeSiO_{3(l)}$$ ✓

The ore is heated ✓ in a controlled amount of air to convert it to impure copper ✓ and sulphur dioxide.

$$Cu_2S_{(s)} + O_{2(g)} \longrightarrow 2Cu_{(s)} + SO_{2(g)}$$ ✓

[OR $2Cu_2S_{(s)} + 3O_{2(g)} \longrightarrow 2Cu_2O_{(s)} + 2SO_{2(g)}$]

$Cu_2S_{(s)} + 2Cu_2O \longrightarrow 6Cu + SO$ [cut off]

The impure copper is purified by electrolysis using copper (II) sulphate as electrolyte, impure copper as anode and pure copper as cathode.

(1) Pure copper is deposited at the cathode.

$$Cu^{2+}_{(aq)} + 2e \longrightarrow Cu_{(s)}$$ (1 1/2)

(C) (i) Copper is oxidised by concentrated nitric acid to copper (II) nitrate, the other products being nitrogen dioxide and water.

ie. $Cu_{(s)} + 4HNO_{3(aq)} \longrightarrow Cu(NO_3)_{2(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$ (2)

(ii) Copper is oxidised by concentrated sulphuric acid to copper (II) sulphate, the other products being sulphur dioxide and water.

ie. $Cu_{(s)} + 2H_2SO_{4(aq)} \longrightarrow CuSO_{4(aq)} + SO_{2(g)} + 2H_2O_{(l)}$ (2)

(d) (i) A brown precipitate was formed. (1)

(ii) $2Cu^{2+}_{(aq)} + Fe(CN)^{4-}_{6(aq)} \longrightarrow Cu_2Fe(CN)_{6(s)}$ (1 1/2)

$\boxed{\text{Total} = 20 \text{ MKS.}}$