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Q1 a(i) Percentage of oxygen = 100 − (64.9 + 13.5) = 21.6 %

Elements	C	H	O
moles	$\frac{64.9}{12}$	$\frac{13.5}{1}$	$\frac{21.6}{16}$
	5.4083	13.5	1.35
mole ratio	$\frac{5.4083}{1.35}$	$\frac{13.5}{1.35}$	$\frac{1.35}{1.35}$
	4	10	1

Empirical formula of Q is $C_4H_{10}O$ ✓ 3

(ii) $PV = \frac{Mass}{Mr} \times RT$

$101325 \times 969.8 \times 10^{-6} = \frac{1.85}{Mr} \times 8.31 \times 473$

$Mr = 74$

$(C_4H_{10}O)n = 74$

$(12 \times 4 + 10 + 16)n = 74$

$74n = 74$

$n = 1$ 3

Mf of Q is $C_4H_{10}O$

(b) $CH_3CH_2CH_2CH_2OH$ Butan-1-ol

$CH_3\underset{OH}{C}HCH_2CH_3$ Butan-2-ol 4

$CH_3\underset{CH_3}{C}HCH_2OH$ 2-Methylpropan-1-ol

$CH_3\underset{OH}{\overset{CH_3}{\overset{|}{C}}}-CH_3$ 2-Methylpropan-2-ol

Reject if molecular mass is not calculated or wrong

(c) $CH_3\underset{OH}{C}HCH_2CH_3$ OR Butan-2-ol 1

(d) (i) $CH_3\underset{OH}{C}HCH_2CH_3 \xrightarrow[heat]{CrO_3/H^+} CH_3\overset{O}{\overset{\|}{C}}CH_3$ 1 1

Accept $Cr_2O_7^{2-}/H^+$ 12

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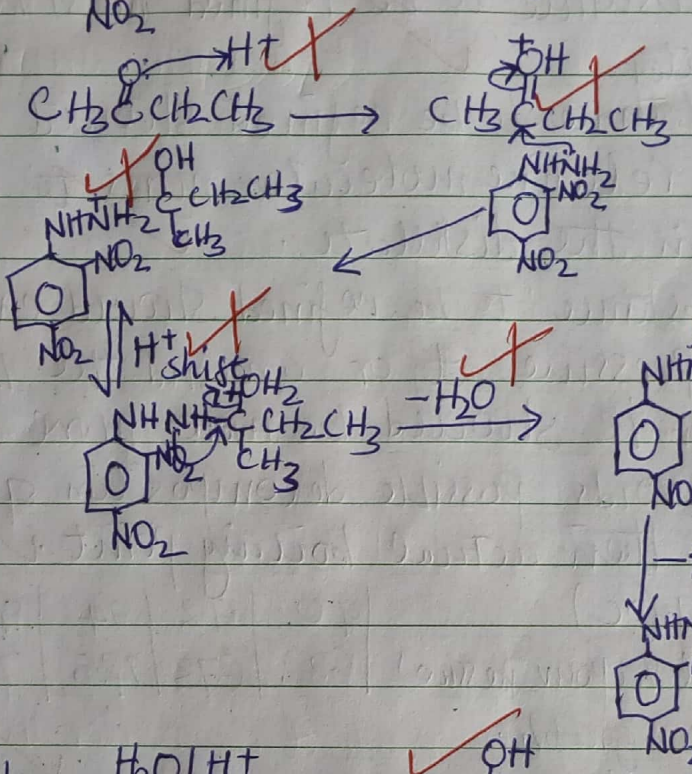
(ii) $CH_3CCH_2CH_3$ + 2,4-dinitrophenylhydrazine $\xrightarrow{H^+}$ 2,4-dinitrophenylhydrazone of $CH_3CCH_2CH_3$ (N=C(CH3)CH2CH3)

Mechanism:



(e) $CH_3CH=CHCH_3 \xrightarrow[\text{Heat}]{H_2O/H^+} CH_3CH(OH)CH_2CH_3$

Mechanism: $CH_3CH=CHCH_3 \xrightarrow{H^+} CH_3\overset{+}{C}HCH_2CH_3 \xrightarrow{:OH_2} CH_3CH(\overset{+}{O}H_2)CH_2CH_3 \xrightarrow{-H^+} CH_3CH(OH)CH_2CH_3$

$4\frac{1}{2}$ $3\frac{1}{2}$ 08

Q2 (a) When a mixture of two immiscible liquids is agitated, each component exerts its independent vapour pressure, the vapour pressure of the mixture is the sum of the vapour pressure of the independent components and the vapour pressure increases with increase in temperature. The mixture boils when the sum of the vapour pressure equals atmospheric pressure at a temperature lower than

$3\frac{1}{2}$

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the boiling point of either of the liquids.

b (i) - The substance to be refined must be immiscible with water.
- The substance to be refined should have a high ~~vapour~~ relative molecular mass to increase its yield in the distillate.
- The substance to be refined should exert a high vapour pressure at or around the boiling point of water ie should be ~~more~~ more volatile.

(ii) It avoids possible decomposition of some compounds close to their actual boiling point.

3

(c) (i)

temp(°C)	90	92	94	96	98	100
Total Vapour pressure	622	673	725	781	839	901

1

See graph.

(ii) Boiling point of the mixture = 95 ± 0.4°C Show from graph 1

(iii) Vapour pressure of water = 640 MMHg
Vapour pressure of C_6H_5Br = 120 MMHg
Rfm of H_2O = 1×2 + 16×1 = 18
Rfm of C_6H_5Br = 12×6 + 5 + 80 = 157

$$\frac{\text{Mass of } H_2O}{\text{Mass of } C_6H_5Br} = \frac{VP_{H_2O} \times Rfm \text{ of } H_2O}{VP \text{ of } C_6H_5Br \times Rfm \text{ of } C_6H_5Br}$$

3½

~~let~~ the percentage of C_6H_5Br be x%
% age of H_2O = (100 - x)%

$$\frac{100-x}{x} = \frac{640 \times 18}{120 \times 157}$$

$x = 62.05\%$ OR 62%

(d) - By introducing a mixture of water and bromobenzene into a separating funnel OR by - Using Calcium oxide.

Any one 2

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(To be fastened together with other answers to paper)

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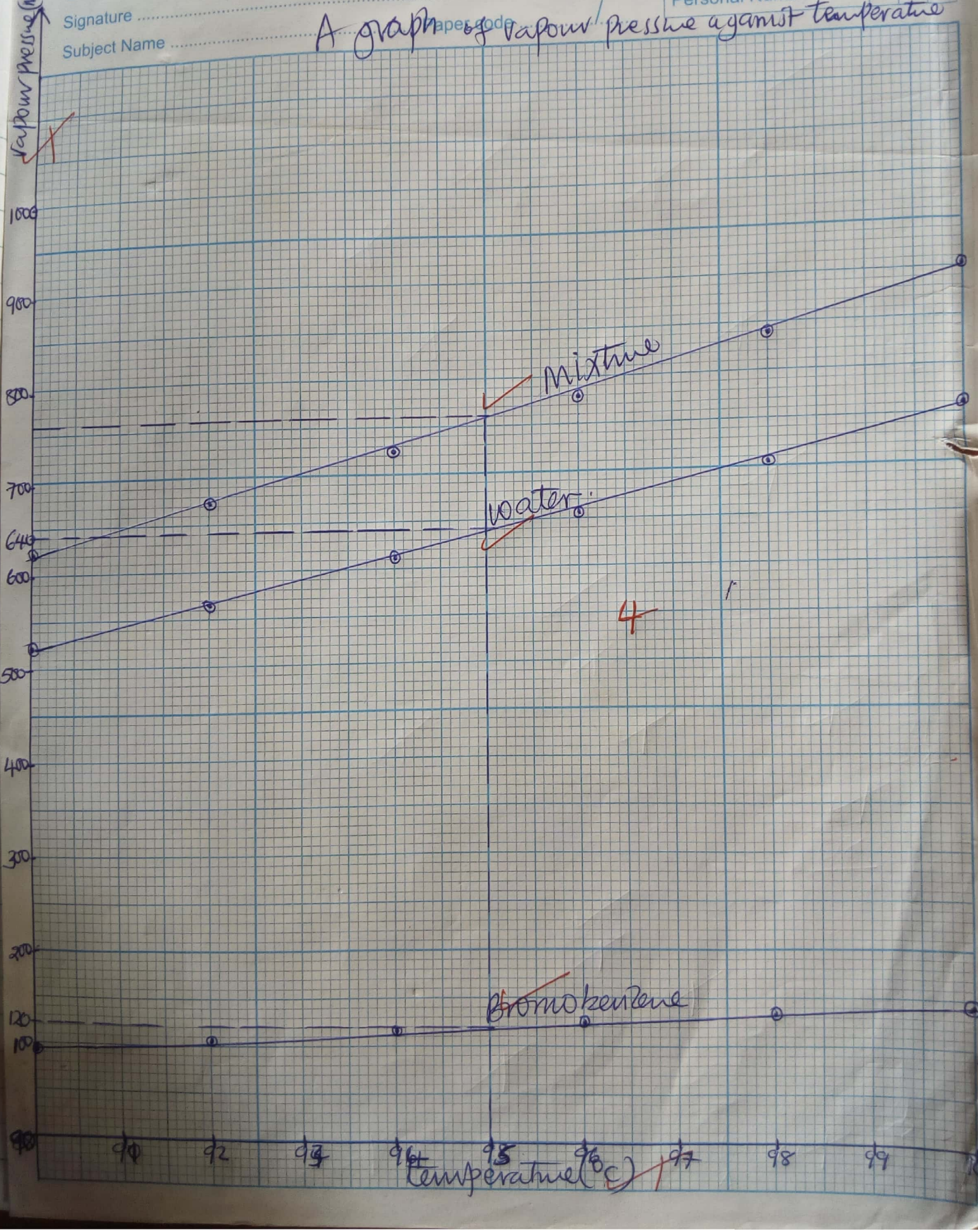
A graph of vapour pressure against temperature



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(e) - Its used to purify organic compounds. 1
- Its used to separate organic compounds like 2-nitrophenol and 4-nitrophenol. Any one
- It can be used to establish relative molecular mass of compounds.

(3) (a) (i) Solubility product is the product of molar concentrations of the ions of a sparingly soluble electrolyte raised to appropriate powers in a saturated solution at a given temperature OR Consider lead(II) sulphate as a sparingly soluble electrolyte 3

$PbSO_4(s) \rightleftharpoons Pb^{2+}(aq) + SO_4^{2-}(aq)$

$K_{sp} = [Pb^{2+}][SO_4^{2-}]$.

(ii) Is the precipitation of a sparingly soluble electrolyte from its saturated solution by adding a solution of a more soluble electrolyte containing one of its ions. OR Using example. 3

(b)(i) Excess magnesium hydroxide is added to ~~water~~ a known volume of water in a flask. The mixture is shaken and left to settle at constant temperature ~~to~~ to reach equilibrium. The mixture is filtered and a known volume pipetted and titrated with a standard solution of hydrochloric acid using methyl orange indicator. 4½

$Mg(OH)_2(aq) + 2HCl(aq) \longrightarrow MgCl_2(aq) + 2H_2O(l)$

The molar concentration of Magnesium hydroxide is calculated. If the molar concentration is $c\ moldm^{-3}$ 10½

$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$

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$K_{sp} = [Mg^{2+}][OH^-]^2$

$= c(2c)^2 = 4c^3 \ mol^3 dm^{-9}$. H2

(ii) The Conductivity of Magnesium hydroxide is measured. The molar Conductivity of Magnesium at infinite dilution is determined by adding the molar Conductivities of ions of Magnesium ions and hydroxide at infinite dilution.

$\lambda_o Mg(OH)_2 = \lambda_o Mg^{2+}(aq) + 2\lambda_o OH^-(aq)$

The solubility of Magnesium hydroxide is Calculated using the expression $\lambda c = K$ or $\lambda c = 1000K$, $s = c$

$K_{sp} = [Mg^{2+}][OH^-]^2$

$K_{sp} = c(2c)^2 = 4c^3 \ mol^3 dm^{-9}$.

(ii) Consider $PbSO_4(s) \rightleftharpoons SO_4^{2-}(aq) + Pb^{2+}(aq)$.

If the solubility product is greater than the ionic products of the ions, the solution is unsaturated and more of the electrolyte dissolves.

If the solubility product is equal to the ionic product of the ions in the solution, the solution is saturated and no more of the electrolyte dissolves. 3.

If the solubility product is less than the ionic product of the ions in the solution, precipitation occurs.

(c)(i) $CaSO_4(s) \rightleftharpoons Ca^{2+}(aq) + SO_4^{2-}(aq)$.

$K_{sp} = [Ca^{2+}][SO_4^{2-}]$

let $[Ca^{2+}] = s = [SO_4^{2-}]$

$K_{sp} = s^2$

$s^2 = 2.4 \times 10^{-5} \ mol^2 dm^{-6}$ 2

$s = 4.899 \times 10^{-3} \ mol \ dm^{-3}$

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(ii) Let the Solubility of $CaSO_4$ be x mol dm^{-3}
$[Ca^{2+}] = x$ $[SO_4^{2-}] = x + 0.5 \simeq 0.5$
$2.4 \times 10^{-5} = 0.5x$
$x = 4.8 \times 10^{-5}$ mol dm^{-3}.

(d) - Temperature must be Constant
- Electrolyte must be sparingly soluble by one
- The solution must be Saturated.

(4) (a) Carbon dioxide has a simple molecular structure with molecules held by weak Vander waals forces. Silicon (IV) oxide and germanium (IV) oxide have giant Covalent structure held by strong Covalent bonds. Germanium has a bigger atomic radius than silicon which makes the Covalent bonds in germanium (IV) oxide weaker than that in Silicon (IV) oxide. Tin (IV) oxide and lead (IV) oxide have giant ionic structures with strong ionic bonds. The ionic radius of Sn tin (IV) ion is smaller than that of lead (IV) ion. Therefore the ionic bonds in lead (IV) oxide are weaker than those in tin (IV) oxide.

(b) Carbon dioxide is acidic and reacts with dilute alkalis to form Carbonates and water.

$2OH^-(aq) + CO_2(g) \longrightarrow CO_3^{2-}(aq) + H_2O(l)$

Other dioxides do not react with dilute alkalis.

Silicon (IV) oxide reacts with dilute hydrofluoric acid to form Silicon tetrafluoride and water or Hexafluorosilicic acid and water.

$SiO_2(s) + 6HF(aq) \longrightarrow H_2SiF_6(aq) + 2H_2O(l)$

Other dioxides are acidic and donot react with dilute acids.

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or $SiO_2(s) + 4HF(aq) \longrightarrow SiF_4(g) + 2H_2O(l)$.

(c) Brown solid dissolves with effervescence/bubbles of greenish yellow gas. 3½

$PbO_2(s) + 4HCl(aq) \longrightarrow PbCl_2(aq)(s) + 2H_2O(l) + Cl_2(g)$.

(d) Sulphur dioxide reduces lead(IV) oxide to lead(II) sulphate. 4½

$PbO_2(s) + SO_2(g) \longrightarrow PbSO_4(s)$

or $PbO_2(s) + SO_2(g) \longrightarrow PbO(s) + SO_3(g)$.
$PbO(s) + SO_3(g) \longrightarrow PbSO_4(s)$. 8

(5) (a) $C_6H_5Cl \xrightarrow[350^\circ C / 150-200\,atm]{NaOH(s)} C_6H_5ONa \xrightarrow{dil\ H^+} C_6H_5OH \xrightarrow[heat]{Zn\ dust} C_6H_6$. 4

For any wrong intermediate or reagents stop marking.

or $C_6H_5Cl \xrightarrow[(ii)\ CO_2\ (iii)\ H_2O/H^+]{(i)\ Mg/Dry\ ether} C_6H_5COOH \xrightarrow[heat]{NaOH(s)/CaO(s)} C_6H_6$ 4

or $C_6H_5Cl \xrightarrow[CH_3Br]{Na/Dry\ ether} C_6H_5CH_3 \xrightarrow[heat]{MnO_4^-/OH^-} C_6H_5COO^- \xrightarrow[CaO(s)]{heat/NaOH(s)} C_6H_6$

or $C_6H_5Cl \xrightarrow[high\ pressure,\ 200^\circ C]{NH_3/Cu_2O} C_6H_5NH_2 \xrightarrow[0-5^\circ C]{NaNO_2/Conc.\ HCl} C_6H_5N_2^+$

$C_6H_5N_2^+ \xrightarrow{H_3PO_2} C_6H_6$

$C_6H_5N_2^+ \xrightarrow[50^\circ C]{H_2O} C_6H_5OH \xrightarrow[heat]{Zn\ dust} C_6H_6$

or $C_6H_5Cl \xrightarrow[CH_3Br]{Na/Dry\ ether} C_6H_5CH_3 \xrightarrow[H_2,\ 600^\circ C]{Al_2O_3/Pt} C_6H_6$

or $C_6H_5Cl \xrightarrow[425^\circ C]{H_2O/Si} C_6H_5OH \xrightarrow[heat]{Zn\ dust} C_6H_6$

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(b) $CH_3CH(OH)CH_2CH_3 \xrightarrow[heat]{Cr_2O_7^{2-}/H^+} CH_3COCH_2CH_3 \xrightarrow{PCl_5} CH_3C(Cl)CH_2CH_3$ 4½

$CH_3CH(OH)CH_2CH_3 \xrightarrow[170^oC]{Conc.H_2SO_4} CH_3CH=CHCH_3 \xrightarrow{Cl_2/CCl_4} CH_3CH(Cl)CH(Cl)CH_3$

$CH_3CH(OH)CH_2CH_3 \xrightarrow{PCl_5} CH_3CH(Cl)CH_2CH_3$

$CH_3CH=CHCH_3 \xrightarrow[heat]{KOH/C_2H_5OH} CH_3CH(Cl)CH_2CH_3$

$CH_3C(Cl)CH_2CH_3 \xrightarrow[heat]{KOH/C_2H_5OH} CH_3C\equiv CCH_3$

$CH_3C\equiv CCH_3 \xrightarrow[heat]{KOH/C_2H_5OH} CH_3CH(Cl)CH(Cl)CH_3$

(c) $CH_3CH_2CH_2OH \xrightarrow[170^oC]{Conc.H_2SO_4} CH_3CH=CH_2$

$CH_3CH=CH_2 \xrightarrow[heat]{H_2O/H^+} CH_3CH(OH)CH_3$ 5

$CH_3CH(OH)CH_3 \xrightarrow[heat]{Cr_2O_7^{2-}/H^+} CH_3COCH_3$

$CH_3CH=CH_2 \xrightarrow{Br_2/CCl_4} CH_3CH(Br)CH_2Br$

$CH_3CH=CH_2 \xrightarrow{HBr} CH_3CH(Br)CH_3$

$CH_3CH(Br)CH_2Br \xrightarrow[heat]{KOH/C_2H_5OH} CH_3C\equiv CH$

$CH_3CH(Br)CH_3 \xrightarrow[heat]{OH^-(aq)} CH_3CH(OH)CH_3$

$CH_3C\equiv CH \xrightarrow[HgSO_4,\ 60^oC]{Conc.H_2SO_4/H_2SO_4} CH_3COCH_3$

(d) $C_6H_5CH=CH_2 \xrightarrow[heat]{H_2O/H^+} C_6H_5CH(OH)CH_3$

$C_6H_5CH(OH)CH_3 \xrightarrow[heat]{Cr_2O_7^{2-}/H^+} C_6H_5COCH_3$ 4½

$C_6H_5CH=CH_2 \xrightarrow{Cl_2/CCl_4} C_6H_5CH(Cl)CH_2Cl$

$C_6H_5CH(Cl)CH_2Cl \xrightarrow[heat]{KOH/C_2H_5OH} C_6H_5C\equiv CH$

$C_6H_5C\equiv CH \xrightarrow[HgSO_4,\ 60^oC]{Conc.H_2SO_4/H_2O} C_6H_5COCH_3$

$C_6H_5COCH_3 \xrightarrow{C_6H_5NHNH_2/H^+} C_6H_5C(CH_3)=NNHC_6H_5$

(e) $CH_3CH_2OH \xrightarrow{PCl_5} CH_3CH_2Cl \xrightarrow{Na/Dry\ ether} CH_3CH_2CH_2CH_3$ 2

$CH_3CH_2OH \xrightarrow[180^oC]{Conc.H_2SO_4} CH_2=CH_2 \xrightarrow{HCl} CH_3CH_2Cl$

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6 (a)(i) Concentration of sulphur trioxide increases. The position of equilibrium shifts from left to right. Excess sulphur dioxide reacts with oxygen to form sulphur trioxide. H2

(ii) Concentration of sulphur trioxide decreases. The forward reaction proceeds with decrease in volume. The pressure of the system will decrease if volume is increased decreasing the concentration of sulphur trioxide. H2

(iii) Concentration of sulphur trioxide increases because the forward reaction is exothermic. H2

(b) $P_{SO_3} = 1.0 - (0.27 + 0.41) = 0.32$ atm

$$K_p = \frac{P^2_{SO_3}}{(P^2_{SO_2})(P_{O_2})} = \frac{(0.32)^2}{(0.27)^2(0.41)} = 3.43 \text{ atm}^{-1}$$ 4 3

(c)(i) $H_2SO_4(l) + SO_3(g) \longrightarrow H_2S_2O_7(l)$

$H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4(aq)$ 3

(ii) $1\,cm^3$ of solution contains $\left(\frac{1.84 \times 98}{100}\right)$ g of sulphuric acid

$1000\,cm^3$ of solution contains $\left(\frac{1.84 \times 98}{100}\right) \times 1000$

$= 1,803.2\,g\,l^{-1}$ 3

RFM of $H_2SO_4 = 2\times1 + 32 + 16\times4 = 98$

Molarity of $H_2SO_4 = \frac{1803.2}{98} = 18.4\,M$.

Since volume of 0.2M is 98 not given

(d)(i) The solution changes to reddish brown (fumes). Concentrated sulphuric acid oxidises hydrobromic acid to bromine and itself reduced to sulphur dioxide and water 3

$H_2SO_4(l) + 2HBr(aq) \longrightarrow Br_2(l/g) + SO_2(g) + 2H_2O(l)$

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(11) The solution changes to brown or black solid formed. Concentrated sulphuric acid oxidises hydroiodic acid to iodine or hydrogen sulphide and itself reduced to sulphur or sulphur dioxide or hydrogen sulphide and water 3½

$H_2SO_4(l) + 8HI(aq) \longrightarrow 4I_2(s) + H_2S(g) + 4H_2O(l)$

or $H_2SO_4(l) + 2HI(aq) \longrightarrow I_2(s) + SO_2(g) + 2H_2O(l)$

or $H_2SO_4(l) + 6HI(aq) \longrightarrow 3I_2(s) + S(s) + 4H_2O(l)$.

(7) (a) (i) Saponification

$$\begin{array}{l} CH_2-O-C(=O)-R \\ | \\ CH-O-C(=O)-R \\ | \\ CH_2-O-C(=O)-R \end{array} + 3NaOH(aq) \longrightarrow 3RCOONa(aq) + C_3H_8O_3(aq)$$

2½

(ii) Simsim / Sunflower / Cotton seed oil / Animal fats / Vegetable oil. ½

(b) (i) The animal fat is boiled with concentrated sodium hydroxide solution while stirring until it completely dissolves. The solution is cooled and concentrated sodium chloride solution added. Soap floats and is skimmed off. 5

(ii) Benzene is reacted with alkyl chain alkene or alkyl halide in the presence of an acid / aluminium chloride to form alkyl benzene. The alkyl benzene is heated with concentrated sulphuric acid to form a sulphonic acid which is reacted with sodium hydroxide solution to form a detergent / alkyl benzene sulphonate.

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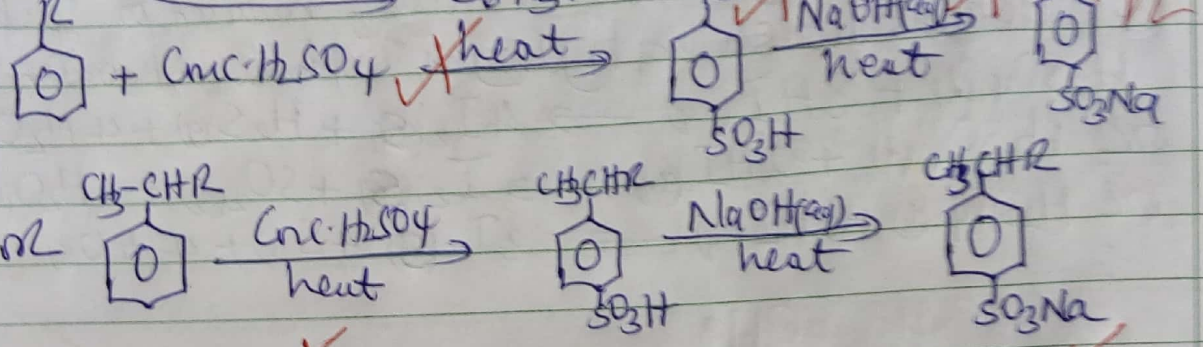
$C_6H_6 + RCH=CH_2 \xrightarrow{H^+} C_6H_5CHR$ (CH3)

OR $\xrightarrow{RX/AlCl_3} C_6H_5R$



OR A long chain alcohol is reacted with Cold Concentrated Sulphuric acid to form an alkyl hydrogen Sulphate. The alkyl hydrogen Sulphate is reacted with Sodium hydroxide solution to form a detergent.

$RCH_2OH \xrightarrow{Conc.H_2SO_4} RCH_2OSO_3H \xrightarrow{NaOH(aq)} RCH_2OSO_3Na$

(b)(iii) The Soap molecules has an alkyl group which is hydrophobic and Carboxylate group which is hydrophilic. The alkyl group is attracted to the dirt/oil which reduces the surface tension between the water and the oil or dirt. The dirt particles are removed and suspended in water (or emulsified) 4½

(c)(i) Soap reacts with hard water to form Scum and hence leads to wastage. 2

(ii) Soapless detergents are non-biodegradable which leads to pollution. They also contain inorganic phosphates. 2

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(8) (a) $CuFeS_2$.

(b) The ore is crushed and mixed with water containing a frothing agent. Air is blown through the mixture. The ore particles float as the impurities sink to the bottom. The froth is skimmed off and dilute sulphuric acid added to break down the particles. It is then filtered and dried. 1 3

(ii) $2CuFeS_2(s) + 4O_2(g) \longrightarrow Cu_2S(l) + 2FeO(s) + 3SO_2(g)$. 3

$Cu_2S(s) + O_2(g) \longrightarrow 2Cu(l) + SO_2(g)$.

OR $2Cu_2S(l) + 3O_2(g) \longrightarrow 2Cu_2O(l) + 2SO_2(g)$

$Cu_2S(l) + 2Cu_2O(l) \longrightarrow 6Cu(l) + SO_2(g)$

(iii) To remove impurities of iron (slag)

(iv) A solution containing copper(II) ions is electrolysed using impure copper as anode and pure copper as the cathode. Pure copper is deposited at the cathode. 3

Anode; $Cu(s) \longrightarrow Cu^{2+}(aq) + 2e$

Cathode, $Cu^{2+}(aq) + 2e \longrightarrow Cu(s)$.

(c) (i) Copper(II) ions oxidises iodide ions into iodine as the copper(II) ions are reduced to copper(I) iodide 2½

$2Cu^{2+}(aq) + 4I^-(aq) \longrightarrow 2CuI(s) + I_2(aq)$

OR $2Cu^{2+}(aq) + 4I^-(aq) \longrightarrow Cu_2I_2(s) + I_2(aq)$.

(ii) Insoluble copper(II) hydroxide is formed and reacts with excess ammonia to form a soluble complex tetraammine copper(II) ion. 4

$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$

$Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow Cu(NH_3)_4^{2+}(aq) + 2OH^-(aq)$

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(ii) Insoluble basic copper(II) carbonate is formed 2½

$2\bar{O}H_{(aq)} + CO_3^{2-}{}_{(aq)} + Cu^{2+}{}_{(aq)} \longrightarrow CuCO_3(OH)_{2(s)}$

OR $3Cu^{2+}{}_{(aq)} + 2CO_3^{2-}{}_{(aq)} + 2\bar{O}H_{(aq)} \longrightarrow Cu(OH)_2 2CuCO_{3(s)}$.

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READ THE INSTRUCTIONS BELOW CAREFULLY BEFORE USING THE ANSWER BOOKLET.

1. Use a blue or black ink ball pen. Work in pencil, other than graphs and drawings, will **not** be marked.
2. List the question numbers, in the order attempted, in the left-hand column of the boxes opposite.
   Do **not** list the multiple choice questions.
3. Write your answers on both sides of each sheet.
4. Do your rough work in this answer booklet. Cross through any work you do not want marked.
5. Do **not** fold, dismantle or tear any part of the answer booklet. Do **not** accept an answer booklet with missing pages. Folding, dismantling or tearing of the answer booklet is a malpractice and shall lead to cancellation of results. All work must be handed in.
6. Check that you have written the information required on each additional answer booklet used. Tie all the booklets used together.
7. Do **not** share your work with another candidate or expose your work such that another candidate can copy from it. Sharing or exposing your work may lead to cancellation of results.
8. Answer only the number of questions as instructed on the question paper. Answers to extra questions will **not** be marked.

Question number attempted	For Examiners' use only	
	Mark	**Examiners' initials**
Total		

Write here the number of answer booklets you have used.	