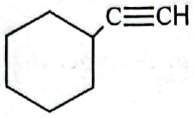
SECTION A (46 MARKS)

1. Name the reagent(s) that can be used to distinguish between the following compounds. In each case state what would be observed when each compound is separately treated with the reagent.

(a)  and  *(2 marks)*

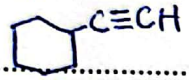
Reagent(s)

Ammoniacal silver nitrate solution ✓

OR Ammoniacal copper(I) chloride solution.

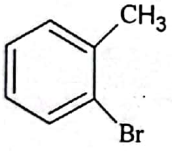
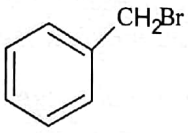
Observation:

 - No observable change ✓

 - White precipitate. ✓ 2

OR  - No observable change.

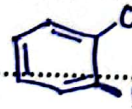
 - Red precipitate

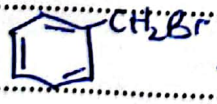
(b)  and  *(2 marks)*

Reagent(s)

Hot sodium hydroxide solution followed by dilute nitric acid and silver nitrate solution. ✓

Observation:

 - No observable change. ✓

 - Pale yellow precipitate. ✓ 2

04

2. (a) A buffer solution was obtained by mixing 8.3 g of ethanoic acid and 16 g of sodium ethanoate in 1 litre of distilled water. Calculate the pH of the buffer solution if 0.70 cm^3 of 1 M hydrochloric acid is added. *[the acid dissociation constant, K_a, for ethanoic acid at 25°C is 1.8×10^{-5} mol l^{-1}]* *(3 ½ marks)*

RFM of $CH_3COOH = 24+4+32 = 60$

RFM of $CH_3COONa = 24+3+32+23 = 82$

$[CH_3COOH] = \frac{8.3}{60} = 0.138M$ ✓

$[CH_3COONa] = \frac{16}{82} = 0.195M$ ✓

Moles of $HCl = \frac{0.7 \times 1}{1000} = 7.0 \times 10^{-4}$ moles ✓

New $[CH_3COOH] = 0.138 + 7.0 \times 10^{-4} = 0.1387M$

New $[CH_3COONa] = 0.195 - 7.0 \times 10^{-4} = 0.1943M$

$[H^+] = Ka \times \frac{[CH_3COOH]}{[CH_3COONa]}$ ✓

$= 1.8 \times 10^{-5} \times \frac{0.1387}{0.1943} = 1.28 \times 10^{-5}M$ ✓

$pH = -\log_{10}[H^+]$ ✓

$= -\log_{10}(1.28 \times 10^{-5}) = 4.89$ ✓ $3\frac{1}{2}$

Assumption: $[CH_3COO^-] = [salt]$ ✓

(b) State **two** applications of buffer solutions *(1 mark)*

- Maintenance of pH of body fluid (blood) ✓
- Fermentation. ✓ 1
- Manufacture of medicines/drugs.
- Making culture medium in microbiology.

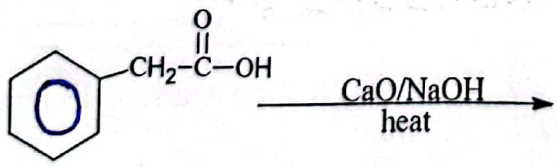
$0 4\frac{1}{2}$

3. Complete the following equations and in each case name the major product(s)

(a) $(CH_3COO)_2Ca \xrightarrow{heat}$ $CH_3\overset{O}{\overset{\|}{C}}CH_3$ ✓

Name of product *(1 ½ marks)* $\frac{1}{2}$

Propanone ✓

(b) 

✓

Name of product *(1 ½ marks)* $\frac{1}{2}$

Methylbenzene ✓

(c) $CH_3CH_2CON(CH_3)_2 \xrightarrow[heat]{\bar{O}H/H_2O}$ $CH_3CH_2COOH + (CH_3)_2NH$ ✓ ✓

Name of product(s) *(2 marks)*

Propanoic acid ✓

Dimethylamine ✓ 2

05

4. (a) The following data of results was obtained for the reaction

$$2NO_{(g)} + Cl_{2(g)} \rightleftharpoons 2NOCl_{(g)}$$

Experiment No.	Initial concentration (mol dm^{-3})		Initial rate $\frac{d[NOCl]}{dt}$ (mol l^{-1} s^{-1})
	$[Cl_2]$	[NO]	
1	0.10	0.10	1×10^{-4}
2	0.10	0.20	4×10^{-4}
3	0.30	0.10	3×10^{-4}

(i) Deduce the order of reaction with respect to

- Chlorine *(1 mark)*

order 1 ✓ 1

- Nitrogen(II) oxide *(1 mark)*

order 2 ✓ 1

(ii) Write the rate equation for the reaction. *(½ mark)*

Rate = $K[Cl_2][NO]^2$ ✓ ½

(b) Calculate the rate constant, **K**, for the reaction and state its units. *(1½ marks)*

$K = \frac{Rate}{[Cl_2][NO]^2} = \frac{1 \times 10^{-4}}{(0.10)(0.10)^2}$ ✓

$= 0.1$ ✓ $mol^{-2} L^2 s^{-1}$ ✓ 1½

04

5. A white crystalline solid **Z** decomposes on heating leaving a yellow residue. When **Z** is warmed with concentrated sulphuric acid, a gas is evolved which burns with a blue flame and had no effect on lime water. **Z** dissolves in dilute nitric acid forming a colourless solution. The solution decolourises alkaline potassium manganate(VII) solution and forms a reddish-brown solution when reacted with iron(III) chloride.

(a) Identify **Z** *(½ mark)*

Lead(II) methanoate ✓ or $(HCOO)_2Pb$ ..... ½

(b) Write equations for the reactions that took place when **Z**

(i) Decomposed to a yellow residue *(1 ½ marks)*

$(HCOO)_2Pb(s) \longrightarrow PbO(s) + HCHO(g) + CO_2(g)$ ✓✓ 1½

(ii) was warmed with concentrated sulphuric acid *(1 ½ marks)*

$(HCOO)_2Pb(s) + H_2SO_4(l) \longrightarrow PbSO_4(s) + 2CO(g) + 2H_2O(l)$ ✓✓ 1½

(iii) solution was reacted with iron(III) chloride *(1 ½ marks)*

$3HCOO^-(aq) + Fe^{3+}(aq) \longrightarrow (HCOO)_3Fe(aq)$ ✓✓ 1½

6. State what is observed and write the ionic equations when each of the following pairs of substances are mixed. 05

(a) Aqueous solution of copper(II) sulphate and potassium iodide.

(02 marks)

Observation

White precipitate ✓ in a brown ✓ solution.

Equation

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

(b) Zinc metal and aqueous solution of Iron(III) chloride. *(02 marks)*

Observation

Brown precipitate and bubbles of a colourless gas.

Equation

$2Fe^{3+}_{(aq)} + 3Zn_{(s)} + 6H_2O_{(l)} \longrightarrow 2Fe(OH)_{3(s)} + 3Zn^{2+}_{(aq)} + 3H_{2(g)}$ 2

(c) A saturated aqueous solution of sulphur dioxide and aqueous solution of potassium manganate(VII). *(02 marks)*

Observation

Purple solution turns colourless.

Equation

$2MnO^-_{4(aq)} + 5SO^{2-}_{3(aq)} + 6H^+_{(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + 5SO^{2-}_{4(aq)} + 3H_2O_{(l)}$ 2

06

7. The standard electrode potentials for some half-cell reactions are given below

Half-cell reaction	E^θ/V
$MnO^-_{4(aq)} + e^- \rightarrow MnO^{2-}_{4(aq)}$	+0.56
$MnO^{2-}_{4(aq)} + 2H_2O_{(l)} + 2e^- \rightarrow MnO_{2(s)} + 4\bar{O}H_{(aq)}$	+0.60
$MnO^-_{4(aq)} + 8H^+_{(aq)} + 5e^- \rightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)}$	+1.52
$Br_{2(aq)} + 2e^- \rightarrow 2Br^-_{(aq)}$	-1.06

(a) Write the

(i) cell convention of the cell formed when bromine half-cell is combined with the cell of acidified potassium manganite(VI) *(1 mark)*

$Pt_{(s)}/Br^-_{(aq)}, Br_{2(aq)} // MnO^{2-}_4/MnO_2, \bar{O}H_{(aq)}/Pt_{(s)}$ 1

(ii) Overall cell reaction in a(i). *(1 mark)*

$2Br^-_{(aq)} + MnO^{2-}_{4(aq)} + 2H_2O_{(l)} \longrightarrow MnO_{2(s)} + Br_{2(aq)} + 4\bar{O}H_{(aq)}$ 1

(b) Calculate the electromotive force of the cell in (a). *(1 mark)*

$E^{\ominus}_{cell} = E^{\ominus}_{Right} - E^{\ominus}_{Left}$

$= 0.60 - (-1.06) = +1.66V$ 1

(c) State what would happen when a solution of potassium manganate(VI) is exposed to air and write equation for the reaction that took place. *(2 marks)*

Observation:

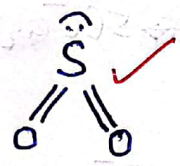
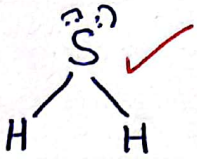
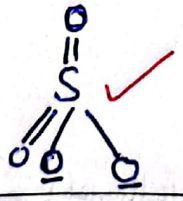
Green solution turns purple and black/brown solid formed

Equation

$3MnO_4^{2-}(aq) + 2H_2O_{(l)} \longrightarrow 2MnO_4^{-}(aq) + MnO_{2(s)} + 4OH^{-}(aq)$ 2

05

8. Draw the structures and name the shapes for the following species. *(4½ marks)*

species	Structure	Name
(i) SO_2		V-shape / Bent shape
(ii) H_2S		V-shape / Bent shape
(iv) SO_4^{2-}		Tetrahedral

4½

9. (a) Explain briefly why chlorine is a stronger oxidising agent than bromine. *(2 marks)*

The electrode potential values becomes less positive down the group due to decrease in atomisation energy, electron affinity and hydration energy of the ions. This reduces their oxidising power down the group as atomic radius increases, thus chlorine is a stronger oxidising agent than bromine. 2

(b) Write equation(s) for the reaction of chlorine and bromine with

(i) cold dilute sodium hydroxide.

Chlorine *(1½ marks)*

$Cl_2(g) + 2\bar{O}H(aq) \longrightarrow Cl^-(aq) + ClO^-(aq) + H_2O(l)$ 1½

Bromine *(1½ marks)*

$Br_2(l) + 2\bar{O}H(aq) \longrightarrow Br^-(aq) + BrO^-(aq) + H_2O(l)$ 1½

(ii) hot concentrated sodium hydroxide

Chlorine *(1½ marks)*

$3Cl_2(g) + 6\bar{O}H(aq) \longrightarrow 5Cl^-(aq) + ClO_3^-(aq) + 3H_2O(l)$ 1½

Bromine *(1½ marks)*

$3Br_2(l) + 6\bar{O}H(aq) \longrightarrow 5Br^-(aq) + BrO_3^-(aq) + 3H_2O(l)$ 1½

08

SECTIONB

(Attempt any six questions)

Additional questions answered will **not** *be marked.*

10. Write equations to show how the following compounds can be synthesized. Indicate the reagents and conditions for the reaction.

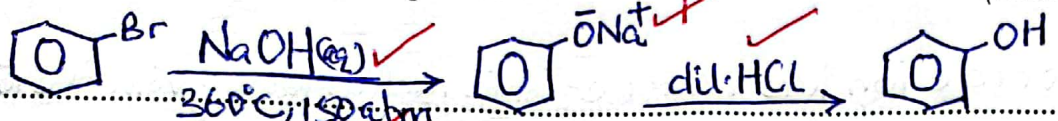
(a) ethene to propanoic acid *(03 marks)*

$CH_2=CH_2 \xrightarrow{HBr} CH_3CH_2Br \xrightarrow[\text{heat}]{KCN/\text{Ethanol}} CH_3CH_2CN \xrightarrow[\text{heat}]{H^+/H_2O} CH_3CH_2COOH$ 3

OR

$CH_2=CH_2 \xrightarrow{HBr} CH_3CH_2Br \xrightarrow[\text{dry ether}]{Mg} CH_3CH_2MgBr \xrightarrow[(2)\ H_2O/H^+]{(1)\ CO_2} CH_3CH_2COOH$

(b) bromobenzene to phenol *(03 marks)*



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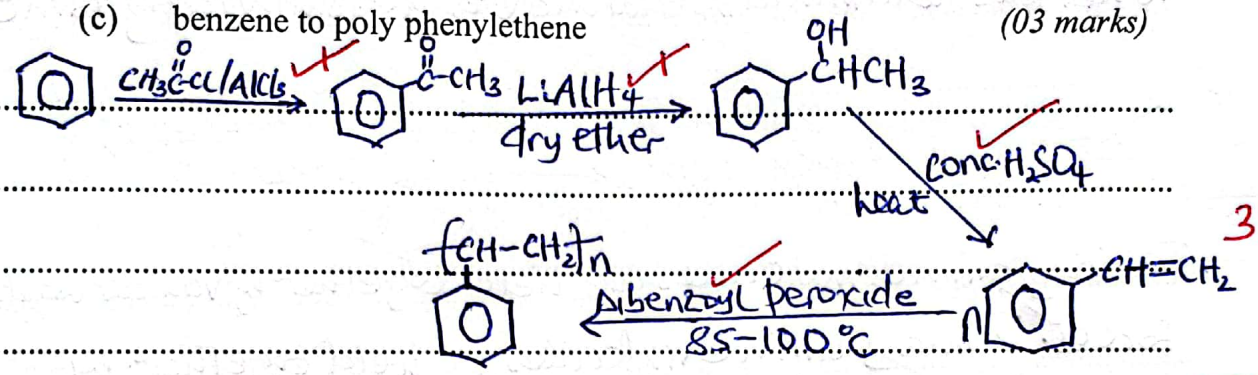
(c) benzene to poly phenylethene *(03 marks)*



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11. Explain each of the following observations

(a) Berrylium carbonate is thermally less stable than calcium carbonate *(03 marks)*

Beryllium ion has a smaller ionic radius than calcium ion, hence has higher charge density/Polarising power than calcium ion. Thus beryllium carbonate is less ionic (mainly covalent) whereas calcium carbonate is mainly ionic. Beryllium carbonate easily decomposes than calcium carbonate.

3

(b) Aluminium fluoride is purely ionic whereas aluminium bromide is covalent *(03 marks)*

Fluoride ion has a smaller ionic radius than bromide ion. Aluminium ions with very high charge density can easily polarise the bromide ions than fluoride ions. Aluminium bromide is predominantly covalent whereas aluminium fluoride is predominantly ionic. 3

(c) The boiling points of tertiary amines are lower than those of primary amines with the same molecular masses. *(03 marks)*

Tertiary amines molecules are held together by van der waals forces. Primary amine molecules are held together by hydrogen bonds. The hydrogen bonding forces are stronger than the van der waals forces. 3

In tertiary amines there is no hydrogen atom bonded to nitrogen atom. In primary amines there is lone hydrogen atom bonded to nitrogen atom, which has a higher electronegativity

12. Sulphur dioxide reacts with oxygen according to the following equation: 09

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} \quad \Delta H^{\phi} = -97\ kJ\ mol^{-1}$$

(a) State the actual conditions for the reaction that favour maximum yield of sulphur trioxide. *(1½ marks)*

Low temperature.
High pressure.
Vanadium(V) oxide catalyst
Excess oxygen. 1½

(b) State what would happen to the concentration of sulphur trioxide in the equilibrium mixture and give a reason for your answer if

(i) the temperature is increased *(1½ marks)*

Increasing temperature shifts the equilibrium position from right to left since the forward reaction is endothermic, therefore the concentration of sulphur trioxide decreases. 1½

(ii) nitrogen gas is added to the mixture at constant pressure. *(1½ marks)*

Adding nitrogen gas increases the volume of the system to keep pressure constant. The equilibrium position shifts from right to left, therefore the concentration of sulphur trioxide decreases. 1½

(c) The equilibrium mixture of the above reaction at 700°C was found to contain 0.40 mol of sulphur dioxide, 0.30 mol of oxygen and 1.00 mol of sulphur trioxide in a 2 litre vessel.

(i) Write the expression for the equilibrium constant, K_c. *(1 mark)*

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$ 1

(ii) Calculate the value of K_c for the reaction at 700°C. *(3½ marks)*

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

	$2SO_2(g)$	$O_2(g)$	$2SO_3(g)$
Moles at equilibrium	0.40	0.30	1.00
Moles per litre at equilibrium	$\frac{0.40}{2}$	$\frac{0.30}{2}$	$\frac{1.00}{2}$
	0.20	0.15	0.50

$$K_c = \frac{(0.5)^2}{(0.20)^2(0.15)}$$ 3½

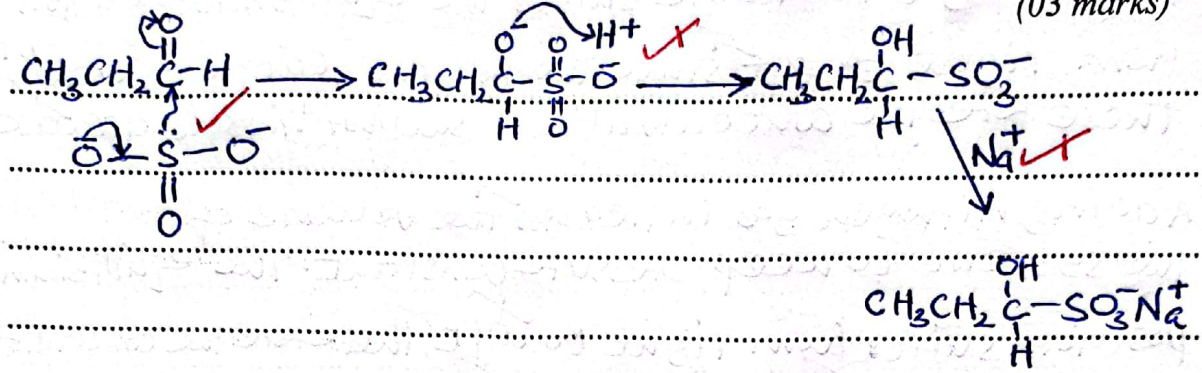
$$= 41.6667 \text{ mol}^{-1}\text{L}$$

09

13. Complete the following equations and in each case write the accepted mechanisms for the reactions

(a) $CH_3CH_2\overset{O}{\overset{\|}{C}}H \xrightarrow[H^+]{Na_2SO_3} CH_3CH_2\underset{H}{\overset{OH}{C}}-SO_3^-Na^+$

(03 marks)



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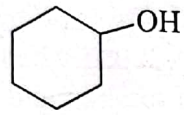
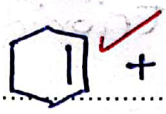
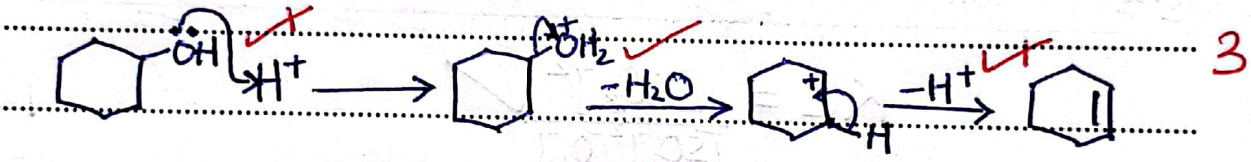
(b)  $\xrightarrow[\text{heat}]{H_3PO_4}$  $+ H_2O$

(03 marks)



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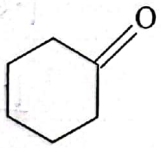
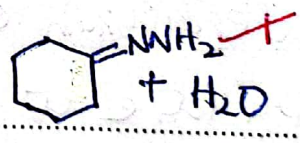
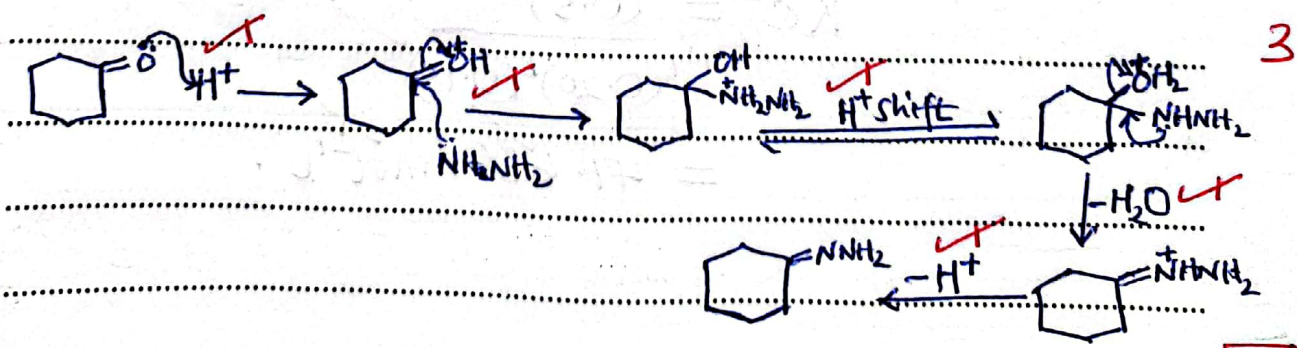
(c)  $\xrightarrow{NH_2NH_2/\,H^+}$ 

(03 marks)



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14. (a) A compound **P** contains carbon, hydrogen and oxygen. When 0.0291 g of P was burnt, it gave 0.0581 g of carbon dioxide and 0.0239 g of water Calculate the empirical formula of P *(3½ marks)*

% of Carbon $= \frac{12}{44} \times \frac{0.0581}{0.0291} \times 100 = 54.45\%$

% of hydrogen $= \frac{2}{18} \times \frac{0.0239}{0.0291} \times 100 = 9.13\%$

% of oxygen $= 100 - (54.45 + 9.13)$

$= 36.42\%$

Elements	C	H	O
moles	$\frac{54.45}{12}$	$\frac{9.13}{1}$	$\frac{36.42}{16}$
	$= 4.54$	9.13	2.28
	$\frac{4.54}{2.28}$	$\frac{9.13}{2.28}$	$\frac{2.28}{2.28}$
simplest ratio	2	: 4	: 1

∴ Empirical formula of P is C_2H_4O 3½

(b) When 0.140 g of P was vapourised at 20°C at 740 mm Hg pressure, it occupied a volume of 39.5 cm^3.

(i) Calculate the molecular mass of P *(2 marks)*

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

$M_r = \frac{0.140 \times 8.31 \times 293 \times 760}{740 \times 101325 \times 39.5 \times 10^{-6}} = 87.5g$ 2

(ii) Determine the molecular formula of P. *(1 mark)*

$(C_2H_4O)_n = 87.5$

$24n + 4n + 16n = 87.5$

$44n = 87.5$

$n = 2$

∴ Molecular formula of P is $C_4H_8O_2$ 1

(c) When P was treated with sodium hydrogen carbonate, effervescence of a colourless gas occurred. P gave a brown ~~precipitate~~ solution when treated with iron(III) chloride solution.

(i) Identify P *(1 mark)*

Butanoic acid OR $CH_3CH_2CH_2COOH$. 1

(ii) Write equation of reaction for the formation of the brown ~~precipitate~~ solution. *(1½ marks)*

$3CH_3CH_2CH_2COO^-_{(aq)} + Fe^{3+}_{(aq)} \longrightarrow (CH_3CH_2CH_2COO)_3Fe_{(aq)}$ 1½

09

15. a) Briefly describe the physical principles involved in the separation of two immiscible liquids *(2½ marks)*

The principle involved is based on the difference in the densities of the liquids in the mixture. The two liquids are taken in a separating funnel and allowed to stand for some time. The cap of the funnel is opened and the heavier liquid is completely run down in a beaker and the lighter liquid remains in the funnel. 2½

(b) Phenylamine and water are immiscible liquids. The saturated vapour pressures of pure phenylamine and pure water at various temperatures are given in the table below.

Temperature/°C	85	90	95	100	105
Phenylamine: Vapour pressure (kPa)	3.0	3.9	4.9	6.1	7.3
Water: Vapour pressure (kPa)	57.9	70.1	84.5	101.3	120
Vapour pressure of mixture (kPa)	60.9	74.0	89.4	107.4	127.3 ½

(i) Plot on the same axes graphs of phenyl amine, pure water and the mixture against temperature. *(3 marks)*

(ii) Using the graphs, determine and state the temperature at which the mixture of phenylamine and water boils
[atmospheric pressure = 101.325 kPa] *(½ mark)*

98°C (±0.5°C) ½

(iii) Calculate the percentage by mass of phenylamine if the distillate mixture was steam distillate. *(2 marks)*

V.P of water = 95.0 kPa
V.P of $C_6H_5NH_2$ = 6.0 kPa
RFM of $C_6H_5NH_2$ = 93

$\frac{\text{Mass of } C_6H_5NH_2 \text{ in distillate}}{\text{Mass of } H_2O \text{ in distillate}} = \frac{V.P_{C_6H_5NH_2} \times M_{C_6H_5NH_2}}{V.P_{H_2O} \times M_{H_2O}}$

$\frac{x}{100-x} = \frac{6.0 \times 93}{95.0 \times 18}$

$x = 24.60\%$ 2

(c) State one advantage of steam distillation over fractional distillation. *(½ mark)*

- It avoids possible decomposition of some compounds close to their boiling points.
- The components are separated at a lower temperature than their actual boiling points. ½

14

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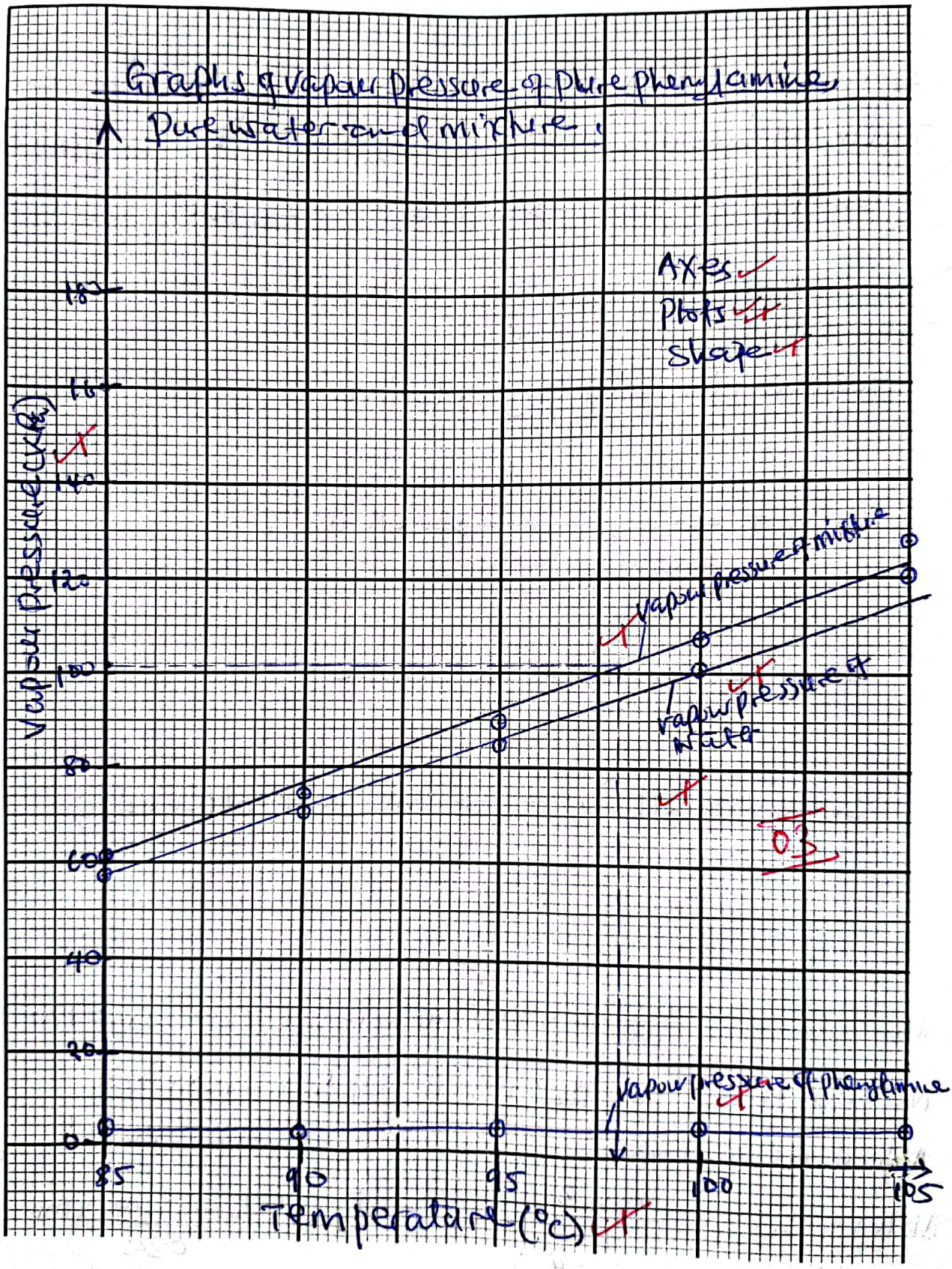
Graphs of vapour Pressure of Pure phenylamine,
Pure water and of mixture
Axes ✓
Plots ✓✓
Shape ✓
Vapour Pressure (KPa)
160
140
120
100
80
60
40
20
0
vapour pressure of mixture
vapour pressure of water
vapour pressure of phenylamine
85
90
95
100
105
Temperature (°C)

16. (a) Compare the thermal stabilities of silicon(IV) chloride and tin(IV) chloride. *[Include equations of reactions if any]* *(2½ marks)*

Silicon(IV) chloride is more stable than tin(IV) chloride.

Tin(IV) chloride decomposes on heating to tin(II) chloride and chlorine.

$SnCl_4(l) \longrightarrow SnCl_2(s) + Cl_2(g)$ ✓✓ 2½

(b) State conditions of reaction between tin and chlorine and write equation of the reaction that took place. *(2½ marks)*

Conditions

Heated tin and dry chlorine.

Equation

$Sn(s) + 2Cl_2(g) \longrightarrow SnCl_4(l)$ ✓✓ 2½

(c) Silicon(IV) chloride was dissolved in water.

(i) State what was observed *(0½ mark)*

White fumes / Misty fumes. ½

(ii) Write equation for the reaction that took place. *(1½ marks)*

$SiCl_4(l) + 2H_2O(l) \longrightarrow SnO_2(s) + 4HCl(aq)/(g)$ ✓✓ 1½

(d) When 0.325 g of silicon(IV) chloride was dissolved in water, the resultant solution required 48 cm^3 of 0.1 M sodium hydroxide for complete neutralisation. Calculate the percentage purity of silicon(VI) chloride. *(2 marks)*

Moles of $NaOH = \frac{48 \times 0.1}{1000} = 4.8 \times 10^{-3}$

$NaOH(aq) + HCl(aq) \longrightarrow NaOH(aq) + HCl(aq)$

Moles of $HCl = 4.8 \times 10^{-3}$

Moles of $SiCl_4 = \frac{4.8 \times 10^{-3}}{4}$

$= 1.2 \times 10^{-3}$ moles

RFM of $SiCl_4 = 28 + 35.5 \times 4 = 170$

Mass of $SiCl_4 = 1.2 \times 10^{-3} \times 170$

$= 0.204$ g

% purity of $SiCl_4 = \frac{0.204}{0.325} \times 100$

$= 62.77\%$ 2

09

17. (a) Silver ethanedioate is sparingly soluble in water. Write:

(i) equation for the solubility of silver ethanedioate in water. *(1½ marks)*

$Ag_2C_2O_4(s) \rightleftharpoons 2Ag^+(aq) + C_2O_4^{2-}(aq)$ ✓✓ 1½

OR $Ag_2C_2O_4(s) + (aq) \rightleftharpoons 2Ag^+(aq) + C_2O_4^{2-}(aq)$

(ii) the expression for the solubility product, K_{sp} of silver ethanedioate. *(½ mark)*

$Ksp = [Ag^+]^2[C_2O_4^{2-}]$ ✓ ½

(b) The solubility product, *Ksp*, of silver ethanedioate is 5.3×10^{-2} mol^3l^{-3} at 25°C. Calculate the concentration of the following ions in a saturated solution of silver ethanedioate.

(i) Silver ions.

Let the solubility of $Ag_2C_2O_4$ be x $moll^{-1}$

$[Ag^+] = 2x\ moll^{-1}$, $[C_2O_4^{2-}] = x\ moll^{-1}$

$5.3 \times 10^{-2} = (2x)^2(x)$ ✓

$x = \sqrt[3]{\frac{5.32 \times 10^{-2}}{4}}$ ✓ *(2½ marks)*

$x = 0.2366\ moll^{-1}$ ✓

$\therefore [Ag^+] = 2 \times 0.2366$ ✓

$= 0.4732\ moll^{-1}$. ✓ 2½

(½ mark)

(ii) Ethanedioate ions

$[C_2O_4^{2-}] = 0.2366\ moll^{-1}$. ✓ ½

(c) Calculate the mass of silver nitrate should be added to the saturated solution in (b) in order to reduce the concentration of the ethanedioate ions to a fifth of its original value. *(2½ marks)*

New $[C_2O_4^{2-}] = \frac{1}{5} \times 0.2366 = 0.04732\ moll^{-1}$ ✓

$5.3 \times 10^{-3} = [Ag^+]^2 \times 0.04372$ ✓

$[Ag^+] = \sqrt{\frac{5.3 \times 10^{-2}}{0.04372}} = 1.0583\ moll^{-1}$ ✓

$[Ag^+]$ need to reduce $C_2O_4^{2-} = 1.0583 - 0.4732 = 0.5851\ moll^{-1}$ ✓ 2½

RFM of $AgNO_3 = 108 + 14 + 48 = 170$

$\therefore$ Mass of $AgNO_3 = 0.5851 \times 170 = 99.467g$ ✓

(d) Sodium ethanedioate solution was added to the solution in (b). State how the concentration of the silver ions was affected and give a reason for your answer. *(1½ marks)*

The concentration of silver ions decreases ✓

Reason. Addition of sodium ethanedioate increases ✓ the concentration of ethanedioate ion which combine ✓ with silver ions to form solid silver ethanedioate. 1½

09