10/4/23

CHAPTER-1
SOLUTIONS   [BINARY LIQUID SOLUTION]

MATTER
├── Pure Substance
│   ├── Element
│   └── Compound
└── Mixtures
    ├── Homogeneous (One phase)
    │   ├── Solid
    │   ├── Liquid
    │   └── Gas
    └── Heterogeneous (More than one phase)
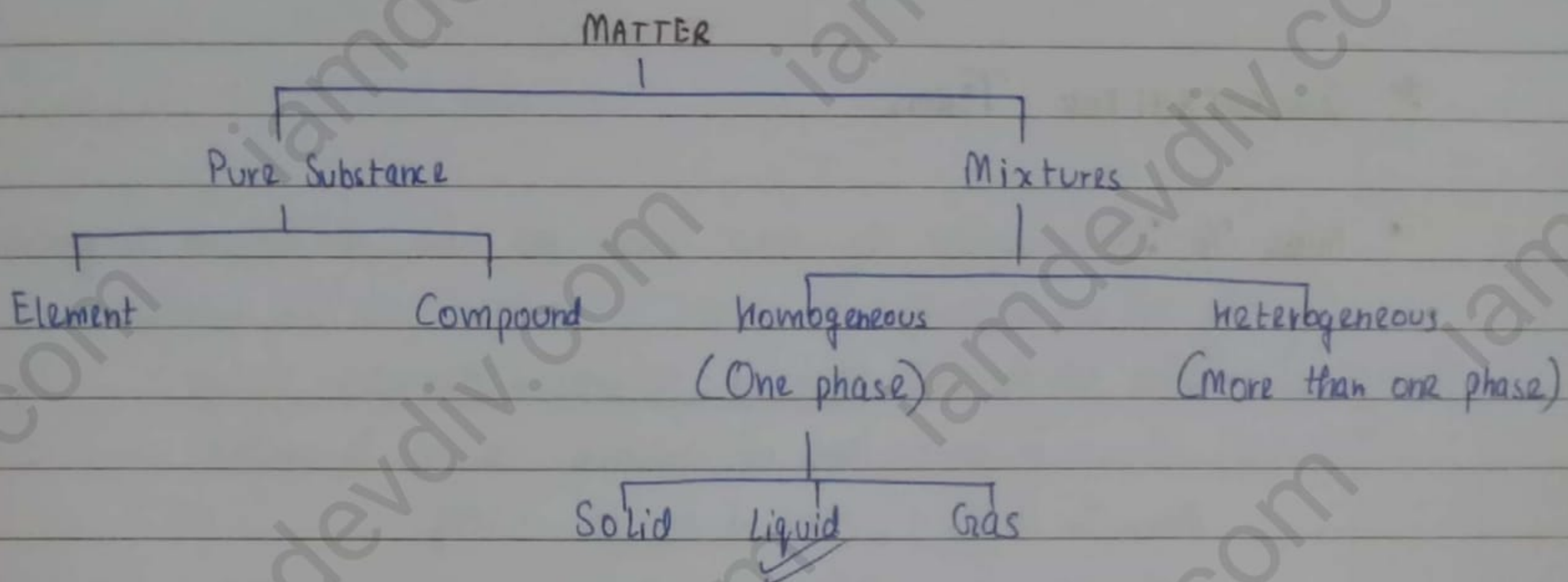
★ CONCENTRATION TERMS

• MASS PERCENT
    ├── (w/w)
    ├── (v/v)
    ├── (w/v)
    └── ppm

• MOLE FRACTION

• MOLARITY

• MOLALITY

★ BINARY LIQUID SOLUTION

SOLUTION ⟨ solute
          solvent (always one)
                   always liquid

NOTE → BINARY ——→ Two components

Solute   Solvent
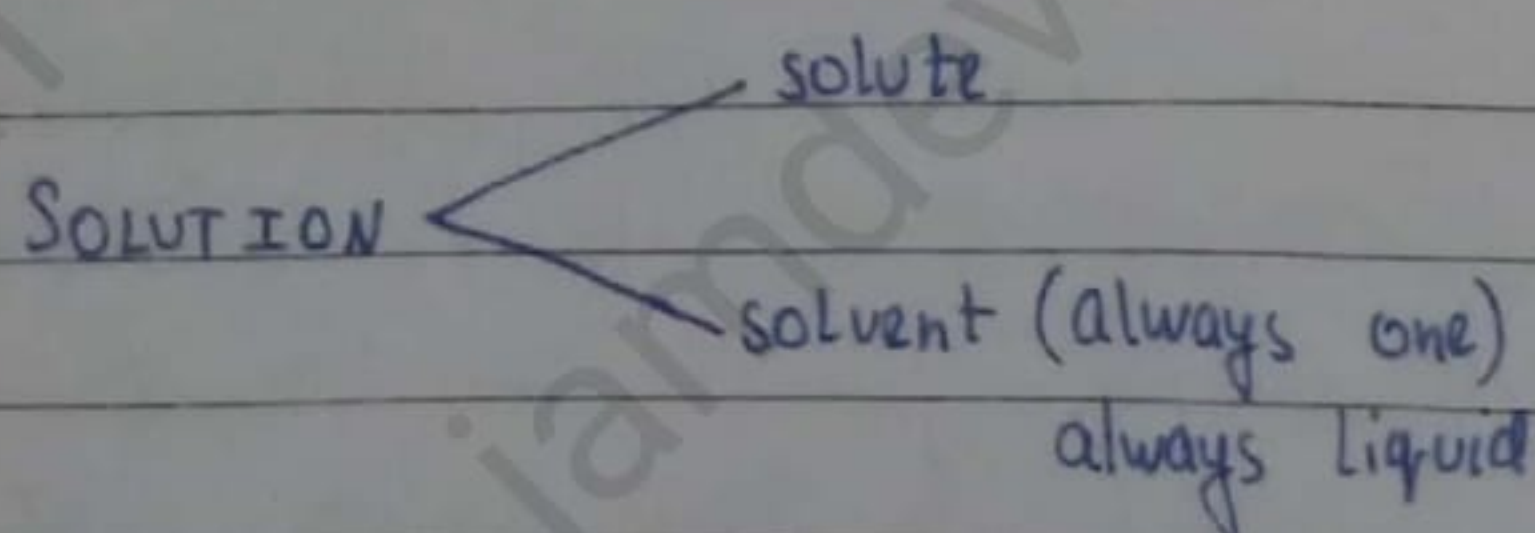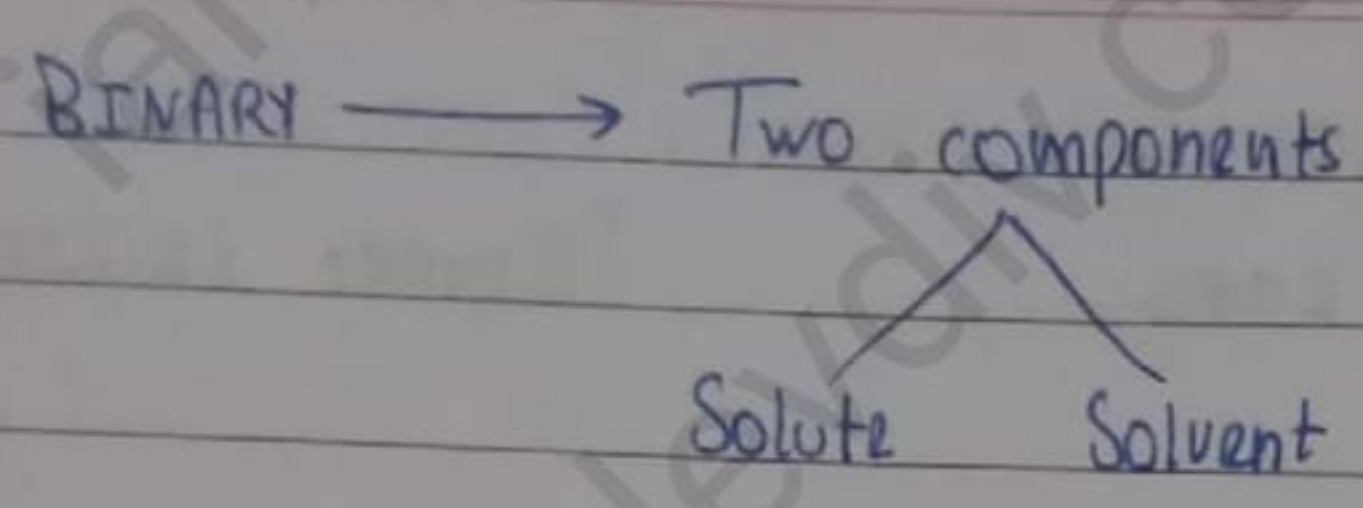
☆ CONCENTRATION TERMS

• MASS % : The Percentage by mass means the mass of solute in grams present in 100g of solution.

$$\text{Mass \% (w/w)} = \frac{\text{Mass of Solute}}{\text{Mass of solution}} \times 100$$

$$\text{Mass \% (w/v)} = \frac{\text{Mass of Solute}}{\text{Volume of solution}} \times 100$$

$$\text{Mass \% (v/v)} = \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100$$

Example: 4% (w/w) ⎱ Mass of solute = 4g
⎰ Mass of solvent = 96g
Mass of solution = 100g

• MOLE FRACTION $[x]$

Mole fraction of constituent is the fraction obtained by dividing number of moles of that constituent by total number of moles, of all constituents present in solution.

$n_1 \rightarrow$ solute, $n_2 \rightarrow$ Solvent

$$\text{Mole fraction of solute } (x_1) = \frac{n_1}{n_1 + n_2}$$

$$x_2 = \frac{n_2}{n_1 + n_2}$$

NOTE → $x_1 + x_2 = 1$

$$\frac{x_1}{x_2} = \frac{n_1}{n_2}$$

Q If a solution contains 4 moles of alcohol and 6 moles of water then what will be mole fraction of both?

Sol. $X_{alcohol} = \dfrac{4}{4+6} = \dfrac{4}{10} = 0.4$ ⎫ Ans

$X_{water} = 1 - 0.4 = 0.6$ ⎭

• MOLARITY (M)

It is defined as the number of moles dissolved per litre of solution.

$$M = \dfrac{\text{no. of moles of solute}}{\text{Volume of Solution (in L)}} = \dfrac{\text{no. of moles of solute} \times 1000}{\text{Volume of solution (in mL)}}$$

Density $= \dfrac{m}{v}$ ⟹ $V = \dfrac{mass}{d} \times density$

$\downarrow$ L $\downarrow$ d $\nearrow kg$ $\neq kg/L$

kg/L OR

$V = \dfrac{mass}{d} \times density$

$\downarrow$ mL $\downarrow$ d $\nearrow g$ $\neq g/mL$

$$M = \dfrac{\text{no. of moles of solute} \times \text{density of solution (g/mL)} \times 1000}{\text{mass of solution (g)}}$$

Q Calculate the molality of solution containing 9.8g H_2SO_4 in 500mL solution.

Sol. $H_2SO_4 \Rightarrow 2 + 32 + 64 \Rightarrow 98 \, g/mol$ 0.5L

$n = \dfrac{9.8}{98.0} = \dfrac{1}{10} = 0.1$ moles

$\begin{array}{r} .2 \\ 5\overline{\smash{)}10}(\\ \underline{10} \\ 8 \end{array}$

Molarity $= \dfrac{0.1}{0.5} = 0.2 \, M$ Ans

• MOLALITY (m)

Molality is defined as the number of moles of solute dissolved in 1 kg of solvent.

$$m = \dfrac{\text{no. of moles of solute}}{\text{mass of solvent (in kg)}} = \dfrac{\text{no. of moles of solute} \times 1000}{\text{mass of Solvent (in g)}}$$

$$m = \frac{\text{no. of moles of solute}}{(\text{mass of solution} - \text{mass of solution})g} \times 1000$$

$$m = \frac{\text{no. of moles of solute}}{(\text{density of solution} \times \text{volume of solution} - \text{mass of solute})g} \times 1000$$

Q Calculate the molality and mole fraction of 2.5g of Ethanoic acid (CH_3COOH) in 75g of Benzene (C_6H_6)

Sol. $CH_3COOH \Rightarrow 24 + 4 + 32 \Rightarrow 60\,g/mol$

$C_6H_6 \Rightarrow 72 + 6 \Rightarrow 78\,g/mol$

Moles of $CH_3COOH \Rightarrow \dfrac{2.5}{600} = \dfrac{1}{24} = 0.0416 \text{ moles}$

Moles of $C_6H_6 \Rightarrow \dfrac{75}{78} = 0.961 \text{ moles}$

$$S_{CH_3COOH} = \frac{n_{CH_3COOH}}{n_{CH_3COOH} + n_{C_6H_6}} = \frac{0.04}{0.04 + 0.961} = \frac{0.04}{1.377}$$

$$= \frac{0.04}{1} = 0.04$$

$$S_{C_6H_6} = 1 - 0.04 = 0.96$$

Molality $= \dfrac{2.5}{2460} \times 1000 = \dfrac{40}{72} = 0.55\,m$

(side calculations)

122
1377
23
4132

24
×6
144

.0416
24)100
  96
   40
   24
  160
  144

.961
78)750
   702
    480
    468
     120

4
78
×6
468

416
961
1377

.3
1377)4410
     4132

Q 4% (w/v) aqueous NaOH solution. Density of solution = 1.0 g/ml.
Find mass percent, mole fraction, molarity and molality.

Sol. Mass of solute = 4g

Volume of solution = 100 ml

Mass of solution = volume × density = 100 × 1 = 100 g

Mass of solvent = 96g

$n_{NaOH} = \dfrac{4}{40} = 0.1$ moles , $n_{H_2O} = \dfrac{96}{18} = 5.5$ moles

$\chi_{NaOH} = \dfrac{0.1}{0.1 + 5.5} = \dfrac{0.1}{5.6} = 0.017$

$\chi_{H_2O} = 1 - 0.017 = 0.983$

Mass percent $= \dfrac{4}{96} \times 100 = 4.167\%$

Molarity $= \dfrac{0.1}{0.1} = .1 \text{ M}$

Molality $= \dfrac{0.1}{96} \times 1000 = \dfrac{100}{96} = 0.104 \text{ m}$

P.T.O.

- EFFECT OF ~~PRESSURE~~ TEMPERATURE ON CONCENTRATION TERMS

The quantities in which volume is involved directly will be affected by temperature.

Mass %   X

Mole fraction   X

Molarity   ✓

Molality   X

Q   Calculate mole fraction of ethylene glycol $\left(\begin{array}{c} CH_2-OH \\ | \\ CH_2-OH \end{array} \right)$ and water in a

solution containing 20% of $C_2H_6O_2$ by mass.

Sol. $\begin{array}{l} CH_2-OH \\ | \\ CH_2-OH \end{array}$ ⟹ 24 + 6 + 32 ⟹ 62 g/mol

20g $C_2H_6O_2$ in 80g water

$n_{C_2H_6O_2}$ ⟹ $\dfrac{20}{62}$ ⟹ $\dfrac{10}{31}$ moles ⟹ 0.32 moles

n_{H_2O} ⟹ $\dfrac{80}{18}$ ⟹ $\dfrac{40}{9}$ ⟹ 4.45 moles

$\chi_{C_2H_6O_2}$ ⟹ $\dfrac{0.32}{0.32+4.45}$ = $\dfrac{0.32}{4.77}$ = 0.067

$$\begin{array}{r} .322 \\ 31 \overline{)100} \\ 93 \\ \overline{70} \\ 62 \\ \overline{80} \\ 62 \end{array}$$

$$\begin{array}{r} 44 \\ 477 \\ \times 6 \\ \overline{2862} \\ +477 \\ \overline{3339} \end{array}$$

$$\begin{array}{r} 4. \\ 9 \overline{)40} \\ 36 \\ \overline{40} \end{array}$$

$$\begin{array}{r} .067 \\ 477 \overline{)3200} \\ 2862 \\ \overline{3480} \\ 3339 \end{array}$$

☆   SOLUBILITY

The amount of solute (maximum amount) which can be dissolved in a specific amount of solvent is called solubility.

- SOLID IN LIQUID

① The solubility of solids in liquid increases on increasing the temperature and vice versa.

② The solubility of solid in liquid is not affected by pressure because

solids are highly incompressible.
Example : Sugar + Water

- GASES IN LIQUID
① The solubility of gases in liquid increases on increasing the pressure.
② The solubility of gases in liquid decreases on increasing temperature.
Example: Soft drink tastes better when chilled (Low temperature)

Q A = The amount of CO_2 dissolved in specific amount of water is independent of temperature.

R = The solubility of gases in liquid is inversely proportional to temperature.

Sol. A is False but R is true.

Q Find the % by mass of ~~spring~~ aspirin in the solution prepared by dissolving 3.65 g of ~~spring~~ aspirin in 25.08g water.

Sol. Total mass of solution = 3.65g + 25.08g = 28.73g

Mass % of aspirin = $\dfrac{3.65 \times 100}{28.73}$ = $\dfrac{36500}{2873}$

= 12.6 % Ans

```
            12.6
      2873 )36500 (
           2873
           7770
           5746
          19 240
          17 238
```

```
   11
  2873
  x 2
  5746
   5 11
  2873
   xx
  17 238
```

Q 20.6g NaBr is dissolved in 500 ml solution. What is the molarity of resulting solution?

Sol. NaBr $\Rightarrow$ 23 + 79.9 $\Rightarrow$ 102.9 g/mol

$$n_{NaBr} = \frac{20.6}{102.9} = 0.2$$

$$Volume = \frac{500}{1000} = 0.5\ l$$

$$Molarity = \frac{0.2}{0.5} = 0.4\ M\ \text{Ans}$$

$$102.9\ )\overline{2060}\ (\ .2 \\ \underline{2058} \\ 2$$

Q If 25ml, 3 molar solution of HNO_3 is mixed with 75 ml of 4 molar HNO_3, If the solution are additive, find the molarity of resulting solution.

Sol. Final molarity $= \dfrac{M_1 V_1 + M_2 V_2}{V_1 + V_2} = \dfrac{3 \times 0.025 + 4 \times 0.075}{0.025 + 0.075} = \dfrac{0.075 + 0.3}{0.1}$

$$= \frac{0.375 \times 10}{0.1}$$

$$= 3.75\ M$$

☆ VAPOUR PRESSURE

At constant temperature, the pressure exerted by vapours of liquid on its surface when rate of evaporation is equal to rate of condensation.
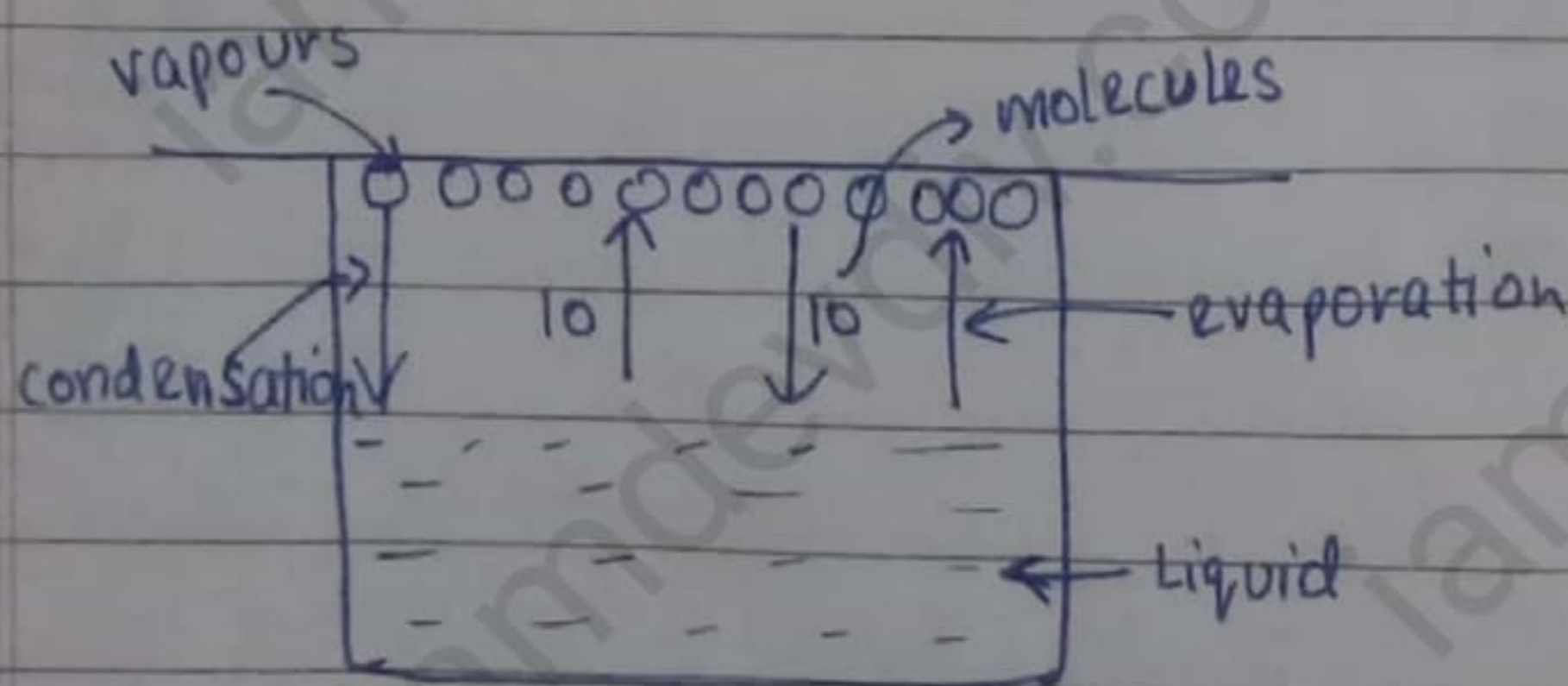
• FACTORS AFFECTING VAPOUR PRESSURE

(i) NATURE OF LIQUID

Q Out of two, H_2O and H_2S whose vapour pressure will be high?

Sol. The vapour pressure of H_2S will be higher because of the presence of hydrogen bonding between ~~more~~ water molecules.
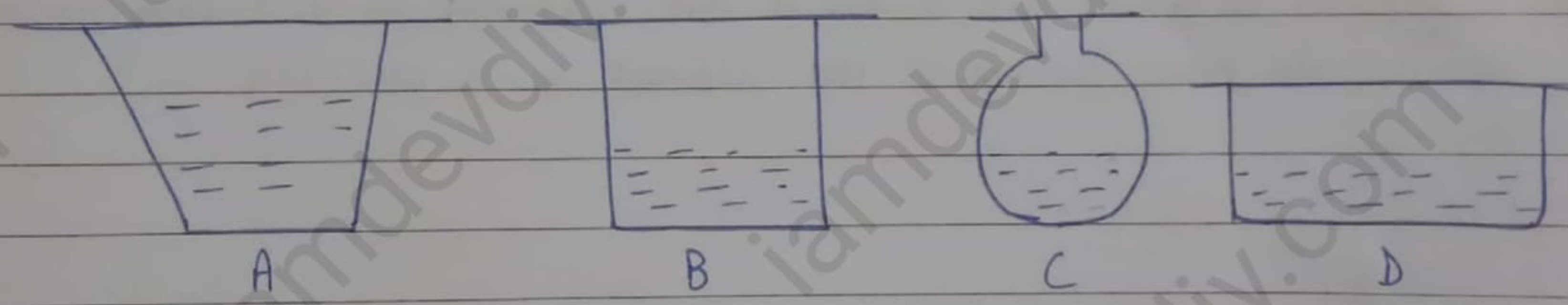
Q Out of two, HF and H_2O whose vapour pressure will be high?

Sol. $H_2O \Rightarrow$ F more electronegative than O $\Rightarrow$ weaker bond in $H_2O \Rightarrow$ more vapour pressure.

(ii) TEMPERATURE

If two same liquids are present on a difference of temperature. The liquid having higher temperature will exert more vapour pressure.

NOTE →

A   B   C   D

Same liquid   (Vapour pressure does not depend upon surface area
Same temperature   of vessel, only depends upon nature and temperature
of liquid)

Q What will be the vapour pressure of a solution of containing 2 moles of liquid A + 3 moles of liquid B.

Given, $P_A^0 = 400$ torr   (A) 550 torr   (C) 290 torr

$P_B^0 = 300$ torr.   (B) 340 torr   (D) 480 torr

Sol. Vapour pressure of solution is always between the pressure of components ∴ (B) 340 torr

Q What will be the vapour pressure of solution containing 8 moles of liquid A + 6 moles of liquid B.

$P_A^0 = 900$ torr

$P_B^0 = 500$ torr

Sol. $P_s = \dfrac{8}{14}(900) + \dfrac{6}{14}(500)$

$\Rightarrow P_s = \dfrac{4}{7}(900) + \dfrac{3}{7}(500)$

$\Rightarrow P_s = \dfrac{3600}{7} + \dfrac{1500}{7}$

$\Rightarrow P_s = \dfrac{5100}{7} = 728.5$ torr

$\begin{array}{r} 728.5 \\ 7\,\overline{)5100}\,(\\ 49 \\ \hline 20 \\ 14 \\ \hline 60 \\ 56 \\ \hline 40 \\ 35 \\ \hline \end{array}$

0_1

- **RAULT'S LAW**

Deals with vapour pressure of solution.

In a solution, vapour pressure of a component at a given temperature is equal to mole fraction of that component in a solution multiplied by the vapour pressure of that component in a pure state.

A   B   A + B

$P_A^o =$ Pure state $P_B^o =$ Pure state P_A, P_B

$P_A \propto S_A$

$P_B \propto S_B$

$P_s = P_A + P_B \underline{\qquad} Ⓐ$

$P_A = P_A^o S_A \underline{\qquad} ①$

$P_B = P_B^o S_B \underline{\qquad} ②$
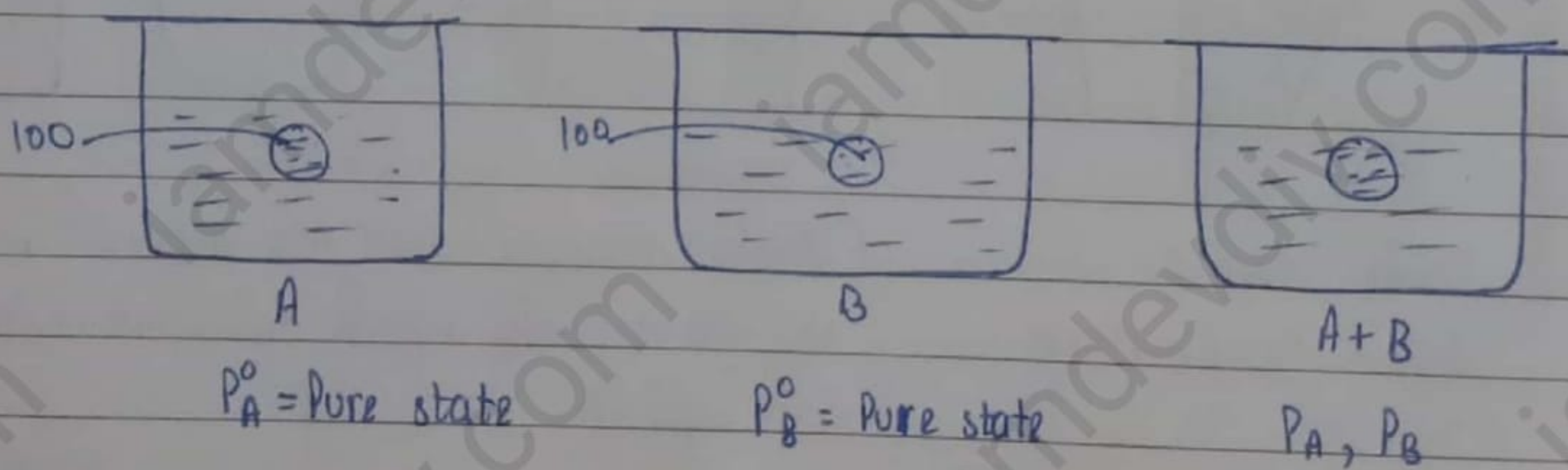
Eq^n ① and ② in Ⓐ

$\Rightarrow \boxed{P_s = P_A^o S_A + P_B^o S_B}$

Q Liquid A and liquid B make ideal solution which contain three moles of A and 2 moles of B. $P_A^o = 800$ torr, $P_B^o = 400$ torr. Find P_s^o.

Sol. $S_A = \dfrac{3}{5}$, $S_B = \dfrac{2}{5}$

$P_s = P_A^o S_A + P_B^o S_B$

$\Rightarrow P_s = \overset{160}{800} \times \dfrac{3}{5} + \overset{80}{400} \times \dfrac{2}{5}$

$\Rightarrow P_s = 480 + 160$

$\Rightarrow P_s = 640$ torr ___

Q Solution made by mixing 2 moles of A and 3 moles of B. $P_A^o = 800$ torr, $P_B^o = 200$ torr. Find P_s.

Sol. $S_A = \dfrac{2}{5}$, $S_B = \dfrac{3}{5}$
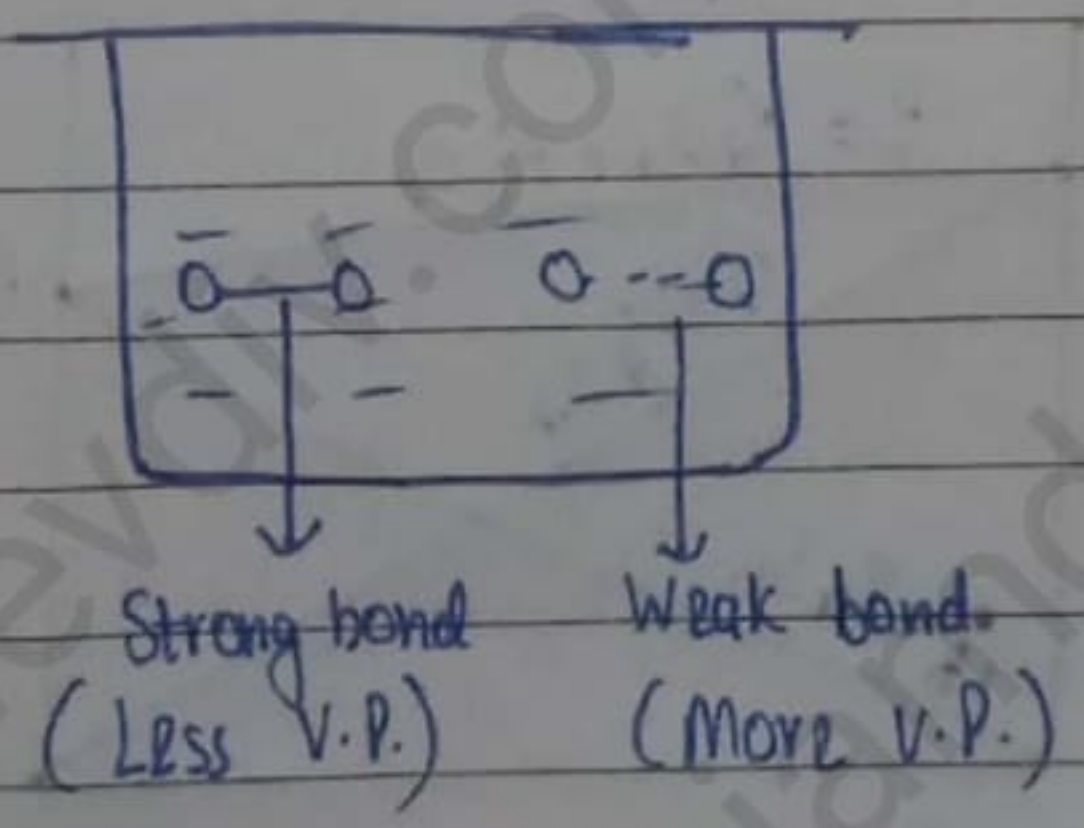
$P_s = P_A^o S_A + P_B^o S_B$

$\Rightarrow P_s = \overset{160}{800} \times \dfrac{2}{5} + \overset{40}{200} \times \dfrac{3}{5}$

$\Rightarrow P_s = 320 + 120$

$\Rightarrow P_s = 440$ torr ___

- **MOLE FRACTION IN VAPOUR PHASE**

For liquid-liquid mixture, the liquid whose vapour pressure is higher, will create more vapour and vice versa.

Strong bond (Less V.P.)   Weak bond (More V.P.)

⊛ ~~beta given,~~ H_2O ~~and~~ H_2S ⊛

★ IDEAL AND NON-IDEAL SOLUTIONS

• IDEAL SOLUTIONS

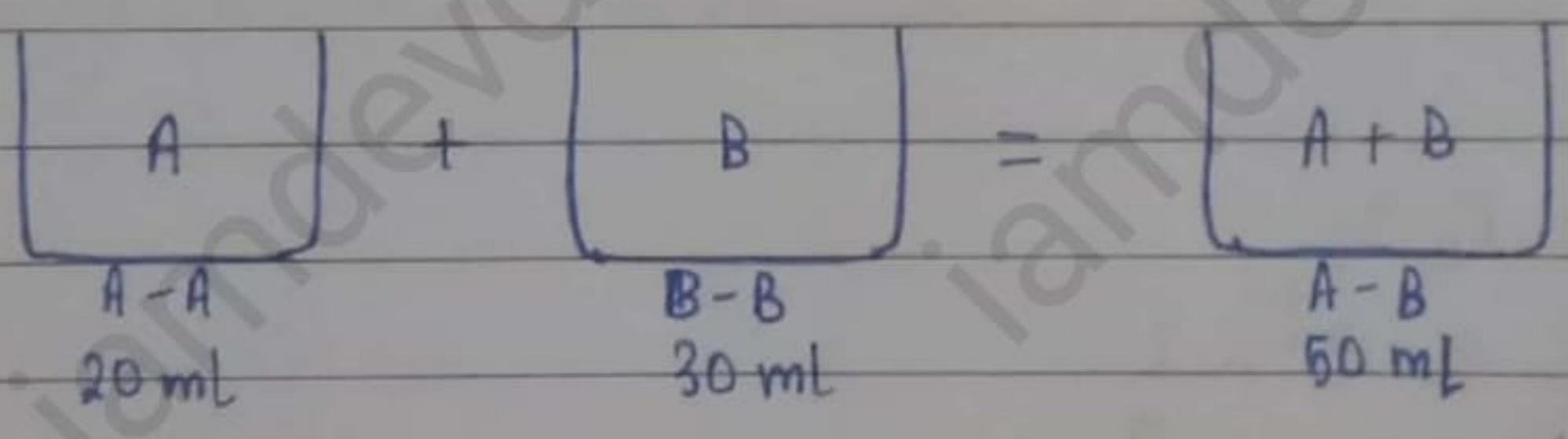1. The solutions which obey Raoult's law exactly under any temperature and concentration ⚹ conditions

2. If a solution is ideal, then

$$A-A \text{ int.} = B-B \text{ int.} = A-B \text{ int.}$$
↳ interaction

3. Volume change on mixing should be zero.
$$\Delta V_{mix} = 0$$

| A | + | B | = | A + B |

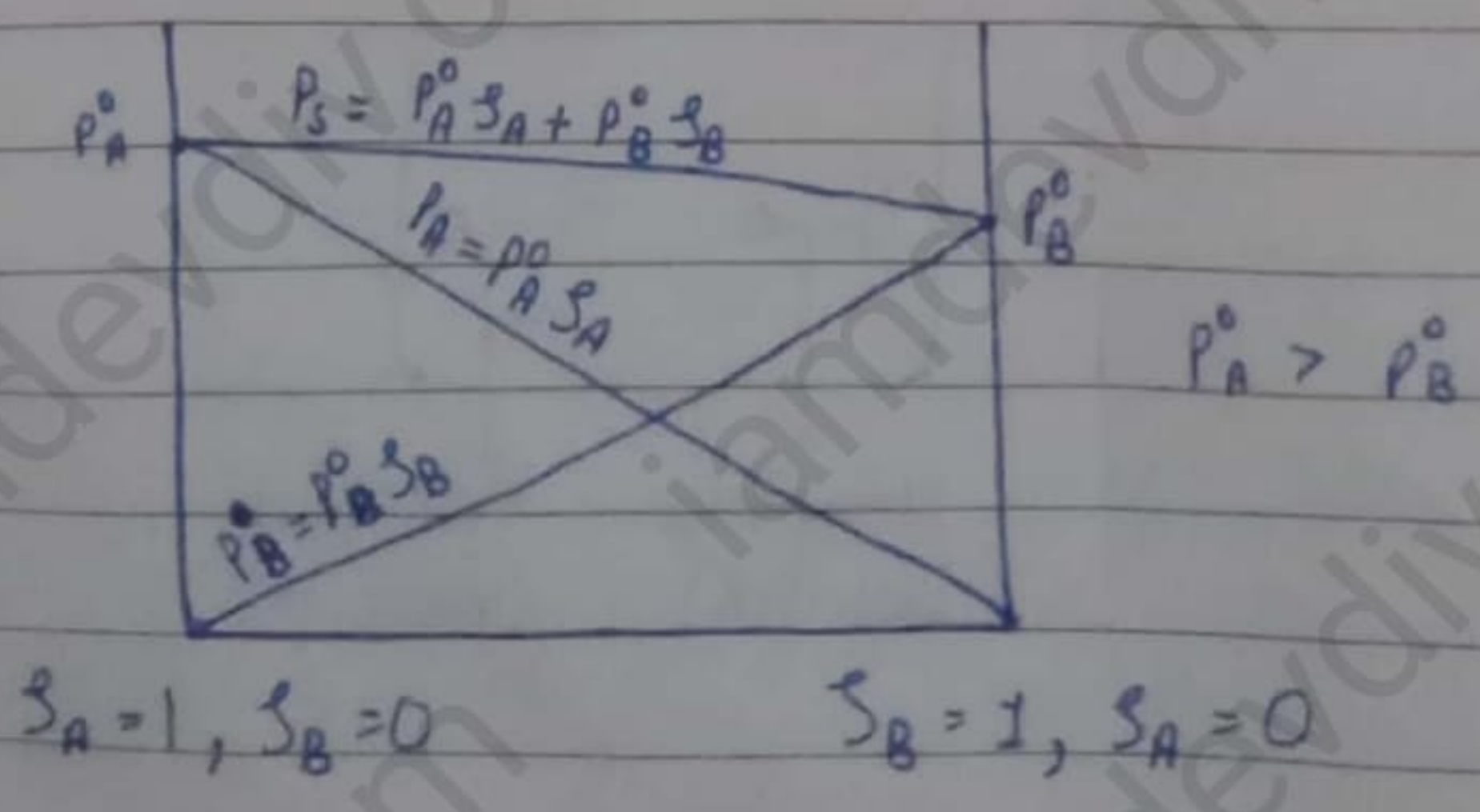A - A   B - B   A - B
20 mL   30 mL   50 mL

4. Heat change on mixing should be zero.
$$\Delta H_{mix} = 0$$

5. Entropy change in this process is greater than zero.
$$\Delta S_{mix} > 0$$

6. $\Delta G_{mix} < 0$

P_A^o $P_S = P_A^o S_A + P_B^o S_B$

$P_A = P_A^o S_A$

$P_B = P_B^o S_B$ P_B^o

$P_A^o > P_B^o$

$S_A = 1, S_B = 0$ $S_B = 1, S_A = 0$

Examples: Conditions = ① Nearly same size

② Nearly same polar nature

① Benzene + Toluene
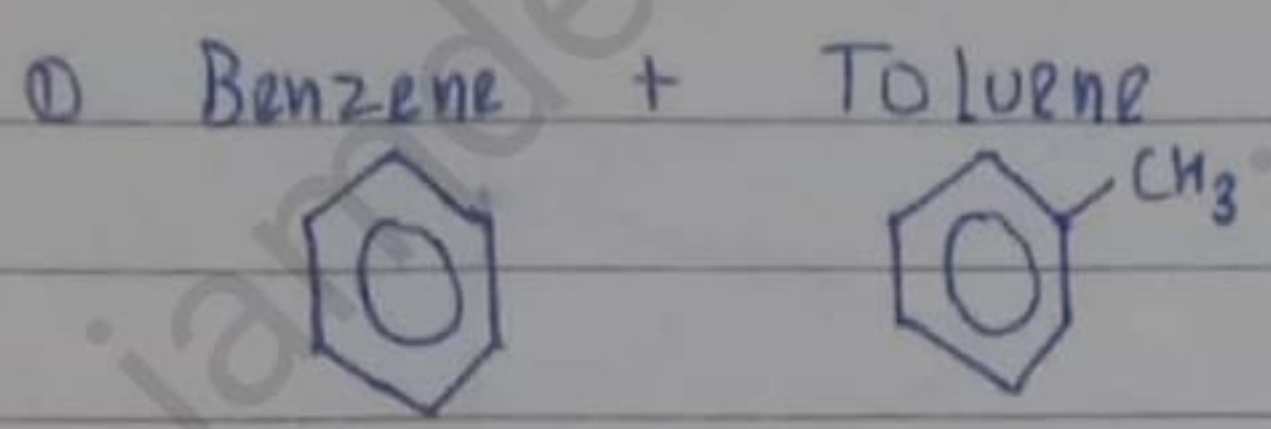
② $C_2H_5Br + C_2H_5Cl$

③ $CCl_4 + SiCl_4$

④ $PhCl + PhBr$

⑤ n-butyl bromide + n-butyl chloride

⑥ n-hexane + n-heptane

- **NON-IDEAL SOLUTIONS**

1. The solutions which do not obey Rault's law at any constant temperature and concentration are called non-ideal solutions.

2. $\underset{\text{interaction}}{A-A} \, / \, \underset{\text{interaction}}{B-B} \neq \underset{\text{interaction}}{A-B}$

3. $\Delta V_{mix} \neq 0$

4. $\Delta H_{mix} \neq 0$

5. $\Delta S_{mix} > 0$

6. $\Delta G_{mix} < 0$

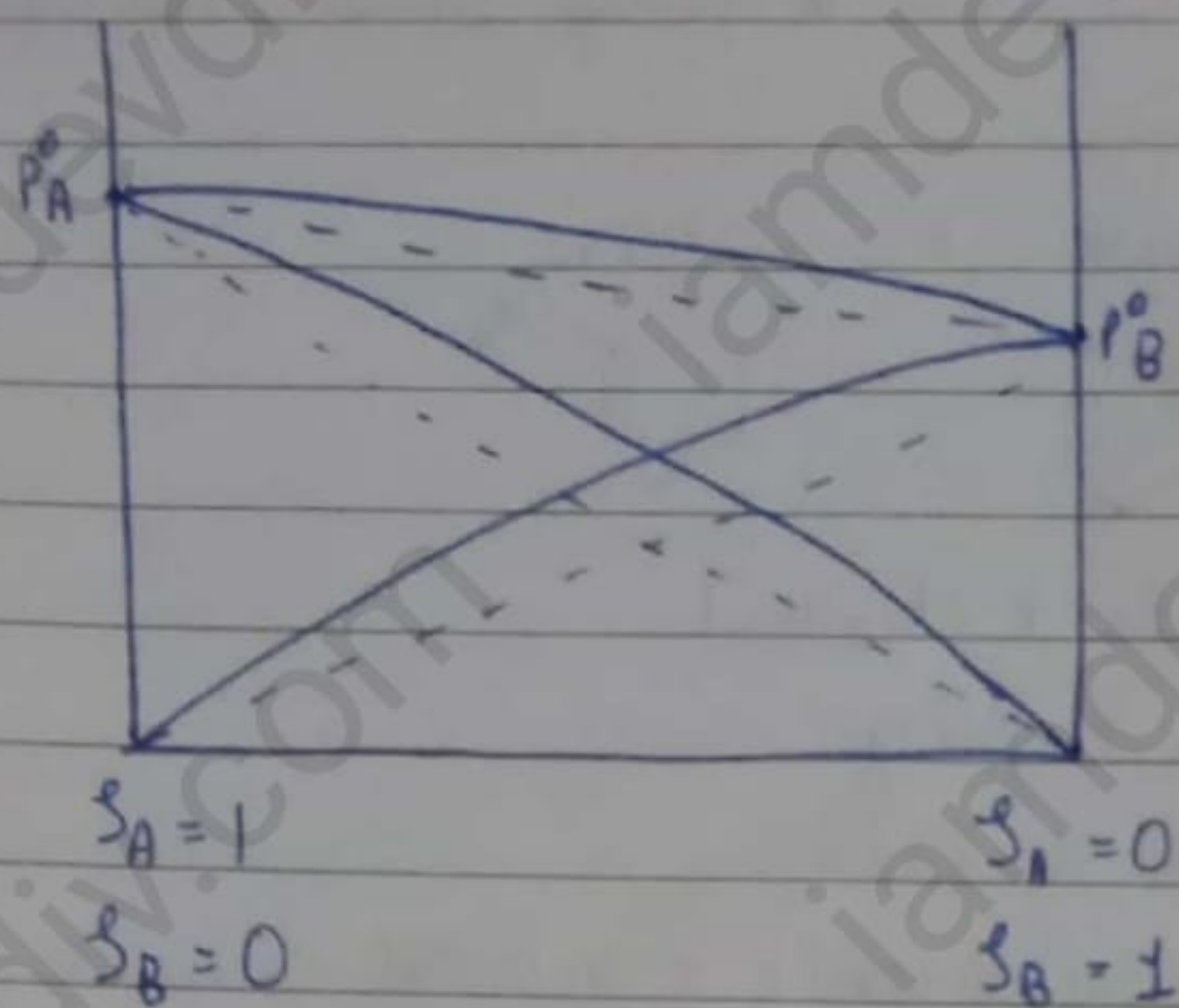- **NON-IDEAL SOLUTIONS SHOWING POSITIVE DEVIATION**

1. $\Delta V_{mix} > 0$

2. ~~₹~~

2. In these solutions, A-B interactions are weaker than A-A/B-B interaction

3. $\Delta V_{mix} > 0$

4. $\Delta S_{mix} > 0$

5. ΔG_{mix}

$S_A = 1$
$S_B = 0$

$S_A = 0$
$S_B = 1$

Examples: (i) Ethanol + Water

(ii) Methanol + H_2O

(iii) CCl_4 + $CHCL_3$

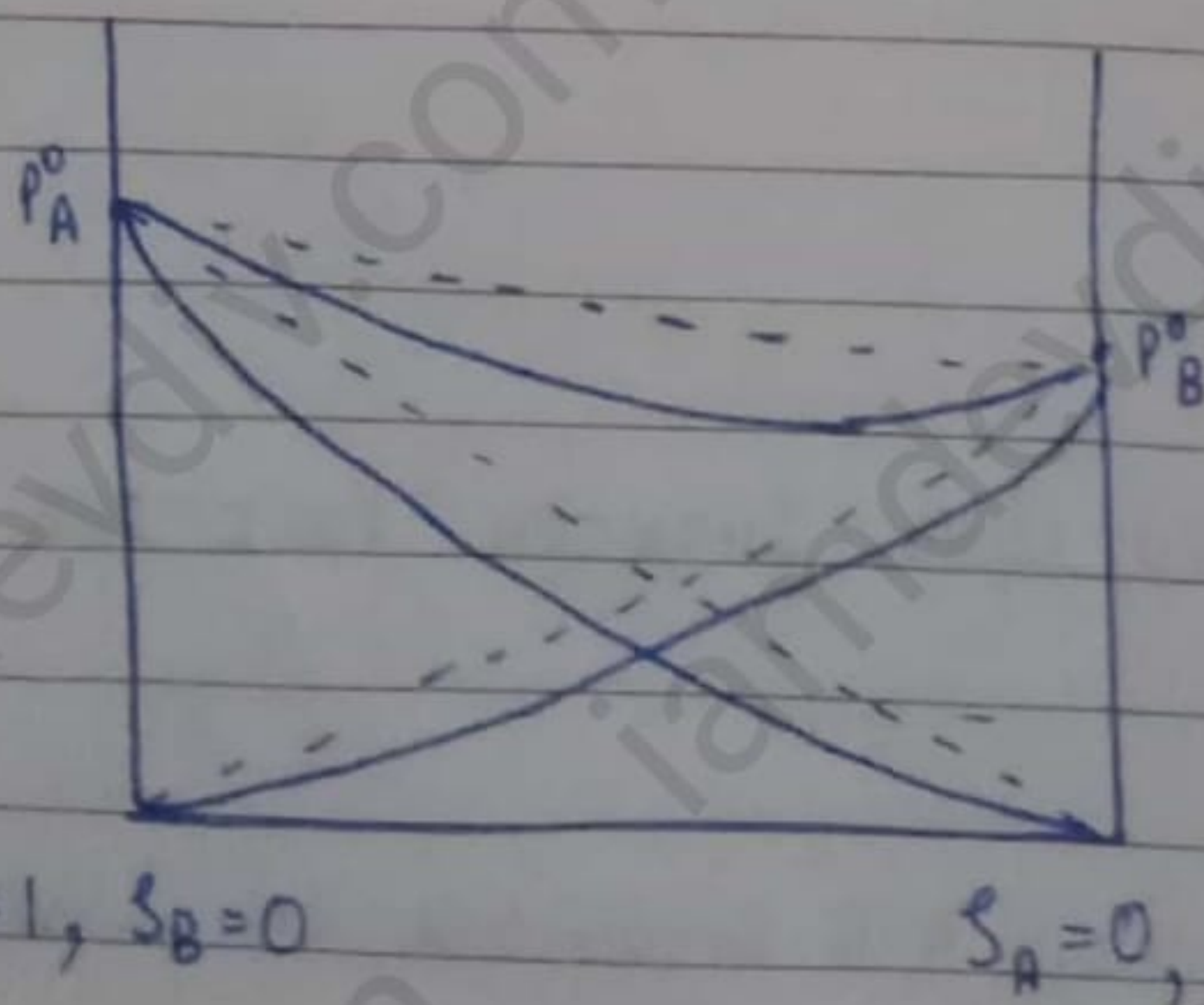(iv) CCl_4 + Acetone

(v) CS_2 + any organic compound

(vi) CCl_4 + $CHCl_3$ C_6H_6

- NON-IDEAL SOLUTIONS SHOWING NEGATIVE DEVIATION

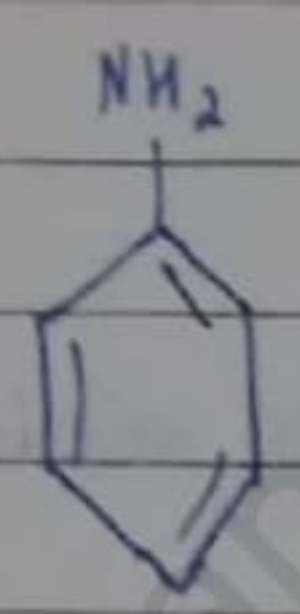1. A-B interactions are stronger than A-A/B-B interactions.

2. $\Delta V_{mix} < 0$

3. $\Delta H_{mix} < 0$

$S_A = 1, S_B = 0$

$S_A = 0, S_B = 1$

Examples: (i) Acid + water

(ii) Aniline $(C_6H_5NH_2)$ + Acetone

(iii) CHX_3 + any organic compound containing oxygen and nitrogen
$X = Cl, Br, I$

(iv) $CHCl_3$ + diethyl ether
$(C_2H_5 - O - C_2H_5)$

★ COLLIGATIVE PROPERTIES

➤ ~~RELATIVE~~ ~~LOWERING~~ Those physical properties of a solution which depends upon relative number of solute particles irrespective of nature of the solute

• RELATIVE LOWERING IN VAPOUR PRESSURE

Pure solvent (volatile)

$P_A > P_S$

Solute + solvent
(non-volatile) (volatile)
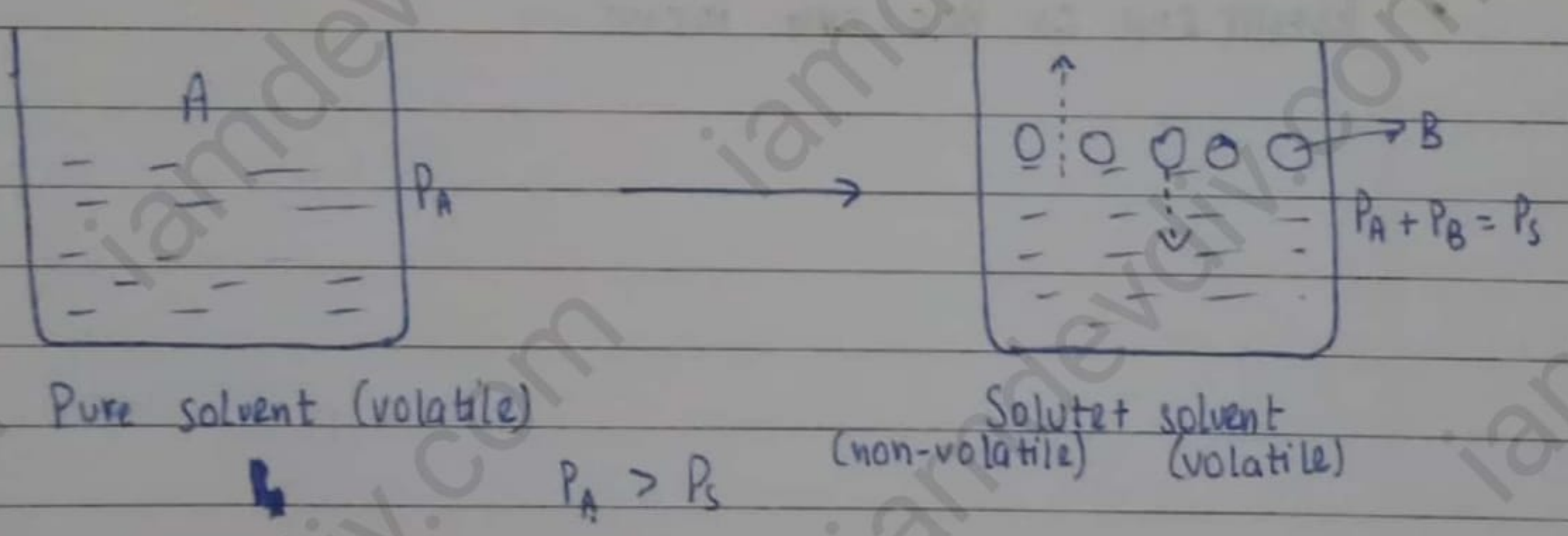
1. Suppose we have a solid solute B which is non-volatile and solvent A which is volatile in nature.

2. In case of pure solvent A, the vapour pressure will be higher than that of this solid liquid mixture.

3. The ~~vapour~~ Lowering in vapour pressure is basically due to solid solute because it decreases the rate of evaporation of volatile liquid A.

→ DERIVATION

$$P_S = P_A^0 S_A + P_B^0 S_B$$

$\quad \therefore$ B is a non-volatile solid solute

$$P_B^0 = 0$$

$\Rightarrow P_S = P_A^0 S_A$

$\quad \therefore S_A + S_B = 1$

$\quad \Rightarrow S_A = 1 - S_B$

$\Rightarrow P_S = P_A^0 (1 - S_B)$

$\Rightarrow P_S = P_A^0 - P_A^0 S_B$

$\Rightarrow P_A^0 S_B = P_A^0 - P_S$

$\Rightarrow \boxed{S_B = \dfrac{P_A^0 - P_S}{P_A^0}}$

It is a colligative property depending on amount/no. of moles of solute in solution.

✄ ~~ELEVATION IN BOILING POINT~~

• DETERMINATION OF MOLAR MASS BY RELATIVE LOWERING IN VAPOUR PRESSURE

$$\frac{P_A^0 - P_S}{P_A^0} = \frac{n_B}{n_A + n_B}$$

For dilute solution $\quad n_B <<< n_A$

$\quad \therefore n_A + n_B \approx n_A$

$\Rightarrow \dfrac{P_A^0 - P_S}{P_A^0} = \dfrac{n_B}{n_A}$

$\quad \therefore n = \dfrac{W \text{ (given mass)}}{m \text{ (molar mass)}}$

$\Rightarrow \dfrac{P_A^0 - P_S}{P_A^0} = \dfrac{\dfrac{W_B}{m_B}}{\dfrac{W_A}{m_A}}$

$$\Rightarrow \boxed{\frac{P_A^o - P_s}{P_A^o} = \frac{W_B \times m_A}{W_A \times m_B}}$$

Also,

$$\frac{P_A^o - P_s}{P_A^o} = \frac{n_B}{n_A + n_B}$$

$$\Rightarrow \frac{P_A^o}{P_A^o - P_s} = \frac{n_A + n_B}{n_B}$$

$$\Rightarrow \frac{P_A^o}{P_A^o - P_s} = \frac{n_A}{n_B} + 1$$

$$\Rightarrow \frac{P_A^o}{P_A^o - P_s} - 1 = \frac{n_A}{n_B}$$

$$\Rightarrow \frac{P_A^o - P_A^o + P_s}{P_A^o - P_s} = \frac{n_A}{n_B}$$

$$\Rightarrow \frac{P_s}{P_A^o - P_s} = \frac{n_A}{n_B}$$

$$\Rightarrow \boxed{\frac{P_A^o - P_s}{P_s} = \frac{n_B}{n_A}}$$

Q The vapour pressure of pure water at $20^\circ C$ is 17.5 mmHg. A solution of sucrose is prepared by dissolving 68.4g of sucrose in 1000g of water. Calculate the vapour pressure of solution.

Sol. Values given: $P_A^o = 17.5$ mmHg

$P_s = ??$

$W_B = 68.4g$

$m_B = 342 g/mol$

$W_A = 1000g$

$m_A = 18 g/mol$

Formula $\Rightarrow \frac{P_A^o - P_s}{P_s} = \frac{W_B \times m_A}{W_A \times m_B}$

$$\Rightarrow \frac{17.5 - P_s}{ } = \frac{68.4 \times 18}{1000 \times 342 \times 10} = 0.0036$$

$$\Rightarrow \frac{17.5}{P_s} - \frac{P_s}{P_s} = 0.0036$$

$$\Rightarrow \frac{17.5}{P_s} = 1.0036$$

$$\Rightarrow P_s = \frac{17.5 \times 10000}{1.0036 \times 10} = \frac{175000}{10036}$$

$$\Rightarrow P_s = \cancel{17.3} \; 17.4 \text{ mmHg} \quad \underline{Ans}$$

```
              17.4
      10036 ) 175000  (
             10036
             74640
             70252
             43980
             40144
              3836
```

```
  10036      10036
   x 7        x 4
  70252      40144
```

Q The vapour pressure of pure benzene at a certain temperature is 0.850 bar. A non-volatile and non-electrolyte solid weighing 0.5g is dissolved to 39g of Benzene. It lowers the vapour pressure to 0.845 bar. Calculate the molar mass of solid substance.

Sol. Values given: $P_A^0 = 0.850$ bar

$P_s = 0.845$ bar

$W_B = 0.5g$

$W_A = 39g$

$m_A = 78g/mol$

$m_B = ?$

Formula $\Rightarrow \dfrac{P_A^0 - P_s}{P_s} = \dfrac{W_B \times m_A}{W_A \times m_B}$

$$\Rightarrow \frac{0.850 - 0.845}{0.845} = \frac{0.5 \times \overset{2}{78}}{39 \, m_B}$$

$$\Rightarrow m_B = \frac{0.845}{0.005}$$

$$\Rightarrow m_B = 169g/mol \quad \underline{Ans}$$

Q The vapour pressure of 5% (w/w) aqueous solution of non-volatile organic substance at 373 K is 745 mmHg. Calculate the molar mass of that solute.

Sol. Values given: $P_A^0 = 760$ mmHg (because pure water is present as solvent)

$P_s = 745$ mmHg

$W_B = 5g$

$W_A = 95g$

$m_A = 18 g/mol$

$m_B = ??$

Formula $\Rightarrow \dfrac{P_A^o - P_s}{P_s} = \dfrac{W_B \times m_A}{W_A \times m_B}$

$\Rightarrow \dfrac{760 - 745}{745} = \dfrac{5 \times 18}{95 \times m_B}$

$\Rightarrow \dfrac{\cancel{15}^{3}}{745} = \dfrac{\cancel{5}\times\cancel{18}^{6}}{95 \times m_B}$

$\Rightarrow m_B = \dfrac{4470}{95}$

$\Rightarrow m_B = 47\ g/mol$ Ans

Q What weight of solute (molar mass = 60 g/mol) is required to be dissolved in 180g of water to reduce the vapour pressure to $\dfrac{4}{5}$ of pure water.

Sol. Values given: $P_s = 0.8 P_A^o$

$W_A = 180g$

$m_A = 18 g/mol$

$W_B = ??$

$m_B = 60 g/mol$

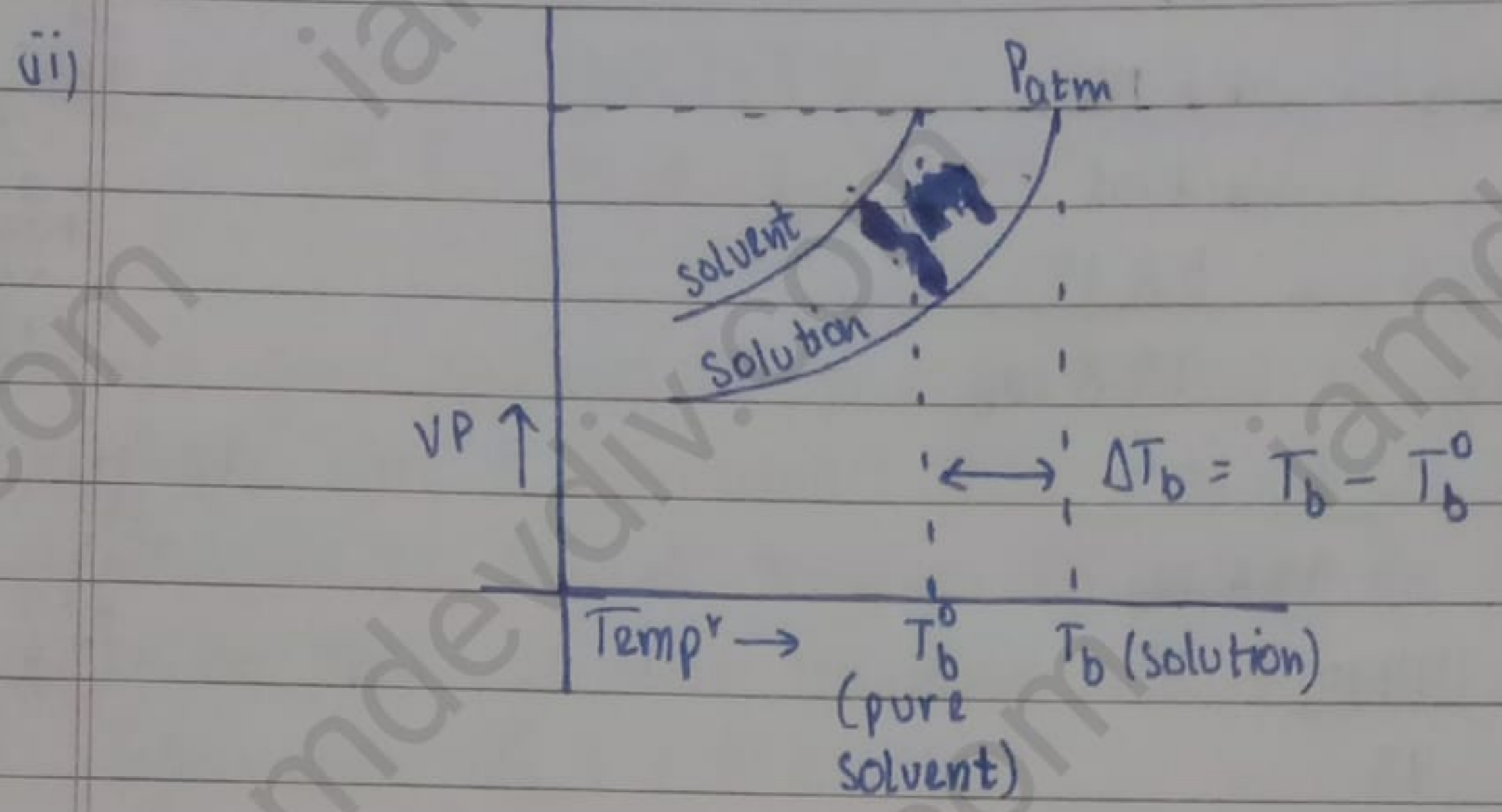Formula $\Rightarrow \dfrac{P_A^o - P_s}{P_s} = \dfrac{W_B \times m_A}{W_A \times m_B}$

$\Rightarrow \dfrac{P_A^o - 0.8 P_A^o}{0.8 P_A^o} = \dfrac{W_B \times 18}{180 \times 60}$

$\Rightarrow 0.25 = \dfrac{W_B}{600}$

$\Rightarrow W_B = 150g$ Ans

- ELEVATION IN BOILING POINT

i) Boiling point is the temperature at which vapour pressure of liquid is just equal to atmospheric pressure.

ii)

$$\Delta T_b = T_b - T_b^0$$

Temp$^r \to$ T_b^0 T_b (solution)
(pure Solvent)

VP↑

iii) IF a small amount of non-volatile solute B is added to pure solvent A, it lowers the vapour pressure. This means that the solution will have to be heated to higher temperature in order to make vapour pressure and atmospheric pressure equal. This increase in temperature is elevation in boiling point.

iv) For a small range of concentration, the rise in temperature (ΔT_b) is directly
proportional to ~~increase~~ decrease in ~~temperature~~ pressure

$$\Delta T \propto \Delta P$$

v) Since, for dilute solutions, the decrease in vapour pressure is proportional to molality.

$$\Delta T_b \propto m$$
$$\Rightarrow \Delta T_b = K_b \times m$$

If $m = 1$
$$\Rightarrow \Delta T_b = K_b$$
$$\Rightarrow T_b - T_b^0 = K_b$$

where, K_b = molal elevation constant

$$\Delta T_b = K_b \times \frac{W_B}{m_B \times W_A \text{ (kg)}}$$

$$\Rightarrow \Delta T_b = K_b \times \frac{W_B \times 1000}{m_B \times W_A \text{ (g)}}$$

* Determination of molar mass of solute

$$m_B = \frac{K_b \times W_B \times 1000}{\Delta T_b \times W_A \text{ (g)}}$$

Q.) The boiling point of solution containing 50g of non-volatile solute in 1000g of solvent is 0.5° higher than that of pure solvent. Determine the molar mass of solute (given values, molar mass of solvent = 78 g/mol and K_b for solvent is 2.53).

Sol. Given values: $\Delta T_b = 0.5$

$W_B = 50g$

$W_A = 1000g$

$m_B = ?$

$K_b = 2.53$

Formula $\Rightarrow m_B = \frac{K_b \times W_B \times 1000}{\Delta T_b \times W_A}$

$$\Rightarrow m_B = \frac{2.53 \times \overset{10}{\cancel{50}} \times \cancel{1000} \times 10}{0.5 \times \cancel{1000}}$$

$$\Rightarrow m_B = 253 \text{ g/mol } \underline{Ans}$$

Q2.) 18g of glucose is dissolved in 1000g of solvent (water). At what temp, will water boil under 1 bar pressure. Given K_b for water = 0.52 K Kg/mol

Sol. Given values: $\Delta T_b = ?$

$W_B = 18g$

$W_A = 1000 g = 1 kg$

$$m_B = 180 \, g/mol$$
$$K_b = 0.53$$

Formula $\Rightarrow$ $\Delta T_b = K_b \times \dfrac{W_B}{m_B \times W_A}$

$\Rightarrow \Delta T_b = 0.53 \times \dfrac{\cancel{18}}{\underset{10}{\cancel{180}} \times 1\cancel{000}}$

$\Rightarrow \Delta T_b = 0.053$

At 1 bar, $P \Rightarrow$ B.P. $= 100°C$

$\Rightarrow 100 + 273 \Rightarrow 373 K$

Final temp$^r \Rightarrow 373 + 0.052$

$\Rightarrow 373.052 \, K$ Ans

0.70g of an organic compound when dissolved in 32g of acetone produces an elevation in boiling point of 0.25°C. calculate the molar mass of organic compound. Given values : K_b for acetone = 1.72 K kg /mol.

Given values: $\Delta T_b = 0.25°C = 0.25 K$

(the difference in °C is always equal to difference in K)

$W_B = 0.70 \, g$

$W_A = 32 g$

$m_B = ??$

$K_b = 1.72 \, K kg/mol$

Formula $\Rightarrow$ $m_B = \dfrac{K_b \times W_B \times 1000}{\Delta T_b \times W_A}$

$\Rightarrow m_B = \dfrac{1.72 \times 0.70 \times 1000}{0.25 \times 32}$

$\Rightarrow m_B = 150.5 \, g$ Ans

Q B If the The boiling point of water becomes too, 52 ∈ 100.52°C. If 1.5g of non-volatile and non-electrolyte substance is added to 100 ml solvent. which is water, calculate the molar mass of the solute. $K_B = 0.6$ Kkg/mol and $\rho_{water} = 1$ g/ml.

Sol. Values given: $\Delta T_b = 0.52$ °C = 0.52 K

$W_b = \cancel{100g}$ 1.5g

$m_b = ??$

$W_A = \cancel{1.5g}$ 100g

$K_B = 0.6$ Kkg/mol

Formula $\Rightarrow m_B = \dfrac{K_b \times W_B \times 1000}{\Delta T_b \times W_A}$

$\Rightarrow m_B = \dfrac{0.6 \times \cancel{100} \times 1000 \times \cancel{10} \times 100}{0.52 \times 1.5 \times \cancel{10}}$

$\Rightarrow m_B = \dfrac{0.6 \times 1.5 \times 1000}{0.52 \times 100}$

$\Rightarrow m_B = 17.3g$

```
        9
   13 ) 500000
        39
       ─────
        110

        17.3
   52 ) 908
        52
       ─────
        380
        364
       ─────
        160
        156
```
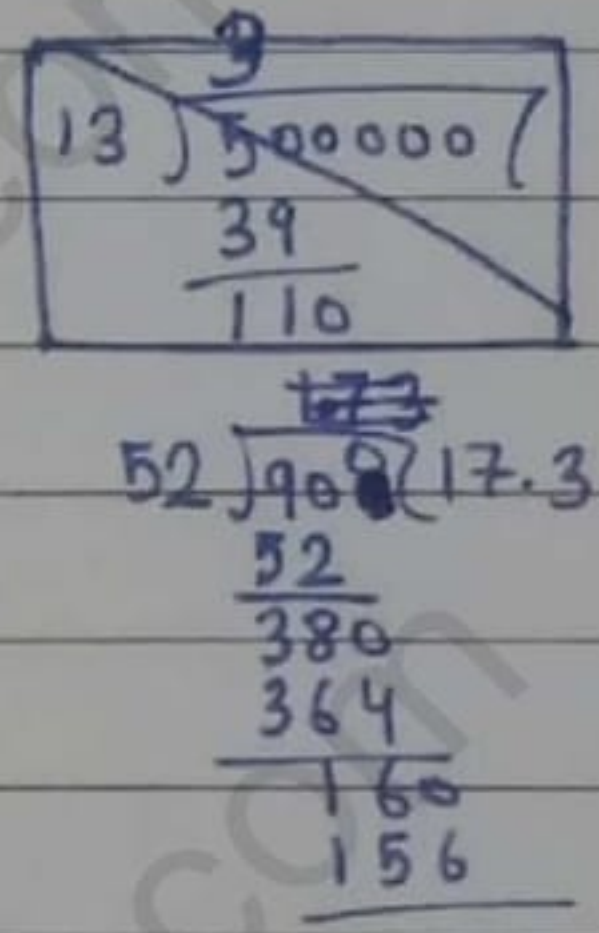
- DEPRESSION IN FREEZING POINT

(i) Freezing point is the temperature at which solid phase is in equilibrium with liquid phase of a substance.

(ii) Freezing point is the temperature at which the vapour pressure of liquid is just equal to the vapour pressure of solid.

(iii)
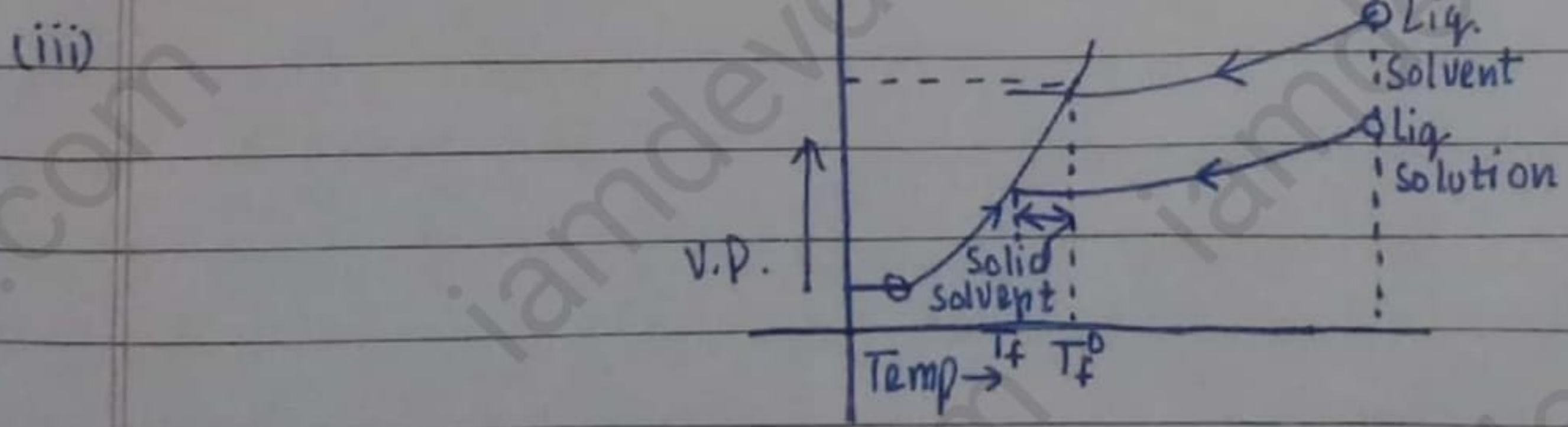
$\Delta T_f = T_f^0 - T_f$

$\hookrightarrow$ Depression in Freezing point

Just as in case of elevation in boiling point, the depression in freezing point also depends upon vapour pressure which again depends upon amount of solute added. Hence, it is related to molality and the relation between two is following:

$$\Delta T_f \propto m$$
$$\Rightarrow \Delta T_f = K_f \times m$$

$\llcorner\rightarrow$ Molal Depression constant

$$\Rightarrow \Delta T_f = K_f \times \frac{W_B \times 1000}{m_B \cancel{M_B} \times W_A (g)}$$

An aqueous solution of an organic compound containing 0.6g dissolved in 21.7g of H_2O freezes at 272.187 K. The value of K_f is 1.86 kkg/mol. Calculate the molecular mass of organic compound.

Values given: $\Delta T_f = \cancel{272.187K} \cancel{6.187K}$ $273 - 272.187 = 0.813 K$

$T_f^\circ = 273 K$

$W_b = \cancel{0.6g}\ 0.6g$

$m_b = ?$

$W_A = 21.7 g$

$K_f = 1.86\ K\,Kg/mol$

Formula $\Rightarrow \Delta T_f = \dfrac{K_f \times W_B \times 1000}{m_B \cancel{M_B} \times W_A}$

0.813

$\Rightarrow \cancel{272.187} = \dfrac{1.86 \times 0.6 \times 1000}{m_B \times 21.7}$

$$\Rightarrow m_B = \frac{1.86 \times 0.6 \times 1000 \times 1000}{\cancel{272.187} \times 21.7 \times 0.813 \times 100}$$

$\Rightarrow m_B \cong 63 g/mol$ Ans

[Calculating approximately]

Side calculations:

$$\begin{array}{r} 220 \\ \times 62 \\ \hline 440 \\ 1320\ \\ \hline 13640 \end{array}$$

$$217\overline{)13640}\ (62.8 \\ \underline{1302}\ \\ 620 \\ \underline{434} \\ 1860 \\ \underline{1736}$$

1g of non-electrolyte solute dissolved in 50g of Benzene lowers the freezing point of benzene by 0.40 K. The freezing depression constant of benzene is 5.12 Kkg/mol. Find the molar mass of solute.

Sol. Values given: $\Delta T_f = 0.40 K$.

$$W_B = 1g$$
$$W_A = 50g$$
$$m_B = ?$$
$$K_f = 5.12 \text{ K Kg/mol}$$

Formula $\Rightarrow \Delta T_f = \dfrac{K_f \times W_B \times 1000}{W_A \times m_B}$

$\Rightarrow 0.40 = \dfrac{5.12 \times 1 \times 1000}{50 \times m_B}$

$\Rightarrow m_B = \dfrac{5.12 \times 1000}{50 \times 0.40}$

$\Rightarrow m_B = 256 \, g/mol$ **Ans.**

Q. What mass of ethylene glycol $\left(\begin{smallmatrix} CH_2 OH \\ CH_2 OH \end{smallmatrix}\right)$ must be dissolved in 5.5 kg of water to lower the freezing point of water from 0°C to −10°C. K_f for water is 1.86 K Kg/mol.

Sol. Values given: $\Delta T_f = 10°C = 10K$

$~~~~~~~~~~~~~~~~~\cancel{m_B \, W_A = 5.5 \, kg}$

$~~~~~~~~~~~~~~~~~m_B = 62 \, g/mol$

$~~~~~~~~~~~~~~~~~W_A = 5.5 \, kg$

$~~~~~~~~~~~~~~~~~K_f = 1.86 \text{ K Kg/mol}$

$~~~~~~~~~~~~~~~~~W_B = ??$

Formula $\Rightarrow \Delta T_f = \dfrac{K_f \times W_B}{W_A \times m_B}$

$\Rightarrow 10 = \dfrac{1.86 \times W_B}{5.5 \times 62}$

$\Rightarrow W_B = \dfrac{5.5 \times 62}{1.86 \times 10}$

$\Rightarrow W_B = 16.3 \, g$ **Ans.**

$$\begin{array}{r} 16.3 \\ 3\overline{)55(} \\ \underline{3} \\ 25 \\ \underline{24} \\ 10 \\ \underline{3} \end{array}$$

* ANTIFREEZE SOLUTION

In severe cold conditions, mixture of Ethylene glycol and water in an equal ratio by volume is used in the radiator of cars and other automobiles which are expected to freeze. This solution is also called coolant.

• OSMOSIS

* SEMI-PERMEABLE MEMBRANE [SPM]

These are the membranes which allow only movement of solvent molecules through them. These are of two types:

(i) Natural SPM

These exist in nature.

Examples: Plant hyde, Animal skin, Bladder of goat/pig, cell membranes

(ii) Artificial SPM

These are made artificially.

Examples: Copper ferrocyanide, Cellulose acetate

* DEFINITION OF OSMOSIS

The spontaneous movement of solvent molecules from —

(i) Lower concentration to higher concentration
(ii) Higher vapour pressure to lower vapour pressure } through SPM
(iii) Hypotonic solution to hypertonic solution

... is called osmosis.

* DIFFERENCE BETWEEN OSMOSIS AND DIFFUSION

| OSMOSIS	DIFFUSION
(i) It only takes place through SPM.	(i) In diffusion, both solute and solvent can move but in opposite direction
(ii) In osmosis, only the solvent molecules can travel or move.	(ii) It takes place without SPM

(iii) The osmosis is common in liquid only.	(iii) Can take place in liquid and gases.
(iv) It can be restricted.	(iv) It cannot be restricted.

* OSMOTIC PRESSURE

The excess hydrostatic pressure that develops due to osmosis at a particular temperature is called osmotic pressure.
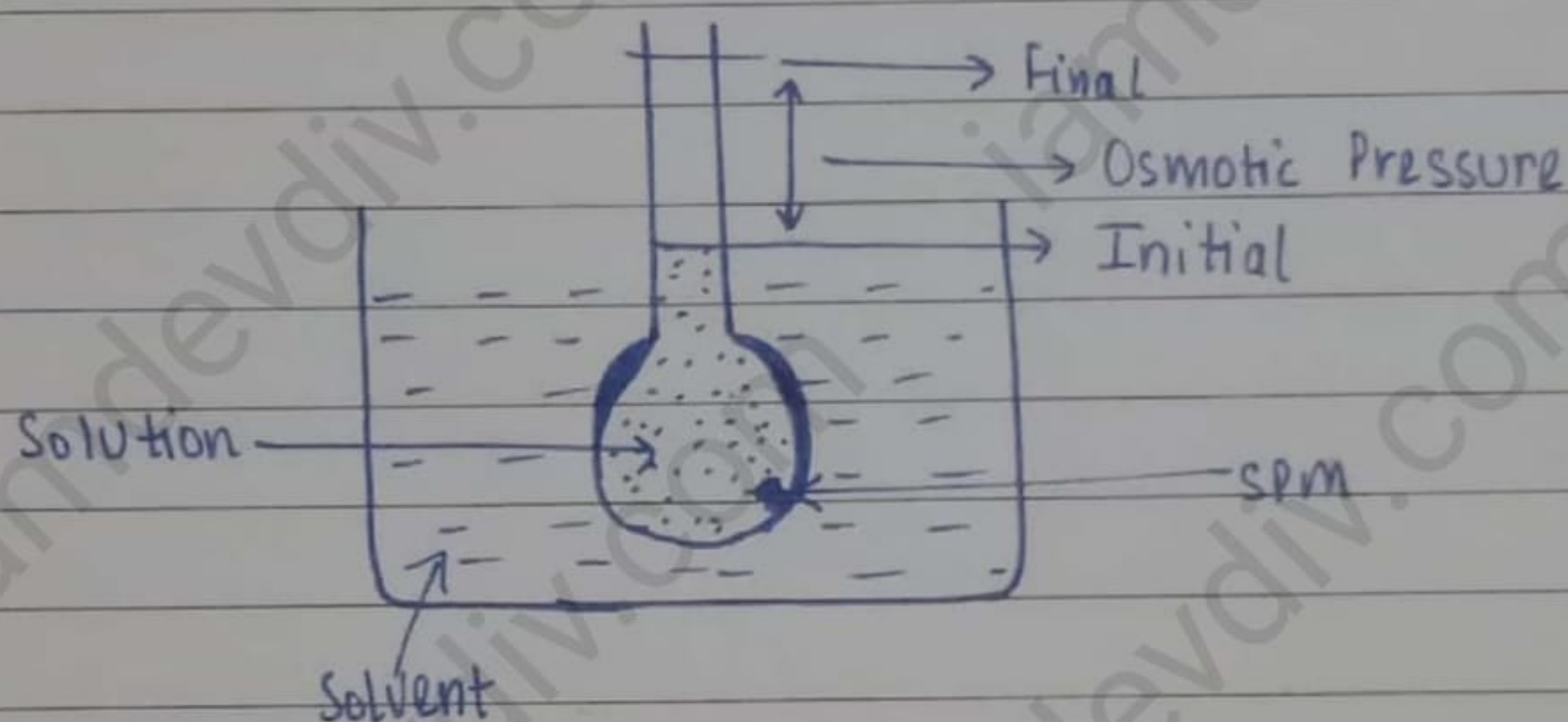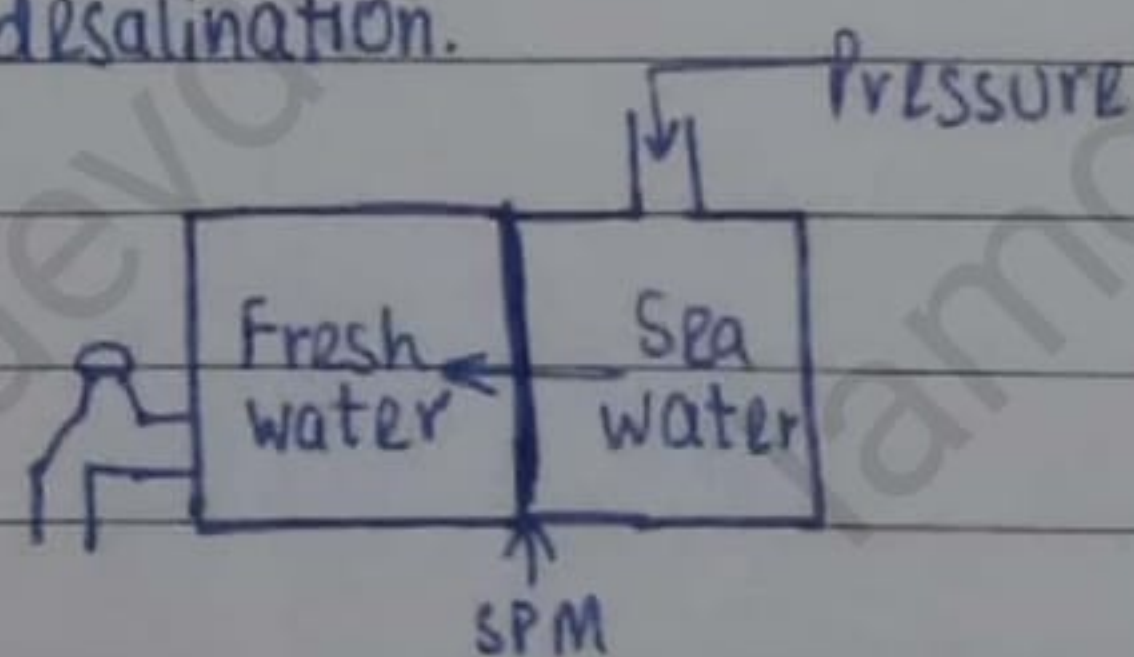

* REVERSE OSMOSIS

(i) The direction of osmosis can be reversed if the pressure is higher than osmotic pressure which is applied on the solution. This is known as reverse osmosis.

(ii) As a result, pure solvent out of the solution flows through the SPM.

(iii) APPLICATION – Desalination of water

Sea water contains a large amount of dissolved salts in it which is not fit for ~~water~~ drinking.

It can be converted into portable water fit for drinking by reverse osmosis is called desalination.

* DETERMINATION OF MOLAR MASS WITH THE HELP OF OSMOTIC PRESSU

(i) Osmotic pressure (π) $\propto$ molar concentration (c) ──① ①

(ii) Osmotic pressure (π) $\propto$ Temperature (T) ── ②

By combining ① and ②

$$\pi \propto CT$$

$$\Rightarrow \boxed{\pi = CRT}$$

$\hookrightarrow$ constant

$$\therefore C = \frac{n}{V}$$

$$\Rightarrow \pi = \frac{n}{V} RT$$

$$\Rightarrow \pi V = nRT$$

Also, we know $PV = nRT$

$\therefore$ R is a constant which is known as solution constant and it's value is same as that of Gas constant.

Now, $\therefore n = \dfrac{W_B}{m_B}$

$$\Rightarrow \boxed{\pi V = \frac{W_B}{m_B} RT}$$

$$\Rightarrow \boxed{m_B = \frac{W_B \, RT}{\pi V}}$$

* ISOTONIC SOLUTION

(i) The solution having higher concentration is called hypertonic, while the one with lesser concentration is called hypotonic solution.

(ii) Two dilute solutions with same concentration at a given temperature having

same osmotic pressure are called isotonic or iso-osmotic solutions.

* IMPORTANCE OF OSMOSIS

(i) Raisins ~~Resins~~ swell when kept in water overnight because water (hypotonic) ~~solution~~ enter cell membrane of raisins (hypertonic) which acts as SPM. There fore, raisins grows.

(ii) While making pickles, raw mango pieces are first placed in concentrated table salt solution, water escapes through outer skin of mango pieces which acts as SPM.

(iii) Doctors generally advise person suffering from high BP to restrict common salt in their diet. The reason is NaCl is going to increase the concentration of ions in the body as well as osmotic pressure. To neutralise the effect, water intake by the body increases leading to swelling ~~which in~~ or Edema.

Q What will happen if RBCs are placed in
(i) 1.0% NaCl solution
(ii) 0.1% NaCl solution
Ans. (i) Osmotic pressure of 1% NaCl solution is higher. As a result, water present inside move into NaCl solution through SPM. RBCs will therefore shrink. ~~Therefore,~~ This is known as Plasmolysis.

(ii) However, reverse process will take place in 0.1% NaCl solution and RBCs ~~wit~~ will swell. This is known as hemolysis.

* ~~ABNORMAL COLLIGATIVE PROPERTY~~

Q Calculate the osmotic pressure of 5% of cane sugar at 15°C.
Sol. Given values: T = 15°C + 273 = 288K

$$R = 0.0821 \ L \ atm/K \ mol$$
$$W_B = 5g$$
$$V = 100 \ mL = 0.1 \ \ell$$
$$m_B = 342 \ g/mol$$

Formula ⇒ $\pi V = \dfrac{W_B \times RT}{m_B}$

⇒ $\pi = \dfrac{W_B \times RT}{m_B \times V}$

⇒ $\pi = \dfrac{5 \times 0.0821 \times 288}{342 \times 0.1}$

⇒ $\pi = \dfrac{6.568 \times 10}{1.9 \times 100}$

⇒ $\pi = 3.45 \ atm$ Ans

```
          0.0821
          x 80
          00000
        6 568x
        6.5 680
```

```
      3.45
1900 )65680
     5700
     8680
     7600
     10800 0
      9500
```

Q 300 cm³ of aqueous solution of pot protein contains 1.26g of protein. The osmotic pressure of such solution at 300 K is 2.57×10^{-3} bar. Calculate the molar mass of protein?

Sol. Values given: $W_B = 1.26g$

$$m_B = ?$$
$$V = 300 \ cm^3 = 0.3 \ L$$
$$T = 300 \ K$$
$$\pi = 2.57 \times 10^{-3} \ bar \approx 2.57 \times 10^{-3} \ atm$$
$$R = 0.0821 \ L \ atm/K \ mol$$

Formula ⇒ $m_B = \dfrac{W_B \times RT}{\pi V}$

⇒ $m_B = \dfrac{1.26 \times 0.0821 \times 3000}{2.57 \times 10^{-3} \times 0.3}$

⇒ $m_B = 0.5 \times 82.1 \times 10^3$

⇒ $m_B = 41.05 \times 10^3 \ g/mol$ Ans

```
       .49
257 )1260
    1028
    2320
    2313
```

```
  2 2
  257
  x 4
  1028
```

```
  257
  x 9
  231 3
```

```
   82.1
   x 0.5
   41.05
```
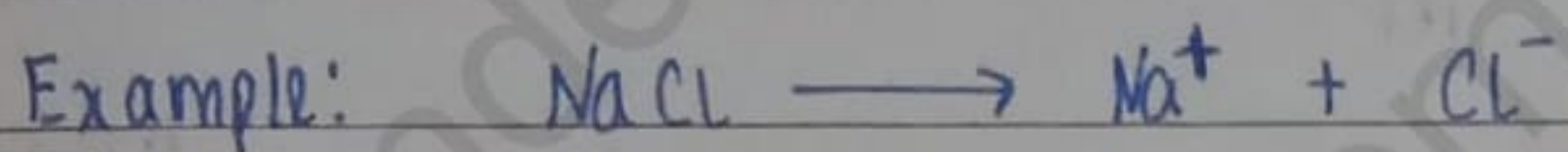
☆ ABNORMAL COLLIGATIVE PROPERTIES

● In case of electrolytes, the observed colligative property are not similar to normal colligative properties because in case of electrolytes (acids, bases and salts), two cases take place:
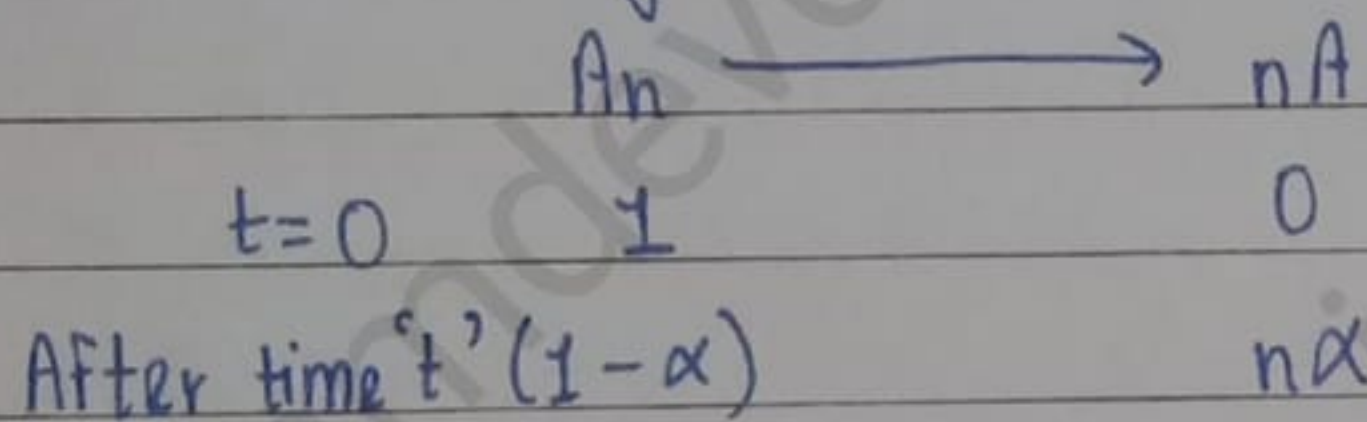(i) Dissociation
(ii) Association

• **DISSOCIATION OF SOLUTE PARTICLES**

① Solute particles are expected to undergo dissociation in polar solvents like water.

Example: $NaCl \longrightarrow Na^+ + Cl^-$

② As a result, the number of ions formed increase and the colligative properties are likely to be increased.

$$An \longrightarrow nA$$

$t=0$	1	0
After time 't'	$(1-\alpha)$	$n\alpha$

Number of moles of ions formed $= n\alpha$
Number of moles of electrolytes undissociated $= (1-\alpha)$
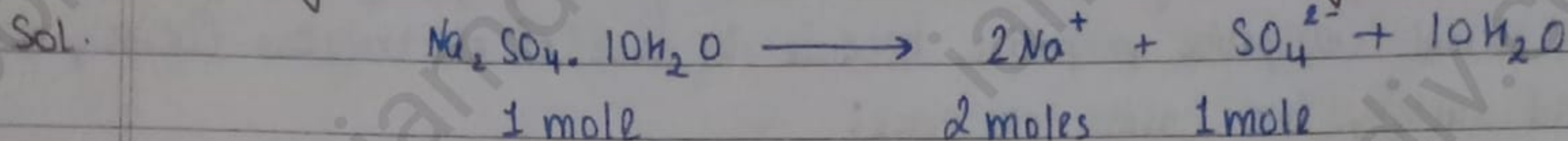Total number of moles after dissociation $= 1-\alpha + n\alpha$

$$i = \frac{\text{Total number of moles}}{1 \text{ (normal number of moles)}}$$

$$\Rightarrow i = \frac{1-\alpha + n\alpha}{1}$$

$$\Rightarrow i - 1 = \alpha(n-1)$$

$$\Rightarrow \boxed{\alpha = \frac{i-1}{n-1}}$$

Q Assuming complete dissociation, calculate the expected freezing point of a solution ♯ prepared by dissolving 6g of Glauber's salt ($Na_2SO_4.10H_2O$) in 0.1 kg of water. Given value of $K_f = 1.86$ K kg/mol.

Sol.
$$Na_2SO_4.10H_2O \longrightarrow 2Na^+ + SO_4^{2-} + 10H_2O$$
$$\text{1 mole} \qquad\qquad \text{2 moles} \quad \text{1 mole}$$

$$i = \frac{3}{1} = 1$$

$$\begin{array}{r} 75 \\ 18.6 \\ \times 9 \\ \hline 167.4 \end{array}$$

$$\Delta T_f = K_f \times m \times i$$

$$\Rightarrow \Delta T_f = \frac{1.86 \times 322 \times \overset{3}{3}}{6 \times 0.1} = \frac{1.86 \times 6 \times 3 \times 10}{\underset{161}{322} \times 0.1} = \frac{18.6 \times 9}{161} = \frac{167}{161}$$

$$\Rightarrow \Delta T_f = 1.04 \text{ K}$$

$$\begin{array}{r} 1.037 \\ 161 \overline{)167}\ (\\ \underline{161} \\ 600 \\ \underline{483} \\ 1170 \\ \underline{1147} \end{array}$$

$$T_f^° = 273 \text{ k}$$
$$\Delta T_f = T_f^° - T_f$$
$$\Rightarrow 1.04 = 273 - T_f$$
$$\Rightarrow T_f = 273 - 1.04$$
$$\Rightarrow T_f = 271.96 \quad \underline{Ans}$$

Q Calculate the amount of sodium chloride which must be added to 1kg of water so that the freezing point of the solution is depressed by 3K. K_f for water is 1.86 k kg/mol. ~~$\Delta T_f =$~~

Sol.
$$NaCl \longrightarrow Na^+ + Cl^-$$
$$\text{1 mol} \qquad \text{1 mol} \quad \text{1 mol}$$
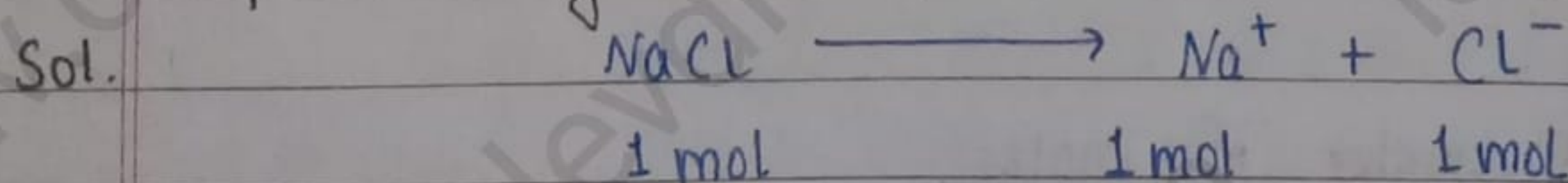
$$i = \frac{2}{1}$$

$$\Delta T_f = K_f \times m \times i$$

$$\Rightarrow 3 = 1.86 \times \frac{\text{given mass of NaCl}}{\text{molar mass of NaCl}} \times 2$$
$$\overline{\qquad\qquad\qquad 1 \qquad\qquad\qquad}$$

$$\Rightarrow 3 = 1.86 \times \frac{x}{58.5} \times 2$$

$\Rightarrow \quad x = \dfrac{58.5 \times 3}{1.86 \times 2} = \dfrac{58.5 \times 1.5}{1.86}$
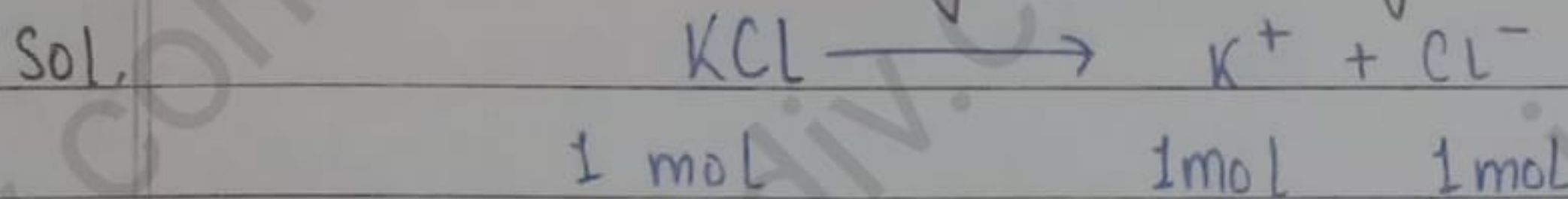
$186\overline{)8775}(47.1$
$\underline{744}$
1335
1302
$\underline{}320$
186

58.5
$\underline{\times 1.5}$
2925
$585\times$
$\overline{87.75}$

$\Rightarrow \quad x = \dfrac{87.75 \times \cancel{3}}{1.86}$

$\Rightarrow \quad x = 47.1 \; g \quad \underline{Ans}$

Q Calculate boiling point of aqueous solution of KCl whose molarity is 1 M and density is 1.04 g/mL. Given value of $K_b = 0.52 \; k.kg/mol$

Sol. $KCl \longrightarrow K^+ + Cl^-$

1 mol $\qquad$ 1mol $\quad$ 1mol

$i = \dfrac{2}{1}$

$M = 1 \; molar$

$V = 1000 \; ml$

$mass \Rightarrow density \times volume \Rightarrow 1.04 \times 1000 \Rightarrow \underline{1040 \; g}$

$KCl \Rightarrow 39 + 35.5 \Rightarrow 74.5 \; g/mol$

$\underline{Solution = solute + solvent}$

$\Rightarrow 1040 = 74.5 + solvent$

$\Rightarrow solvent = 1040 - 74.5$

$\Rightarrow \underline{solvent = 965.5 \; g} = \dfrac{965.5}{1000} = 0.9655 \; kg$

433
9655
$\underline{\times 7}$
67585

$\Delta T_b = K_b \times m \times i$

$\Rightarrow \Delta T_b = 0.52 \times \dfrac{1}{0.9655} \times 2$

$\Rightarrow \Delta T_b = \dfrac{1.04 \times 10000}{0.9655 \times 100} = \dfrac{10400}{9655}$

$9655\overline{)10400}($
$\underline{9655}$
1.07
$9655\overline{)10400}($
$\underline{9655}$
74500
67585

$\Rightarrow \Delta T_b = 1.07 \; K$

$\Rightarrow T_b - T_b^\circ = 1.07 \; K$

$\Rightarrow$ $T_b - 373 = 1.07$

$\Rightarrow$ $T_b = 373 + 1.07$

$\Rightarrow$ $T_b = 374.07$ K **Ans**

Q Calculate the amount of $CaCl_2$ which must be added to 500g water to lower the freezing point by 2K. K_f for water $= 1.86$ k kg/mol.

Sol.

$$CaCl_2 \longrightarrow Ca^{2+} + 2Cl^-$$

    1 mol   1 mol   2 moles
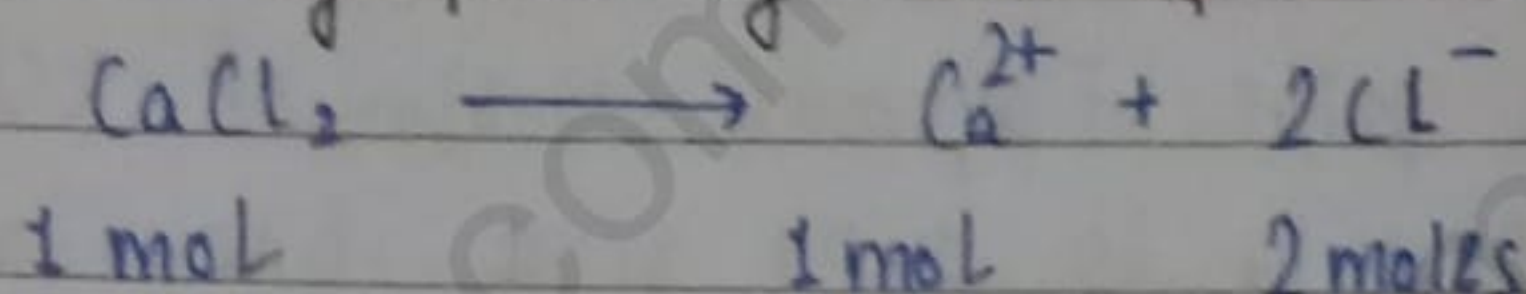
$i = 3$

$CaCl_2 \Rightarrow 40 + 71 \Rightarrow 111$ g/mol

$\Delta T_f = K_f \times m \times i$

$\Rightarrow$ $2 = 1.86 \times \dfrac{x}{\dfrac{111}{0.5}} \times 3$

$\Rightarrow$ $2 = 1.86 \times \dfrac{x}{55.5} \times 3$

$\Rightarrow$ $x = \dfrac{111^{37}}{1.86 \times 2}$

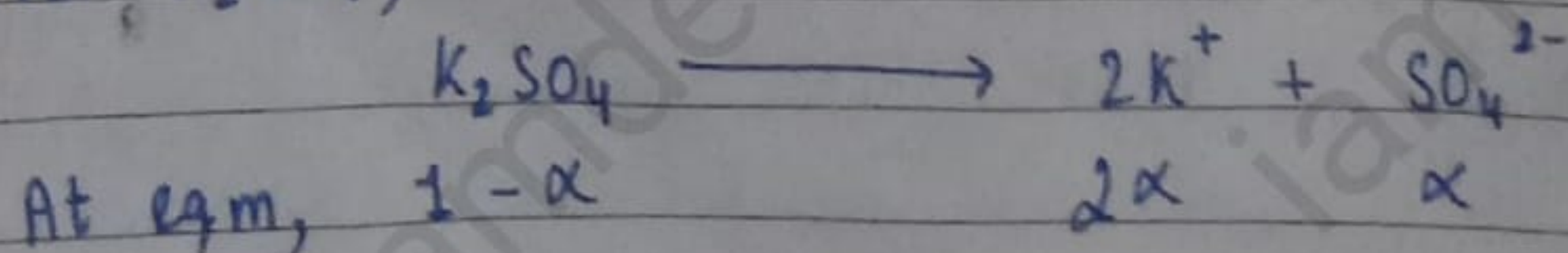$\Rightarrow$ $x = \dfrac{3700}{1.86}$

$\Rightarrow$ $x = 19.89$ g **Ans**

$$\begin{array}{r} 19.89 \\ 186\overline{)3700} \\ 186 \\ \hline 1840 \\ 1674 \\ \hline 1660 \\ 1488 \\ \hline 1720 \\ 1674 \end{array}$$

Q 17.4% K_2SO_4 solution at 27°C is isotonic with 4% NaOH at same temperature. If NaOH is 100% ionised, what is the degree of dissociation of K_2SO_4 in aqueous solution. Calculate percentage ionisation also.
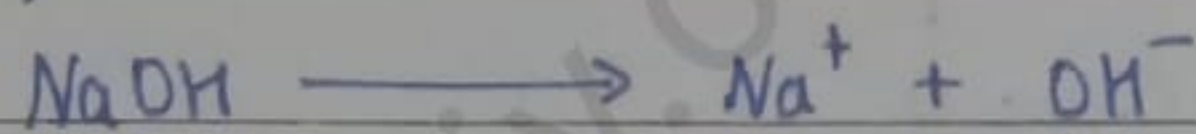
Sol. For K_2SO_4,

$$K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}$$

At eqm, $1 - \alpha$ 2α α

$$i_1 = \frac{1 - \alpha + \alpha \cancel{2\alpha} + 2\alpha}{1} = 1 + 2\alpha$$

$$\pi_1 = i_1 CRT = (1 + 2\alpha) \frac{174}{\frac{174 \times 10}{0.1}} RT = (1 + 2\alpha) RT$$

For NaOH,

$$NaOH \longrightarrow Na^+ + OH^-$$

at atm, $1 - \beta$ β β

$$i_2 = \frac{1 - \beta + \beta + \beta}{1} = 1 + \beta$$

$$\pi_2 = i_2 CRT = (1 + \beta) \frac{4^{\text{gt}}}{\frac{40}{RT}} RT = (1 + \beta) RT$$

$\because$ Both solutions are isotonic

$$\pi_1 = \pi_2$$

$\Rightarrow (1 + 2\alpha) RT = (1 + \beta) RT$ $[\because$ temperature is same$]$

$\Rightarrow 1 + 2\alpha = 1 + 1$ $[NaOH$ is 100% ionised $\therefore \beta = 1]$

$\Rightarrow 1 + 2\alpha = 2$
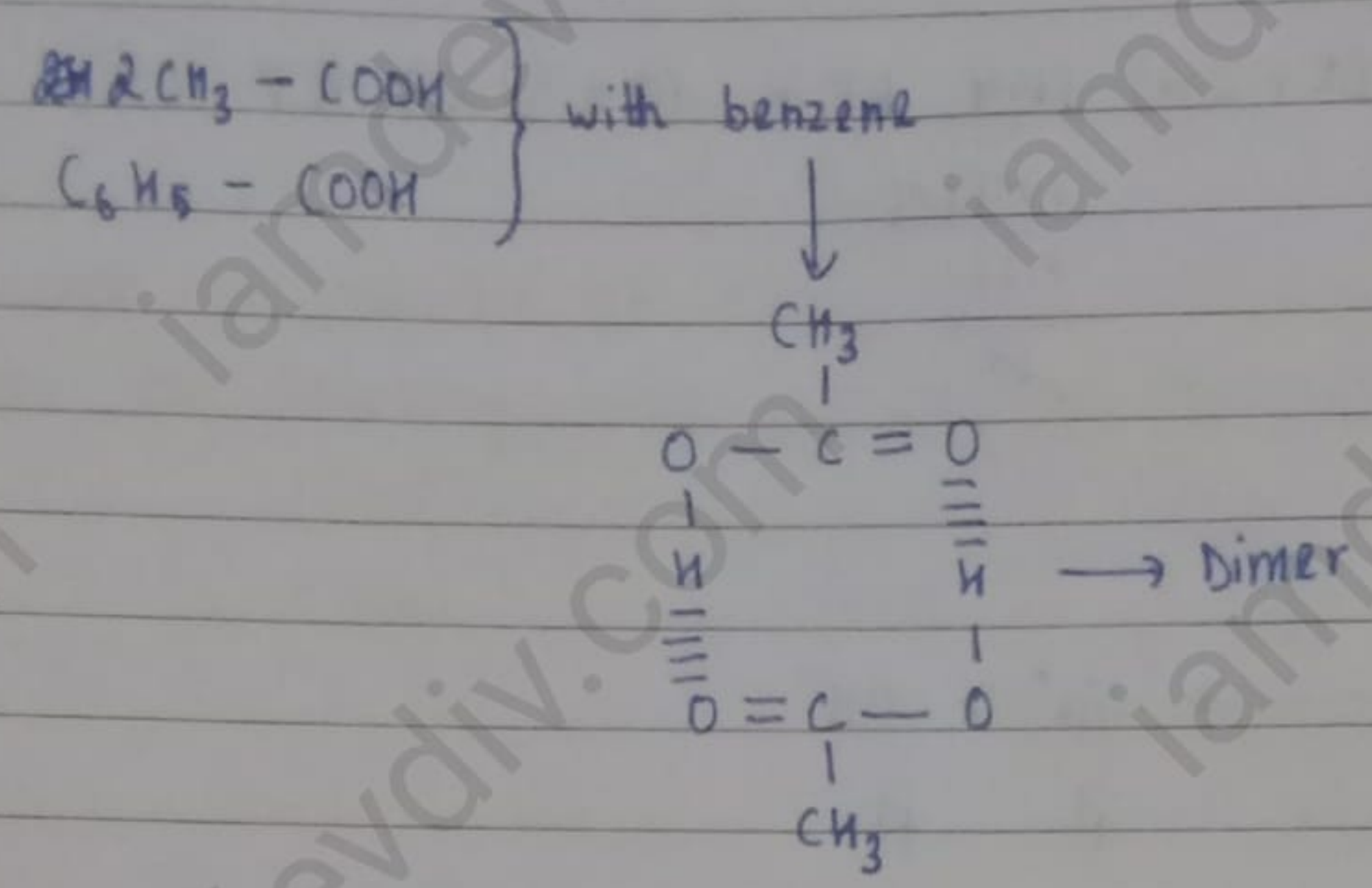
$\Rightarrow 2\alpha = 1$

$\Rightarrow \alpha = 0.5$

$\therefore$ Degree of dissociation of $K_2SO_4 = 0.5$ $\left. \vphantom{\begin{matrix}a\\b\end{matrix}} \right\}$ Ans

and Percentage ionisation $= 0.5 \times 100 = 50\%$

- ASSOCIATION OF SOLUTE PARTICLES

$$\alpha = \frac{i - 1}{\frac{1}{n} - 1}$$

(1) Acetic acid and Benzoic acid in presence of benzene forms dimer and in

this process, association takes place.

$$2 CH_3 - COOH$$
$$C_6H_5 - COOH \Big\} \text{ with benzene}$$

→ Dimer

Q. 2g of Benzoic acid dissolved in 25g of Benzene shows a depression in freezing point of 1.62 K, molal depression constant K_f for benzene is 4.9 K kg/mol. What is the percentage association of acid?

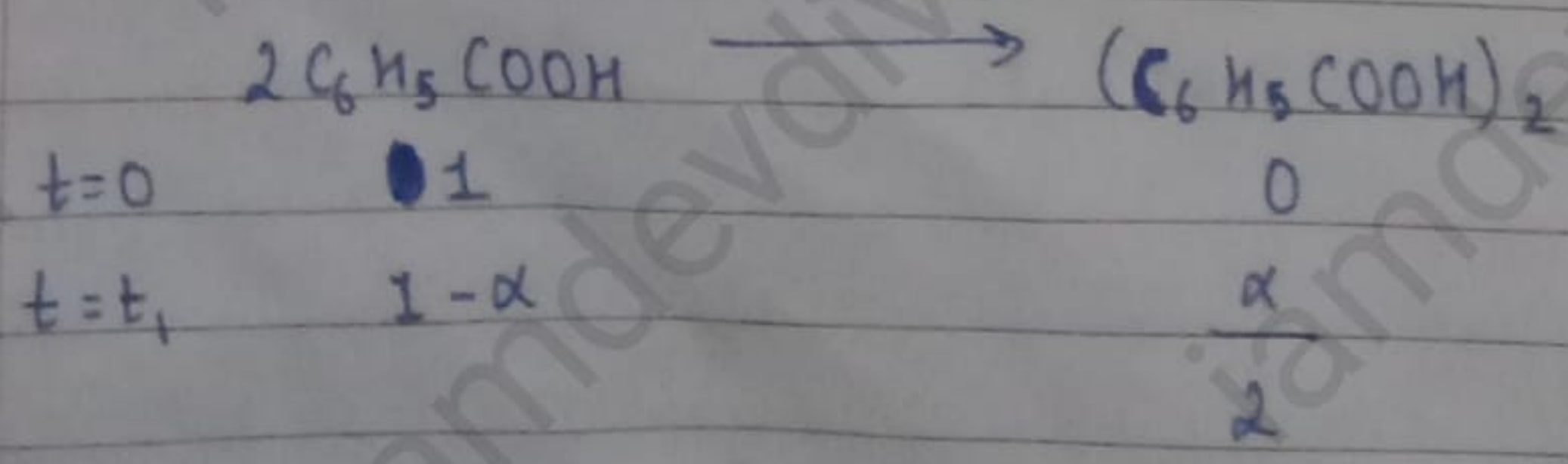Sol. Given $\Delta T_f = \dfrac{K_f \times W_B \times 1000}{m_B \times W_A}$

$\Rightarrow 1.62 = \dfrac{4.9 \times 2 \times 1000}{m_B \times 25}$

$\Rightarrow m_B = \dfrac{4.9 \times 2 \times 1000^{40} \times 100}{1.62 \times 25 \times 10_{81}} = \dfrac{49 \times 4 \times 100}{81}$

$\Rightarrow m_B = 2.419 \times 100 = 241.9$

$\Rightarrow m_B = 242 \text{ g/mol}$

$i = \dfrac{\text{Normal molar mass}}{\text{Abnormal molar mass}} = \dfrac{122}{242} = 0.504$

$$
\begin{array}{ccc}
2 C_6H_5COOH & \longrightarrow & (C_6H_5COOH)_2 \\
\end{array}
$$

	$2 C_6H_5COOH$	$(C_6H_5COOH)_2$
$t=0$	1	0
$t=t_1$	$1-\alpha$	$\dfrac{\alpha}{2}$

$n = 2$

$\begin{array}{r}3\\ \hline 4\,9 \quad 8| \\ \times 4 \quad \times 9 \\ \hline 196 \quad 729\end{array}$

$\begin{array}{r}81\,\overline{)196}\,(2.419 \\ 162 \\ \hline 340 \\ 324 \\ \hline 160 \\ 81 \\ \hline 740 \\ 729 \\ \hline \end{array}$

$\begin{array}{r}1 \\ 242 \\ \times 4 \\ \hline 968\end{array}$

$\begin{array}{r}.504 \\ 242\,\overline{)1220}(\\ 1210 \\ \hline 1000 \\ 968 \\ \hline\end{array}$

$$\alpha = \frac{i-1}{\frac{1}{n}-1} = \frac{0.504-1}{\frac{1}{2}-1} = \frac{\div 0) \, 496 \times 10^2}{\div 0.8 \times 1000} = 0.992$$

$$\begin{array}{r} 496 \\ \times 2 \\ \hline 992 \end{array}$$

Percentage association (OR) degree of association

$$= 0.992 \times 100$$
$$= 99.2 \% \ \underline{\text{Ans}}$$

★ SOME EXTRA TOPICS

• AZEOTROPES

① Components forming azeotropes cannot be separated with the help of fractional distillation.

② Some liquids on mixing form azeotropes which are binary mixtures.

③ Binary mixtures having same composition in liquids as well as in vapour phase and boil at a temperature, the liquid and vapour phase have the same composition and no further solution will take place.

* MINIMUM BOILING AZEOTROPES
The solution which shows large positive deviation from Raoult's law will form minimum boiling azeotropes.
Example: C_2H_5OH (95%) + H_2O (5%)
$\underbrace{80°C \qquad\qquad\qquad 100°C}$
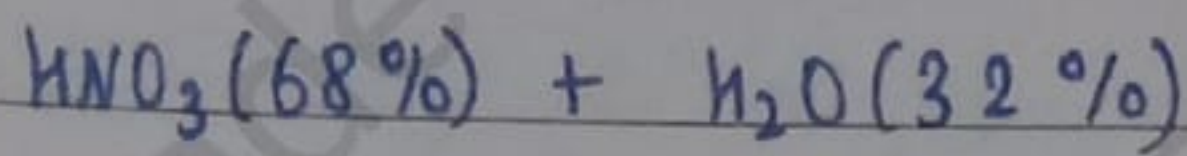
$79.5°C \rightarrow$ Minimum Boiling azeotropes

Ethanol - water mixture on fractional distillation gives 95% alcohol and 5% water which boils at 79.5°C and can be separated further.

* MAXIMUM BOILING AZEOTROPES
The solution that shows large -ve deviation from Raoult's law will form

NOTE → maximum boiling azeotrope.↑

Example: Acid + Water

$$HNO_3 (68\%) + H_2O (32\%)$$

$$120°C \qquad\qquad 100°C$$

$$120.5°C \longrightarrow Max \ boiling \ azeotrope$$

★ HENRY'S LAW

(i) This law is about solution of gases in liquid.

(ii) Solubility of gases which can be estated as mole fraction of gases.

(iii) At constant temperature, the solubility of any gas in any solvent is proportional to its partial pressure.

(iv) Solubility of gases is proportional to partial pressure.

$$Solubility \ of \ gases \ \propto \ Partial \ Pressure$$
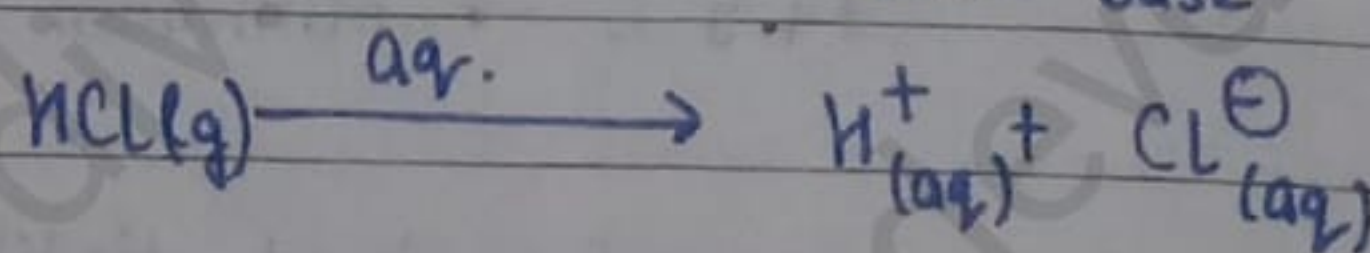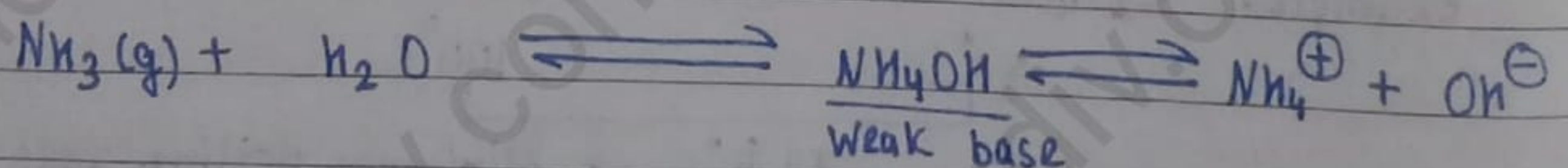$$S \propto P$$
$$P = S K_H$$

where, K_H = henry's constant

• LIMITATIONS OF HENRY'S LAW

(i) Cannot be applied at high temperature and low pressure.

(ii) Not applicable to those gases which dissociate or ~~rent~~ react in solvent.

Example:

$$NH_3 (g) + H_2O \rightleftharpoons \underset{\text{weak base}}{NH_4OH} \rightleftharpoons NH_4^{\oplus} + OH^{\ominus}$$

$$HCl(g) \xrightarrow{\text{aq.}} H^+_{(aq)} + Cl^{\ominus}_{(aq)}$$

NOTE → (i) Dimensions of henry's constant is same as pressure.

$$\underset{atm \hookleftarrow}{P} = \underset{\hookrightarrow unitless}{S K_H} \longrightarrow atm$$

(iii) Henry's constant is not a universal constant. It's value depends upon two factors: ① Nature of gas and ② Temperature.

Q An untrained nurse used distilled water to inject the patient. What will happen after this mistake? What mistake did she commit? What precaution should she take in the future?

Ans. The hypotonic distilled water will move into the hypertonic RBCs through SPM due to difference in osmotic pressure. RBCs will therefore swell and this is known as Hemolysis. She did the mistake of not concentrating the water equal to the concentration inside RBCs. Hence, as a precaution, she should always concentrate water with 0.9% NaCl (saline water) in the future to prevent Hemolysis.

Q The vapour pressure of a Liquid A is 400mmHg and the liquid B is 200mmHg. If the number of moles of A and B are 1 and 2 respectively, calculate the vapour pressure of solution.

(a) 800 mm Hg   (b) 100 mm Hg   (c) 500 mmHg   (d) None of the above

Q
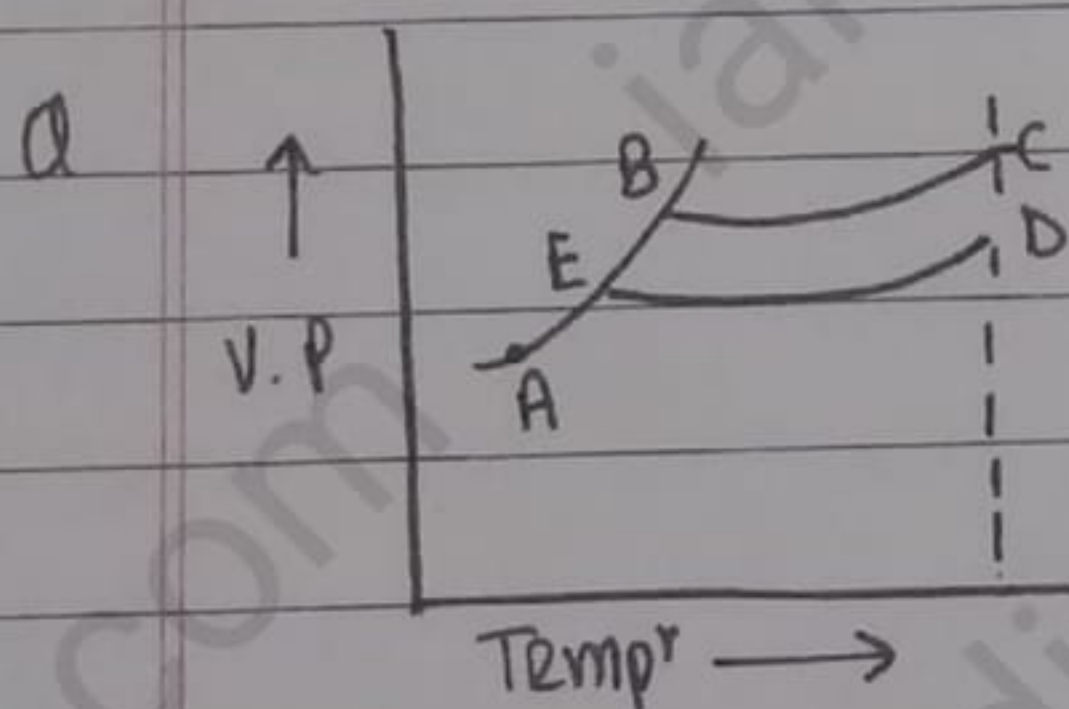
AB = Solid solvent
BC = Liquid solvent
DE = Liquid solution
What does this graph represent = Depression in Freezing point

Q Out of 1M glucose and 2M glucose, which will show higher boiling point and why?
Ans. Boiling point elevation ∝ conc. of solute particles ∴ 2M will show higher boiling point.

Q Will osmosis take place when 0.1 M aqueous urea and glucose solutions are separated by SPM?
Ans. No, since there is no difference in concentration

Q What happens when external pressure applied becomes more than osmotic pressure of the solution?
Ans. Reverse osmosis will take place.