Solution – It is a homogenous mixture of solute and solvent

(i) Solid dissolved in liquid
(ii) Gas in liquid
(iii) Liquid in liquid
(iv) Solid in solid (ex. all alloys)

Note: When the physical state of solute and solvent is same, component with higher no. of moles will be solvent and lesser no. of moles will be solute.

(i) Weight / Weight % (W/W) = $\frac{\text{Wt of solute}}{\text{Wt of solution}} \times 100$

25% (w/w)
↓
25 g of solute in 100 g solution

(ii) Weight / Volume % (W/V) = $\frac{\text{Wt of solute}}{\text{Vol. of solution}} \times 100$

25% (w/v)
↓
25 g solute in 100 ml solution

Mass of solution = 100 × d
Mass of solvent = (100 × d − mass of solute)

(iiii) Part Per million (PPm) -

It is used when solute is present is very small amount.

$$PPm = \frac{\text{wt of solute}}{\text{wt of solvent}} \times 10^6$$

$$\Rightarrow PPm \times 10^{-6} = \frac{\text{wt of solute}}{\text{wt of solvent}}$$

$$\Rightarrow PPm \times 10^{-6} \times 100 = \frac{\text{wt of solute}}{\text{wt of solvent}} \times 100$$

~~$\Rightarrow PPm \times$~~

$$\Rightarrow PPm \times 10^{-4} = \text{wt by wt \% (w/w)}$$

(iv) Mole - Fraction (x)

~~Salt~~ Solute + Solvent

$\downarrow$ n (mole of solute) $\quad$ $\downarrow$ N (moles of solvent)

Total mass in mixture $= n + N$

$$x_{solute} = \frac{n}{n+N}$$

$$x_{solvent} = \frac{N}{n+N}$$

$$x_{solute} + x_{solvent} = \frac{n}{N+n} + \frac{N}{N+n} = 1$$

(v) Molarity (M) :-

It is moles of solute in 1 L solution

$$M = \frac{n}{V_{sol}\,(litre)}$$

$$M = \frac{\text{wt of solute}/\text{mass of solute}}{V_{sol}\,(litre)}$$

$$M = \frac{w}{m \times V_{sol}}$$

$$M = \frac{w \times 1000}{m \times V_{sol}\,(ml)} \quad mol\,L^{-1}$$

(vi) Molality (m):-

Moles of solute per 1 kg solvent.

$$m = \frac{n}{W_{kg}}$$

$$m = \frac{W/m}{W_{kg}}$$

$$m = \frac{W}{m \times W_{kg}}$$

$$m = \frac{W \times 1000}{m \times W} \text{ mol kg}^{-1} \quad \left(\text{if } W \text{ of solvent is given in } g\right)$$

(vii)

Note- Molarity and Molality are interconvertable, if we know the ~~dens~~ density of the solution.

2m → 2 molal

↓

2 moles solute in 1 kg solvent (or 1000g solvent)

Wt of solution = 1000 + Wt of 2 moles solute

d = Density

$$V = \frac{\text{Mass}}{\text{Density}}$$

(From this we can take out molality)

Note ⇒ $$M = \frac{\% \text{ by wt} \times 10 \times d}{\text{Mol wt Solute}}$$

(vii) Strength (S):

Wt of solute in 1 L solution.

$$S = \frac{w}{V_{sol}(\text{litre})}$$

$$S = \frac{w \times 1000}{V_{sol}}$$

We know,

$$M = \frac{w \times 1000}{m \times V_{sol}} \Rightarrow M \times m = \frac{w \times 1000}{V_{sol}}$$

Now,

M x molecular (mol) wt solute = $S (g L^{-1})$

(i) Wt - Wt %

(ii) PPm

(iii) Mole Fraction (x)

(iv) Molality (m)

} Do not depend on temperature as there is no volume factor involved.

(i) Wt - Vol %

(ii) Strength

(iii) Molarity (M)

} · Depend on temperature due to volume factor.
· Decrease with rise in temperature due to increase in volume. vice-versa.

Q. In an eq. sol of $NaSO_3$ mole fraction of HNO_3

A. $x_{HNO_3} = \frac{n}{n+N}$

$\frac{2}{5} = \frac{n}{n+N}$

moles of $HNO_3 = 2$

moles of $H_2O = 3$

wt of $H_2O = 18 \times 3 = 5$

Q. wt % of HNO_3 is 69% and density 1.41 gml^{-1}. Find molarity.

A. $$M = \frac{\% \text{ by wt} \times 10 \times d}{\text{Mol wt of solvent}}$$

$$\Rightarrow M = \frac{69 \times 10 \times 1.41}{63} \text{ mol } L^{-1}$$

$$\Rightarrow M = 15.44 \text{ mol } L^{-1}$$

Dilution equation $\Rightarrow M_1V_1 = M_2V_2$

M x Val = millimole

Q. 0.1 M 200 ml HCl sol diluted to 800ml Find final molarity.

A. $M_1V_1 = M_2V_2$

$$\Rightarrow 0.1 \times 200 = M_2 \times 800$$

$$\Rightarrow M_2 = \frac{1}{40} \text{ mol } L^{-1}$$

Q. Which sol is more concentrated ~~sol~~, if its density is $1\ g\ ml^{-1}$. 1M or 1m.

A.

1M	1m
1 mole Solute in 1000ml Solution	1 mole Solute in 1000g Solvent
Wt of solution $\Rightarrow 1000 \times 1 = 1000g$	Wt of Solvent $\Rightarrow 1000g$
Wt of Solvent $\Rightarrow 1000 - $ wt of 1 mole solute	
Wt of solvent $< 1000g$	
$\therefore$ Higher concentration	$\therefore$ Lesser concentration

Q. Find No. of moles of methanol in 5L of its 2 m Solution, if density is $0.987\ kg\ L^{-1}$

A. 2m →
2 moles CH_3OH in 1000g Solvent
64 g CH_3OH in 1000g Solvent

Wt of solution $= 1000 + 64 = 1064\ kg$

Now,

$$d = \frac{m}{V} \Rightarrow .987 = \frac{m}{5}$$

wt of SL Sal = .987 × 5 = 4.925 kg

Now,

1.064 kg → 2 moles

4.925 kg → $\frac{2}{1.064} \times 4.925$

4.925 kg → 9.26 moles

Solubility of gas in liquid depends on, pressure of gas and temperature.

Effect of Pressure.

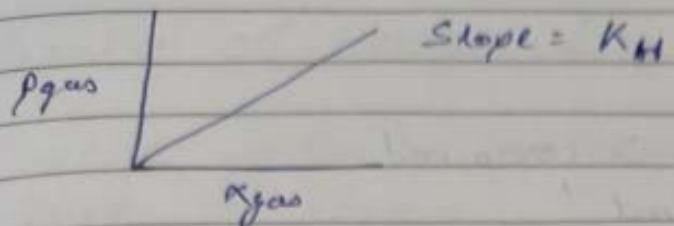
~~Mass~~ mass (m) $\propto$ Pressure (P) (Given that temp. is constant)

$$m = K \cdot P \quad \text{--(i)}$$

$K \rightarrow$ depends on
(i) Type of gas
(ii) Temp.
(iii) Solvent

$$P_{gas} \propto X_{gas\ (solution)}$$
$$\Rightarrow P_{gas} = K_H X_{gas}$$

$K_H \rightarrow$ Henry's Const
$\hookrightarrow$ Depends on :-
(i) Type of gas
(ii) Temp.
(iii) Solvent.



$$p_{gas} = K_H \cdot x_{gas} \quad \text{—(ii)}$$

$$K_H = \frac{p_{gas}}{x_{gas}}$$

↓

unit → $\frac{mm\ Hg}{atm}$ or bar or Pa or KPa

If the unit in inverse,

$$x_{gas} = K_H \cdot p_{gas} \quad \text{— (iii)}$$

Now,
In (ii) eq.

$$p_{gas} = K_H \cdot x_{gas} \text{ (solution)}$$

$$p_{gas} = K_H \cdot \left(\frac{n_{gas}}{n_{gas} + N_{solvent}}\right)$$

For Diluted solution,

$n_{gas} << N_{solvent}$

$$\therefore p_{gas} = K_H \cdot \frac{n_{gas}}{N_{solvent}}$$

For g

$H_2O \rightarrow 1L \rightarrow 1000\ ml$

$d = 1\ g\ ml^{-1}$

$1000\ ml = 1000\ g\ H_2O$

Moles of $H_2O = \frac{1000}{18} = 55.5$ moles

To cal. the partial pressure for each gas in gaseous state,

$$P_{gas} = P_{Total} \times \text{mole Fraction of gas in gaseous state}$$

If 2 gases are used at Same Partial pressure

$P_{gas} = const$

$K_H \cdot X_{gas(sol)} = const$

$K_H \propto \frac{1}{X_{gas(sol)}}$

$K_H \propto \frac{1}{\text{Solubility}}$

Application of Henry's Law

(i) Soda water contains excess of CO_2 gas dissolved at high at pressure, on opening the bottle, pressure falls and CO_2 escape with effervescence.

(ii) Climbers suffers from disease Anoxia, at ~~hi~~ because at higher ~~att~~ altitude, pressure is less so less O_2 goes in blood of a person.

(iii) Sea divers use breathing slinders in which helium gas is used as dilutent, to reduce the partial pressure of ~~N_2O~~ N_2 gas in air.

Gases dissolved in liquid to give solution, and this is exothermic, therefore on increasing the temperature, equilibrium shift backward which means dissolved gas in solution state, or in other word, solubility decrease with temperature rise.

A. Aquatic animals are more comfortable in cold waters, because it contains more amount of dissolved O_2, as temperature rises in summer O_2 in content in waters decreases and animal face breathing problems.

Note → we know,

$K_H \propto \frac{1}{\text{Solubility}}$ And Solubility $\propto \frac{1}{\text{Temperature}}$

$\therefore K_H \propto$ Temperature.

Numerical based on Henry's Law

Q. H_2S gas is toxic gas, its solubility in H_2O at S.T.P. is 0.195 m. Find K_H.

A. 0.195 m

↓

0.195 moles of H_2S gas in 1000g H_2O

moles of H_2O in 1000g = 55.5 moles

Now,

$P_{H_2S} = K_H \cdot X_{H_2S}$ (solution)

$\Rightarrow 1 = K_H \cdot X_{H_2S}$ ($\because P_{H_2S}$ at S.T.P. = 1 atm.

$$\Rightarrow K_H = 1 \times \frac{.195 + 55.5}{.195}$$

Part III

Colligative properties (C.P.) –

Properties of solution, which are depends upon No. of moles of solute in solution, and doesn't depends on nature of solute.

(i) Relative lowering in vapour-pressure. (V.P.)

(ii) Osmatic pressure. (π)

(iii) Elevation in boiling point. (ΔT_b)

(iv) Depression in Freezing point (ΔT_f)

This properties help in finding molecular weight solute.

(i) Relative Lowering in V.P.

V.P. of Liquid :-

Pressure exerted by vapours of liquid on liquid surface is called its vapour pressure.

It depends on :-

(i) Nature of liquid :-

- If inter-molecular attraction is strong, then V.P. will be low, therefore boiling point will be high. Such kind of liquids are called non-volatile liquid.

inter-molecular attraction $\propto \frac{1}{\text{V.P.}}$ $\propto$ Boiling point.

- If inter-molecular attraction is weak, then V.P. will be high, therefore boiling will be low. Such liquid are called volatile liquid.

(ii) Temperature :-

- ~~Temperature $\propto \frac{1}{\text{V.P.}}$~~
- Temperature $\propto$ V.P.

Q. We cool liquid ammonia bottle before opening. Why?

A. We cool liquid ammonia bottle before opening, to lower its vapour pressure, since vapour is directly proportional to temperature. If we don't cool the bottle, the liquid ammonia will burst out of the bottle due to high V.P..

Raoult's Law for non-volatile solute -

$$\frac{P_A^\circ - P_S}{P_A^\circ} = X_{solute}$$

$$\frac{P_A^\circ - P_S}{P_A^\circ} = \frac{n}{n+N}$$

For dil sol $n << N$

$$\Rightarrow \frac{P_A^\circ - P_S}{P_A^\circ} = \frac{n}{N} = \frac{w/m}{W/M}$$

$$\Rightarrow \frac{P_A^\circ - P_S}{P_A^\circ} = \frac{w}{m} \times \frac{M}{W}$$

$$\Rightarrow \frac{1}{M} \times \left(\frac{P_A^\circ - P_S}{P_A^\circ}\right) = \frac{w}{m \times W}$$

$$\Rightarrow \frac{1}{M} \times \left(\frac{P_A^\circ - P_S}{P_A^\circ}\right) \times 1000 = \frac{w \times 1000}{m \times W}$$

$$\Rightarrow \frac{1}{M} \times \left(\frac{P_A^\circ - P_S}{P_A^\circ}\right) \times 1000 = \text{molality } (m)$$

Q. 3g H_2 H

(i)

(ii)

A.

$\Rightarrow$

Q. 30 g non-volatile solute dissolve in 90 g H_2O & V.P. of sol is 2.8 KPa. Further 18 g more H_2O is added V.P. become 2.9 KPa.
Find
(i) Mol wt of solute
(ii) V.P. of H_2O.

A. $$\frac{P_A^\circ - P_S}{P_A^\circ} = \frac{w}{m} \times \frac{M}{W}$$

$$\Rightarrow \frac{P_A^\circ - 2.8}{P_A^\circ} = \frac{30}{m} \times \frac{18}{90} \quad \text{---(i)}$$

$$\Rightarrow \frac{P_A^\circ - 2.9}{P_A^\circ} = \frac{30}{m} \times \frac{18}{108} \quad \text{---(ii)}$$

On dividing, $P_A^\circ = 3.4$ KPa

$m = 34$ g mol^{-1}

Q. V.P. of water H_2O is 12.3 KPa. Find the V.P. of 1 molal aqueous solution.

Sol. Given,

$P_A^\circ = 12.3$ KPa

molality = 1

$P_S = ?$

We know,

$$\frac{1000 \times 1}{M} \times \left(\frac{P_A^\circ - P_S}{P_A^\circ}\right) = \text{molality}$$

$$\Rightarrow \frac{1000 \times 1}{18} \times \left(\frac{12.3 - P_S}{12.3}\right) = 1$$

$$\Rightarrow 1 - \frac{P_S}{12.3} = \frac{18}{1000}$$

$$\Rightarrow \frac{P_S}{12.3} = \frac{982}{1000}$$

$$\Rightarrow P_S = \frac{982}{1000} \times 12.3 \text{ KPa}$$

Solution of 2 volatile liq.

Liq A + Liq B → Solution

Let

V.P. of pure A = P_A°

V.P. of pure B = P_B°

Mole Fraction of A in solution = x_A

Mole Fraction of B in solution = x_B

Partial Pressure of A = p_A

Partial Pressure of B = p_B

Now

By Raoult's Law,

$p_A = P_A^\circ \cdot x_A$

$p_B = P_B^\circ \cdot x_B$

~~Partial~~ P_{Total} (solution) = $p_A + p_B$

$= P_A^\circ \cdot x_A + P_B^\circ \cdot x_B$

$= P_A^\circ x_A + P_B \cdot x_{(1-x_A)}$ $(\because x_A + x_B = 1)$

Mole Fraction in vapour phase (Y) –

$= \frac{\text{Partial Pressure}}{\text{Total Pressure}}$

$\Rightarrow Y_A = \frac{p_A}{P_{Total}}$

Now,

$Y_A = \frac{P_A^\circ \cdot x_A}{P_A^\circ \cdot x_A + P_B^\circ \cdot x_B}$

Now,

$Y_B = \frac{P_B}{P_{Total}}$

$\Rightarrow Y_B = \frac{P_B^\circ \cdot x_B}{P_A^\circ \cdot x_A + P_B^\circ \cdot x_B}$

Note:- $\boxed{Y_A + Y_B = 1}$

Q. V.P. of pure A and B are 300 mm and 800 mm respectively. Find V.P. of solution if mixture is equimolar and find composition in vapour phase.

A Given,

$P_A^\circ = 300 mm$

$P_B^\circ = 800 mm$

moles of A = moles of B (∵ mixture is equimolar)

$\therefore x_A = x_B = \frac{1}{2}$

Now,

$P_A = P_A^\circ \cdot x_A = 300 \times \frac{1}{2} = 150 mm$

$P_B = P_B^\circ \cdot x_B = 800 \times \frac{1}{2} = 400 mm$

$\boxed{P_{Total} = 550 mm}$

Now,

$Y_A = \frac{P_A}{P_{Total}} = \frac{150}{550} = \frac{3}{11}$

$Y_B = \frac{P_B}{P_{Total}} = \frac{400}{550} = \frac{8}{11}$

Ideal solution –

Mixture of 2 liquid which follows Raoult's law at all concentration and temperature range.

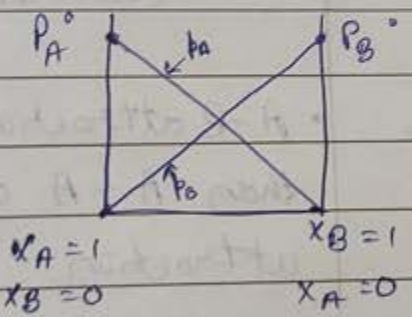
(i) $p_A = p_A^\circ \cdot x_A$
$p_B = p_B^\circ \cdot x_B$
$p_{total} = p_A + p_B$

(ii) $\Delta H_{mix} = 0$ (ΔH is change in heat temperature)

(iii) $\Delta V_{mix} = 0$ (No expantion or contraction)

(iv) A - B attraction, almost equal to A - A and B - B attraction.

Graph



$p_A = p_A^\circ \cdot x_A$
$p_A \propto x_A$

$p_B = p_B^\circ \cdot x_B$
$p_B \propto x_B$

Non-Ideal Solution

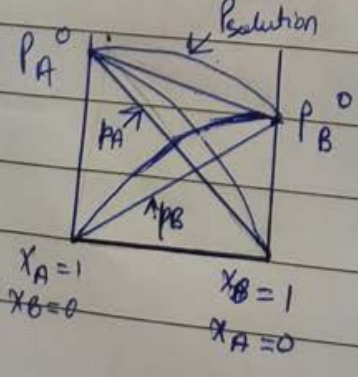
Mixture of 2 liquid which does not follow Raoult's Law.

Two types of non-ideality are known.

Positive Deviation

- $p_A > P_A^\circ \cdot x_A$
  $p_B > P_B^\circ \cdot x_B$
  $P_{Total} > p_A + p_B$
- ΔH_{mix} = +ve (endothermic) (cooling effect)
- ΔV_{mix} = +ve (expansion)
- A-B attraction is weaker than A-A and B-B attraction.

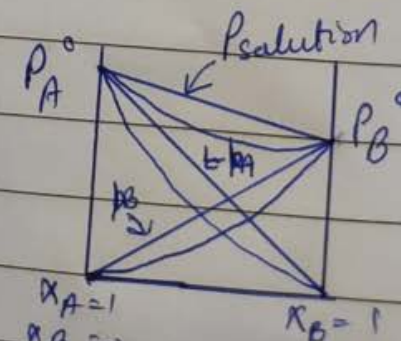
ex. (i) $C_2H_5OH + H_2O$
(ii) C_2H_5OH + cyclohexane



Negative Deviation

- $p_A < P_A^\circ \cdot x_A$
  $p_B < P_B^\circ \cdot x_A$
  $P_{Total} < p_A + p_B$
- ΔH_{mix} = -ve (exothermic) (heating effect)
- ΔV_{mix} = -ve (contraction)
- A-B attraction is stronger than A-A and B-B attraction.

ex. (i) $HNO_3 + H_2O$
(ii) $CH_4 + CH_3COOH$



Azeotropic Mixture –
Mixture of 2 miscible liquid in which both boils at same temperature is known as Azeotropic mixture.
Non-ideal liquid mixture makes azeotropes.
Azeotropes are of two types:-

(i) Minimum boiling azeotropes-

Boiling of mixture is less than the boiling point of both liquids.
Liquid showing positive deviation are minimum boiling azeotropes.

(ii) Maximum Boiling Azeotropes -

Boiling of mixture is more than the boiling point of both liquids.
Liquid showing negative deviation are maximum boiling azeotropes