SOLUTIONS

KEY CONCEPTS

SOLUTION is the homogeneous mixture of two or more than two components. Most of the solutions are binary i.e. consists of two components out of which that is present in the largest quantity called solvent & one which is present in smaller quantity called solute.

EXPRESSING CONCENTRATIONS OF SOLUTIONS

- Mass percentage: Mass of solute per 100g of solution. Mass%= (mass of solute/total mass solution) x 100
- Volume percentage: volume of solute per 100 mL of solutions.
- Parts per million: parts of a component per million (10^6) parts of the solution.
- Mole fraction(x): It is the ratio of no. of moles of one component to the total no. of moles of all the components present in the solution.
- Molarity: No. of moles of solute dissolved in one litre of solution.
- Molality(m): No. of moles of solute per kg of the solvent.
- Molality is independent of temp. whereas molarity is a function of temp. because vol. depends on temp. and mass does not.

HENRY'S LAW

It states that at a constant temp. the solubility of the gas in liquid is directly proportional to the pressure of the gas above the surface of the liquid.

It also states that the partial pressure (p) of a gas in vapour phase is proportional to the mole fraction of the gas (x) in the solution.

$$P=K_HX$$

K_H is Henry's law constant.

APPLICATION OF HENRY'S LAW

- To increase the solubility of CO_2 in soda water and soft drinks the bottle is sealed under high pressure.
- To avoid bends, toxic effects of high concentration of nitrogen in the blood the tanks used by scuba divers are filled with air diluted with He.

RAOULT'S LAW:- It states that:

1) For a solution of volatile liquid, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution.

$$P_A = P^0_A X_A; \quad P_B = P^0_B X_B$$

The total pressure is equal to sum of partial pressure.

$$P_{total}=P_A+P_B$$

2) For a solution containing non-volatile solute the vapour pressure of the solution is directly proportional to the mole fraction of the solvent.

$P_A \alpha X_A \quad P_A = P^0_A X_A$

IDEAL SOLUTION

The solution which obeys Raoult's law over the entire range of concentration when enthalpy of mixing and vol. of mixing of pure component to form solution is zero.

CONDITIONS

I. $P_A = P^0_A X_A \qquad P_B = P^0_B X_B$ II $\Delta Hmix = 0$ III $\Delta Vmix = 0$

This is only possible if A-B interaction is nearly equal to those between A-A and B-B interactions.

Ex:- solution of n-hexane and n-heptane.

NON IDEAL SOLUTION

The solution which do not obey Raoult's law over the entire range of concentrations.

CONDITIONS

I. $P_A \neq P^0_A X_A \qquad P_B \neq P^0_B X_B$ II $\Delta Hmix \neq 0$ III $\Delta Vmix \neq 0$

The vapour pressure of such solutions is either higher or lower than that predicted for Raoult's law.

I. If vapour pressure is higher, the solutions shows positive deviation (A-B interaction are weaker than those between A-A and B-B).

Ex: mixture of ethanol and acetone.

$P_A > P^0_A X_A \; ; \quad P_B > P^0_B X_B$

$\Delta Hmix = Positive, \; \Delta Vmix = Positive$

II. If vapour pressure is lower, the solution shows negative deviation (A-B interaction are stronger than those between A-A and B-B).

Ex: mixture of chloroform and acetone.

$P_A < P^0_A X_A \qquad P_B < P^0_B X_B$

$\Delta Hmix = negative, \; \Delta Vmix = negative$

AZEOTROPE

Mixture of liquid having the same composition in liquid and vapour phase and boil at constant temp.

Azeotrope are of two types:-

a) Minimum boiling azeotrope :- The solution which shows a large positive deviation from Raoult's law. ex- ethanol-water mixture.

b) Maximum boiling azeotrope :- the solution which shows large negative deviation from Raoult's law. Ex- nitric acid-water mixture.

COLLIGATIVE PROPERTIES Properties of ideal solution which depends upon no. of particles of solute but independent of the nature of the particles are called colligative properties.

1. RELATIVE LOWERING OF VAPOUR PRESSURE

$(P^O_A - Ps)/P^O_A = X_B, \qquad X_B = n_B / n_A + n_B$

For dilute solution, $n_B << n_A$, hence n_B is neglected in the denominator. $(P^O_A - Ps)/P^O_A = n_B / n_A \; (P^O_A - Ps)/P^O_A$

$= W_B \times M_A / M_B \times W_A$

2. ELEVATION OF BOILING POINT

$\Delta T_b = k_b m$ Where $\Delta T_b = T_b - T^O_b$

k_b = molal elevation constant/ Ebullioscopic constant m=molality

$M_B = k_b \times 1000 \times W_B / \Delta T_b \times W_A$

3. DEPRESSION IN FREEZING POINT

$\Delta T_f = k_f m$ Where $\Delta T_f = T^O_f - T_f$

K f= molal depression constant/ Cryoscopic constant m=molality

$M_B = k_f \times 1000 \times W_B / \Delta T_f \times W_A$

4. OSMOTIC PRESSURE

The excess pressure that must be applied to a solution side to prevent osmosis i.e. to stop the passage of solvent molecules into it through semi-permeable membrane.

$\pi = CRT$

$\pi = n_B/VRT$ (n_B =no.of moles of solute; V= volume of solution(L) R= 0.0821Latmmol^{-1}; T= temperature in kelvin

ISOTONIC SOLUTION

Two solutions having same osmotic pressure and same concentration.

Hypertonic solution have higher osmotic pressure and hypotonic solution have lower osmotic pressure than the other solution.

0.91% of sodium chloride is isotonic with fluid present inside blood cell.

VAN'T HOFF FACTOR (i)

Ratio of normal molecular mass to the observed molecular mass of the solute.

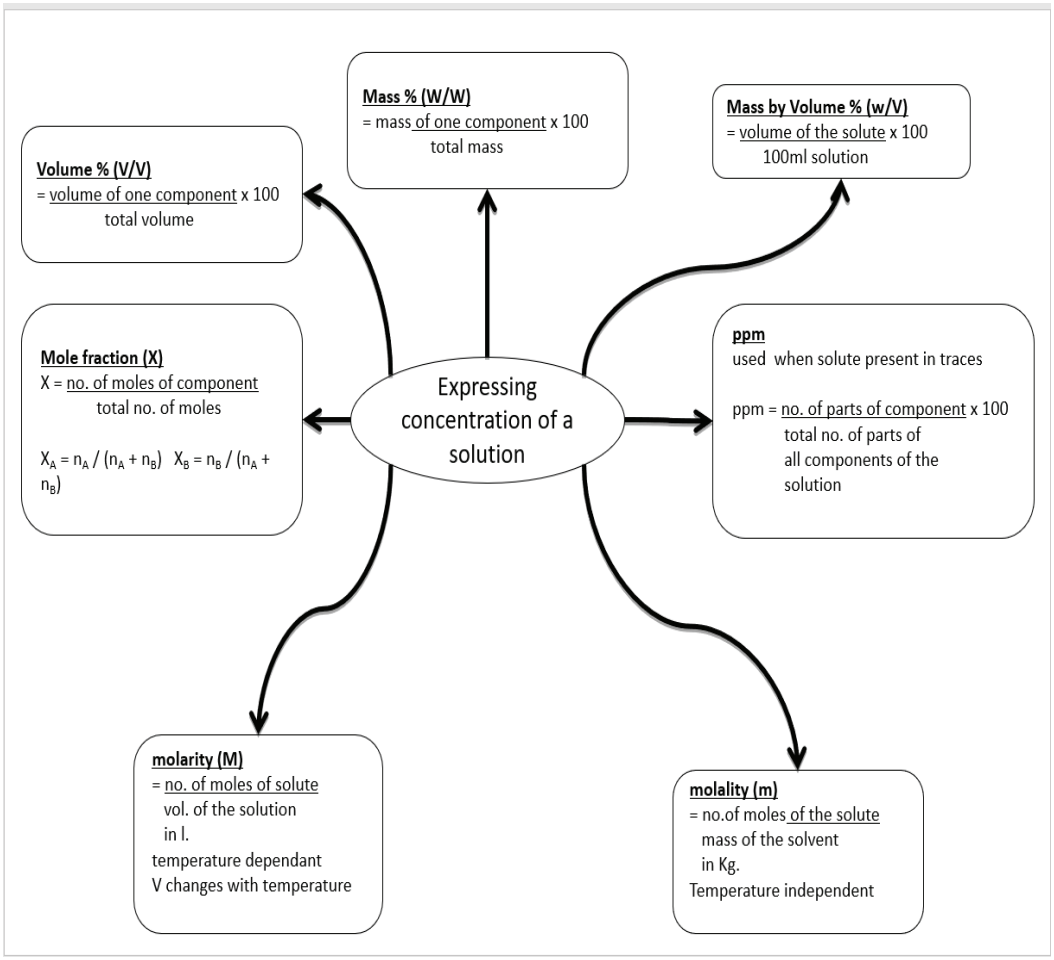
i = normal molecular mass/ observed molecular mass

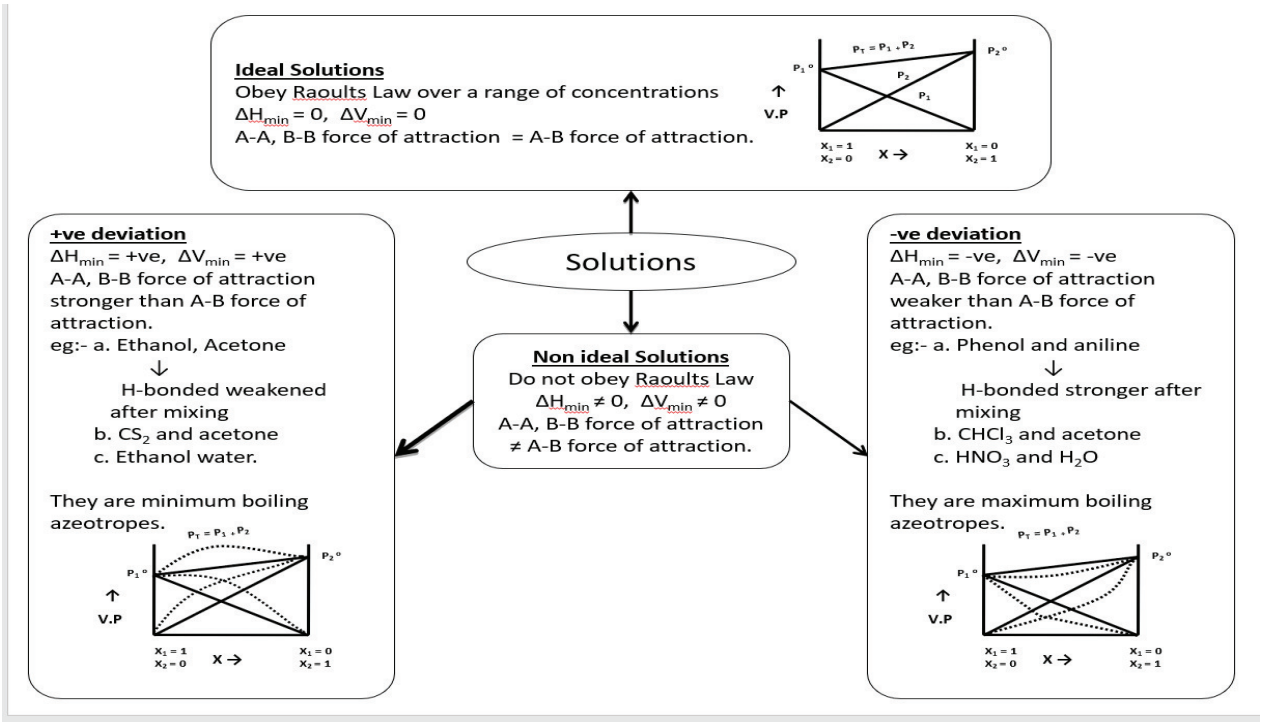
= observed colligative properties/ calculated value of colligative properties i<l

(for association) i>l (for dissociation)

MODIFIED FORMS OF COLLIGATIVE PROPERTIES

1) $(P^O_A - Ps)/P^O_A = i x X_B$ 2) $\Delta_{Tb} = i \times k_b m$ 3) $\Delta T_f = ix\ k_f m$ 4) $\pi = ix\ CRT$


Expressing concentration of a solution
Mass % (W/W)
= mass of one component x 100
total mass
Mass by Volume % (w/V)
= volume of the solute x 100
100ml solution
Volume % (V/V)
= volume of one component x 100
total volume
Mole fraction (X)
X = no. of moles of component
total no. of moles
$X_A = n_A / (n_A + n_B)$ $X_B = n_B / (n_A + n_B)$
ppm
used when solute present in traces
ppm = no. of parts of component x 100
total no. of parts of
all components of the
solution
molarity (M)
= no. of moles of solute
vol. of the solution
in l.
temperature dependant
V changes with temperature
molality (m)
= no.of moles of the solute
mass of the solvent
in Kg.
Temperature independent


Solutions
Ideal Solutions
Obey Raoults Law over a range of concentrations
$\Delta H_{min} = 0$, $\Delta V_{min} = 0$
A-A, B-B force of attraction = A-B force of attraction.
V.P
X →
Non ideal Solutions
Do not obey Raoults Law
$\Delta H_{min} \neq 0$, $\Delta V_{min} \neq 0$
A-A, B-B force of attraction
≠ A-B force of attraction.
+ve deviation
ΔH_{min} = +ve, ΔV_{min} = +ve
A-A, B-B force of attraction stronger than A-B force of attraction.
eg:- a. Ethanol, Acetone
↓
H-bonded weakened after mixing
b. CS_2 and acetone
c. Ethanol water.
They are minimum boiling azeotropes.
-ve deviation
ΔH_{min} = -ve, ΔV_{min} = -ve
A-A, B-B force of attraction weaker than A-B force of attraction.
eg:- a. Phenol and aniline
↓
H-bonded stronger after mixing
b. $CHCl_3$ and acetone
c. HNO_3 and H_2O
They are maximum boiling azeotropes.

Relative lowering of V.P.

$\frac{P_1^\circ - P_1}{P_1^\circ} = \frac{W_2 \times M_1}{M_2 \times W_1}$ or $\frac{P_1^\circ - P_1}{P_1^\circ} = i\,\frac{W_2 \times M_1}{M_2 \times W_1}$

W_1 and W_2 are mass of solvent and solute
M_1 and M_2 molar mass of solvent and solute
i = Vant Hoff Factor
P_1° = V.P of pure solvent
P_1 = V.P of solution

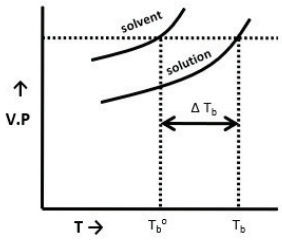
Colligative properties

Elevation in B.P.

$\Delta T_b = K_b \cdot m$
$\Delta T_b = K_b \cdot \frac{w_2 \times 1000}{m_2 \times w_1}$
$\Delta T_b = T_b - T_b^\circ$

T_b = B.P. of solution
T_b° = B.P. of solvent

w_1 and w_2 are mass of solvent and solute
M_2 molar mass of solute
Or
$\Delta T_b = iK_b \cdot m$
i = Vant Hoff Factor
K_b = molal elevation constant



Osmotic Pressure

$\pi V = \frac{W_2 RT}{M_2}$
$\pi V = iCRT$ ($C = W_2 / M_2$)
R = gas constant
i = Vant Hoff Factor
T = Temperature
V = Vol. of solution in L.
Π = osmotic pressure

Depression in F.P.

$\Delta T_f = K_f \cdot m$
$\Delta T_f = T_f^\circ - T_f$
K_f = Cryoscopic constant
$\Delta T_f = K_f \cdot \frac{w_2 \times 1000}{m_2 \times w_1}$
$\Delta T_f = T_f^\circ - T_f$

T_f = F.P. of solution
T_f° = F.P of solvent

w_1 and w_2 are mass of solvent and solute
m_2 molar mass of solute
Or
$\Delta T_f = iK_f \cdot m$
i = Vant Hoff Factor