

Solution

- Solution is a homogeneous mixture of two or more substance in same or different physical phases. The substances forming solution are called component of solution i.e. solute and solvent. Solvent is the component which is present in large quantity while the other component is known as solute.
- If H_2O is used as a solvent the solution is called aqueous soln. and if not solution is called non-aqueous solution. Depending upon the amount of solute dissolved in it solvent we have the following types of solution.

(1) Unsaturated solution:-

A solution in which more solute can be dissolved without raising temperature is called an unsaturated solution.

(2) Saturated solution:-

A solution in which no solute can be dissolved further at a given temperature is called a saturated solution.

(3) Super-saturated solution:-

A solution which contains more solute than that would be necessary to saturate it at a given temperature is called super-saturated solution.

* Methods of expressing concentration of solution

(1) % / weight :-

It is defined as the amount of solute present in 100g of solution.

(2) \Rightarrow

$$\boxed{W/W \% = \frac{\text{wt. of solute}}{\text{wt. of solvent}} \times 100}$$

(2) % / volume :-

It is defined as the volume of solute in ml present in 100ml solution

*

$$\boxed{V/V \% = \frac{\text{volume of solute}}{\text{vol. of solution}} \times 100}$$

(3) % mass / volume :-

It is defined as the mass of solute in 100ml of solution.

*

$$\boxed{\% w/v = \frac{\text{mass of solute}}{\text{vol. of solution}} \times 100}$$

(4) Strength or Concentration (g/l) :-

\rightarrow It is defined as the amount of the solute in gram present in one liter of solution.

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$$\boxed{\text{conc of solution} = \frac{\text{solute in gram}}{\text{vol. of soln in liters}}}$$

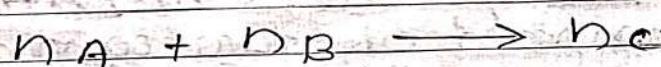
⑤ Parts per million (ppm) :-

When the solute is present in trace quantity quantities it is convenient to express the concentration in parts per million. It is defined as the quantity of solute in gram present in 10^6 gram of the soln.

$$\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$$

Mole fraction:-

It is defined as the ratio of the no. of moles of a component to the total no. of moles of the component.



$$X_A = \frac{n_A}{n_A + n_B}$$

$$X_B = \frac{n_B}{n_A + n_B}$$

~~H₂O 100
Monomer~~

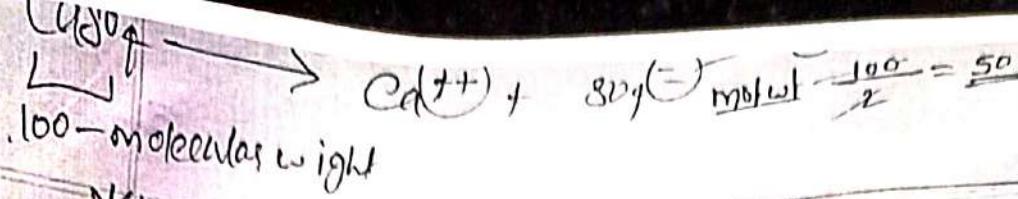
Molarity:-

It is defined as the no. of moles of the solute present in 1 kg of solvent it is denoted by "m".

$$\text{Molarity} = \frac{\text{no. of moles of solute}}{\text{wt (kg) of solution}}$$

Molality:-

It is defined as the no. of moles of the solute present in 1 litre of solvent it is denoted by "M".



* **Molarity** = $\frac{\text{no. of moles of solute}}{\text{volume of solution in litres}}$

* **Normality**:-

It is defined as no. of gram equivalent of solute per litre of solution. It is denoted by "N".

* **Normality** = $\frac{\text{no. of gram equivalent}}{\text{no. of volume of solution}}$

* **Ideal Solution**:-

An ideal solution is one in which the molecule attract one another with equal force irrespective to their nature thus a solution composed of two components A and B will be an ideal (1) if the forces b/w A & A, B & B should be same.

→ An ideal solution passes the following characteristics

(1) * Volume change of mixing should be zero (0).

$$|\Delta V_{\text{mix}} = 0|$$

(2) * Heat change on mixing should be zero (0).

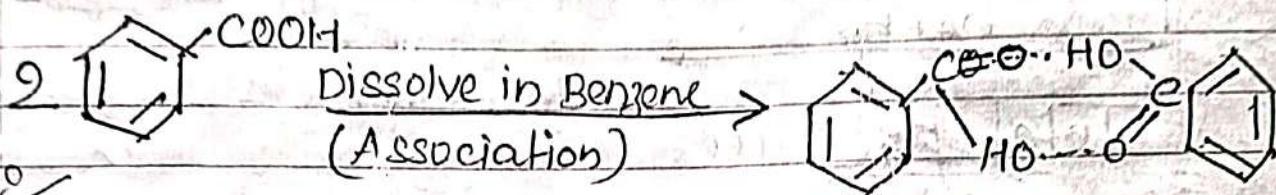
$$|\Delta H_{\text{mix}} = 0|$$

(3) * There should be no chemical rxn b/w solvent

and solute.

(4) Solute molecules should not dissociate in the ideal solution.

(5) Solute molecules should not associate in ideal solution.



Ideal solution must obey Raoult's Law at all concentrations. The following are some of the binary mixtures which show the properties of ideal solution.

(A) Benzene & Toluene

(B) Carbon tetrachloride & Chloro tetrachloride

Raoult's law :-

According to this law, the partial pressure of any volatile constituents of a solution at a constant temperature is equal to the vapour pressure of pure constituent multiplied by the mole fraction of that constituent in ~~this~~ this solution.

→ Let a mixture (solution) be prepared by mixing n_A mole of liquid A and n_B mole of liquid B. Let P_A and P_B be the partial pressure of two constituents A & B. In solution and $P^{\circ}A$ and $P^{\circ}B$ the vapour pressure in pure state respectively.

Thus according to Raoult's law

$$P_A = \frac{n_A}{n_A + n_B} P^{\circ}_A \quad \left[= \text{mole fraction of A} \times P^{\circ}_A = X_A P^{\circ}_A \right]$$

$$P_B = \frac{n_B}{n_A + n_B} P^{\circ}_B \quad \left[\text{mole fraction of B} \times P^{\circ}_B = X_B P^{\circ}_B \right]$$

Total pressure

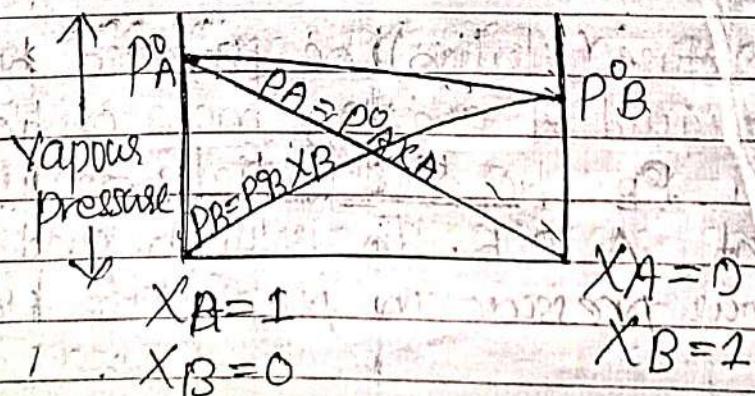
$$P = P_A + P_B$$

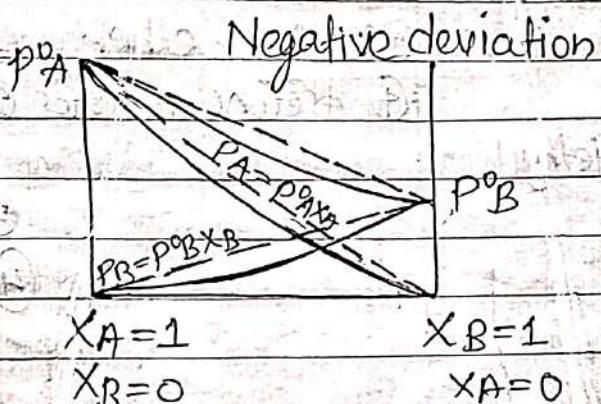
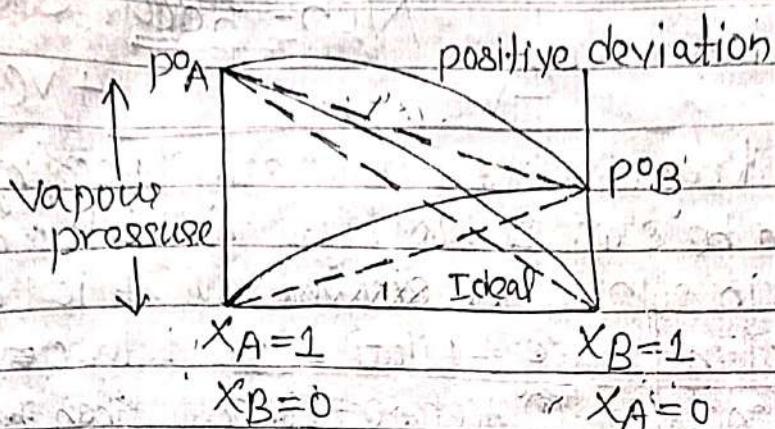
$$P = X_A P^{\circ}_A + X_B P^{\circ}_B$$

→ This law in fact is the major deciding factor whether a solution will be ideal or non-ideal. Ideal solution obey Raoult's law at every range of concentration. Non-ideal solution don't obey Raoult's law, they show either +ve or -ve deviation from Raoult's law.

Ideal or Non-Ideal Solution:-

Ideal deviation:-





Ideal solution - $\Delta H_{mix} = 0$

(i) Obey Raoult's law every range of concentration

(ii) $\Delta H_{mix} = 0$ either heat is evolved or released

(iii) $\Delta V_{mix} = 0$ total volume of soln is equal to sum of value of the component.

(iv) $P = P_A + P_B = P_A^0 X_A + P_B^0 X_B$ i.e. $P_A = P_A^0 X_A - P_B = P_B^0 X_B$

(v) A-A, A-B, B-B attractive forces of interaction should be same that is A & B are identical and same size and character.

Non-ideal solution - $\Delta H_{mix} \neq 0$

Don't obey Raoult's law.

$\Delta H_{mix} > 0$, Endothermic, dissociation heat is absorbed

$\Delta V_{mix} > 0$ volume increases after dissolution.

$P_A > P_A^0 X_A$

$P_B > P_B^0 X_B$

$P_A + P_B > P_A^0 X_A + P_B^0 X_B$

Don't obey Raoult's law.

$\Delta H_{mix} < 0$, Exothermic dissociation heat is released.

$\Delta V_{mix} < 0$ volume decreases after dissolution.

$P_A < P_A^0 X_A, P_B < P_B^0 X_B$

$P_A + P_B < P_A^0 X_A + P_B^0 X_B$

A, B attractive force AB attractive force should be weaker than A-B, B-B attractive force A & B have different size, shape & character.

Ideal solution

Non-Ideal solution

-ve

+ve

- (vi) Escaping tendency of A and B should be same in pure liq. and in solns.
e.g.- Dilute solns.

- ① Benzene + Toluene
- ② N-hexane + N-heptane
- ③ Chlorobenzene + Bromobenzene
- ④ Ethyl bromide + ethyl iodide

A & B escape easily showing higher than the expected value
e.g.- Dilute solns.

- ① Acetone + Ethanol
- ② water + Methanol
- ③ water + ethanol
- ④ Acetone + water

Escaping tendency both components A & B is lowered than lower evap. pres.

- than the expected value
- e.g.-
- ① Acetone + Aniline
- ② Acetone + Chloroform
- ③ water + HCl
- ④ Acetic acid + pyridine.

* Solution of gases in liquid:-

→ The solubility of gas in a liquid represent the concentration of dissolved gas in a liquid when it is in equilibrium with some of the pure gas about this solution.

Eg:- Pharmaceutical aerosols containing hydrogen also be considered as solution of the gases in liquid.

* Factors affecting solubility of gases in liquid:-

→ This solubility of gas in a solvent depend on temperature, pressure, presence of salts and chemical reaction. If any between the gas and the solvent.

Effect of Pressure:

The pressure of the gas above the solution, since this significant changes this these significant changes the solubility of the dissolved gas. The effect of pressure on the solubility of the gas is given by Henry's law which states that in a dilute solution the mass of the gas which dissolves in a given volume of a liquid at a constant temperature is directly proportional to the partial pressure of the gas.

A/C to Henry's law

$$C \propto P$$

$$C = kP$$

\approx low

- C is the conc of dissolved gas in grams per liter of solvent.
- P is partial pressure in mm of Hg of the undissolved gas above the solution can be obtained by subtracting the vapour pressure of the solvent from the total pressure.
- C is the proportionality constant and is referred to as the solubility coefficient.

(1) The solubility of gases generally increases with increase pressure and on the release on the pressure a solubility decrease and the gases escape.

(2) Effect of Temperature:-

Solubility of most gases decreases with a rise in temperature because of

The greater tendency of the gases to expand is comprison to the solvent. It is therefore essential that caution must be exercised when opening the containers containing gaseous soln under elevated temperature. It is better to reduce the temperature by immersing an ice coated water before opening such containers.

③ Effect of electrolytes and non-electrolytes:-

→ Solubility of gases in a solvent is generally reduced by the addition of electrolytes such as sugars. This is referred as salting out. This is due to more affinity between the solvent and the electrolyte or non-electrolyte than between the solvent and the gas.

④ Effect of chemical rxns:-

→ Henry's law generally applies to gases that are only slightly soluble in solvent and then don't react in anyway with this solvent. Chemical rxn between a gas and a solvent greatly increases the solubility of the gases in the solvent.

for e.g. - Hydrogen chloride gas reacts with water by Hydrogen bonding when it dissolved in water. This increases the solubility of HCl gas in water.

⑤ Colligative properties of dilute soln:-

A dilute soln is one in which the amount of the solute is very small in comparison to the

amount of the solvent. The dilute soln show more or less ideal behaviour as the heat and volume changes accompanying the mixing of solute and solvent are negligible for all practical purpose.

→ Dilute soln obey Raoult's law.

→ Dilute soln containing non-volatile solute exhibit some special properties which depends only upon the no. of solute particles present in the solution irrespective of their nature.

These properties are termed as colligative properties.
The colligative properties are:-

- (i) Lowering of vapour pressure.
- (ii) Elevation in the boiling point.
- (iii) Depression in the freezing point.
- (iv) Osmotic pressure.

(i) Lowering in Vapour pressure-

→ When a non-volatile solute is added to a solvent, the vapour pressure is lowered due to following reasons:-

- (1) % surface area occupied by the solvent decreases. Thus, the rate of evaporation and vapour pressure decreases. The solute molecules occupied the surface area and so the % surface area occupied by the solvent decreases.

- (2) According to Graham's law - rate of evaporation $\propto \frac{1}{\text{density}}$

→ When a non-volatile solute is dissolved in a liquid its density increases their both rate of evaporation and

Vapour pressure lowered. If P^o is the vapour pressure of the pure solvent and P_s is the vapour pressure of the solution the difference ($P^o - P_s$) is termed lowering of vapour pressure and the ratio $\frac{P^o - P_s}{P^o}$ is termed relative lowering of vapour pressure.

According to Raoult's law →

The relative lowering in vapour pressure of a dilute solution is equal to mole fraction of solute present in the solution. If n moles of solute be dissolved in N moles of the solvent the mole fraction of solute will be $\frac{n}{n+N}$

According to Raoult's law

$$\frac{P^o - P_s}{P^o} = \frac{n}{n+N}$$

mole of solvent
mole of solute

or, it can be written as,

$$\frac{P^o}{P^o - P_s} = \frac{n+N}{n} = 1 + \frac{N}{n}$$

or,

$$\frac{P^o}{P^o - P_s} = 1 = \frac{N}{n} \quad \text{or} \quad \frac{P_s}{P^o - P_s} = \frac{n}{N}$$

or,

$$\frac{P^o - P_s}{P_s} = \frac{w_A}{m_A} \times \frac{m_B}{w_B}$$

→ After adding of non-volatile solute dissolved in a volatile solvent:

$$P_s \propto \frac{1}{\frac{n}{N}}$$

$$P_s = K \cdot \frac{N}{n+N}$$

(i)

K = proportionality factor

* For pure solvent $n=0$

$$\text{and hence, } P_0 = K \frac{N}{0+N} = K \quad \text{(ii)}$$

putting the value of K in eqn (i)

$$P_S = P_0 \frac{N}{n+N}$$

$$\frac{P_S}{P_0} = \frac{N}{n+N}$$

$$\frac{1-P_S}{P_0} = \frac{1-N}{n+N}$$

$$\left[\frac{P_0 - P_S}{P_0} = \frac{n}{n+N} \right] \quad \text{(iii)}$$

→ If a solution is made by dissolving w_B gram of solute (molecular mass m_B) in w_A gr. of the solvent (molecular mass m_A) the mole fraction of the solute will be

$$\frac{w_B}{m_B}$$

$$\frac{w_A}{m_A} + \frac{w_B}{m_B}$$

→ If the solution is very dilute w_B/m_B can be neglected in the denominator as compare to w_A/m_A then equation (iii) thus becomes,

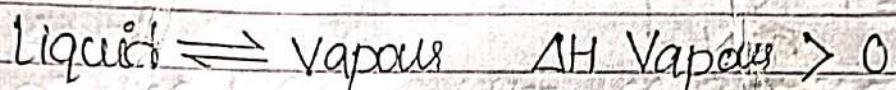
$$\left[\frac{P_0 - P_S}{P_0} = \frac{w_B \times m_A}{w_A \times m_B} \right] \quad \text{(iv)}$$

→ This relationship is useful in the determination of the molecular mass of dissolved solute by measuring relative lowering of vapour pressure.

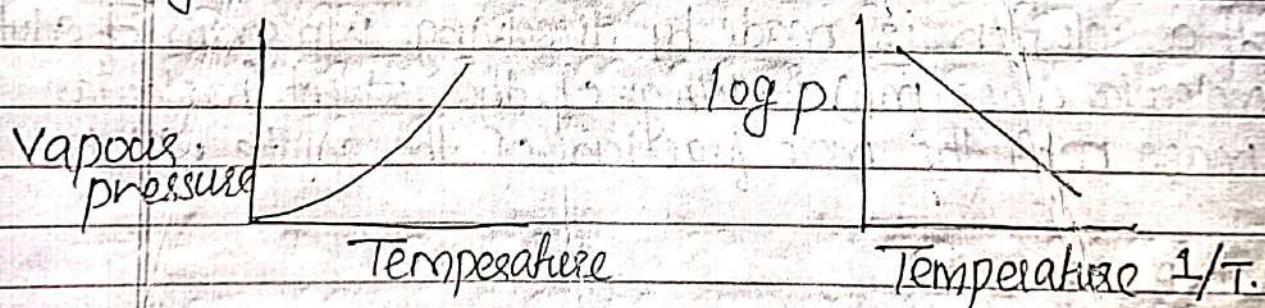
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Effect of Temperature on lowering of Vapour pressure:-

→ Vapour of liquid increases with increase in temperature.



→ Here ΔH is enthalpy of vaporization. A graphical representation of vapour pressure vs temperature is given below.



* A vapour pressure of liquid is known at a temperature. It can be calculated at another temperature using Clausius Clapeyron equation.

$$\log\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{\text{vap}}}{2.303RT} \left[\frac{1}{T_1} - \frac{1}{T_2} \right]$$

P_1 = Vapour pressure at temperature T_1 .

P_2 = Vapour pressure at temperature T_2 .

Elevation of Boiling point :-

Evallioscopy:- The boiling point of a liquid is the temperature at which its vapour pressure is equal to the atmospheric pressure.

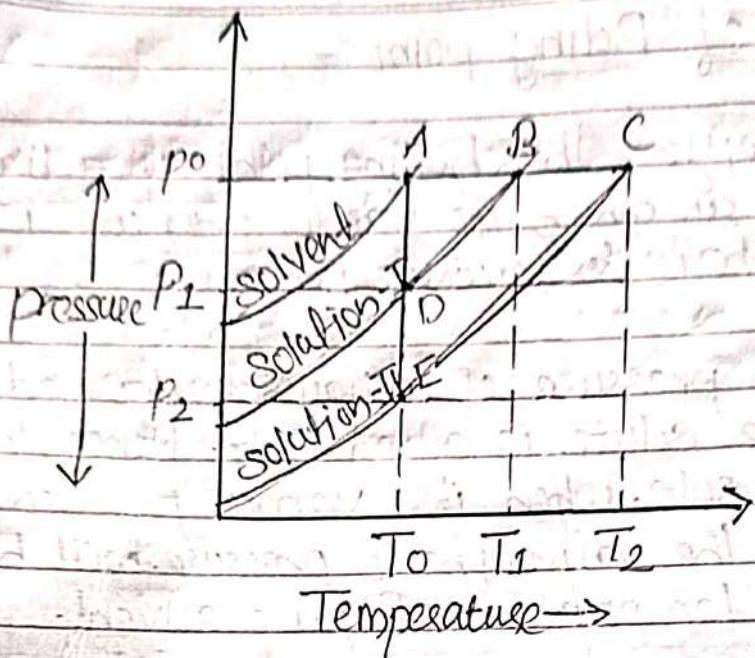
→ The vapour pressure of a liquid is lowered when a non volatile solute is added to it. Hence the temperature of the soln. when its vapour pressure will be equal to the atmospheric pressure will be higher than the temperature of pure solvent.

→ In other words the boiling point of the solvent is elevated by the addition of non-volatile solute.

→ The difference in the boiling point of the solution and the boiling point of the pure solvent is termed as elevation of boiling point.

$$\Delta T = \text{Boiling point of soln} - \text{Boiling point of pure solvent}$$

→ This can be better understand by a graph of vapour pressure against temperature for a pure solvent and two (2) solution of different concentration. The curve of the solution always lies ~~under~~ below the curve of the pure solvent.



→ The line P^oC represent the atmospheric pressure,
 T_0 , T_1 and T_2 represent the boiling point of
 pure solvent of solution-I & solution-II respectively.

→ The vapour pressure of pure solvent solution-I &
 solution-II at temperature T_0 are P^o , P_1 &
 P_2 respectively.

→ Assuming that the solution are very dilute
 this cause may be approximately taken as
 straight line near the boiling point, thus
 $\triangle ACE$ & $\triangle ABD$ are similar.

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 Therefore

$$\frac{AC}{AB} = \frac{AE}{AD}$$

$$\frac{T_2 - T_0}{T_1 - T_0} = \frac{P^o - P_2}{P^o - P_1}$$

$$\frac{\Delta T_2}{\Delta T_1} = \frac{\Delta P_2}{\Delta P_1}$$

$$\boxed{\Delta T \propto \Delta P \propto \frac{W_B}{M_B \times W_A}} \quad \textcircled{1} \textcircled{2}$$

From Raoult's law for dilute solution.

$$\frac{P_0 - P_s}{P_0} = \frac{W_B \times M_A}{M_B \times W_A}$$

or

$$P_0 - P_s = \frac{W_B \times M_A}{W_A \times M_B} P_0$$

For the pure solvent, P_0 (its vapour pressure at the boiling point) M_A (its molecular mass) are constant.
Therefore

$$P_0 - P_s \propto \frac{W_A}{M_A \times W_A}$$

$$\Delta T = K \frac{W_B}{M_B \times W_A} \quad K = \text{elevation constant}$$

when $\frac{W_B}{M_B} = 1$ (1 mole of solute) and $W_A = 1 \text{ g}$, then,

$$\boxed{\Delta T = K}$$

→ Thus boiling point constant is equal to the elevation in boiling point which the theoretically produced when 1 mole of non-volatile solute is dissolved in 1 gram of the solute-solvent.

$$\text{of } \frac{W_B}{M_B} = 1 \text{ and } W_A = 100 \text{ g.}$$

$$\Delta T = \frac{K}{100}$$

$$\boxed{\Delta T = K'}$$

K' = molecular elevation constant.

* K' is called molecular elevation constant.
It is defined as the elevation in boiling point produced when one mole of solute is dissolved in 100 g of solvent.

$$\Delta T = \frac{K}{100}$$

$$\Delta T = K' = \frac{K}{100}$$

$$\boxed{100K' = K}$$

~~Now~~ putting this value in eqn: ①

$$\boxed{\Delta T = \frac{100K' w_B}{M_B w_A}}$$

$$\text{If } \frac{w_B}{M_B} = 1 \text{ and } w_A = 1000 \text{ g}$$

This relation may also be written as

$$\boxed{\text{Then } \Delta T = \frac{K}{1000} = K_b}$$

K_b = molal elevation constant

(K_b) → It is defined as the elevation in boiling point produced when one mole of solute is dissolved 1000 g of the solvent.

$$\boxed{K = 1000 K_b}$$

NOTE

$$K_b = \frac{R K_b^2}{1000 L_v}$$

$K = \text{molar gas constant}$
 $T_b = \text{boiling point of the solvent}$
 $L_v = \text{latent heat of vaporization}$

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putting this value in eqn - (i)

$$\Delta T = \frac{1000 K_b M_A}{M_A + M_B}$$

$$\boxed{\Delta T = \text{Molality} \times K_b}$$

→ The elevation in boiling point of a solution of non-electrolyte is proportional to its molality and equimolar solution of all substances in a same solvent will show equal elevation in boiling point. This are known as Raoult's laws of elevation of boiling point.

Note: 0.515 is

→ Molal elevation constant is of water.