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UNIT- SOLUTION, CLASS-12TH CHEMISTRY

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SOLUTION

Solutions : Solutions are homogeneous mixtures of two or more components.

Example - sugar in water

Solute + Solvent → Solution

Solute = the Component present in small amount.
Solvent = The Component present in larger amount.

Types of solution

Solid soluiton

In which solid acts as Solvent Or present in large amounts, e.g. Alloys.

Liquid solution

In which liquid acts as solvent . e.g. O_2 dissolved in water.

Gaseous solution

In which gas acts as Solvent, e.g. mixture of O_2 and N_2.

Molarity

Molarity (M) =

$$\frac{\text{Number of moles of solute}}{\text{Volume of solution (in Litre)}} = \frac{\text{Number of moles of solute x 1000}}{\text{Volume of solution (in ml)}}$$

$$\text{Moles of solute(n)} = \frac{\text{Mass of solute}(w)}{\text{Molar Mass of solute }(M)}$$

Unit of Molarity = M or mol l^{-1}

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

Molality

Molality(m) =

$$\frac{\text{Number of moles of solute}}{Mass\ of\ solvent\ (\ in\ Kg)} = \frac{\text{Number of moles of solute x 1000}}{Mass\ of\ solvent\ (\ in\ g)}$$

Moles of solute(n) = $\frac{Mass\ of\ solute(w)}{Molar\ Mass\ of\ solute\ (M)}$

Unit of

Molality = m or mol Kg^{-1}

Mole fraction ($\varkappa$)

Mole fraction of solute, $\varkappa_2 = \dfrac{n_2}{n1 + n2}$

Mole fraction of solvent, $\varkappa_1 = \dfrac{n1}{n1 + n2}$

where,

n_2 = Number of moles of solute

n_1 = Number of moles of solvent

Parts per million (ppm)

When a solute is present in trace quantities, the concentration is expressed in parts per million.

$$\text{Parts per million} = \frac{\text{Number of parts of the component x106}}{\text{Total number of parts of all the components of the solution}}$$

or

$$\text{Parts per million} = \frac{\text{Mass of solute} \quad \text{x} \quad 106}{\text{Mass of solution}}$$

Mass percent (w/w)

$$\text{Mass percent} = \frac{\text{Mass of solute} \times 100}{\text{Mass of solution}}$$

Volume percentage (V/V)

$$\text{Volume percentage} = \frac{\text{Volume of solute} \times 100}{\text{Volume of solution}}$$

Mass by Volume percentage (W/V)

$$\text{Mass by volume percentage} = \frac{\text{Mass of the solute} \times 100}{\text{Volume of the solution}}$$

RELATION BETWEEN MOLARITY AND MOLALITY

$$\text{Molality}(m) = \frac{M \times 1000}{(1000 \times d) - (M \times M_2)}$$

where,

M =Molarity

M_2 = Molar mass ofsolute

d = density

Ques – Calculate the molarity of 9.8% (w/w) solution of H_2SO_4 if the density of the solution is 1.02 g ml^{-1} .
(C.B.S.E – 2014).

QUES – A Solution of glucose ($C_6H_{12}O_6$) in water is labelled as 10% by weight. What would be the molality of the solution?
(CBSE- 2013).

Ques- A solution of glucose in water is labelled as 10% . What would be the molality and molarity of the solution? (Density of solution = 1.2 g ml^{-1}).

(CBSE- 2014)

QUES- If the density of water of a lake is 1.25 g ml^{-1} and 1 kg of lake water contain 92 g of Na^+ ions, calculate the molarity of Na^+ ions is this lake water. (CBSE- 2008,2012).

Solubility

The maximum amount of a substance that will dissolve in a given amount of solvent at a specified temperature.

Saturated Solution

It is the solution in which no more solute can be dissolved at the same temperature and pressure.

Unsaturated solution

I t is the solution in which more solute can be dissolved at the same temperature.

HENRYS LAW

It states that the solubility of a gas in a liquid is directly proportional to the pressure of the gas.

$$p = k_H \, s$$

It can also be stated that mole fraction of the gas in the solution is proportional to the partial pressure of the gas over the solution.

$$p = K_H \, x$$

It states that mass of gas dissolved is directly proportional to pressure of gas.

$$m = k_H \, p$$

APPLICATION OF HENRYS LAW

1. To increase the solubility of CO_2 in soft drinks, the bottle is sealed under high pressure.
2. To avoid bends and the toxic effects of high concentrations of N_2 in the blood, the cylinders used by scuba divers are filled with air diluted with He.
3. For climbers or people living at high altitudes.

or

The partial pressure of oxygen at high altitudes is smaller than at the sea level. This results in low concentration Of oxygen in the blood and tissues. Low blood oxygen causes climbers to become weak and unable to think.

Such symptoms are known as anoxia.

Ques – Henry's law constant for CO_2 dissolved in water is 1.67×10^8 Pa at 298 k. Calculate the quantity of CO_2 in1 L of soda water .When packed under 2.5 atm CO_2 pressure at 298 K.

(CBSE- 2008)

Ques - If N_2 gas is bubbled through water at 293 k, how many millmoles of N_2 Gas would dissolved in 1L of water ? Assume that N_2 exerts a partial pressure of 0.987 bar. Given that Henry's Law constants for N_2 at 293K is 76.48 K bar.
(CBSE-2012)

Ques- The solubility of pure nitrogen gas at 25^0 c and 1 atm is 6.8×10^{-4} mol l^{-1} . What is the concentration of nitrogen dissolved In water under atmospheric conditions ? The partial pressure of nitrogen gas in the atmosphere is 0.78 atm.

(CBSE-2008)

Ques – What concentration of nitrogen should be present in a glass of water at room temperature? Assume a temeperature Of 25^0 C, a total pressure of 1 atmosphere and mole fraction of nitrogen in air is 0.78. (K_H for nitrogen = 8.42×10^{-7} M/mm Hg).
(CBSE- 2009).

Ques – The partial pressure of ethane over a saturated solution containing 6.56×10^{-2} g of ethane is 1 bar. If the solution contains 5.0×10^{-2} g of ethane, then what will be the partial pressure of the gas? (CBSE-2012, 2013).

Vapour pressure of liquid solutions, Ideal and Non-Ideal solutions.

Raoults law for volatile solute

This law states that for a solution of volatile liquids, the partial vapour pressure of each components in the solution is directly Proportional to its mole fraction.

For volatile Solute

For Component 1, $P_1 \propto X_1$ or $P_1 = P_1^\circ X_1$

Similarly for component 2, $P_2 = P_2^\circ X_2$;

$P_{Total} = P_1 + P_2 = P_1^\circ X_1 + P_2^\circ X_2$;

$P_{Total} = (1 - X_2) P_1^\circ + X_2 P_2^\circ$

$P_{Total} = P_1^\circ + (P_2^\circ - P_1^\circ) X_2$ as $(X_1 + X_2 = 1)$.

where, P_1° and P_2° are the vapour pressure of pure component 1 and 2 respectively.

Roult's law in Vapour Phase

If y_1 and y_2 are the mole fractions of the components 1 and 2 respectively in vapour phase, then

$P_1 = y_1 \times P_{Total}$.

and

$P_2 = y_2 \times P_{Total}$.

Raoults law for non- volatile solute

This law states that relative lowering of vapour pressure for a solution is equal to the mole fraction of solute.

Relative lowering in vapour pressure

$$\frac{P_1^0 - P_2}{P_1^0} = ℵ_2 = \frac{n_2}{n_2 + n_1} = \frac{n_2}{n_1}$$

Where,

P_1^0 =vapour pressure pure state of water.

P_1 = vapour pressure of solution.

$ℵ_2$ = mole fraction of solute.

n_2 = number of moles of solute.

n_1 = number of moles of solvent.

IDEAL AND NON IDEAL SOLUTION

IDEAL SOLUTION

1. Ideal Solutions obey Raoult's Law.
2. $\Delta_{mix} H = 0$ and $\Delta_{mix} v = 0$
3. The interaction of A-B is same as interaction A-A And A-B
4. Example

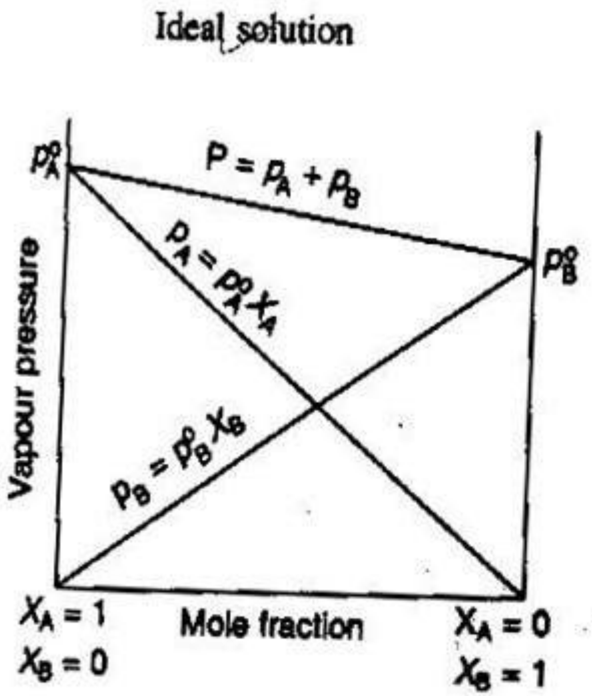
   Solutions of n- hexane and n-heptane , bromoethane and chloroethane, benzene and Toluene., etc.,
   are nearly ideal in behavior.

NON IDEAL SOLUTION

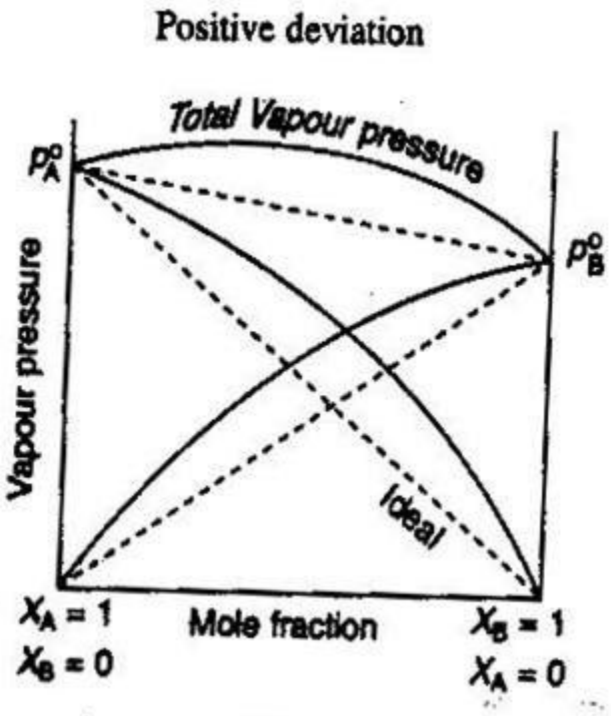
1. Non- Ideal Solutions do not obey Raoults Law.
2. $\Delta_{mix} H \neq 0$ and $\Delta_{mix} V \neq 0$
3. The interaction of A-B is not same as interaction A-A And A-B
4. Example

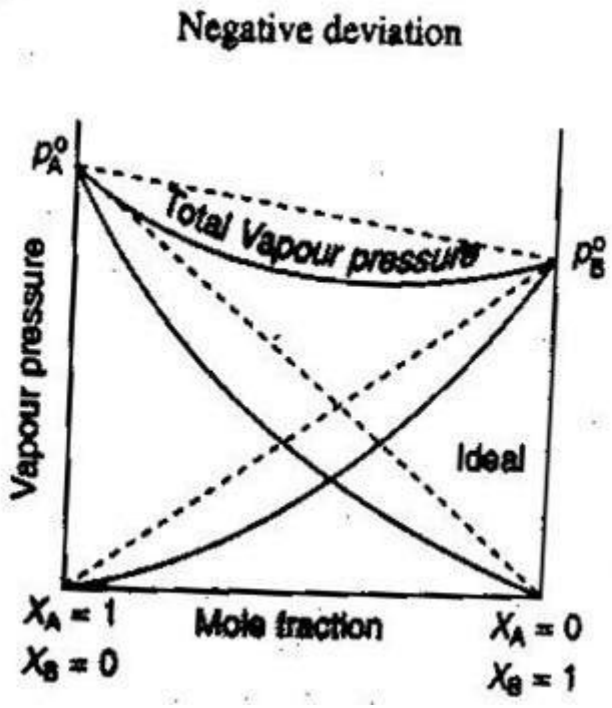
   ethanol and acetone, carbon disulphide and acetone, acetone and benzene, etc.

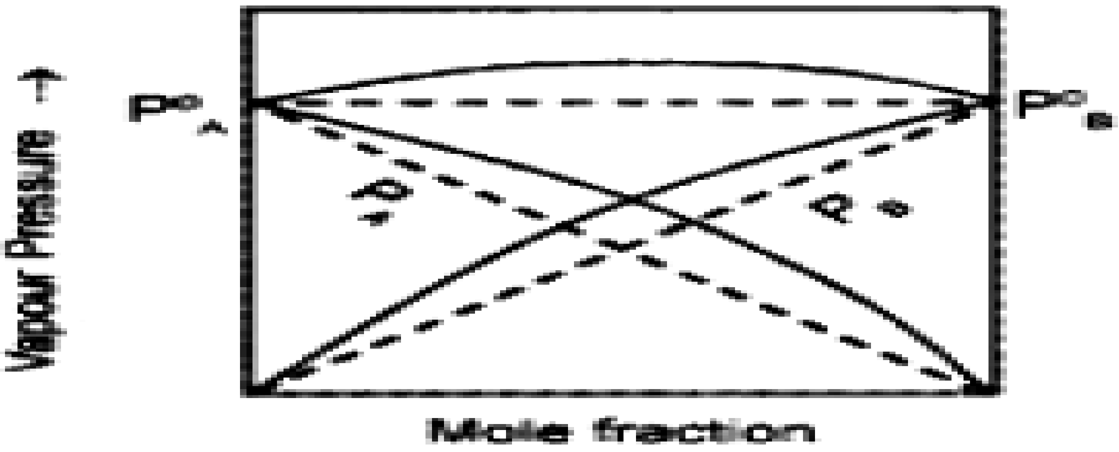
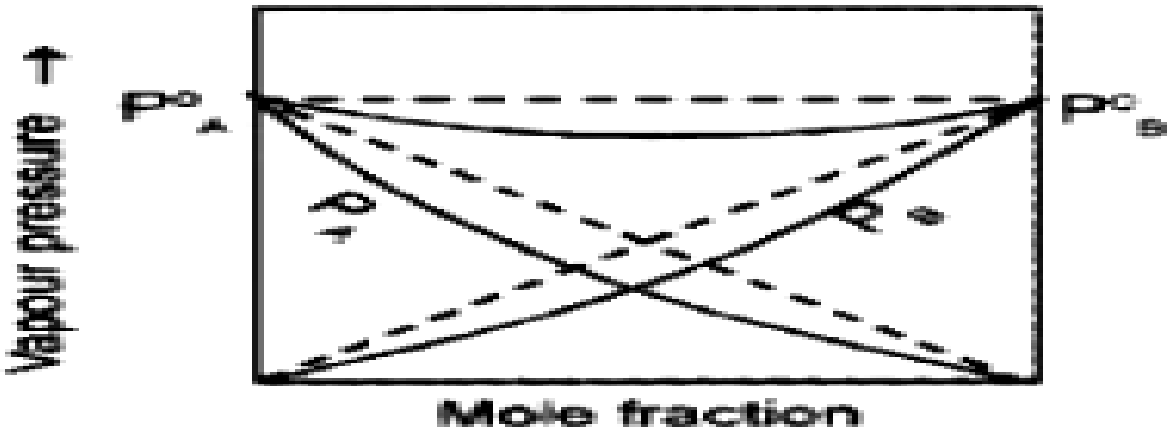
IDEAL SOLUTION



NON IDEAL SOLUTION





+ Positive deviation	-ve deviation
1. $P_A > P^o_A \chi_A$ $P_B > P^o_B \chi_B$	$P_A < P^0_A \chi_A$ $P_B < P^0_B \chi_B$
2. $\Delta H_{mix} > 0$	$\Delta H_{mix} < 0$
3. $\Delta V_{mix} > 0$	$\Delta V_{mix} < 0$
4. A-B interaction are weaker than A-A or B-B interaction	A-B interaction are stronger than A-A or B-B interaction
5. Minimum boiling azeotropes  	Maximum boiling azeotropes 

Colligative property

The properties of soluiton which depend on the number of solute particels but not on the nature of solute.

The following four properties are Colligative properties:

1. Relative lowering of vapour pressure

2. Elevation in boiling point

3. Depression in freezing point

4. Osmosi and Osmotic and Pressure.

Elevation in boiling point

The elevation in boling point of a dilute solutions, the elevation in boiling point is directly proportional to the molality Of the solution

Elevation in boiling point

$\Delta T_b = T_b - T_b^0$

$\Delta T_b \; \alpha \; m$

$\Delta T_b = K_b m$

$$\Delta T_b = \frac{K_b \times W_2 \times 1000}{M_2 \times W_1}$$

Where,

ΔT_b = change in boiling point

m = molality

K_b = boiling constant

W_2 = mass of solute

W_1 = mass of solvent

M_2 = molar mass of solute

Ques – calculated the boiling point of solution when 4 g of Mg SO_4 was dissolved in 100g of water assuming $MgSO_4$ undergoes complete Ionisation.
(K_b for water = 0.52 k kg mol^{-1}) (CBSE-2016)

Ques – Find the boiling point of a solution containing 0.520 g of glucose ($C_6 H_{12} O_6$) dissolved in 80.2 g of water. (given, K_b for water = 0.52 km^{-1}).

(CBSE- 2010)

Ques – 18 g glucose, $C_6 H_{12} O_6$ (molar mass = 180 g mol^{-1}) is dissolved in 1 kg of water in a sauce pan. At what temperature, will this Solution boil ?
(k_b for water = 0.52 K kg mol^{-1} , boiling point of pure water = 373.15 K).
(CBSE-2013).

Depression in freezing point

The Depression in boling point of a dilute solutions, is directly proportional to the molality Of the solution.

Depression in Freezing point

$\Delta T_f = T_f^0 - T_f$

$\Delta T_f \ \alpha \ m$

$\Delta T_f = K_f m$

$$\Delta T_f = \frac{Kf \times W_2 \times 1000}{M_2 \times W_1}$$

Where,

ΔT_f = change in freezing point

m = molality

K_f = freezing constant

W_2 = mass of solute

W_1 = mass of solvent

M_2 = molar mass of solute

Ques - Calculate the mass of compound (molar mass = 256 g mol^{-1}) to be dissolved in 75 g of benzene to lower its freezing Point by 0.48 K (K_f = 5.12 K kg Mol^{-1}). (CBSE-2014)

Osmosis

The process of flow of solvents molecules from solution of lower concentration to solution of higher to concentration through semi Permiable membrane is known as osmosis.

Osmotic pressure

The excess pressure that applied on the solution to prevent osmosis is called osmotic pressure.

Osmosis and osmatic pressure

$\pi \; \alpha \; C$

π =CRT or $\pi = \frac{n_2}{V}$ RT where, $C = \frac{n_2}{V}$

Or $\pi V = \frac{W_2 RT}{M_2}$

Or $M_2 = \frac{W_2 RT}{\pi V}$

Isotonic solution = Two solution having same osmotic pressure at a given temperature.

Hypotonic solution = A solution having lower osmostic pressure than the other solution.

Hypertonic solution = A solution having Higher osmostic pressure than the other solution.

Reverse osmosis = If a pressure higher than the osmotic pressure of a solution is applied to the solution side, pure solvent flows Out of the solution through the semipermeable membrane. This phenomenon is called
reverse osmosis.
(It is used for the desalination of sea water.)

Abnormal molar mass = A molar mass obtained experimentally sometimes comes out to be either lower or higher than the Expected or normal value. This is called abnormal molar mass.

- If the solute dissociates in the solvent, molar mass comes out to be higher than the expected value.
- If the solute associates in the solvent, the molar mass comes out to be lower than the expected value.

Van't Hoff Factor

It is the ratio of the experimental value of colligative property to the calculated value of the colligative property.

$$i = \frac{\text{Normal molar mass}}{\text{Abnormal molar mass}}$$

or

$$i = \frac{\text{Total number of moles of particles after association / dissociation}}{\text{Number of moles of particles before association/ dissociation}}$$

or

$$i = \frac{\text{Observed value of the colligative property}}{\text{Calculated value of the colligative property}}$$

If $i > 1$, solute undergoes dissociation,
and if $i<1$, solute undergoes association.

Degree of association, $= \dfrac{i - 1}{\frac{1}{n} - 1}$

Where, n = number of particles associated.

Degree of dissociation, $= \dfrac{i - 1}{m - 1}$

Where, m = number of particles dissociated.

Inclusion of van't hoff factor modifies the equation for colligative properties as follows:

1. Relative lowering of vapour pressure of solvent,

$$\frac{P_1^0 - P}{P_1^0} = i\aleph_2 = \frac{i\, n_2}{n_1}$$

2. Elevation in oiling point

$$\Delta T_b = iK_b m$$

3. Depression in freezing point,

$$\Delta T_f = iK_f m$$

4. Osmotic pressure of solution,

$$\pi = i\frac{n_2}{V}RT$$

Ques- The vapour pressure of pure liquids A and B are 450 mm and 700 mm of Hg respectively at 350 k. Find out the composition Of the liquid mixture if total vapour pressure is 600 mm of Hg. Also, find the composition in the vapour phase. (CBSE-2013)

Ques – A 1.00 molal aqueous solution of trichlroacetic acid (CCl_3COOH) is heated to its boiling pont. The solution has the boiling point. The solution has the boiling point 100.18^0 C. Determine the van't Hoff factor for trichlroacetic acid. (K_b for water = 0.512 K kg mol^{-1}). **(CBSE-2012)**

Ques – Find the freezing point of a solution containing 0.520 g glucose ($C_6H_{12}O_6$) dissolved in 80.2 g of water .(given, K_f for water = 1.86 km^{-1}).

(CBSE – 2010)

Ques – A 10 % solution of sucrose in water has freezing point of 269.15 K. Calculate te freezing point of 10% glucose in water If freezing point of pure water is 273.15 K. (CBSE-2017)

Ques – What mass of NaCl Must be dissolved in 65.0 g of water to lower the freezing point of water by 7.50^0 C ? The freezing Point depression constant (k_f) for water is 1.86^0 C/m. Assume van't Hoff factor for NaCl is 1.87.
(CBSE-2011,2010).

Ques – An aqueos solution containing 12.48 g of barium chloride in 1.0 kg of water boils at 373.0832 k. calculate the degree Of dissociation of barium chloride.
(given, k_b for H_2O = 0.52 k kg mol^{-1}) . (CBSE- 2011)

Ques – At 300K, 36 g of glucose present per litre in its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of 4.98 bar . If the osmotic pressure of another glucose solution is 1.52 bar at the same temperature, calculate the concentration Of the other solution.
(CBSE – 2011)

Ques- Calculate the boiling point of one molar aqueous solution. Density of KBr solution is 1.06 g ml^{-1} (k_b for H_2O = 0.52 k kg mol^{-1}) (CBSE- 2011)

Ques – What mass of ethylene glycol (molar mass – 62 g mol^{-1}) must be added to 5.50 kg of water to lower the freezing Point of water from 0^0 C to 10 ^{0} C ?
(K_f for water = 1.86 k kg mol^{-1}) (CBSE=2010).

Ques- Calculate the mass of ascorbic acid ($C_6H_8O_6$) to be dissolved in 75 g of acetic acid to lower its melting point by 1.5^0 c. (K_f for acetic acidis 3.9 k kg mol^{-1}). (CBSE- 2010)

Ques- Calculate the freezing point depression expected for 0.0711 m aqueous solution of $Na_2 SO_4$. if this solution actually freezes At -0.320^0c, what would be the value of van't hoff factor ? (kf for water is 1.86 k kg mol^{-1}) (CBSE- 2009)

Ques – A 1.00 molal aqueous solution of tricholroacetic acid (CCl_3COOH) is heated to its boiling point. The Solution has the boiling point 100.18^0 c . Determine the vant's hoff factor for trichloroacetic acid. (k_b for water = 0.512 K kg mol^{-1}). (CBSE Delhi – 2012)

Ques – Calculate the freezing point of a solution containg 18 g glucose, $C_6 H_{12}O_6$ and 68.4 g sucrose, $C_{12} H_{22} O_{11}$ in 200g of water. The freezing Point of pre water is 273 K and K_f for water is 1.86 K kg mol^{-1} . (CBSE- 2009)

Ques- Caluclate the temperature at which a solution containing 54 g of glucose in 250 g of water will freeze. (k_f for water = 1.86 k kg mol^{-1+} and molar mass of glucose = 180 g mol^{-1}) .
(CBSE- 2008, 2009)

Ques – A solution containing 8 g of a substance in 100 g of diethyl ether boils at 36.86^0 c , whereas pure ether boils at 35.60^0 c. Determine the molecular mass of the solute (for ether, k_b = 2.02 k kg mol^{-1}). (CBSE- 2008)

Ques – Calculate the mass of a non- volatile solute (molar mass = 40 g mol^{-1}), which should be dissolved in 114g of octane to reduce. Its vapour pressure to 80% .
(molar mass of octane = 114g mol^{-1}). (CBSE- FOREIGN – 2008).