# CHAPTER
# 2
# SOLUTIONS

## Syllabus

*Types of solutions, expression of concentration of solutions of solids in liquids, solubility of gases in liquids, solid solutions, Raoult's law, colligative properties - relative lowering of vapour pressure, elevation of boiling point, depression of freezing point, osmotic pressure, determination of molecular masses using colligative properties, abnormal molecular mass, van't Hoff factor.*

## Trend Analysis

| List of Concepts | 2018 | 2019 | | 2020 | |
|---|---|---|---|---|---|
| | OD | D | OD | D | OD |
| Henry's Law, Raoult's Law | | 2 Q<br>(2 marks) | | 2 Q<br>(2 marks) | - |
| Ideal and Non-ideal Solution | | 1 Q<br>(2 marks) | 2 Q<br>(2 marks) | 1 Q<br>(1 mark) | - |
| Colligative Properties | 1 Q<br>(3 marks) | - | 1 Q<br>(2 marks) | 2 Q<br>(1 mark) | - |
| Numericals based on Colligative Properties | 1 Q<br>(2 marks) | 1 Q<br>(3 marks) | 1 Q<br>(3 marks) | 1 Q<br>(3 marks) | 1 Q<br>(3 marks) |

# TOPIC-1
## Types of Solutions, Expression of Concentration of Solutions and Solubility

## Revision Notes

- **Solution :** A homogeneous mixture of two or more pure substances is known as solution.
- If the constituents of the solution are two, it is called binary, if three then ternary, if four then quaternary and so on.
- **Two constituents of the solution are :**
  - **(i) Solute :** A substance that is dissolved in another substance in lesser amount, forming a solution. For example : Sugar, salt, etc.
  - **(ii) Solvent :** A substance in which another substance is dissolved in larger amount forming a solution. For example : Water, milk, etc.

  ***Note :*** *Solvent determines the physical state of the solution.*
- **Types of Solutions :** Any state of matter (solid, liquid or gas) can act both as a solvent and as a solute during the formation of a solution. Therefore, depending upon the physical states of solute and solvent, we can have following nine different types of solutions :

| S. No. | Types of Solution | Solute | Solvent | Examples |
|---|---|---|---|---|
| **1.** | Solid – Solid | Solid | Solid | Alloys like brass, bronze, etc. |
| **2.** | Solid – Liquid | Solid | Liquid | Solution of sugar, salt, urea etc. in water. |
| **3.** | Solid – Gas | Solid | Gas | Sublimation of substances like iodine, camphor, etc, into air, dust or smoke particles in air. |
| **4.** | Liquid – Solid | Liquid | Solid | Hydrated salts, mercury in amalgamated zinc, etc. |
| **5.** | Liquid – Liquid | Liquid | Liquid | Alcohol in water, benzene in toluene. |
| **6.** | Liquid – Gas | Liquid | Gas | Aerosol, water vapour in air. |
| **7.** | Gas – Solid | Gas | Solid | Hydrogen adsorbed in palladium. |
| **8.** | Gas – Liquid | Gas | Liquid | Aerated drinks. |
| **9.** | Gas – Gas | Gas | Gas | Mixture of gases, etc. |

- **Aqueous solution :** A solution containing water as solvent is known as aqueous solution. For example, sugar solution.
- **Non-aqueous solution :** A solution containing solvent other than water is known as non-aqueous solution. For example, iodine dissolved in alcohol.
- **Saturated solution :** A solution in which no more solute can be dissolved at the same temperature is known as saturated solution.
- **Unsaturated solution :** A solution in which more amount of solute can be dissolved at the same temperature is known as unsaturated solution.
- **Solubility :** Solubility can be defined as the maximum amount of solute that can be dissolved in 100 g of solvent to form a saturated solution at a given temperature.
  - **Causes of Solubility :**
    - **(i) Inter ionic attraction in the solute molecules :** Molecules are stabilised in the lattice due to electrostatic forces and the energy released is known as lattice energy.
    - **(ii)** Inter molecular attraction between solvent molecules.
    - **(iii) Solvation :** It denotes the force of attraction between solute and solvent molecules.
    - **(iv)** Temperature.
  - **Factors affecting Solubility :**
    - **(i) Nature of Solute and Solvent :** "Like dissolves like" *i.e.*, polar solvents like water and ammonia can dissolve polar solute or ionic solute while non-polar solvents can dissolve non-polar organic solutes.
    - **(ii) Temperature :** Solubility increases with increase in temperature. It increases for endothermic reaction while it decreases for exothermic reaction.
    - **(iii) Pressure :** The solubility of solid in liquid is not affected significantly by pressure because solids and liquids cannot be compressed.
    - **(iv) Hydration Energy :** It is the amount of energy released when ions formed by 1 mole of ion get hydrated. It is an exothermic process.
- **Method of expressing Concentration of Solution :** The concentration of solution is the amount of solute present in the given quantity of solute or solvent. It can be expressed in any of the following types :

**(i) Mass percentage $\frac{w}{W}$ :** It is the amount of solute in grams dissolved per 100 gm of solution.

$$\text{Mass\% of a solute} = \frac{\text{Mass of solute in the solution}}{\text{Total mass of the solution}} \times 100$$

**(ii) Volume percentage $\frac{v}{V}$ :** It is defined as volume of a solute dissolved per 100 ml of solution.

$$\text{Volume\% of a solute} = \frac{\text{Volume of solute}}{\text{Total volume of the solution}} \times 100$$

**(iii) Mass by volume percentage $\frac{v}{V}$ :** It is defined as mass of solute dissolved per 100 ml of solution. It is commonly used in medicine and pharmacy.

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

**(iv) Parts per million (ppm) :** It can be defined as the parts of a component per million ($10^6$) parts of the solution. It is used to express the concentration of a solute present in trace quantities.

$$\text{ppm (A)} = \frac{\text{Number of the parts of the component (A)}}{\text{Total number of parts of all the components of the solution}} \times 10^6$$

**Parts per million can be expressed in three ways :**

**(a)** Mass to mass

$$\text{ppm (mass to mass)} = \frac{\text{Mass of a component}}{\text{Total mass of solution}} \times 10^6$$

**(b)** Volume to volume

$$\text{ppm (volume to volume)} = \frac{\text{Volume of a component}}{\text{Total volume of solution}} \times 10^6$$

**(c)** Mass to volume

$$\text{ppm (mass to volume)} = \frac{\text{Mass of a component}}{\text{Volume of solution}} \times 10^6$$

**(v) Mole Fraction :** It is the ratio of number of moles of a particular component to the total number of moles of all the components. *e.g.*, mole fraction of component A.

$$\chi_A = \frac{n_A}{n_A + n_B},$$

where $n_A$ is the number of moles of component 'A' and $n_B$ is the number of moles of component 'B'.

Similarly, $$\chi_B = \frac{n_B}{n_A + n_B}$$

Sum of mole fractions of all the components is always one.

$$\chi_A + \chi_B = 1$$

**(vi) Molarity (M) :** It is defined as the number of moles of solute per litre of solution.

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in Litres)}}$$

$$M = \frac{W_B \times 1000}{M_B \times V}$$

where, $W_B$ = Weight of solute, $V$ = Volume of solution in ml, $M_B$ = Molar mass of solute.
Unit is mol $L^{-1}$ or M (molar).

And $$\frac{\text{Weight of solute } (W_B)}{\text{Molar mass of solute } (M_B)} = \text{Moles of solute}$$

**(vii) Molality (*m*) :** It is defined as the number of moles of solute per 1000 g or 1 kg of solvent.

$$\text{Molality} = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}}$$

$$m = \frac{W_B \times 1000}{M_B \times W}$$

where, $W_B$ = Weight of the solute, $M_B$ = Molar mass of solute, W = Mass of solvent in g
Unit is mol $kg^{-1}$ or molal (*m*). Molality and mole fraction do not change with change in temperature.

**(viii) Normality (N) :** It is defined as number of gram equivalents of solute dissolved per litre of solution.

$$\text{Normality} = \frac{\text{Number of gram equivalent of solute}}{\text{Volume of solution in Litre}}$$

$$N = \frac{W_B \times 1000}{E_B \times V}$$

where, $W_B$ = Mass of solute, $E_B$ = Equivalent weight of solute, $V$ = Volume of solution in ml

- **Relationship between Molarity (M) and Molality (*m*) :**

$$\frac{1}{m} = \frac{d}{M} - \frac{M_B}{1000}$$

where, $m$ = Molality of solution, $M$ = Molarity of solution,
$M_B$ = Molar mass of solute, $d$ = Density of solution in g ml$^{-1}$

- **Relationship between Mole fraction of solute ($\chi_B$) and Molality ($m$) :**

$$\boxed{m = \frac{\chi_B \times 1000}{(1-\chi_B)\times M_A}}$$

where $\chi_B$ is mole fraction of solute, $m$ is molality and $M_A$ is molar mass of solvent.
The relationship between pressure and solubility is guided by Henry's Law. According to this law, "The mass of a gas dissolved in given volume of the liquid at a constant temperature depends upon the pressure applied."
It can also be stated as the partial pressure of the gas ($p$) in vapour phase is proportional to the mole fraction of the gas ($\chi$) in the solution.

$$p = K_H\chi,$$

where $K_H$ = Henry's constant.

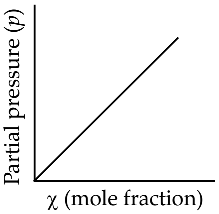


**Fig. 1 : The slope of the line in Henry's constant, ($K_H$)**

- **Applications of Henry's law :**
  - **(i)** To increase the solubility of $CO_2$ in soda water and soft drinks, the bottle is sealed under high pressure.
  - **(ii)** To avoid the toxic effects of high concentration of nitrogen in blood, the tanks used by scuba divers are filled with air diluted with helium (11.7%), nitrogen (56.2%) and oxygen (32.1%).
  - **(iii)** At high altitudes, low blood oxygen causes climber to become weak and make them unable to think clearly, which are symptoms of a condition known as anoxia.
- **Limitations of Henry's law :** This law is applicable only when :
  - **(i)** The pressure of gas is not too high and temperature is not too low.
  - **(ii)** The gas should not undergo any chemical change.
  - **(iii)** The gas should not undergo association or dissociation in the solution.

# Know the Formulae

- $$\text{Mole fraction of a component} = \frac{\text{Number of moles of the component}}{\text{Total number of moles of all the components}}$$

$$x_1 = \frac{n_1}{n_1+n_2},\ x_2 = \frac{n_2}{n_1+n_2} \qquad (x_1+x_2=1)$$

- $$\text{Molarity (M)} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in Litre}}$$
- $$\text{Molality } (m) = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}}$$
- $$\text{Normality (N)} = \frac{\text{Number of gram equivalent of solute}}{\text{Volume of solution in Litre}}$$
- $$\text{Mass percentage } \left(\frac{w}{W}\right) = \frac{\text{Mass of solute in the solution}}{\text{Total mass of the solution}}\times 100$$
- $$\text{Volume percentage } \left(\frac{v}{V}\right) = \frac{\text{Volume of solute}}{\text{Total volume of the solution}}\times 100$$
- $$\text{Mass by volume percentage } \left(\frac{w}{V}\right) = \frac{\text{Mass of solute}}{\text{Volume of solution}}\times 100$$
- $p = K_H . x$

where $K_H$ = Henry's law constant
$p$ = partial pressure of the gas in vapour phase
$x$ = mole fraction of the gas in the solution

- $$\text{ppm of component A} = \frac{\text{Mass of component A}}{\text{Total mass of solution}}\times 10^6$$

## How is it done on the GREENBOARD?

**Q. Calculate the mole fraction of benzene in solution containing 30% by mass in carbon tetrachloride.**

**Solution:**

**STEP-1:** Let the total mass of the solution be 100 g and the mass of benzene be 30 g.

$\therefore$ Mass of carbon tetrachloride

$= (100 - 30)$ g

$= 70$ g **[½]**

Molar mass of benzene ($C_6H_6$)

$= (6 \times 12 + 6 \times 1)$ g mol$^{-1}$

$= 78$ g mol$^{-1}$

$\because$ Number of moles of $C_6H_6 = \frac{30}{78}$ mol **[1]**

$= 0.3846$ mol

**STEP-2:** Molar mass of carbon tetrachloride ($CCl_4$)

$= 1 \times 12 + 4 \times 35.5$

$= 154$ g mol$^{-1}$

$\therefore$ Number of moles of $CCl_4$

$= \frac{70}{154}$ mol

$= 0.4545$ mol **[1]**

**STEP-3:** Thus, the mole fraction of $C_6H_6$ is given as :

$$\frac{\text{Number of moles of } C_6H_6}{\text{Number of moles of } C_6H_6 + \text{Number of moles of } CCl_4}$$

$$= \frac{0.3846}{0.3846 + 0.4545}$$

$= 0.458$ **[½]**

## Objective Type Questions

**(1 mark each)**

[A] MULTIPLE CHOICE QUESTIONS :

**Q. 1. A molar solution is one that contains one mole of a solute in**

**(a) 1000 g of the solvent**
**(b) one litre of the solvent**
**(c) one litre of the solution**
**(d) 22.4 litre of the solution** $\boxed{R}$

**Ans. Correct option : (c)**

*Explanation :* A molar solution is one that contains one mole of a solute in one litre of the solution.

$$\text{Molarity}(M) = \frac{\text{Number of moles of solute}}{\text{Volume of solution in L}}$$

**Q. 2. In which mode of expression, the concentration of a solution remains independent of temperature?**

**(a) Molarity** **(b) Normality**
**(c) Formality** **(d) Molality** $\boxed{R}$

**Ans. Correct option : (d)**

*Explanation :* The molality of a solution does not change with temperature.

**Q. 3. The increase in the temperature of the aqueous solution will result in its**

**(a) Molarity to increase**
**(b) Molarity to decrease**
**(c) Mole fraction to increase**
**(d) Mass % to increase** $\boxed{R}$

**Ans. Correct option : (b)**

*Explanation :* An increase in temperature increase the volume of solution and therefore it will result in its molarity to decrease.

**Q. 4. $K_H$ value for Ar(g), $CO_2$(g), HCHO(g) and $CH_4$(g) are 4.039, 1.67, $1.83 \times 10^{-5}$, and 0.143, respectively. Arrange these gases in the order of their increasing solubility**

**(a) HCHO < $CH_4$ < $CO_2$ < Ar**
**(b) HCHO < $CO_2$ < $CH_4$ < Ar**
**(c) Ar < $CO_2$ < $CH_4$ < HCHO**
**(d) Ar < $CH_4$ < $CO_2$ < HCHO** $\boxed{A}$

**Ans. Correct option : (c)**

*Explanation :* According to Henry's law,

$$P = K_H C$$

$$K_H \propto \frac{1}{C}$$

Where P = Partial pressure of gas
C = Concentration of gas
$K_H$ = Henry's constant

It implies that as the value of $K_H$ increases, mole fraction of gas solute in solvent decreases.

Hence, higher the $K_H$ value, lower is the solubility of gas.

The order of increasing solubility of gases in :

$Ar < CO_2 < CH_4 < HCHO$

**[B] ASSERTION AND REASON TYPE QUESTIONS :**

**In the following questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.**

**(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**
**(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.**
**(c) Assertion is correct statement but reason is wrong statement.**
**(d) Assertion is wrong statement but reason is correct statement.**

**Q. 1. Assertion : A molar solution is more concentrated than molal solution.**

**Reason : A molar solution contains one mole of solute in 1000 mL of solution.**

**Ans. Correct option : (a)**

*Explanation :* A molar solution is more concentrated than molal solution because 1 molar solution contains 1 mole of solute in 1 litre of the solution which include both solute and solvent.

**Q. 2. Assertion : Molarity of 0.1 N solution of HCl is 0.1 M.**

**Reason : Normality and molarity of a solution are always equal.**

**Ans. Correct option : (c)**

*Explanation :* Normality and molarity of a solution are not always equal. Normality depends on chemical equivalent of the substance while molarity depends on molecular mass of the substance.

**Q. 3. Assertion : Molarity of a solution changes with temperature.**

**Reason : Molarity is dependent on volume of solution.**

**Ans. Correct option : (a)**

*Explanation :* As molarity is dependent on volume of solution and volume rises with increase in temperature. Molarity is inversely proportional to temperature. So, as temperature increases, volume increases and molarity decreases.

**[C] VERY SHORT ANSWER TYPE QUESTIONS :**

**Q. 1. Define Normality of a solution.**

**Ans.** It is defined as the number of gram equivalents of the solute dissolved per litre of the solution.

**Q. 2. What is the Normality of 0.2 M aqueous solution of a tribasic acid?**

**Ans.** Normality = molarity × basicity of acid
$= 0.2 \times 3 = 0.6$ N

**Q. 3. Give the type of solution in Aerated drinks.**

**Ans.** Gas – Liquid
(Solute = Gas, Solvent = Liquid)

**Q. 4. Why soda bottle kept at room temperature fizzes on opening?**

**Ans.** Carbon dioxide gas is filled in the soda bottle under pressure. It leads to higher amount of gas to dissolve in the water, which is released as bubbles or fizz when the bottle is kept open at room temperature.

## Short Answer Type Questions-I

**(2 marks each)**

**AI Q. 1. State Henry's law. Calculate the solubility of $CO_2$ in water at 298K under 760 mm Hg.**
**($K_H$ for $CO_2$ in water at 298 K is $1.25 \times 10^6$ mm Hg)**
**R + U [CBSE Outside Delhi Set-1, 2020]**

**Ans. Henry's law :** The mass of a gas dissolved in a given volume of the liquid at a constant temperature depends upon the pressure which is applied.

$K_H$ for $CO_2 = 1.25 \times 10^6$ mm Hg

$$x_{CO_2} = \frac{\text{Partial pressure of } CO_2}{K_H \text{ for } CO_2}$$

$$= \frac{760 \text{ mm Hg}}{1.25 \times 10^6 \text{ mm Hg.}}$$

$$= 608 \times 10^{-6}$$

Mole fraction represents the solubility of $CO_2$ in water. **[2]**

**AI Q. 2. State Henry's law and write its two applications.**
**R [CBSE Delhi Set-3 2019]**

**Ans.** Henry's law states that "the partial pressure of the gas ($p$) in vapour phase is proportional to the mole fraction of the gas ($\chi$) in the solution". **[1]**

- To increase the solubility of $CO_2$ in soft drinks
- At high altitudes the partial pressure of oxygen is less than that at the ground level. This leads to low concentrations of oxygen in the blood and tissues of people living at high altitudes or climbers.
- Scuba divers must cope with high concentrations of dissolved gases while breathing air at high pressure underwater. Increased pressure increases the solubility of atmospheric gases in blood. **(Any two)**

**[½ + ½] [CBSE Marking Scheme, 2019]**

**Q. 3. Calculate the molality of ethanol solution in which the mole fraction of water is 0.88.** U

**Ans.** Mole fraction of water, $X_{H_2O} = 0.88$
Mole fraction of ethanol,
$X_{C_2H_5OH} = 1 - 0.88$

$= 0.12$ [½]

$$X_{C_2H_5OH} = \frac{n_2}{n_1 + n_2} \quad \text{...(1)}$$

$n_2$ = number of moles of ethanol.
$n_1$ = number of moles of water.
Molality of ethanol means the number of moles of ethanol present in 1000 g of water.

$$n_1 = \frac{1000}{18} = 55.5 \text{ moles} \quad [½]$$

Substituting the value of $n_1$ in equation (1)

$$\frac{n_2}{55.5 + n_2} = 0.12 \quad [½]$$

$$n_2 = 7.57 \text{ moles} \quad [½]$$

Molality of ethanol ($C_2H_5OH$) = 7.57 m

Alternatively,

Mole fraction of water = 0.88 [½]

Mole fraction of ethanol = 1 – 0.88 = 0.12 [½]

Therefore 0.12 moles of ethanol are present in 0.88 moles of water.

Mass of water = 0.88 × 18 =15.84 g of water. [½]

Molality = number of moles of solute (ethanol) present in 1000 g of solvent (water)

$= 0.12 \times 1000 / 15.84$

$= 7.57$ m [½]

Molality of ethanol ($C_2H_5OH$) = 7.57 m

**[CBSE Marking Scheme 2018]**

**Commonly Made Error**

- Students get confused between the terms molarity and molality.

**Answering Tip**

- Students should remember that molarity is volume based concept and molality is mass based concept.

**Q. 4. Calculate the molarity of NaOH solution obtained by dissolving 2g of NaOH in 50 ml of its solution.** $\boxed{\text{U}}$

**Ans.** ∵ 50 ml of NaOH solution contains = 2g of NaOH

∴ 100 ml of NaOH solution will contain

$$= \frac{2}{50} \times 1000$$

= 40 g of NaOH [1]

Molecular mass of NaOH = 23 + 16 + 1 = 40

$$\text{Number of moles of NaOH} = \frac{\text{Mass}}{\text{molecular mass}}$$

$$= \frac{40}{40} = 1 \text{ mol}$$

∴ Molarity of the solution = 1 M [1]

## Short Answer Type Questions-II

**(3 marks each)**

**Q. 1. (i) What is the relationship between Molarity and Normality?** $\boxed{\text{R}}$

**(ii) One litre of Water at N.T.P. dissolves 0.08 g of nitrogen. Calculate the amount of nitrogen that can be dissolved in four litres of water at 0°C and at a pressure of 1520 mm.**

**Ans. (i)** Molarity (M) × Molecular mass of solute
= Normality (N) × Equivalent mass of solute [1]

**(ii)** Solubility of gas ($C_1$) = 0.08 g/litre

$P_1$ = 760 mm

$P_2$ = 1520 mm

Solubility of gas ($C_2$) at pressure $P_2$ = ?

By Henry's law,

$$\frac{C_1}{C_2} = \frac{P_1}{P_2}$$

$$C_2 = \frac{C_1 \times P_2}{P_1} = \frac{0.08 \times 1520}{760} = 0.16 \text{ g/litre}$$

∴ Solubility of nitrogen in 4 litres of water

$= 0.16 \times 4 = 0.64$ g [1]

**Commonly Made Error**

- Some students get confused in using correct formula for calculation of solubility of gas.

**Answering Tip**

- Students must understand Henry's law.

**Q. 2. $8.0575 \times 10^{-2}$ kg of Glaubers's salt is dissolved in water to obtain 1 $dm^3$ of a solution of density 1077.2 kg $m^{-3}$. Calculate the molarity, molality and mole fraction of $Na_2SO_4$ in the solution.** $\boxed{\text{A}}$

**Ans.** Mass of Glauber's salt $= 8.0575 \times 10^{-2}$ kg

$= 8.0575 \times 10^{-2} \times 10^3$ g

$= 80.575$ g

Molecular mass of Glauber's salt ($Na_2SO_4.10H_2O$)

$= 322$

Number of moles Glauber's salt

$$= \frac{80.575}{322} = 0.25$$

Mass of solution per $dm^3$ = 1077.2 g $m^{-3}$

$= 1077.2 \times 10^3$ g $m^{-3}$

$= 1077.2 \times 10^3 \times 10^{-3}$ g $dm^{-3}$

$= 1077.2$ g

Mass of water = 1077.2 – 80.575 = 996.625g

$$\text{Molarity} = \frac{0.25}{1 \text{ dm}^3} = 0.25$$

$$\text{Molality} = \frac{0.25 \text{ mol} \times 1000}{996.625} = 0.2508$$

$$\text{mole fraction} = \frac{\text{Molarity}}{\text{Molarity} + \dfrac{\text{mass of water}}{\text{molecular mass of water}}} \quad [1]$$

$$= \frac{0.25}{0.25 + \dfrac{996.625}{18}} = 4.49 \times 10^{-3}$$

**Q.3.** **Calculate the concentration of a solution that is obtained by mixing 300 g of 25% solution $NH_4NO_3$ with 150 g of 40% solution of $NH_4NO_3$.** $\boxed{U}$

**Ans.** Total mass of solution = 300 + 150 = 450 g

Amount of solute present in 300 g of 25% solution

$$= 300 \times \frac{25}{100} = 75 \text{ g} \qquad \textbf{[1]}$$

Similarly,

Amount of solute present of 150 g of 40% solution

$$= 150 \times \frac{40}{100} = 60 \text{ g} \qquad \textbf{[1]}$$

Total mass of solute = 75 + 60 = 135 g

Concentration of solution (in %)

$$= \frac{\text{mass of solute in gm}}{\text{mass of solution in gm}} \times 100$$

$$= \frac{135}{450} \times 100$$

= 30% **[1]**

**Q. 4.** **(a) Define mole fraction**

**(b) Explain the following phenomena with the help of Henry's law :**

**(i) Painful condition known as bends.**

**(ii) Feeling of weakness and discomfort in breathing at high altitude.** $\boxed{R}$

**Ans.** **(a)** It may be defined as the ratio of number of moles of one component to the total number of moles of all the components (solvent and solute) present in the solution.

**(b) (i)** Deep sea divers depend upon compressed air for breathing at high pressure under water. The compressed air contains N in addition to $O_2$, which are not very soluble in blood at normal pressure. However, at depths when the diver breathes in compressed air from the supply tank, more $N_2$ dissolves in the blood and other body fluids because the pressure at that depth is far greater than the surface atmospheric pressure. When the diver comes towards the surface, the pressure decreases, $N_2$ comes out of the body quickly forming bubbles in the blood stream. These bubbles restrict blood flow, affect the transmission of nerve impulses. The bubbles can even burst the capillaries or block them and starve the tissues of $O_2$. This condition is called the bends, which are painful and life-threatening. **[1]**

**(ii)** At high altitudes, the partial pressure of $O_2$ is less than that at the ground level. This results in low concentration of oxygen in the blood and tissues of the people living at high altitudes or climbers. The low blood oxygen causes climbers to become weak and unable to think clearly known as anoxia. **[1]**

## Long Answer Type Questions **(5 marks each)**

**Q. 1.** **(i) Calculate the mass percentage of aspirin ($C_9H_8O_4$) in acetonitrile ($CH_3CN$) when 6.5 g of $C_9H_8O_4$ is dissolved in 450 g of $CH_3CN$.**

**(ii) Commercially available concentrated hydro chloric acid contains 38% HCl by mass and has density 1.19g $cm^{-3}$. What is the molarity of this solution?** $\boxed{U}$ + $\boxed{A}$

**Ans.(i)** 6.5 g of $C_9H_8O_4$ is dissolved in 450 g of $CH_3CN$.

Then, total mass of the solution = (6.5 + 450) g

= 456.5 g

Therefore, mass percentage of $C_9H_8O_4$

$= \frac{6.5}{456.5}$ ´ 100%

= 1.424% **[2]**

**(ii)** Density of HCl = 1.19 g $cm^{-3}$

Mass of 1000 $cm^3$ of commercial HCl

$= 1000 \times 1.19 = 1190$ g **[1]**

Mass of HCl in 1190 g (1000 $cm^3$) of the solution

$$= \frac{1190 \times 38}{100} = 452.2 \text{ g} \qquad \textbf{[1]}$$

Molar mass of HCl = 1 + 35.5 = 36.5 g

$$452.2 \text{ g of HCl} = \frac{452.2}{36.5} \text{ moles of HCl}$$

= 12.4 moles of HCl

∴ 1.0L of the commercial HCl solution contains 12.4 moles of HCl.

Molarity of the commercial HCl solution

= 12.4 M **[1]**

**Q. 2.** **Concentration terms such as mass percentage, ppm, mole fraction and molality are independent of temperature, however molarity is a function of temperature. Explain.** $\boxed{R}$

**Ans.** **(a) Mass Percentage (w/W) :** It is defined as the ratio of mass of the component of the solution and total mass of the solution multiplied by 100%.

**(b) Parts per million :** It is defined as the ratio of number of parts of the component to the total number of parts of all components of the solution multiplied by $10^6$ and it is used to express concentration of a solution where solutes are present in traces. It is denoted by the alphabet *x* and subscript written on the right hand side of *x* denotes the component of which mole fraction is being calculated.

**(c) Mole Fraction :** It is defined as the ratio of number of moles of the component in the solution to the total number of moles of all components in the solution.

**(d) Molality :** It can be defined as the ratio of number of moles of solute to the mass of solvent in kg or it can also be defined as the number of moles of solute present in unit kilogram of solvent.

$$\text{Molality (m)} = \frac{\text{Moles of solute}}{\text{Mass of solvent in kilogram}}$$

**(e)** **Molarity :** It is defined as the ratio of number of moles of solute to the volume of solution in litre or it can also be defined as the number of moles of solute present in unit litre or cubic decimetre of solution. It is function of temperature due to the dependence of volume on temperature whereas Mass %, ppm, mole fraction and molality are independent of temperature because mass does not depend on temperature. **[5]**

**Q.3.** **4.0 g of NaOH are contained in one decilitre of solution. Calculate the following :**
**(i) Molality fraction of NaOH**
**(ii) Molarity of NaOH**
**(iii) Molality of NaOH**
**Density of solution = 1.038 g/cm$^3$** $\boxed{U}$

**Ans.** **(i)** Density of solution = 1.038 g/cm$^3$

Mass of 100 cm$^3$ of solution $= 1.038 \times 100 = 103.8$ g

Mass of NaOH in 100 cm$^3$ solution = 4g

Mass of water = 103.8 – 4.0 = 99.8 g **[1]**

$$\text{Number of moles of NaOH } (n_A) = \frac{4.0}{40} = 0.1 \text{ mol}$$

$$\text{Number of moles of water } (n_B) = \frac{99.8}{18} = 5.54 \text{ mol}$$

$$\therefore \text{Mole fraction of NaOH } X_A = \frac{n_A}{n_A + n_B}$$

$$= \frac{0.1}{0.1 + 5.54} = 0.018$$ **[1]**

**(ii)** Molarity of NaOH solution

$$= \frac{\text{Mass of NaOH per litre of solution}}{\text{Molecular mass of NaOH}} = \frac{40}{40} = 1\text{M}$$

**(iii)** Mass of NaOH in 99.8 g of water = 4.0 g

$\therefore$ Mass of NaOH in 1000 g of water

$$= \frac{4.0}{99.8} \times 1000$$

= 40.08 g **[1]**

Molality of NaOH solution

$$= \frac{\text{Mass of NaOH per 100 g of water}}{\text{Molecular mass of NaOH}}$$

$$= \frac{40.08}{40}$$

= 1.002 mol kg$^{-1}$ **[1]**

**Commonly Made Error**

- Sometimes, students are unable to calculate the concentration of solution from given data.

**Answering Tip**

- Understand the formulae to calculate the concentration of solution in different ways.

# TOPIC-2

## Vapour Pressure, Raoult's Law, Ideal and Non-ideal Solutions

## Revision Notes

- Vapour pressure is the pressure exerted by vapours over a liquid at equilibrium state at constant temperature.
- Vapour pressure depends on the following factors :
  **(i)** Nature of the liquid.
  **(ii)** **Temperature :** Vapour pressure of a liquid increases with increase in temperature.
- **Raoult's law for a solution of volatile liquids :** It states that for a solution of volatile liquids, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction in solution.

  Suppose a solution is prepared by mixing two volatile liquids A and B. Let $\chi_A$ and $\chi_B$ respectively be their mole fractions, and let $p_A$ and $p_B$ be their partial vapour pressures respectively in the solution at a particular temperature.

  If $p_A^o$ and $p_B^o$ are their vapour pressures in the pure state respectively, then according to Raoult's law :

$$p_A = p_A^o \chi_A$$

$$p_B = p_B^o \chi_B$$

Considering Dalton's law of partial pressure,

$$p_{\text{total}} = p_A + p_B$$

Substituting values of $p_A$ and $p_B$,

$$p_{\text{total}} = \chi_A p_A^o + \chi_B p_B^o = (1 - \chi_B)\, p_A^o + \chi_B\, p_B^o$$

$$= p_A^o + (p_B^o - p_A^o)\chi_B$$

The composition of the vapour phase in equilibrium with the solution can be determined from the partial pressure of the two components. If $\Upsilon_A$ and $\Upsilon_B$ are the mole fractions of components A and B respectively in the vapour phase, then

$$p_A = \gamma_A p_{total}$$

and $$p_B = \gamma_B p_{total}$$

In general $p_i = \gamma_i\, p_{total}$

- **Raoult's law as a special case of Henry's law :** According to Raoult's law, the vapour pressure of volatile component (A) in a given solution is given as :

  $$p_A = p_A^o\, \chi_A$$

  According to Henry's law, in the solution of a gas in a liquid, the gaseous component is normally so volatile that it exists as a gas and solubility depends upon Henry's law to which :

  $$p_A = K_H \chi_A$$

  On comparing both expressions $p_A^o$ is equal to $K_H$.

- **Raoult's law for non-volatile solute :** For a solution containing non-volatile solute present in a volatile solvent, Raoult's law may be stated as the relative lowering of vapour pressure for a solution is equal to the mole fraction of solute.

  $$\chi_B = \frac{p_A^0 - p_A}{p_A^0},$$

  where, $\chi_B$ = Mole fraction of solute,

  $p_A^o - p_A$ = Lowering of vapour pressure.

- **Ideal solution :** A solution which obeys Raoult's law over a wide range of concentration at specific temperature is called ideal solution.

  **(i)** Raoult's law is obeyed. $p_A = p_A^o\, \chi_A,\ p_B = p_B^o\, \chi_B$
  **(ii)** $\Delta_{mix}H = 0$,
  **(iii)** $\Delta_{mix}V = 0$,
  **(iv)** The force of attraction between A-A and B-B is nearly equal to A-B.

  **Some examples of ideal solutions are :**

  **(i)** *n*-hexane and *n*-heptane,
  **(ii)** Ethyl bromide and ethyl chloride,
  **(iii)** Benzene and toluene,
  **(iv)** Chlorobenzene and bromobenzene.

- **Non-ideal solution :** A solution which does not obey Raoult's law for all the concentrations is called a non-ideal solution.

  **(i)** Raoult's law is not obeyed, *i.e.*, $p_A \neq p_A^o\, \chi_A$ and $p_B \neq p_B^o\, \chi_B$
  **(ii)** $\Delta_{mix}H \neq 0$,
  **(iii)** $\Delta_{mix}V \neq 0$,
  **(iv)** The force of attraction between A-A and B-B is not equal to A-B.

  **Some examples of non-ideal solutions are :**

  **(i)** Water and ethanol
  **(ii)** Chloroform and acetone
  **(iii)** Ethanol and cyclohexane

  A non-ideal solution can show either positive or negative deviation from Raoult's law.

- **Positive deviation from Raoult's law :** In this type of deviation, A-B interactions are weaker than the interaction between A-A or B-B and leads to increase in vapour pressure.

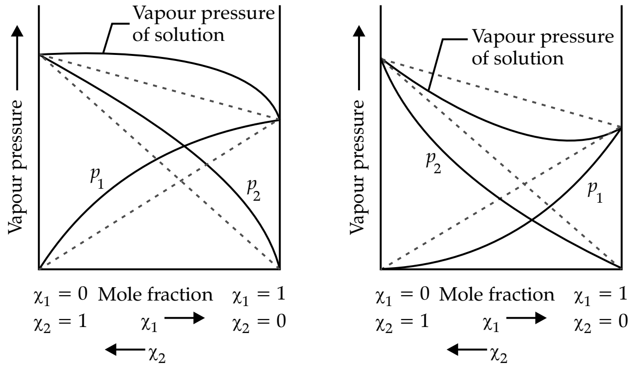
  **Some examples are :**

  **(i)** Water and ethanol,
  **(ii)** Chloroform and water,
  **(iii)** Ethanol and $CCl_4$,
  **(iv)** Methanol and chloroform,
  **(v)** Benzene and methanol,
  **(vi)** Acetic acid and toluene.

- **Negative deviation from Raoult's law :** In this type of deviation in non-ideal solutions, the intermolecular attractive forces between A-A and B-B are weaker than those between A-B and leads to decrease in vapour pressure.

  **Some examples are :**

  **(i)** Chloroform and acetone,
  **(ii)** Chloroform and methyl acetate,
  **(iii)** $H_2O$ and HCl,
  **(iv)** $H_2O$ and $HNO_3$,
  **(v)** Acetic acid and pyridine,
  **(vi)** Chloroform and benzene.



**(a)** **(b)**

**Fig. 2 : The vapour pressures of two component systems as a function of composition :**
**(a) A solution that shows positive deviation from Raoult's law, and**
**(b) A solution that shows negative deviation from Raoult's law.**

- **Azeotropes :** Liquid mixtures which distil over without change in composition are called constant boiling mixtures or azeotropes or azeotropic mixtures.
- **Minimum boiling azeotropes :** Non-ideal solutions showing large positive deviation from Raoult's law form minimum boiling azeotropes at a specific composition. *e.g,* water and benzene, chloroform and methanol.
- **Maximum boiling azeotropes :** Non-ideal solutions showing large negative deviation from Raoult's law form maximum boiling azeotropes which boil at temperature higher than the boiling points of its components. *e.g.* mixture of $HNO_3$ and $H_2O$.

## Know the Formulae

- Raoult's law for a solution of volatile solute in volatile solvent :

$$p_A = p_A^o \chi_A$$
$$p_B = p_B^o \chi_B$$

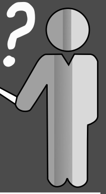
- Raoult's law for a solution of non-volatile solute and volatile solvent :

$$\frac{p_A^o - p_A}{p_A^o} = i\chi_B = i\frac{n_B}{n_A} = i\frac{W_B \times M_A}{W_A \times M_B} \text{ (for dilute solution)}$$

### Mnemonics

- **Concept:** Raoult's law for Non-volatile Solute
- **Mnemonic: R.L. is Very Poor Student = Most Failure Student**
- **Interpretation: Relative Lowering Of Vapour Pressure For A Solution Is Equal To The Mole Fraction Of Solute.**
- **Concept:** Ideal solution
- **Mnemonic: ISRaeL**
- **Interpretation: Ideal Solution Obeys Raoult's Law**
- **Concept:** Non-Ideal solution
- **Mnemonic: Nano Scale Device Research Labaratory**
- **Interpretation: Non-Ideal Solution Does Not Obey Raoult's Law**

## How is it done on the GREENBOARD?



**Q. The vapour pressure of benzene and toluene at 20°C are 75 mm Hg and 22 mm Hg respectively. 23.4 g of benzene and 64.4 g of toluene are mixed. If the two form an ideal solution, calculate the mole fraction of benzene in the vapour phase if the vapours are in equilibrium with the liquid mixture at the same temperature.**

**Solution:**

**STEP-1:** Mass of benzene = 23.4 g

Molecular mass of benzene ($C_6H_6$)

$= 12 \times 6 + 1 \times 6 = 78$

∴ Number of moles of benzene in solution

$$= \frac{23.4}{78} = 0.3 \qquad \textbf{[½]}$$

Mass of toluene = 64.4 g

Molecular mass of toluene ($C_7H_8$)

$= 12 \times 7 + 1 \times 8 = 92$

∴ Number of moles of toluene in solution

$$= \frac{64.4}{92} = 0.7 \qquad \textbf{[½]}$$

**STEP-2:** Mole fraction of benzene

$$= \frac{0.3}{0.3 + 0.7} = 0.3 \qquad \textbf{[½]}$$

Mole fraction of toluene

$$= \frac{0.7}{0.3 + 0.7} = 0.7 \qquad \textbf{[½]}$$

Partial pressure of benzene vapour

$= 75 \times 0.3 = 22.5$ mm **[1]**

Partial pressure of toluene vapour

$= 22 \times 0.7 = 15.4$ mm **[1]**

Total vapour pressure

$= 22.5 + 15.4 = 37.9$ mm

**STEP-3:** Mole fraction of benzene in vapour phase

$$= \frac{\text{Partial vapour pressure}}{\text{Total vapour pressure}}$$

$$= \frac{22.5}{37.9} = 0.59$$

**[1]**

## Objective Type Questions

**(1 mark each)**

**[A] MULTIPLE CHOICE QUESTIONS :**

**Q. 1. When 1 mole of benzene is mixed with 1 mole of toluene the vapour will contain : (Given : vapour of benzene = 12.8kPa and vapour pressure of toluene = 3.85 kPa).** $\boxed{A}$ **[CBSE, SQP, 2020-2021]**

**(a) equal amount of benzene and toluene as it forms an ideal solution**

**(b) unequal amount of benzene and toluene as it forms a non ideal solution**

**(c) higher percentage of benzene**

**(d) higher percentage of toluene**

**Ans. Correct option : (c)**

*Explanation :* When 1 mole of benzene is mixed with 1 mole of toluene the vapour will contain higher percentage of benzene. As it is an ideal solution, it follows Raoult's law.

The vapour pressure of the solution depends on the mole fraction of the solvent.

$$P_{soln} = \chi_{solvent} P^0_{solvent}$$

$P_{soln}$ is the vapour pressure of the solution

$\chi$ is the mole fraction of the solvent

$P^0_{solvent}$ is the vapour pressure of the pure solvent

Since the mole fraction of both the components is same, but the vapour pressure of benzene is higher than the toluene, its percentage will be greater in the vapour of the solution.

**Q. 2. If two liquids A and B form minimum boiling azeotrope at some specific composition then _________.**

**(a) A–B interactions are stronger than those between A–A or B–B.**

**(b) Vapour pressure of solution increases because more number of molecules of liquids A and B can escape from the solution.**

**(c) Vapour pressure of solution decreases because less number of molecules of only one of the liquids escape from the solution.**

**(d) A–B interactions are weaker than those between A–A or B–B.** R

**Ans. Correct Option : (d)**

*Explanation :* When solute-solvent or A-B interactions are weaker than the A-A or B-B interactions, molecules of A or B will find it easier to escape than in pure state. This will increase the vapour pressure and result in positive deviation from Raoult's law. Such solutions are called minimum boiling azeotropes.

**Q. 3. For a dilute solution, Raoult's law states that**

**(a) The lowering of vapour pressure is equal to the mole fraction of solute.**

**(b) The relative lowering of vapour pressure is equal to the mole fraction of solute.**

**(c) The relative lowering of vapour pressure is proportional to the amount of solute in solution.**

**(d) The vapour pressure of the solution is equal to the mole fraction of the solute.** R

**Ans. Correct option : (b)**

*Explanation :* According to Raoult's law, for a dilute solution, the relative lowering of vapour pressure is equal to the mole fraction of solute.

$$\frac{P_A^0 - P_A}{P_A^0} = X_B$$

Where

$$\frac{P_A^0 - P_A}{P_A^0} = \text{Relative lowering of vapour pressure}$$

$X_B =$ mole fraction of solute

**[B] ASSERTIONS AND REASONS:**

**In the following questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.**

**(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**

**(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.**

**(c) Assertion is correct statement but reason is wrong statement.**

**(d) Assertion is wrong statement but reason is correct statement.**

**Q. 1. Assertion : An ideal solution obeys Henry's law.**

**Reason : In an ideal solution, solute-solute as well as solvent-solvent interactions are similar to solute-solvent interaction. [CBSE Delhi Set-3, 2020]**

**Ans. Correct option :** (d)

*Explanation :* An ideal solution obeys Raoult's law.

**Q. 2. Assertion : Dimethyl ether is less volatile than ethyl alcohol.**

**Reason : Dimethyl ether has greater vapour pressure than ethyl alcohol.**

**Ans. Correct option :** (d)

*Explanation :* Dimethyl ether is more volatile than ethyl alcohol.

**Q. 3. Assertion : Vapour pressure increase with increase in temperature.**

**Reason : With increase in temperature, more molecules of the liquid can go into vapour phase.**

**Ans. Correct option :** (a)

*Explanation :* Vapour pressure increase with increase in temperature because more molecules of the liquid can go into vapour phase with increase in temperature.

**[C] VERY SHORT ANSWER TYPE QUESTIONS :**

**Q. 1. What is an ideal solution?**

**Ans.** The solution which obeys Raoult's law is called ideal solution.

**Q. 2. Define azeotropic mixture.**

**Ans.** A solution which distilled without change in composition at a particular temperature is called azeotropic mixture.

**Q. 3. What do you meant by minimum boiling azeotropes?**

**Ans.** The azeotropes which are formed by those liquid pairs which show positive deviation from ideal behaviour.

## Short Answer Type Questions-I

**(2 marks each)**

**Q. 1. State Raoult's law for a solution containing volatile components. What is the similarity between Raoult's law and Henry's law? [CBSE, Delhi Set 1 & 2, 2020]**

**Ans.** Raoult's law for a solution containing volatile components states that the partial pressure of a volatile component present in a solution is directly proportional to the mole fraction of that component at a given temperature.

$$P_A \propto \chi_A \quad \text{or} \quad P_A = K\chi_A$$

Raoult's law and Henry's law are similar as both gives equation to find partial pressure of gases.

$\underset{\text{(Raoult's law)}}{P_A = K\chi_A}$ $\underset{\text{(Henry's law)}}{P_A = K_H\chi_A}$ **[2]**

**Q. 2. State Raoult's law for a solution containing volatile components. Write two characteristics of the solution which obey Raoult's law at all concentrations. [CBSE, Delhi Set-1, 2019]**

**Ans.** For a solution of volatile liquids, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution. **[1]**

(i) $\Delta_{mix} H = 0$ (ii) $\Delta_{mix} V = 0$ (iii) The components have nearly same intermolecular force of attraction **[½, ½]**

**(any two) [CBSE Marking Scheme, 2019]**

**Detailed Answer :**

Raoult's law for a solution containing volatile components - The partial vapour pressure of each volatile components of the solution is directly proportional to mole fraction present in solution.

The ideal solutions have characteristics to obey Raoult's law for the following conditions.

**(i)** The enthalpy of mixing of the pure components to form the solution is zero, $\Delta_{mix} H = 0$. That means no heat is absorbed or released during the mixing of the two pure components.

**(ii)** The volume of the mixing also be zero, $\Delta_{mix} V = 0$. That means the total volume of the solution is equal to the sum of the volume of the two components.

**(iii)** In pure components, A and B, the intermolecular attractions between solute-solute interactions and solvent-solvent interaction are almost similar to the solute-solvent interaction. **[2]**

**Q. 3. Write two differences between ideal solutions and non-ideal solutions. [CBSE, Delhi Set 2, 2019]**

**Ans.**

| Ideal solution | Non-ideal solution |
|---|---|
| Obeys Raoult's law at all range of concentrations. | Does not obey |
| $\Delta_{mix} H = 0, \Delta_{mix} V = 0$ | $\Delta_{mix} H \neq 0, \Delta_{mix} V \neq 0$<br>(or any other difference) |

**[1 + 1] [CBSE Marking Scheme, 2019]**

**Detailed Answer :**

| | Ideal solution | Non-ideal solution |
|---|---|---|
| **(i)** Raoult's Law | Solutions which obey **Raoult's law** over the entire range of concentrations. | Do not obey **Raoult's law** over the entire range of concentrations. |
| **(ii)** $\Delta_{\ddot{u}}\ H$ | The enthalpy of mixing of the pure components to form a solution **is zero.**<br>$\Delta_{mix} H = 0$ | The enthalpy of mixing of pure components to form a solution **is not zero**. $\Delta_{mix} H > 0$ |
| **(iii)** $\Delta_{mix} V$ | The volume of the mixing is also **zero**, $\Delta_{mix} V = 0$.<br>That means the total volume of the solution is equal to the sum of the volume of the two components. | The volume of the mixing **is not zero**, $\Delta_{mix} V \neq 0$. The total volume of the solution is not equal to the sum of the volume of the two components. |
| **(iv)** Intermolecular interactions | In pure components, A and B, the intermolecular attractions between solute-solute interactions and solvent-solvent interactions are **almost similar** to the solute-solvent interaction. | In pure components, A and B, the intermolecular attractions between solute-solute interactions and solvent-solvent interaction are **not similar** to the solute-solvent interaction. |

**[2]**

**AI Q. 4. Give reasons :**

**(a) A decrease in temperature is observed on mixing ethanol and acetone.**

**(b) Potassium chloride solution freezes at a lower temperature than water. [2]**

**A [CBSE, Outside Delhi, 2019]**

**Ans. (a)** Ethanol-acetone interaction is weaker than pure ethanol or acetone interactions.

**(b)** On adding KCl, vapour pressure of the solution decreases **[1 + 1]**

**[CBSE Marking Scheme 2019]**

**Detailed Answer :**

**(a)** When ethanol is mixed with acetone, it shows positive deviation from Raoult's law and acetone molecules get in between the host molecules and break some hydrogen bonds, which requires higher energy than energy released in the formation of new hydrogen bonds. This results fall in temperature.

**(b)** According to Raoult's law, when a non-volatile solid is added to the solvent, its vapour pressure decreases resulting in decrease in freezing point. Also, the freezing point of water is higher than when water contains KCl. **[2]**

**AI Q. 5. Give reasons :**

**(a) An increase in temperature is observed on mixing chloroform and acetone.**

**(b) Aquatic animals are more comfortable in cold water than in warm water. [2]**

**A [CBSE, Outside Delhi Set 3, 2019]**

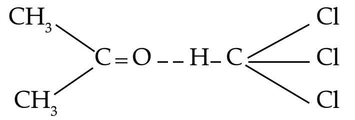
**Ans. (a)** Due to stronger interaction between chloroform and acetone than pure chloroform or acetone interactions. **[1]**

**(b)** Because of high solubility of oxygen gas /low $K_H$ value in cold water than in warm water. **[1]**

**[CBSE Marking Scheme 2019]**

**Detailed Answer :**

**(a)** On addition of chloroform and acetone, chloroform forms strong hydrogen bonding with acetone.



This results in release of energy due to increase in attractive forces. Hence, the dissolution is an exothermic process.

**(b)** At a given pressure, the solubility of oxygen in water increases with decrease in temperature. Therefore, the concentration of oxygen in sea is more in cold water and thus, the presence of more oxygen at lower temperature makes the aquatic animals more comfortable in cold water. **[2]**

AI **Q. 6. Define the following terms :**

**(i) Ideal solution (ii) Molarity (M) [2]**

**[CBSE, Delhi Set 2, 2017]**

**Ans. (i)** The solution that obeys Raoult's Law over the entire range of concentration. **[1]**

**(ii)** Number of moles of solute dissolved per litre of solution or $M = \frac{w_b \times 1000}{M_b \times V(mL)}$. **[1]**

**[CBSE Marking Scheme, 2017]**

**Detailed Answer :**

**(i)** An **ideal solution** which obeys Raoult's law over entire range of concentration. The necessary condition to reach ideal solution is :

Enthalpy of mixing of the pure components to form the solution, $\Delta H_{mix} = 0$ and volume of mixing, $\Delta V_{mix} = 0$ **[1]**

**(ii)** **Molarity** is defined as the number of moles of solute present in 1000 mL of the solution. Molarity is represented by M.

$$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in mL}} \times 1000 \quad \textbf{[1]}$$

**Q. 7. What is meant by positive deviations from Raoult's law ? Give an example. What is the sign of $\Delta_{mix}H$ for positive deviation ?**

**OR**

**Define azeotropes. What type of azeotrope is formed by positive deviation from Raoult's law ? Give an example.** R **[CBSE Delhi 2015]**

**Ans.** In case of positive deviation from Raoult's law, the intermolecular attractive forces between the solute-solvent molecules are weaker than those between the solute-solute and solvent-solvent molecules.

**Example :** Mixture of ethanol and acetone.

Sign for $\Delta_{mix}H$ is positive **[1+½+½]**

**OR**

**Azeotropes :** A liquid mixture which distills at constant temperature without undergoing any change in composition is called azeotrope. **[1]**

Minimum boiling azeotrope is formed by positive deviation from Raoult's law. **[½]**

**Example : (i)** Water and benzene

**(ii)** Chloroform and methanol **[½]**

**Q. 8. The experimentally determined molar mass for what type of substances is always lower than the true value when water is used as solvent. Explain. Give one example of such a substance which does not show a large variation from the true value.** R

**Ans.** When there is dissociation of solute into ions in dilute solutions (ignoring interionic attractions) the number of particles increases. As the value of colligative properties depends on the number of particles of the solute, the experimentally observed value of colligative property will be higher than the true value, therefore the experimentally determined (observed) molar mass is always lower than the true value. **[1]**

For KCl (electrolyte), the experimentally determined molar mass is always lower than the true value when water is used as solvent. **[½]**

Glucose (non-electrolyte) does not show a large variation from the true value. **[½]**

**Q. 9. Why a mixture of carbon disulphide and acetone shows positive deviation from Raoult's law? What type of azeotrope is formed by this mixture ?** A

**Ans.** Intermolecular forces of attraction between carbon disulphide and acetone are weaker than the pure components. **[1]**

Minimum boiling azeotrope at a specific composition. **[1]**

**Q. 10. State Raoult's law for a solution containing volatile components. What is the similarity between Raoult's law and Henry's law ?** R

**Ans.** Raoult's law for a solution containing volatile components states that the partial pressure of a volatile component present in a solution is directly proportional to the mole fraction of that component at a given temperature.

$P_A \propto \chi_A$ or $P_A = K\chi_A$ **[1]**

Raoult's law and Henry's law are similar as both gives equation to find partial pressure of gases.

$P_A = K\chi_A$ $P_A = K_H\chi_A$ **[1]**

(Raoult's law) (Henry's law)

## Short Answer Type Questions-II (3 marks each)

**Q. 1. (a) Define vapour pressure of the liquid.**

**(b) (i) Gas (A) is more soluble in water than Gas (B) at the same temperature. Which one of the two gases will have the higher value of $K_H$ (Henry's constant) and why ?**

**(ii) In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes ?** R + A

**Ans. (a)** The pressure exerted by the vapours above the liquid surface in equilibrium with the liquid at a given temperature is called vapour pressure of the liquid. **[1]**

**(b) (i)** Gas B will have the higher value of $K_H$ (Henry's constant) as lower is the solubility of the gas in the liquid higher is the value of $K_H$. **[1]**

**(ii)** In non-ideal solution, negative deviation shows the formation of maximum boiling azeotropes. **[1]**

**Q. 2. (i) Give the factors affecting the vapour pressure of a liquid.**

**(ii) Suggest the most important type of intermolecular attractive interaction in the following pairs :**

**(a) *n*-hexane and *n*-octane**

**(b) $I_2$ and $CCl_4$** R + A

**Ans. (i) Nature of liquid :** Liquids having week intermolecular forces are volatile and possess higher vapour pressure.

**Temperature :** Vapour pressure increases with increase in temperature. [½ + ½]

**(ii) (a)** van der Waals forces of attraction.

**(b)** van der Waals forces of attraction. **[1]**

**Q. 3. In aqueous solution containing 20% by weight of liquid 'A' (Mol.wt = 140) has vapour pressure of 160 mm at 57° C. Find the vapour pressure of pure A, if that of water is 150 mm at this temperature.** U

**Ans.** Number of moles of A dissolved $= \frac{20}{140} = 0.143$ [½]

Number of moles of B $= \frac{80}{18} = 4.44$ [½]

Mole farction of A $(\chi_A) = \frac{0.143}{0.143 + 4.44} = 0.031$ [½]

Mole farction of B $(\chi_B) = \frac{4.44}{0.143 + 4.44} = 0.969$ [½]

Total pressure = 160mm

$$= P_A \times \chi_A + P_B \times \chi_B$$

$$160 = P_A \times 0.031 + 150 \times 0.969$$

$$\therefore P_A = 472.58 \text{ mm}$$ **[1]**

AI **Q. 4. The vapour pressure of pure liquids A and B at 400 K are 450 and 700 mm Hg respectively. Find out the composition of liquid mixture if total pressure at this temperature is 600 mm Hg.**

A **[CBSE Comptt. Delhi 2017]**

**Ans.** $p_{\text{total}} = p_1^o + (p_2^o - p_1^o)x_2$ **[1]**

$600 = 450 + (700 - 450)\,x_2$ **[1]**

$x_2 = 0.6$ [½]

$x_1 = 1 - 0.6 = 0.4$ [½]

**[CBSE Marking Scheme 2017]**

**Detailed Answer :**

$$p_A^o = 450 \text{ mm Hg}, \; p_B^o = 450 \text{ mm Hg}$$

$$p_{\text{Total}} = 600 \text{ mm Hg}$$

According to Raoult's law,

$$p_A = \chi_A \times p_A^o$$

$$p_B = \chi_B \times p_B^o$$

$$p_{\text{Total}} = p_A + p_B$$

$$= (1 - \chi_B)\, p_A^o + \chi_B\, p_B^o = p_A^o + (p_B^o - p_A^o)\,\chi_B$$

$$600 = 450 + (700 - 450)\chi_B$$

$$600 - 450 = 250\chi_B$$

$$150 = 250\chi_B$$

$$\chi_B = \frac{150}{250} = 0.6$$

$$\Rightarrow \quad \chi_A = 1 - 0.6 = 0.4$$

## Long Answer Type Questions

**(5 marks each)**

AI **Q. 1. (a) 30 g of urea (M = 60 g mol$^{-1}$) is dissolved in 846 g of water. Calculate the vapour pressure of water for this solution if vapour pressure of pure water at 298 K is 23.8 mm Hg.**

**(b) Write two differences between ideal solutions and non-ideal solutions.** U + R

**[CBSE OD Set-1, 2 & 3, 2017]**

Ans. **(a) (i)** $(P_A^0 - P_A)/P_A^0 = (w_B \times M_A)/(M_B \times w_A)$

$\frac{23.8 - P_A}{23.8} = (30 \times 18)/60 \times 846$ **1**

$23.8 - P_A = 23.8 \times [(30 \times 18)/60 \times 846]$ ½

$23.8 - P_A = 0.2532$ ½

$P_A = 23.9 - 0.2532$

$= 23.55$ mmHg 1

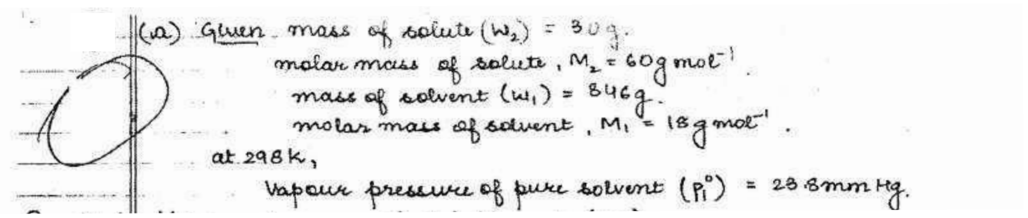
**(b)**

| **Ideal solution** | **Non-ideal solution** |
|---|---|
| (a) It obeys Raoult's law over the entire range of concentration. | (a) Does not obeys Raoult's law over the entire range of concentration. |
| (b) $\Delta_{mix} H = 0$ | (b) $\Delta_{mix}$ H is not equal to 0. |
| (c) $\Delta_{mix} V = 0$ | (c) $\Delta_{mix}$ V is not equal to 0. |

**1 + 1 (Any two correct difference)**

**[CBSE Marking Scheme, 2017]**

**OR**



(a) Given mass of solute $(w_2)$ = 30g.

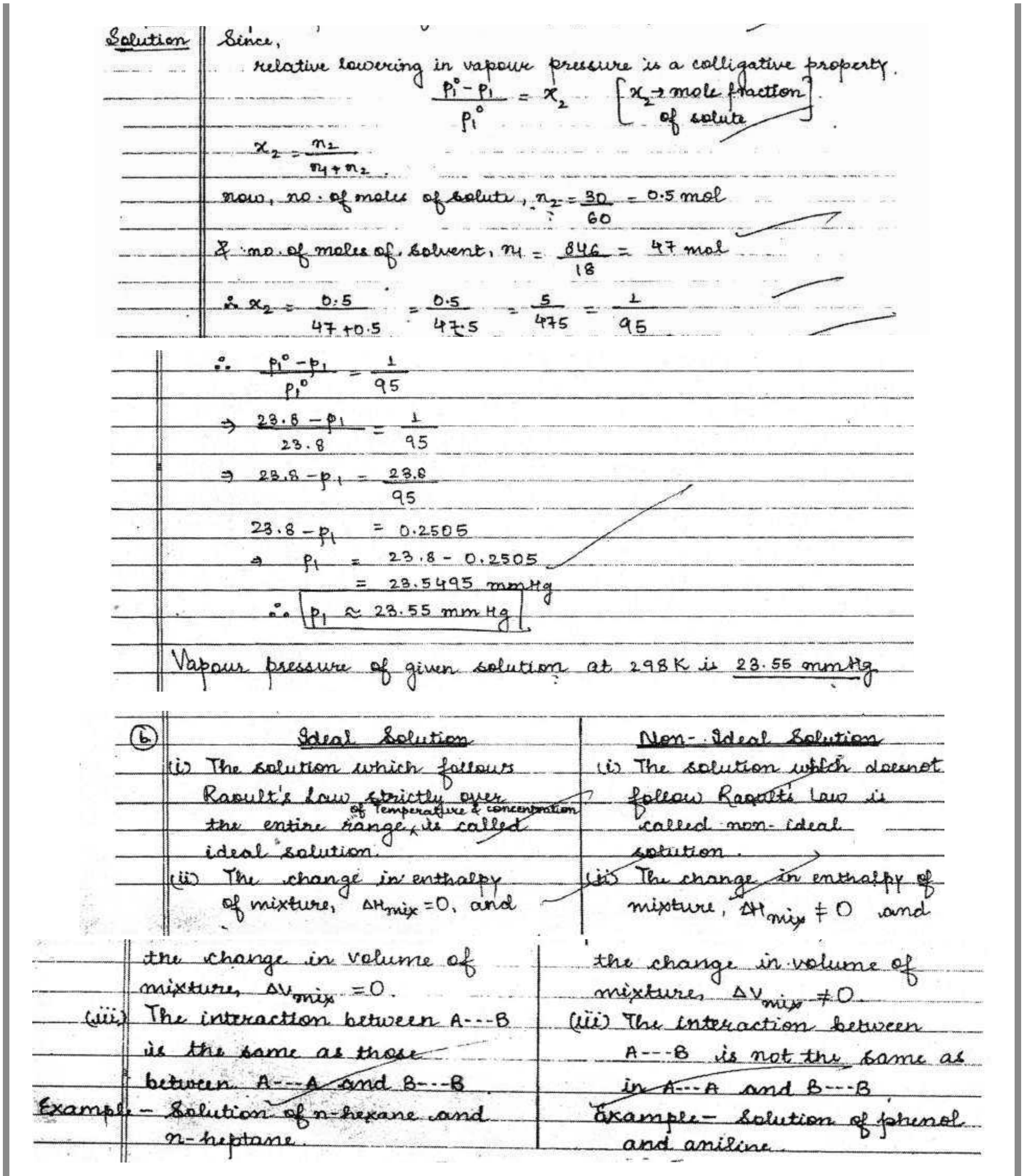
molar mass of solute, $M_2$ = 60g mol$^{-1}$.

mass of solvent $(w_1)$ = 846g.

molar mass of solvent, $M_1$ = 18g mol$^{-1}$.

at 298K,

Vapour pressure of pure solvent $(P_1^o)$ = 23.8mm Hg.



Solution Since,

relative lowering in vapour pressure is a colligative property.

$$\frac{p_1^\circ - p_1}{p_1^\circ} = x_2 \quad \left[x_2 \to \text{mole fraction of solute}\right]$$

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

now, no. of moles of solute, $n_2 = \frac{30}{60} = 0.5$ mol

& no. of moles of solvent, $n_1 = \frac{846}{18} = 47$ mol

$$\therefore x_2 = \frac{0.5}{47 + 0.5} = \frac{0.5}{47.5} = \frac{5}{475} = \frac{1}{95}$$

$$\therefore \frac{p_1^\circ - p_1}{p_1^\circ} = \frac{1}{95}$$

$$\Rightarrow \frac{23.8 - p_1}{23.8} = \frac{1}{95}$$

$$\Rightarrow 23.8 - p_1 = \frac{23.8}{95}$$

$$23.8 - p_1 = 0.2505$$

$$\Rightarrow p_1 = 23.8 - 0.2505$$

$$= 23.5495 \text{ mmHg}$$

$$\therefore \boxed{p_1 \approx 23.55 \text{ mm Hg}}$$

Vapour pressure of given solution at 298K is 23.55 mmHg.

ⓑ

| Ideal Solution | Non-Ideal Solution |
|---|---|
| (i) The solution which follows Raoult's law strictly over the entire range of Temperature & concentration, is called ideal solution. | (i) The solution which doesnot follow Raoult's law is called non-ideal solution. |
| (ii) The change in enthalpy of mixture, $\Delta H_{mix} = 0$, and the change in volume of mixture, $\Delta V_{mix} = 0$. | (ii) The change in enthalpy of mixture, $\Delta H_{mix} \neq 0$ and the change in volume of mixture, $\Delta V_{mix} \neq 0$. |
| (iii) The interaction between A---B is the same as those between A---A and B---B. | (iii) The interaction between A---B is not the same as in A---A and B---B |
| Example – Solution of n-hexane and n-heptane. | Example – Solution of phenol and aniline. |

[Topper's Answer 2017] 5

**Commonly Made Error**

- Some students can not calculate the vapour pressure of water for the solution from given data.

**Answering Tip**

- Students must understand the relationship between relative of vapour pressure and mole fraction.

**Q. 2.** **The vapour pressures of ethanol and methanol are 44.5 mm and 88.7 mm Hg respectively. An ideal solution is formed at the same temperature by mixing 60 g of ethanol with 40 g of methanol. Calculate the total vapour pressure of the solution and the mole fraction of methanol in the vapour.** A

**Ans.** Mass of ethanol = 60 g

Molecular mass of ethanol ($C_2H_5OH$)

$$= 12 \times 2 + 1 \times 5 + 16 + 1 = 46$$

$\therefore$ Number of moles of ethanol = $\dfrac{60}{46} = 1.304$ [½]

Mass of methanol = 40 g

Molecular mass of methanol ($CH_3OH$)

$= 12 \times 1 + 1 \times 3 + 16 + 1 = 32$

$\therefore$ Number of moles of methanol = $\dfrac{40}{32} = 1.250$ [½]

Mole fraction of ethanol $= \dfrac{1.304}{1.304 + 1.250} = 0.51$ [½]

Mole fraction of methanol = 1 – 0.51 = 0.49 [½]

Vapour pressure of pure ethanol

$P^o_{C_2H_5OH} = 44.5$ mm

Vapour pressure of pure methanol

$P^o_{CH_3OH} = 88.7$ mm

Vapour pressure due to ethanol

$P_{C_2H_5OH} = P^o_{C_2H_5OH} \times 0.51$

$= 44.5 \text{ mm} \times 0.51 = 22.69$ mm [½]

Vapour pressure due to methanol

$P_{CH_3OH} = P^o_{CH_3OH} \times 0.49$

$= 88.7 \text{ mm} \times 0.49 = 43.46$ mm [½]

Total Vapour pressure

$= P_{C_2H_5OH} + P_{CH_3OH}$

$= 22.69 + 43.46 = 66.15$ mm **[1]**

Mole fraction of methanol in the vapour state

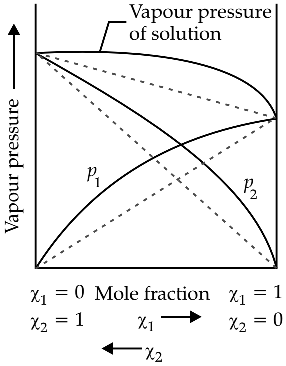
$= \dfrac{P_{CH_3OH}}{\text{Total vapour pressure}} = \dfrac{43.46}{66.15}$ **[1]**

$= 0.657$

**Q. 3. What is meant by positive and negative deviations from Raoult's law and how is the sign of $\Delta_{mix}H$ related to positive and negative deviations from Raoult's law?** R

**Ans.** According to Raoult's law, the partial vapour pressure of each volatile component in any solution is directly proportional to its mole fraction. The solutions which obey Raoult's law over the entire range of concentration are known as ideal solutions. The solutions that do not obey Raoult's law (non-ideal solutions) have vapour pressures either higher or lower than that predicted by Raoult's law (given in figure). **[1]**

If the vapour pressure is higher, then the solution is said to exhibit positive deviation, and if it is lower, then the solution is said to exhibit negative deviation from Raoult's law.



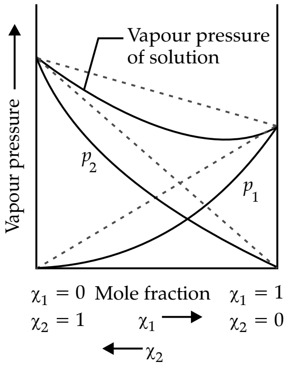
**[1]**

**(a)**

Vapour pressure of a two-component solution showing positive deviation from Raoult's law :

In the case of an ideal solution, the enthalpy of the mixing of the pure components for forming the solution is zero.

$\Delta_{sol}H = 0$



**[1]**

**(b)**

In the case of solutions showing positive deviations, absorption of heat takes place.

so, $\Delta_{sol}H$ = Positive [fig (a)]

In the case of solutions showing negative deviations, evolution of heat takes place.

so, $\Delta_{sol}H$ = Negative [fig (b)] **[2]**

# TOPIC-3

## Colligative Properties, Determination of Molecular Mass, Abnormal Molecular Mass, van't Hoff Factor

## Revision Notes

- **Colligative properties :** Certain properties of solutions depend only on the number of particles of the solute (molecules or ions) and do not depend on the nature of solute, such properties are called colligative properties. These are :
  **(i)** Relative lowering of vapour pressure,
  **(ii)** Depression in freezing point,
  **(iii)** Elevation of boiling point,
  **(iv)** Osmotic pressure of the solution.
- **Relative lowering of vapour pressure :** The relative lowering of vapour pressure is the ratio of lowering of vapour pressure and vapour pressure of pure solvent which is equal to the mole fraction of solute.

Vapour pressure of pure solvent = $p_A^o$

Lowering of vapour pressure = $p_A^o - p_A$

Relative lowering of vapour pressure

$$\frac{p_A^o - p_A}{p_A^o} = \chi_{\text{solute}} = \frac{n}{N+n}$$

where $n$ and $N$ are the number of moles of solute and solvent respectively.

- **Elevation of the boiling point :** The difference in boiling point of solution and pure solvent is called elevation of the boiling point.

  Boiling point of pure solvent = $T_b^\circ$

  Boiling point of solution = $T_b$

  Increase in boiling point $\Delta T_b = T_b - T_b^\circ$ is known as elevation of boiling point for dilute solution.

$$\Delta T_b \propto \frac{\Delta p}{p^\circ} = x_B$$

$$\Delta T_b = K\chi_B$$

$$\Delta T_b = \frac{K_b \times 1000 \times w_2}{M_2 \times w_1}$$

Where, $w_2$ = weight of solute in g

$M_2$ = Molar mass of solute

$w_1$ = weight of solvent in g

$\Delta T_b = K_b m$

$K_b$ = Boiling point elevation constant or molal elevation constant or **Ebullioscopic constant**.

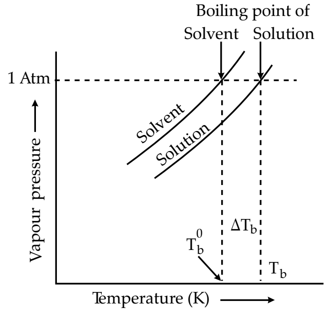


**Fig. 3 : The vapour pressure curve for solution lies below the curve for pure water. The diagram shows that $\Delta T_b$ denotes the elevation of boiling point of a solvent in solution.**

- **Depression of freezing point :** According to Raoult's law, when a non-volatile solid is added to the solvent its vapour pressure decreases and it would become equal to that of solid solvent at lower temperature. Thus, the difference in the freezing point of pure solvent and that of the solution is known as depression in freezing point.

  The freezing point of pure solvent = $T_f^o$

  The freezing point when non-volatile solute is dissolved in it = $T_f$ (Freezing point of solution)

  The decrease in freezing point $\Delta T_f = T_f^o - T_f$ is known as depression in freezing point.

  For dilute solution,

$$\Delta T_f = K\chi_B$$

$$\Delta T_f = K\,\frac{W_B}{M_B} \times \frac{M_A}{W_A}$$

$$\Delta T_f = K_f m.$$

We know,

**(i)** $$\frac{W_B \times 1000}{M_B \times W_A} = \text{molality}$$

**(ii)** $$K \times M_A = K_f$$

$K_f$ = Freezing point depression constant or molal depression constant or **Cryoscopic constant**.

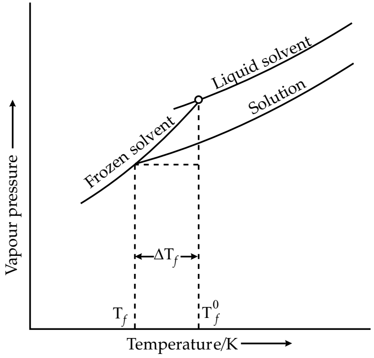


**Fig. 4 : Diagram showing $\Delta T_f$, depression of the freezing point of a solvent in a solution.**

- **Osmosis :** The process in which there is net flow of solvent to the solution by a semipermeable membrane is called osmosis.
- **Osmotic pressure :** The extra pressure that is applied to stop the flow of solvent to solution across a semipermeable membrane is called **osmotic pressure** of the solution.

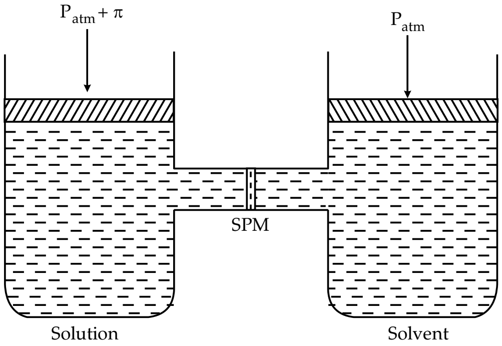


**Fig. 5 : The excess pressure equal to the osmotic pressure must be applied on the solution side to prevent osmosis.**

For dilute solution, osmotic pressure is proportional to the molar concentration (C) of the solution at a given temperature T.

Thus $\pi$ = CRT as $\pi$ is the osmotic pressure and R is the gas constant.

$$\pi = \frac{n}{\text{VRT}} \quad (n \text{ is the number of moles, V is the volume of solution})$$

- **Reverse osmosis :** The direction of osmosis can be reversed, if a pressure larger than the osmotic pressure is applied to the solution side. Now the pure solvent flows out of the solution through the semipermeable membrane. This phenomenon is called reverse osmosis.

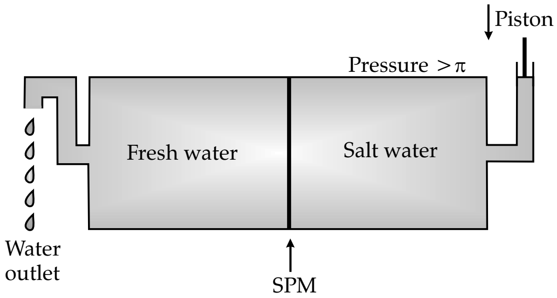


**Fig. 6 : Reverse osmosis occurs when a pressure larger than the osmotic pressure is applied to the solution.**

- **Abnormal molecular mass :** When the molecular mass calculated with the help of colligative property is different from theoretical molecular mass, it is called abnormal molecular mass.
- **van't Hoff factor(*i*) :** The ratio of the observed (experimental) value of a colligative property to the normal (calculated) value of the same property is called as van't Hoff factor.

Mathematically,

$$i = \frac{\text{Observed (experimental) value of a colligative property}}{\text{Normal (calculated) value of the same colligative property}}$$

Or, $$i = \frac{\Delta_{obs}}{\Delta_{cal}}$$

where $\Delta_{obs}$ and $\Delta_{cal}$ respectively represent the observed and calculated value of a colligative property.

Thus,

(i) for lowering of vapour pressure, $$i = \frac{(\Delta p)_{obs}}{(\Delta p)_{cal}}$$

(ii) for elevation of boiling point, $$i = \frac{(\Delta T_b)_{obs}}{(\Delta T_b)_{cal}};$$

(iii) for depression of freezing point, $$i = \frac{(\Delta T_f)_{obs}}{(\Delta T_f)_{cal}};$$

(iv) for osmotic pressure, $$i = \frac{\pi_{obs}}{\pi_{cal}};$$

Since a colligative property is propotional to number of particles of solute.

$$i = \frac{\text{Normal molecular mass}}{\text{Observed molecular mass}}$$

Normal molecular mass = $i \times$ Calculated molecular mass.

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

- ➢ **Hypertonic solution :** A solution is called hypertonic, if its concentration is higher than that of the solution separating it by a semipermeable membrane.
- ➢ **Hypotonic solution :** A solution is called hypotonic, if its concentration is lower than that of the solution separating it by a semipermeable membrane.
- ➢ **Isotonic solution :** Two solutions are called isotonic, if they exert the same osmotic pressure at a given temperature. Isotonic solutions have same molar concentration. When such solutions are separated by semipermeable membrane no osmosis occurs between them.

## Mnemonics

- **Concept:** Different Colligative properties
- **Mnemonic:** RLVP_DFP_EBP_OP
- **Interpretation:**
  - ● Relative Lowering Of Vapour Pressure
  - ● Depression In Freezing Point
  - ● Elevation Of Boiling Point
  - ● Osmotic Pressure

# Know the Formulae

➢ **Modified equations for colligative properties :**

**(i)** Relative lowering of vapour pressure of solvent

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

**(ii)** Elevation of boiling point

$$\Delta T_b = iK_b m$$

**(iii)** Depression of freezing point

$$\Delta T_f = iK_f m$$

**(iv)** Osmotic pressure of solution

$$\pi = \frac{inRT}{V}$$

**or** $$\pi = i\,CRT \quad \left[\because \frac{m}{V} = C\right]$$

➢ **Determination of molecular mass using colligative properties :**

**(i) Relative lowering of vapour pressure :**

$$\frac{p_A^o - p_A}{p_A^o} = \chi_B = \frac{n_B}{n_A + n_B} = \frac{n_B}{n_A}$$

$$\frac{p_A^o - p_A}{p_A^o} = \frac{W_B \times M_A}{W_A \times M_B}$$

$$M_B = \frac{p_A^o}{p_A^o - p_A} \times \frac{W_B \times M_A}{W_A}$$

**(ii) Elevation of boiling point :**

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

$$\Rightarrow \quad \Delta T_b = K_b \times \frac{W_B}{M_B} \times \frac{1000}{W_A \text{ in gms}}.$$

$$M_B = \frac{K_b \times W_B \times 1000}{\Delta T_b \times W_A}$$

**(iii) Depression of freezing point :**

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

$$\Rightarrow \quad \Delta T_f = K_f \times \frac{W_{solute}}{M_{solute}} \times \frac{1000}{W_{solvent}}$$

$$M_B = \frac{1000 \times W_B \times K_f}{\Delta T_f \times W_A}$$

**(iv) Osmotic pressure :**

$$\pi = CRT,$$

$$\Rightarrow \quad \pi = \frac{\text{No. of moles}}{\text{Volume of solution}} \times R \times T$$

$$\pi = \frac{W_B}{M_B} \times \frac{RT}{V}, \text{ here } M_B = \frac{W_B \times RT}{\pi \times V}$$

- **Degree of dissociation (α) :**

$$\alpha = \frac{i-1}{n-1}, \text{ here } i \rightarrow \text{van't Hoff factor}$$

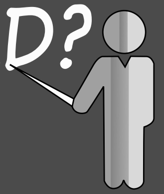
$n$ = No. of ions produced per formula of the compound

- **Degree of association (α) :**

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

- Strength = Molarity × Mol. wt.
  = Normality × Eq. wt.
- $K_b$ = 0.512 K kg/mol for water
- $K_f$ = 1.86 K kg/mol

## How is it done on the GREENBOARD?



**Q. The freezing point of benzene decreases by 2.12 K when 2.5 g of benzoic acid ($C_6H_5COOH$) is dissolved in 25 g of benzene. If benzoic acid forms a dimer in benzene, calculate the van't Hoff factor and the percentage association of benzoic acid. ($K_f$ = for benzene = 5.12 K kg mol$^{-1}$)**

**Solution:**

**STEP-1:** DTf = iKfm

$$2.12\ K = i. \frac{5.12\ K kg mol^{-1} \times 2.5 g \times 1000 g Kg^{-1}}{122\ g mol^{-1} \times 25 g}$$

i = 0.505 **[1]**

**STEP-2:** for association

$$i = 1 - \frac{\alpha}{2}$$ [½]

$$\alpha = 0.99$$ **[½]**

Percentage association of benzoic acid 99.0% **[½]**

## Objective Type Questions **(1 mark each)**

**[A] MULTIPLE CHOICE QUESTIONS :**

**Q. 1. The values of van't Hoff factors for KCl, NaCl and $K_2SO_4$, respectively are ____________ .**

**(a) 2, 2 and 2** **(b) 2, 2 and 3**

**(c) 1, 1 and 2** **(d) 1, 1 and 1**

**Ans. Correct option : (b)**

*Explanation :* KCl ($K^+ + Cl^-$) and NaCl ($Na^+ + Cl^-$) ionize to give 2 ions and $K_2SO_4$ ($K^+ + SO_4^{2-}$) ionize to form 3 ions. So, van't Hoff factors for KCl, NaCl, and $K_2SO_4$ are 2, 2 and 3 respectively

**Q. 2. We have three aqueous solutions of NaCl labelled as 'A', 'B' and 'C' with concentrations 0.1 M, 0.01 M and 0.001 M, respectively. The value of van't Hoff factor for these solutions will be in the order**

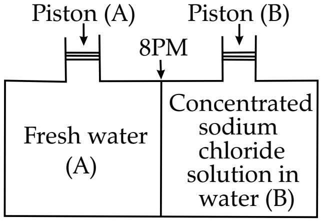
**(a)** $i_A < i_B < i_C$ **(b)** $i_A > i_B > i_C$

**(c)** $i_A = i_B = i_C$ **(d)** $i_A < i_B > i_C$

**Ans. Correct option :** (c)

*Explanation :* The value of van't Hoff factor will be *i*. It is due to complete dissociation of strong electrolyte (NaCl) in dilute solutions and on complete dissociation value of *i* for NaCl is 2.

**Q. 3. Consider the figure and mark the correct option.**



**(a) Water will move from side (A) to side (B) if pressure lower than osmotic pressure is applied on piston (B).**

**(b) Water will move from side (B) to side (A) if pressure greater than osmotic pressure is applied on piston (B).**

**(c) Water will move from side (B) to side (A) if pressure equal to osmotic pressure is applied on piston (B).**

**(d) Water will move from side (A) to side (B) if pressure equal to osmotic pressure is applied on piston (A).**

**Ans. Correct option : (b)**

*Explanation :* Water will move from side (b) to side (a) if a pressure greater than osmotic pressure is applied on piston (b). This is a process of reverse osmosis.

**Q. 4. Which of the following solutions in water has highest boiling point?**

**(a) 1 M NaCl** **(b) 1 M $MgCl_2$**

**(c) 1 M urea** **(d) 1 M glucose**

**Ans. Correct option : (b)**

*Explanation :* 1 M $MgCl_2$ in aqueous solution gives maximum number of ions than other solutions. So, it has highest boiling point.

**Q. 5. Which of the following 0.1 m aqueous solution will have the lowest freezing point?**

**(a) $Al_2(SO_4)_3$** **(b) $C_2H_{10}O_5$**

**(c) KI** **(d) $C_{12}H_{22}O_{11}$**

**Ans. Correct option :** (a)

*Explanation :* Since depression in freezing point is a colligative property so aqueous solution giving maximum number of ions i.e., $Al_2(SO_4)_3$ has the lowest freezing point.

**[B] ASSERTIONS AND REASONS :**

**In the following questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.**

**(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**

**(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.**

**(c) Assertion is correct statement but reason is wrong statement.**

**(d) Assertion is wrong statement but reason is correct statement.**

**Q. 1. Assertion : Elevation in boiling point is a colligative property.**

**Reason : Elevation in boiling point is directly proportional to molarity.**

**[CBSE Delhi Set 1 & 2, 2020]**

**Ans. Correct option : (a)**

*Explanation :* Elevation in boiling point is a colligative property. It is directly proportional to molarity.

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

**Q. 2. Assertion : 0.1 M solution of KCl has great osmotic pressure than 0.1 M solution of glucose at same temperature.**

**Reason : In solution KCl dissociates to produce more number of particles.**

**[CBSE Delhi Set 2, 2020]**

**Ans. Correct option : (a)**

*Explanation :* KCl is ionic compound, hence dissociates into ions but glucose is a covalent compound which doesnot dissociate into ions.

**Q. 3. Assertion : When NaCl is added to water a depression in freezing point is observed.**

**Reason : The lowering of vapour pressure of a solution causes depression in the freezing point.**

**Ans. Correct option : (a)**

*Explanation :* When a non-volatile solute is added to water, freezing point lowers due to lowering of vapour pressure.

**Q. 4. Assertion : When methyl alcohol is added to water, boiling point of water decreases.**

**Reason : When a volatile solute is added to a volatile solvent, elevation in boiling point is observed.**

**Ans. Correct option : (c)**

*Explanation :* When methyl alcohol (volatile) is added to water, boiling point of water decreases because vapour pressure increases when volatile solute is added to volatile solvent.

**[C] VERY SHORT ANSWER TYPE QUESTIONS :**

**AI Q. 1. What happens when a pressure greater than osmotic pressure is applied on the solution side separated from solvent by a semi-permeable membrane?**

**A [CBSE, Outside Delhi, 2020]**

**Ans.** Reverse osmosis will take place and the level of solution will decrease.

**Q.2. Give one practical application of depression of freezing point in automobiles.** A

**Ans.** Use of antifreeze (i.e. solution of ethylene glycol) in radiators.

**Q.3. How is the value of colligative property related to molecular mass of the non-volatile solute?** R

**Ans.** colligative property ∝

$$\frac{1}{\text{molecular mass of the non – volatile solute}}$$

**Q.4. What is the effect of temperature on osmotic pressure?** R

**Ans.** osmotic pressure ∝ temperature

## Short Answer Type Questions-I

**(2 marks each)**

**Q. 1. A glucose solution which boils at 101.04°C at 1 atm. What will be relative lowering of vapour pressure of an aqueous solution of urea which is equimolal to given glucose solution? (Given : $K_b$ for water is 0.52 K kg mol$^{-1}$ )** A

**Ans.** $\Delta T_b = K_b\, m \quad \Delta T_b = 101.04 - 100 = 1.04$ °C

or m = 1.04 /0.52 = 2 m **[1]**

2 m solution means 2 moles of solute in 1 kg of solvent.

2 m aq solution of urea means 2 moles of urea in 1kg of water.

No. of moles of water = 1000/18 = 55.5

Relative lowering of vapour pressure = $x_2$ (where $x_2$ is mole fraction of solute) [½]

Relative lowering of vapour pressure = $n_2/n_1+n_2$ ($n_2$ is no. of moles of solute , $n_1$ is no. of moles of solvent)

= 2/2 + 55.5 = 2/57.5 = 0.034 [½]

**AI Q. 2. Give reasons :**

**(a) Cooking is faster in pressure cooker than in cooking pan.**

**(b) Red Blood Cells (RBC) shrink when placed in saline water but swell in distilled water.**

**U [CBSE OD Set-1 2019]**

**Ans. (a)** In case of liquids, due to increase of pressure inside the cooker, the boiling point of water increases leading to faster cooking than in pan.

**(b)** RBC shrink in saline water due to loss of water owing to exosmosis. In distilled water they swell due to endosmosis as the water enters the RBC.

**[1+1]**

**AI Q. 3. Calculate the freezing point of a solution containing 60 g of glucose (Molar mass = 180 g mol$^{-1}$) in 250 g of water. ($K_f$ of water = 1.86 K kg mol$^{-1}$)** **U [CBSE D/OD, 2018]**

**Ans.**

$$\Delta T_f = K_f\, m$$

$$= K_f \times \frac{w_2 \times 1000}{M_2 \times w_1}$$

$$= \frac{1.86 \times 60 \times 1000}{180 \times 250}$$

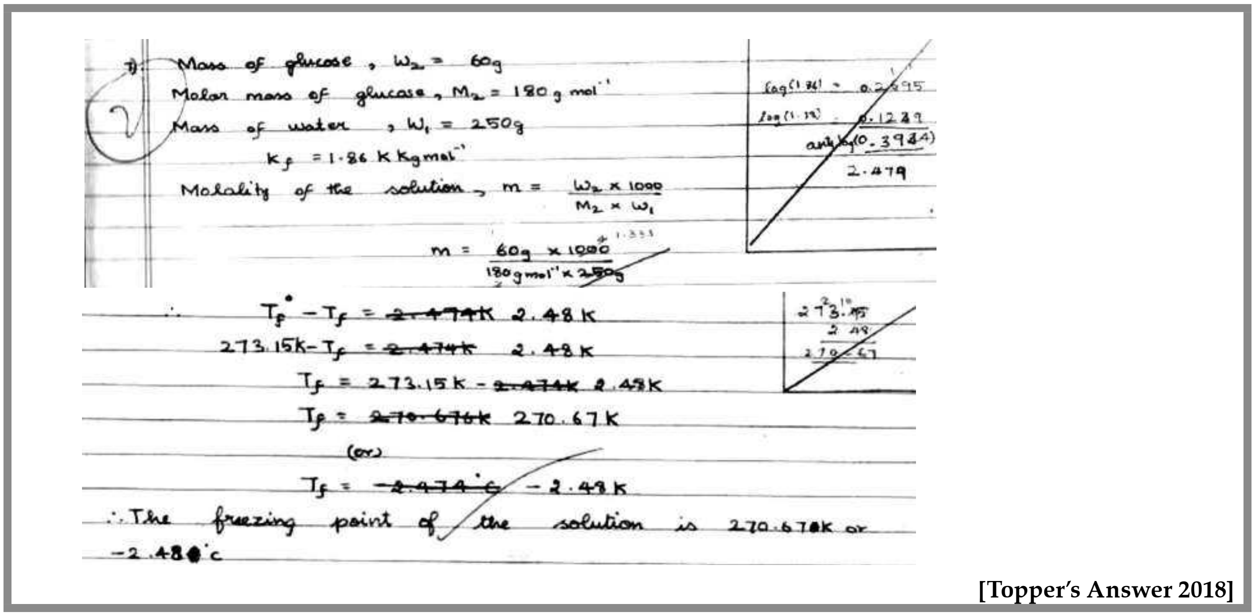
$$= 2.48 \text{ K}$$

$$\Delta T_f = T_f^o - T_f$$

$$2.48 = 273.15 - T_f$$

$$T_f = 273.15 - 2.48 = 270.67 \text{ K}$$ **[2]**

**OR**



1): Mass of glucose , $w_2$ = 60g

Molar mass of glucose , $M_2$ = 180 g mol$^{-1}$

Mass of water , $w_1$ = 250g

$K_f$ = 1.86 K Kg mol$^{-1}$

Molality of the solution , $m = \frac{w_2 \times 1000}{M_2 \times w_1}$

$m = \frac{60g \times 1000}{180 g mol^{-1} \times 250 g}$

∴ $T_f^\circ - T_f$ = ~~2.474K~~ 2.48 K

273.15K − $T_f$ = ~~2.474K~~ 2.48 K

$T_f$ = 273.15 K − ~~2.474K~~ 2.48K

$T_f$ = ~~270.676K~~ 270.67 K

(or)

$T_f$ = ~~2.474°c~~ −2.48 K

∴ The freezing point of the solution is 270.67K or −2.48°c

log(1.86) = 0.2695

log(1.33) = 0.1239

antilog(0.3934)

2.479

273.15

2.48

270.67

**[Topper's Answer 2018]**

**Commonly Made Error**

- Students do not write applied formula or sometimes miss the next step of value assignment to all the entities in it.

**Answering Tip**

- Always state the formula applied before starting the calculations. Write each step clearly as it carries marks.

**Q. 4. Define the following terms :**

**(i) Colligative properties**

**(ii) Molality (m)** $\boxed{\text{R}}$ **[CBSE D/OD, 2017]**

**Ans. (i)** Properties that are independent of nature of solute and depend on number of moles of solute only. **[1]**

**(ii)** Number of moles of solute dissolved per kg of the solvent. **[1]**

**[CBSE Marking Scheme, 2017]**

**Detailed Answer :**

**(i)** Colligative properties are those properties of the solutions which depend upon the number of solute particles present in the solution irrespective of their nature and are relative to the total number of particles present in the solution. Some colligative properties are elevation of boiling point of solvent, depression of freezing point of solvent, etc. **[1]**

**(ii)** Molality is the number of moles of solute dissolved in 100 g of a solvent. It is represented by m and is used to express concentration of a solution. It can be calculated as : **[1]**

$$m = \frac{\text{Number of moles of solute}}{\text{Weight of solvent in grams}} \times 1000.$$

$\boxed{\text{AI}}$ **Q. 5. Define the following terms :**

**(i) Abnormal molar mass**

**(ii) van't Hoff factor (*i*)** $\boxed{\text{R}}$ **[CBSE Delhi set 3, 2017]**

**Ans. (i)** If the molar mass calculated by using any of the colligative properties to be different than theoretically expected molar mass. **[1]**

**(ii)** Extent of dissociation or association or ratio of the observed colligative property to calculated colligative property. **[1]**

**[CBSE Marking Scheme, 2017]**

**Detailed Answer :**

**(i) Abnormal molar mass** – There are certain cases where due to association or dissociation of molecules, the molar mass of a substance calculated from its colligative property is either lower or higher than the expected or normal value. Such molar mass is called abnormal molar mass. **[1]**

**(ii) van't Hoff factor** – To account for the extent of dissociation or association, van't Hoff introduced a factor *i*, known as the van't Hoff factor.

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

$$= \frac{\text{Observed colligative property}}{\text{Calculated colligative property}}$$

Value of *i* is less than 1 in case of association.

Value of *i* is greater than 1 in case of dissociation.

Value of *i* is equal to 1 in case of no association or dissociation. **[1]**

**Q. 6. Explain why on addition of 1 mol glucose to 1 litre water the boiling point of water increases.** $\boxed{\text{A}}$

**Ans.** Vapour pressure of the solvent decreases in the presence of non-volatile solute (glucose) as the mole fraction of water decreases hence boiling point increases. **[2]**

**Q. 7. A 1.00 molar aqueous solution of trichloroacetic acid ($CCl_3COOH$) is heated to its boiling point. The solution has the boiling point of 100.18°C. Determine the van't Hoff factor for trichloroacetic acid. ($K_b$ for water = 0.512 K kg mol$^{-1}$).**

**Ans.** $T_b - 100.18\ °C = 373.18\ K$

$T°_b - 100°C = 373K$

$\Delta T_b = iK_bm$ **[1]**

$(373.18 - 373)\ K = i \times 0.512\ K\ kg\ mol^{-1} \times 1\ m$

$0.18K = i \times 0.512\ K\ kg\ mol^{-1} \times 1m,$

$i = 0.35$ **[1]**

**Q. 8. Explain why on addition of 1 mol of NaCl to 1 litre of water, the boiling point of water increases, while addition of 1 mol of methyl alcohol to one litre of water decreases its boiling point.**

**Ans.** Sodium chloride (NaCl) is a non-volatile solute, therefore, addition of NaCl to water lowers the vapour pressure of water. As a result, boiling point of water increases. Methyl alcohol, on the other hand, is more volatile than water, hence, its addition increases the total vapour pressure of the solution and in decrease in boiling point of water results. **[2]**

**Q. 9. Which of the following solutions has higher freezing point ? 0.05 M $Al_2(SO_4)_3$, 0.1 M $K_3[Fe(CN)_6]$ Justify.**

**Ans.** 0.05 M $Al_2(SO_4)_3$ has higher freezing point. **[1]**

0.05 M $Al_2(SO_4)_3$ : $i = 5$,

$\Delta T_f \propto$ No. of particles;

$\Delta T_f = i \times$ concentration

$= 5 \times 0.05 = 0.25$ moles of ions

0.1 M $K_3[Fe(CN)_6]$ : $i = 4$, **[½]**

$= 4 \times 0.1$

$= 0.4$ moles of ions **[½]**

**Q. 10. 18 g of glucose, $C_6H_{12}O_6$ (Molar Mass = 180 g mol$^{-1}$) is dissolved in 1 kg of water in a saucepan. 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)**

**Ans.** $\Delta T_b = K_b \times m$ **[½]**

$$T_b - T_b° = 0.52\ K\ kg\ mol^{-1} \times \frac{18\ g}{180\ g\ mol^{-1}} \times \frac{1}{1\ kg}$$ **[½]**

$$\Rightarrow T_b - 373.15 = \frac{0.52}{10}$$

$\Rightarrow T_b - 373.15 = 0.052\ K$ **[½]**

$\Rightarrow \quad T_b = 0.052 + 373.15$

$\therefore \quad T_b = 373.202\ K$ **[½]**

**Q. 11. What are colligative properties? Write the colligative property which is used to find the molecular mass of macromolecules.** R

**Ans.** Properties that depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution. **[1]**

Osmotic pressure **[1]**

**Q. 12. Define the following terms :**

**(a) Ideal solution**

**(b) Osmotic pressure.** R

**Ans. (a)** The solution which obeys Raoult's law over the entire range of concentration. **[1]**

**(b)** It is the excess pressure that must be applied to a solution to prevent osmosis. **[1]**

**Q. 13. Calculate the boiling point elevation for a solution prepared by adding 10 g $CaCl_2$ to 200 g of water, assuming that $CaCl_2$ is completely dissociated. ($K_b$ for water = 0.512 K kg $mol^{-1}$; Molar mass of $CaCl_2$ = 111 g $mol^{-1}$)** U

**Ans.** $\Delta T_b = iK_bm$

Here, $m = w_B \times 1000/M_B \times w_A$

$\Delta T_b = [3 \times 0.512 \text{ K kg mol}^{-1} \times 1000 \times 10 \text{ g}/$ **[1]**

$[111 \text{ g mol}^{-1} \times 200 \text{ g}]$ **[1]**

$= 0.69$ K

## Short Answer Type Questions-II

**(3 marks each)**

AI **Q. 1. A 0.01 m aqueous solution of $AlCl_3$ freezes at –0.068°C. Calculate the percentage of dissociation. [Given : $K_f$ for Water = 1.68 K kg $mol^{-1}$]** U **[CBSE Delhi Set 1 & 2, 2020]**

**Ans.** Given, $m = 0.01$ m

$\Delta T_f(s) = -0.068°C$

$K_f(aq) = 1.86 \text{ K kg mol}^{-1}$

$\Delta T_f = i\,K_f m$

$$i = \frac{\Delta T_f}{K_f} \times m$$

$$i = \frac{0.068}{1.86} \times 0.01\text{m} = 3.65$$ **[1]**

$$\begin{array}{llll} & AlCl_3 & \rightarrow Al^{3+} & + 3Cl^- \\ \text{initial} & 1 \text{ mol} & 0 & 0 \\ \text{At equilibrium} & 1-\alpha & \alpha & 3\alpha \end{array}$$

Total number of moles at equilibrium

$= 1 - \alpha + \alpha + 3\alpha = 1 + 3\alpha$ **[1]**

$$i = \frac{\text{Total no. of moles at equilibrium}}{\text{Initial no. of moles}}$$

$$= \frac{1+3\alpha}{1}$$

$3.65 = 1 + 3\alpha$

$$\alpha = \frac{3.65-1}{3}$$

Percentage dissociation = 0.88%. **[1]**

**Commonly Made Error**

- Some student get confused to calculate percentage of dissociation.

**Answering Tip**

- To calculate percentage of dissociation, first find van't Hoff Factor (i).

AI **Q. 2. The freezing point of a solution containing 5g of benzoic acid ($M$ = 122 g $mol^{-1}$) in 35g of benzene is depressed by 2.94 K. What is the percentage association of benzoic acid if it forms a dimer in solution ?**

**($K_f$ for benzene = 4.9 K kg $mol^{-1}$)**

U **[CBSE Outside Delhi Set 1, 2020]**

**Ans.** Observed molar mass of benzoic acid :

$$M_B = \frac{K_f \times W_B}{W_A \times \Delta T_f}$$

$W_B = 5$ gm

$W_A = 0.035$ kg

$$M_B = \frac{4.9 \times 5}{0.035 \times 2.94} = \frac{24.5}{0.1029}$$

$K_f = 4.9$ K kgmol$^{-1}$

$= 238 \text{ g mol}^{-1}$

$\Delta T_f = 2.94$

Normal molar mass of $C_6H_5COOH$

$= 122 \text{ g mol}^{-1}$

$$i = \frac{\text{normal molar mass}}{\text{observed molar mass}} = \frac{122}{238} = 0.513$$

% of association of acid (α)

$$2C_6H_5COOH \rightleftharpoons (C_6H_5COOH)_2$$

$$n = 2\ \alpha = \frac{i-1}{1/n-1} = \frac{0.513-1}{\frac{1}{2}-1} = \frac{(-0.487)}{(-0.5)} = 0.974$$ **[5]**

Percentage association of acid = 0.974 × 100 = 97.4%

AI **Q. 3. A 4% solution $w$/W of sucrose (M = 342g $mol^{-1}$) in water has a freezing point of 271.15K. Calculate the freezing point of 5% glucose (M = 180 g $mol^{-1}$) in water.**

**(Given : Freezing point of pure water = 273.15 K)**

U **[CBSE Delhi Set 1, 2019]**

**Ans.** $\Delta T_f = K_f m$

$$K_f = \Delta T_f \times \frac{M_2 \times w_1}{w_2 \times 1000} \quad \frac{2 \times 342 \times 96}{4 \times 1000}$$

$= 16.4 \text{ Km}^{-1}$

$\Delta T_f = K_f m'$

$$= \frac{K_f w_2 \times 1000}{M_2 \times w_1} = \frac{16.4 \times 5 \times 1000}{95 \times 180}$$

$= 4.8\ K$

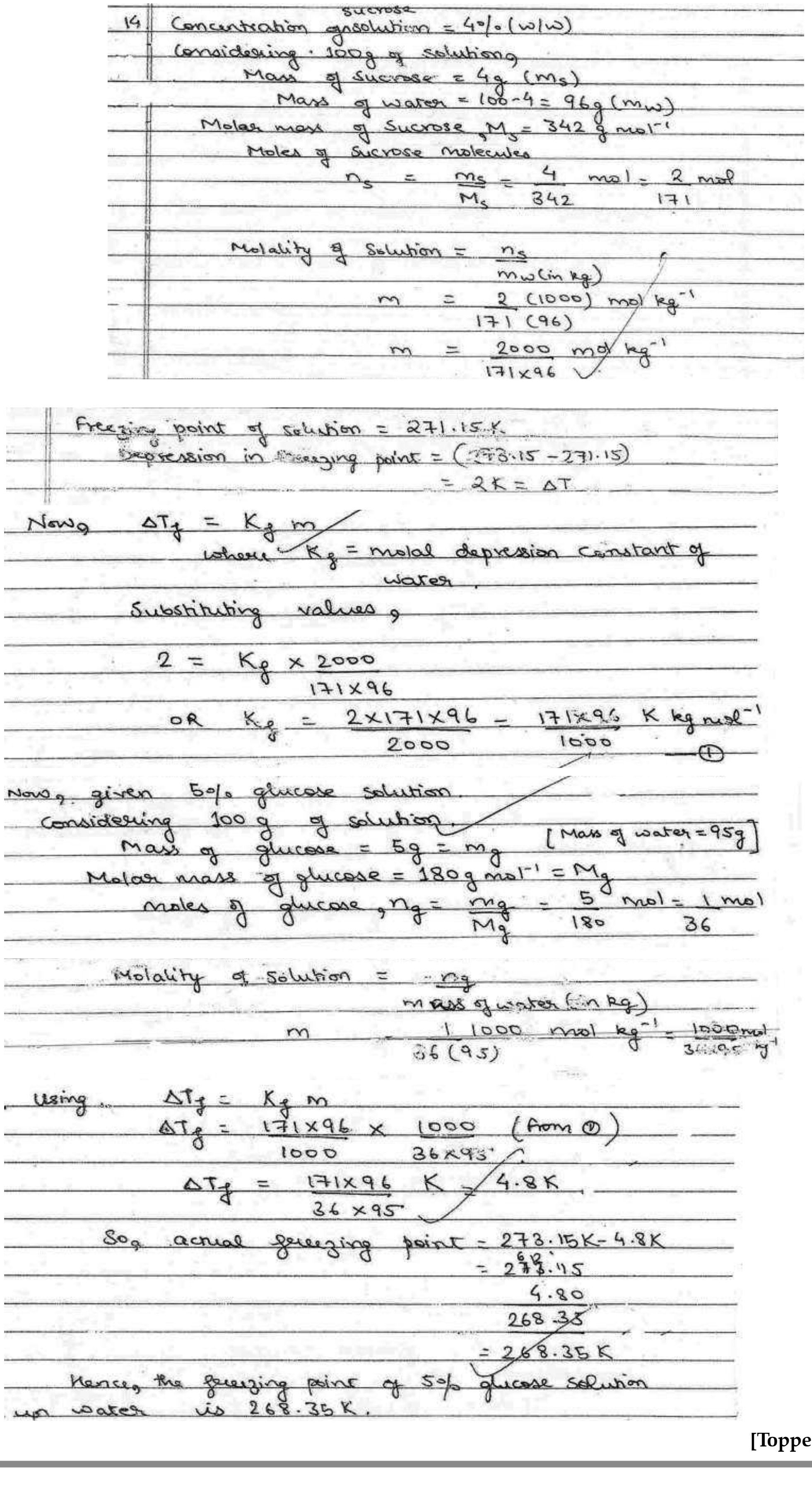
$\Delta T_f = T_f^\circ - T_f$

$4.8 = 273.15 - T_f$

$T_f = 268.35\ K$

**[CBSE Marking Scheme, 2019]**

**OR**



14 Concentration of sucrose solution = 4% (w/w)

Considering 100 g of solution,

Mass of Sucrose = 4 g ($m_s$)

Mass of water = 100 − 4 = 96 g ($m_w$)

Molar mass of Sucrose, $M_s$ = 342 g $mol^{-1}$

Moles of Sucrose molecules

$$n_s = \frac{m_s}{M_s} = \frac{4}{342}\ mol = \frac{2}{171}\ mol$$

$$\text{Molality of Solution} = \frac{n_s}{m_w(\text{in kg})}$$

$$m = \frac{2\ (1000)}{171\ (96)}\ mol\ kg^{-1}$$

$$m = \frac{2000}{171 \times 96}\ mol\ kg^{-1}$$

Freezing point of solution = 271.15 K

Depression in freezing point = (273.15 − 271.15)

= 2 K = $\Delta T$

Now, $\Delta T_f = K_f\, m$

where $K_f$ = molal depression constant of water.

Substituting values,

$$2 = K_f \times \frac{2000}{171 \times 96}$$

$$\text{OR}\quad K_f = \frac{2 \times 171 \times 96}{2000} = \frac{171 \times 96}{1000}\ K\ kg\ mol^{-1} \quad \text{—}①$$

Now, given 5% glucose solution.

Considering 100 g of solution.

Mass of glucose = 5 g = $m_g$ [Mass of water = 95 g]

Molar mass of glucose = 180 g $mol^{-1}$ = $M_g$

$$\text{moles of glucose},\ n_g = \frac{m_g}{M_g} = \frac{5}{180}\ mol = \frac{1}{36}\ mol$$

$$\text{Molality of Solution} = \frac{n_g}{\text{mass of water (in kg)}}$$

$$m = \frac{1\ (1000)}{36\ (95)}\ mol\ kg^{-1} = \frac{1000}{36 \times 95}\ mol\ kg^{-1}$$

Using $\Delta T_f = K_f\, m$

$$\Delta T_f = \frac{171 \times 96}{1000} \times \frac{1000}{36 \times 95} \quad (\text{from } ①)$$

$$\Delta T_f = \frac{171 \times 96}{36 \times 95}\ K = 4.8\ K$$

So, actual freezing point = 273.15 K − 4.8 K

$$\begin{array}{r} = 2\overset{6}{7}\overset{12}{3}.15 \\ 4.80 \\ \hline 268.35 \\ \hline \end{array}$$

= 268.35 K

Hence, the freezing point of 5% glucose solution in water is 268.35 K.

[Topper's Answer 2019]

**Detailed Answer :**

Given :

$$\text{Sucrose solution} = 4\%(w/\text{W})$$

$$M = 342\,g\,\text{mol}^{-1}$$

$$\text{Freezing point of solution} = 271.15\,\text{K}$$

$$\text{Freezing point of pure water} = 273.15\,\text{K}$$

$$\text{Glucose solution} = 5\%$$

$$\text{M} = 180\,\text{g}\,\text{mol}^{-1}$$

**To calculate :**

Freezing point of 5% glucose solution.

**Formula :**

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

$$\text{m} = \frac{\text{moles of solute}}{\text{Kg of solvent}}$$

$$\text{moles} = \frac{\text{mass}}{\text{molar mass}}$$

Sucrose solution is 4% (w/w) which means there is 4.0 grams of sucrose dissolved in 100g of solution.

Mass of solution = mass of solute + mass of solvent

100.0 g = 4.0g + mass of solvent.

Hence, mass of solvent = 100.0 – 4.0 = 96.0 g

$$96\text{ g} \times \frac{1\,\text{kg}}{1000\,\text{g}} = 0.096\,\text{kg}$$

Moles of solute ½

$$\text{moles} = \frac{\text{mass}}{\text{molar mass}} = \frac{4.0\text{g}}{342\,\text{g}\,\text{mol}^{-1}} \quad 1$$

$$= 0.011695\,\text{moles}$$

Molality of solution :

$$\text{m} = \frac{\text{moles of solute}}{\text{kg of solvent}} \quad ½$$

$$= \frac{0.011695\,\text{moles}}{0.096\,\text{kg water}} = 0.1218\,\text{m}$$

Sucrose is a non - electrolyte, hence $i - 1$

$$\Delta \;\; = \text{Freezing point of solvent}$$

$$\text{Freezing point of solution}$$

$$\Delta T_f = 273.15\,\text{K} - 271.15\,\text{K} = 2.00\,\text{K}$$

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

$$2.00\,K = i \times K_f \times 0.1218$$

$$K_f = 16.42\,\text{Km}^{-1}$$

For glucose solution,

Glucose solution is 5% (w/w) which means there is 5.0 grams of glucose dissolved in 100g of solution.

Mass of solution = mass of solute + mass of solvent

100.0 g = 5.0g + mass of solvent.

Hence, mass of solvent = 100.0 – 5.0 = 95.0 g

$$95.0\,\text{g} \times \frac{1\,\text{kg}}{1000\,\text{g}} = 0.095\,\text{kg}$$

Moles of solute

$$\text{moles} = \frac{\text{mass}}{\text{molar mass}}$$

$$= \frac{5.0\text{g}}{180\,\text{g}\,\text{mol}^{-1}} = 0.0277\,\text{moles}$$

Molality of solution :

$$\text{m} = \frac{\text{moles of solute}}{\text{kg of solvent}}$$

$$= \frac{0.0277\,\text{moles}}{0.095\,\text{kg water}} = 0.2923\,\text{m}$$

Glucose is a non - electrolyte, hence $i - 1$

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

$$\Delta T_f = 1 \times 16.42 \times 0.2923$$

$$\Delta T_f = 4.801\,\text{K}$$

$$\Delta T_f = \text{Freezing point of solvent}$$
$$- \text{Freezing point of solution}$$

$$4.801 = 273.15\,\text{K} - \text{Freezing point of solution}$$

$$\text{Freezing point of solution} = 273.15\,\text{K} - 4.801\,\text{K}$$
$$= 268.35\,\text{K}$$

Thus, the freezing point of the glucose solution is 268.35 K. **[3]**

AI **Q. 4. A solution containing 1.9 g per 100 mL of KCl ($M$ = 74.5 g mol$^{-1}$) is isotonic with a solution containing 3 g per 100 mL of urea ($M$ = 60 g mol$^{-1}$). Calculate the degree of dissociation of KCl solution. Assume that both the solutions have same temperature.**

A **[CBSE OD Set 2, 2019]**

**Ans.**

$$\pi_1(\text{urea}) = \pi_2(\text{KCl})$$

$$\text{C}_1\text{RT} = \text{i C}_2\text{RT}$$

$$\frac{n_1}{V_1} = i\frac{n_2}{V_2} \quad (V_1 = V_2)$$

$$\frac{30}{60} = i \times \frac{1.9}{74.5}$$

$$i = 1.96$$

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

$$= \frac{1.96-1}{2-1}$$

$$= 0.96 \text{ or } 96\% \quad ½$$

**[CBSE Marking Scheme 2019]**

**Detailed Answer :**

$$\pi_{\text{KCl}} = \pi_{\text{Urea}}$$

$$\frac{\text{i} \times 0.19 \times 0.0821 \times 300}{74.56 \times 1} = \frac{0.3 \times 0.0821 \times 300}{60 \times 1}$$

(As temperature is same)

$$\frac{\text{i} \times 0.19}{74.5} = \frac{0.3}{60}$$

$$\text{i} = \frac{0.3 \times 74.5}{60 \times 0.19} = 1.96$$

KCl ionizes as : $\text{KCl} \rightleftharpoons \text{K}^+ + \text{Cl}^-$

| | | | |
|---|---|---|---|
| Initial conc. | 1 | 0 | 0 |
| Conc. at equilibrium | $1-\alpha$ | $\alpha$ | $\alpha$ |

Number of effective particles after dissociation

$$= 1 - \alpha + \alpha + \alpha = 1 + \alpha$$

van't Hoff factor

$$= \frac{\text{Number of moles after dissociation}}{\text{Number of moles before dissociation}}$$

$$= \frac{1+\alpha}{1} = 1+\alpha$$

$$1.96 = 1 + \alpha\ ;\ \alpha = 1.96 - 1 = 0.96$$

$$\alpha = 0.96 \times 100 = 96\%$$

**Q. 5. Give reasons for the following :**

**(a) Measurement of osmotic pressure method is preferred for the determination of molar masses of macromolecules such as proteins and polymers.**

**(b) Aquatic animals are more comfortable in cold water than in warm water.**

**(c) Elevation of boiling point of 1 M KCl solution is nearly double than that of 1 M sugar solution.**

A&E **[CBSE Delhi/OD 2018]**

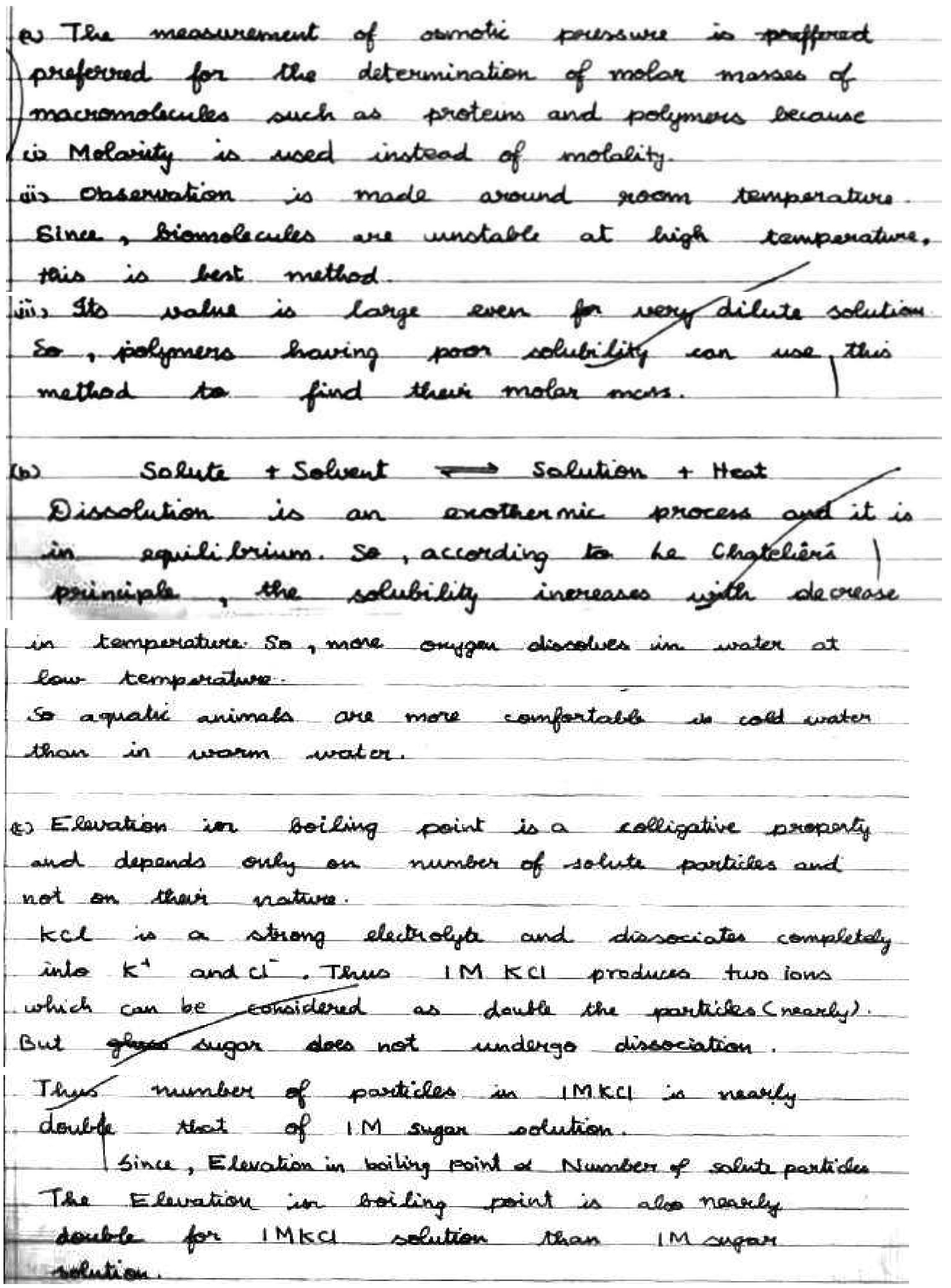
**Ans. (a)** As compared to other colligative properties, its magnitude is large even for very dilute solutions / macromolecules are generally not stable at higher temperatures and polymers have poor solubility / pressure measurement is around the room temperature and the molarity of the solution is used instead of molality. **1**

**(b)** Because oxygen is more soluble in cold water or at low temperature. **1**

**(c)** Due to dissociation of KCl / KCl (aq) → $K^+ + Cl^-$, i is nearly equal to 2. **1**

**[CBSE Marking Scheme, 2018]**

**OR**



(a) The measurement of osmotic pressure is ~~prefered~~ preferred for the determination of molar masses of macromolecules such as proteins and polymers because

(i) Molarity is used instead of molality.

(ii) Observation is made around room temperature. Since, biomolecules are unstable at high temperature, this is best method.

(iii) Its value is large even for very dilute solution So, polymers having poor solubility can use this method to find their molar mass.

(b) Solute + Solvent $\rightleftharpoons$ Solution + Heat

Dissolution is an exothermic process and it is in equilibrium. So, according to Le Chatelier's principle, the solubility increases with decrease in temperature. So, more oxygen dissolves in water at low temperature.

So aquatic animals are more comfortable in cold water than in warm water.

(c) Elevation in boiling point is a colligative property and depends only on number of solute particles and not on their nature.

KCl is a strong electrolyte and dissociates completely into $K^+$ and $Cl^-$. Thus 1M KCl produces two ions which can be considered as double the particles (nearly). But ~~glucose~~ sugar does not undergo dissociation.

Thus number of particles in 1MKCl is nearly double that of 1M sugar solution.

Since, Elevation in boiling point ∝ Number of solute particles The Elevation in boiling point is also nearly double for 1MKCl solution than 1M sugar solution.

**[Topper's Answer 2018]**

**Q. 6. A 10% solution (by mass) of sucrose in water has a freezing point of 269.15 K. Calculate the freezing point of 10% glucose in water if the freezing point of pure water is 273.15 K.**

**Given : (Molar mass of sucrose = 342 g mol$^{-1}$)**

**(Molar mass of glucose = 180 g mol$^{-1}$)**

**[CBSE Delhi/OD2017]**

**Ans.** $\Delta T_f = K_f m$ **1**

Here, $m = w_2 \times 1000/M_2 \times W_1$

$273.15 - 269.15 = K_f \times 10 \times 1000/342 \times 90$ **1**

$K_f = 12.3$ K kg/mol **1**

$\Delta T_f = K_f m$

$= 12.3 \times 10 \times 1000/180 \times 90$

$= 7.6$ K

$T_f = 273.15 - 7.6 = 265.55$ K

(or any other correct method) **1**

**[CBSE Marking Scheme 2017] 1**

**Detailed Answer :**

$\Delta T_t = (273.15 - 269.15)$ K = 4K

Molar mass of sucrose ($C_{12}H_{22}O_{11}$)

$= (12 \times 12) + (22 \times 1) + (11 \times 16)$

$= 342$ g mol$^{-1}$

10% solution of sucrose in water means 10 g of sucrose is present in (100 – 10)g of water.

Number of moles of sucrose $= \frac{10}{342} = 0.0292$ mol

Therefore, molality of the solution

$$= \frac{0.0292 \times 1000}{90} = 0.3244 \text{ mol kg}^{-1}$$

We know that $\Delta T_t = K_f \times m$

$$\Rightarrow \quad K_f = \frac{\Delta T_t}{m} = \frac{4}{0.3244} = 12.33 \text{ K Kg mol}^{-1}$$

Molar mass of glucose ($C_6H_{12}O_6$)

$= (6 \times 12) + (12 \times 1) + (6 \times 16) = 180$ g mol$^{-1}$

10% solution of glucose in water means 10 g of glucose is present in (100 – 10) g of water.

Number of moles of glucose $= \frac{10}{180} = 0.0555$ mol

Therefore,molality of the solution

$$= \frac{0.0555 \times 1000}{90}$$

$= 0.6166$ mol kg$^{-1}$

We know that $\Delta T_t = K_f \times m$

$\Rightarrow \quad \Delta T_t = 12.33 \times 0.6166 = 7.60$ K

So, the freezing point of 10% glucose solution in water is (273.15 – 7.60) K = 265.55 K **3**

**Q. 7. Calculate the boiling point of solution when 4 g of $MgSO_4$ (M = 120 g mol$^{-1}$) was dissolved in 100 g of water, assuming $MgSO_4$ undergoes complete ionization.**

**($K_b$ for water = 0.52 K kg mol$^{-1}$)** U

**Ans.** $\Delta T_b = iK_b.m$ ½

$i = 2$

$$= i \times K_b \times \frac{W_2 \times 1000}{M \times W_1}$$

$$= 2 \times 0.52 \text{ K kg mol}^{-1} \times \frac{4\text{g} \times 1000\text{ g / kg}}{120\text{ g / mol} \times 100\text{g}}$$ **1**

$$= \frac{2 \times 0.52}{3} = 0.346 \text{ K}$$ ½

Boiling point of water

$$= \frac{373.15\text{K}}{373\text{K}}$$

$T_b = T_b^0 + \Delta T_b$

$= 373.15$K + 0.346 K or

373 K + 0.346 K

$= 373.496$ K or 373.346 K **1**

**[CBSE Marking Scheme, 2016]**

**Q. 8. A solution of glucose (molar mass = 180 g mol$^{-1}$) in water has a boiling point of 100.20°C. Calculate the freezing point of the same solution. Molal constants for water $K_f$ and $K_b$ are 1.86 K kg mol$^{-1}$ and 0.512 K kg mol$^{-1}$ respectively.**

A **[CBSE Foreign Set-1, 2, 3 2017]**

**Ans. Given :** $T_b$ of glucose solution = 100.20°C

$\Delta T_b = K_b. m$

$m = 0.20/0.512$

$m = 0.390$ mol/kg **[1]**

$\Delta T_f = K_f . m$ **[½]**

$\Delta T_f = 1.86$ K kg/mol × 0.390 mol/kg **[½]**

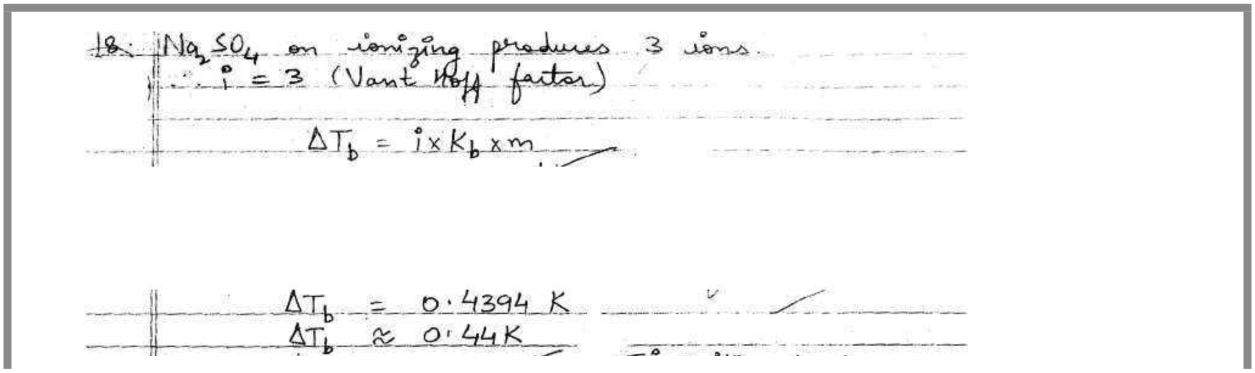
$\Delta T_f = 0.725$ K

Freezing point of solution = 273.15 – 0.725

= 272.425 K **[1]**

**[CBSE Marking Scheme 2017]**

**Q. 10. Calculate the boiling point of solution when 2 g of $Na_2SO_4$ (M = 142 g mol$^{-1}$) was dissolved in 50 g of water, assuming $Na_2SO_4$ undergoes complete ionization.** A **[CBSE OD Set-2 2017]**



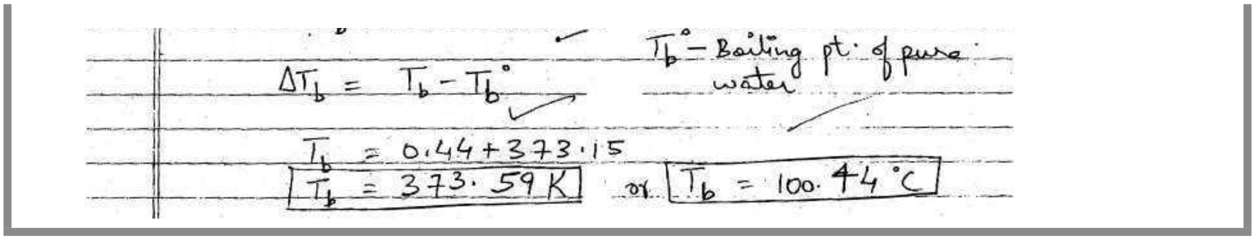
18: $Na_2SO_4$ on ionizing produces 3 ions.

$\therefore$ $i = 3$ (Vant Hoff factor)

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

$\Delta T_b = 0.4394$ K

$\Delta T_b \approx 0.44$K



$\Delta T_b = T_b - T_b^\circ$ $T_b^\circ$ – Boiling pt. of pure water

$T_b = 0.44 + 373.15$

$\boxed{T_b = 373.59\ K}$ or $\boxed{T_b = 100.44\ ^\circ C}$

**Q. 11.45 g of ethylene glycol ($C_2H_4O_2$) is mixed with 600 g of water. Calculate**
**(i) the freezing point depression and**
**(ii) the freezing point of the solution**
**(Given : $K_f$ of water = 1.86 K kg mol$^{-1}$)**
**A [CBSE Comptt. Delhi 2015]**

**Ans.** (i) $\Delta T_f = K_f m$ [½]

$\Rightarrow \Delta T_f = K_f \dfrac{W_B \times 1000}{M_B \times W_A}$ [½]

$\Rightarrow \Delta T_f = \dfrac{1.86\ \text{K kg mol}^{-1} \times 45\text{g} \times 1000\ \text{g kg}^{-1}}{60\ \text{g mol}^{-1} \times 600\ \text{g}}$

$\Delta T_f = 2.325$ K or 2.325 °C [1]

(ii) $T_f^\circ - T_f = 2.325\ ^\circ C$

$\Rightarrow 0\ ^\circ C - T_f = 2.325\ ^\circ C$

$\Rightarrow T_f = -2.325\ ^\circ C$ or 270.675 K [1]

**[CBSE Marking Scheme 2015]**

**Commonly Made Error**

- Students often forget to mention the formula applied. Formula carries marks.

**Answering Tip**

- Write working formula followed by data in the working formula.

**Q. 12. A solution is prepared by dissolving 10 g of non-volatile solute in 200 g of water. It has a vapour pressure of 31.84 mm Hg at 308 K. Calculate the molar mass of the solute.**
**(Vapour pressure of pure water at 308 K = 32 mm Hg)** **A [CBSE OD 2015]**

**Ans.** $\dfrac{p^0 - p}{p^0} = \dfrac{W_s \times M_{solvent}}{M_s \times W_{solvent}}$, $s$ = solute [1]

$\Rightarrow (32 - 31.84)/32 = 10 \times 18/M_s \times 200$ [1]

$M_s = 180$ g/mol [1]

**[CBSE Marking Scheme 2015]**

**Q. 13. 3.9 g of benzoic acid dissolved in 49 g of benzene shows a depression in freezing point of 1.62 K. Calculate the van't Hoff factor and predict the nature of solute(associated or dissociated).**
**(Given : Molar mass of benzoic acid= 122 g mol$^{-1}$, $K_f$ for benzene = 4.9 K kg mol$^{-1}$)**
**A [CBSE Delhi, 2015]**

**Ans.** $\Delta T_f = iK_f m$

$m = \dfrac{W_B \times 1000}{M_B \times W_B}$

$\Delta T_f$ = Depression in freezing point = 1.62

$i$ = van't Hoff factor

$K_f$ = constant = 4.9

$m = \dfrac{3.9 \times 1000}{122 \times 49} = 0.65$

$i = \dfrac{\Delta T_f}{K_f m}$

$= \dfrac{1.62}{4.9 \times 0.65} = 0.50$

$\therefore i = 0.50$

As the value of $i < 1$, the solute is associated. 3

**Commonly Made Error**

- Students forgot to put the value of $i$ in ionic solids

**Answering Tip**

- Remember to put the value of $i$ in questions where complete dissociation is mentioned for ionic solids.

## Long Answer Type Questions (5 marks each)

**AI Q. 1. (i) A 10% solution (by mass) of sucrose in water has a freezing point of 269.15 K. Calculate the freezing point of 10% glucose in water if the freezing point of pure water is 273.15 K.**
**Given : (Molar mass of sucrose = 342 g mol$^{-1}$)**
**(Molar mass of glucose = 180 g mol$^{-1}$)**
**[CBSE Delhi Set-1, 2, 3 2017]**
**(ii) Define the term : Molality (m)**
**A + R [CBSE OD Set-1, 2, 3 2017]**

**Ans.** (i) $\Delta T_f = K_f m$ [1]

Here, $m = w_2 \times 1000/M_2 \times W_1$

$273.15 - 269.15 = K_f \times 10 \times 1000/342 \times 90$ [1]

$K_f = 12.3$ K kg/mol [1]

$\Delta T_f = K_f m$

$= 12.3 \times 10 \times 1000/180 \times 90$

$= 7.6$ K

$T_f = 273.15 - 7.6 = 265.55$ K [½]

**(or any other correct method)[1]**

**(ii)** Number of moles of solute dissolved in per kilo gram of the solvent. [1]

**[CBSE Marking Scheme 2017] [1]**

**Q. 2. (a) Calculate the freezing point of solution when 1.9 g of $MgCl_2$ (M = 95 g $mol^{-1}$) was dissolved in 50 g of water, assuming $MgCl_2$ undergoes complete ionization. ($K_f$ for water = 1.86 K kg $mol^{-1}$)**

**(b) (i) Out of 1 M glucose and 2 M glucose, which one has a higher boiling point and why?**

**(ii) What happens when the external pressure applied becomes more than the osmotic pressure of solution ?**

**Ans.(a)**

$$\Delta T_f = i\frac{K_f W_b \times 1000}{M_b \times W_a} \quad \textbf{[1]}$$

$$\Delta T_f = 3 \times \left(\frac{1.86 \times 1.9}{95 \times 50}\right) \times 1000$$

**[1]**

$$= 2.23 \text{ K}$$

$$T_f - \Delta T_f = 273.15 - 2.23 \text{ or } 273 - 2.23$$

$$T_f = 270.92 \text{ K or } 270.77 \text{ K} \quad \textbf{[1]}$$

**(b) (i)** 2 M glucose has a higher boiling point because higher the number of particles, lesser is the vapour pressure. **[½ + ½]**

**(ii)** Reverse osmosis. **[1]**

**[CBSE Marking Scheme 2016]**

**Detailed Answer :**

**(a)**

$$W_B \text{ (solution)} = 1.9 \text{ g ws}$$

$$W(H_2O) = 50 \text{ g}$$

$$M(MgCl_2) = 95 \text{ g/mol}$$

$$i = 3 (\text{for } MgCl_2)$$

$$m = \frac{W_B \text{ in kg}}{\text{Molar mass} \times \text{mass of solvent}}$$

$$\Delta T_f = iK_f m$$

$$\Delta T_f = 3 \times 1.86 \times \frac{1.9}{95} \times \frac{1000}{50} (\text{kg})$$

$$\Delta T_f = 2.232 \text{ K}$$

$$\Delta T_f = \Delta T^\circ_f - T_f$$

Also, $\Delta T_f = \Delta T^\circ_f - T_f$

$$T_f = T^\circ_f - \Delta T_f = 273.15 - 2.232 = 270.918 \text{ K}$$

**[3]**

**(b) (i)** 2M glucose, because more will be the concentration molality, more will be the elevation in boiling point.

**(ii)** Reverse osmosis takes place. **[½ × 2]**

**Q. 3. (a) When 2.56 g of sulphur was dissolved in 100 g of $CS_2$, the freezing point lowered by 0.383 K. Calculate the formula of sulphur ($S_X$). ($K_f$ for $CS_2$ = 3.83 K kg $mol^{-1}$, Atomic mass of Sulphur = 32 g $mol^{-1}$).**

**(b) Blood cells are isotonic with 0.9% sodium chloride solution. What happens if we place blood cells in a solution containing;**

**(i) 1.2% sodium chloride solution ?**

**(ii) 0.4% sodium chloride solution ?** $\boxed{\text{A}}$

**Ans. (a)**

$$\Delta T_f = \frac{K_f W_b \times 1000}{M_b \times W_a} \quad \textbf{[1]}$$

$$0.383 = \left(\frac{3.83 \times 2.56}{M \times 100}\right) \times 1000 \quad \textbf{[1]}$$

$$M = 256$$

$$S \times x = 256$$

$$32 \times x = 256 \quad \textbf{[1]}$$

$$x = 8$$

**(b)** (i) Shrinks **[1]**

(ii) Swells **[1]**

**[CBSE Marking Scheme, 2016]**

**Detailed Answer :**

**(a)**

$$\Delta T_f = iK_f m$$

$$\Delta T_f = K_f \times \frac{W_B}{W_A(\text{Kg})} \times \frac{1}{W_A}(\text{Kg})$$

$$M_B = \frac{K_f}{\Delta T_f \times W_A(\text{Kg})}$$

$$= \frac{3.83 \times 2.56 \times 1000}{0.383 \times 100(\text{kg})}$$

$$= 256 \text{ g/mol}$$

$$M_B = n \times \text{Atomic mass}$$

$$n = \frac{M_B}{\text{Atomic mass}}$$

$$= \frac{256}{32} = 8$$

$\therefore S_8$ **[3]**

**(b)** (i) Water moves out from blood cell, hence will shrink. (ii) Water will enter into blood cell, hence will swell. **[1 × 2]**

## Visual Case–Based Questions (1 mark each)

**Q. 1. Read the passage given below and answer the following questions : (1 × 4 = 4)**

Scuba apparatus includes a tank of compressed air toted by the diver on his or her back, a hose for carrying air to a mouthpiece, a face mask that covers the eyes and nose, regulators that control air flow, and gauges that indicate depth and how much air remains in the tank.

A diver who stays down too long, swims too deep, or comes up too fast can end up with a condition called "the bends." In this case, bubbles of gas in the blood can cause intense pain, even death.

**In these following questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.**

- **(a)** **Assertion and Reason both are correct statements and Reason is correct explanation for Assertion.**
- **(b)** **Assertion and Reason both are correct statements but Reason is not correct explanation for Assertion.**
- **(c)** **Assertion is correct statement but Reason is wrong statement.**
- **(d)** **Assertion is wrong statement but Reason is correct statement.**

**(i)** **Assertion :** Scuba divers may face a medical condition called 'bends'.

**Reason :** 'Bends' can be explained with the help of Henry's law as it links the partial pressure of gas to that of its mole fraction.

**(ii)** **Assertion :** Bends is caused due to formation of nitrogen bubbles in the blood of scuba divers which blocks the capillaries.

**Reason :** Underwater high pressure increases solubility of gases in blood, while as pressure gradually decreases moving towards the surface, gases are released and nitrogen bubbles are formed in blood.

**(iii)** **Assertion :** Soft drinks and soda water bottles are sealed under high pressure.

**Reason :** High pressure maintains the taste and texture of the soft drinks.

**(iv)** **Assertion :** Anoxia is a condition experienced by climbers which makes them suddenly agile and unable to think clearly.

**Reason :** At high altitudes the partial pressure of oxygen is less than that at the ground level.

**OR**

**Assertion :** Solubility of gases in liquids decreases with rise in temperature.

**Reason :** As dissolution is an exothermic process, the solubility should decrease with increase of temperature.

**Ans. (i) Correct option : (a)**

*Explanation :* Henry's law explains some biological phenomena like the 'bends' experienced by the scuba divers. Since mole fraction of a gas in the solution is a measure of its solubility. **[1]**

**(ii) Correct option : (a)**

*Explanation :* Scuba divers must cope with high concentrations of dissolved gases while breathing air at high pressure underwater. Increased pressure increases the solubility of atmospheric gases in blood. When the divers come towards surface, the pressure gradually decreases. This releases the dissolved gases and leads to the formation of bubbles of nitrogen in the blood. This blocks capillaries and creates a medical condition known as bends. **[1]**

**(iii) Correct option : (c)**

*Explanation :* The bottle is sealed under high pressure to increase the solubility of $CO_2$ in soft drinks and soda water. **[1]**

**(iv) Correct option : (d)**

*Explanation :* At high altitudes the partial pressure of oxygen is less than that at the ground level. This leads to low concentrations of oxygen in the blood and tissues of people living at high altitudes or climbers. This leads to a condition called anoxia caused due to low oxygen in blood, making the climbers to become weak and unable to think clearly. **[1]**

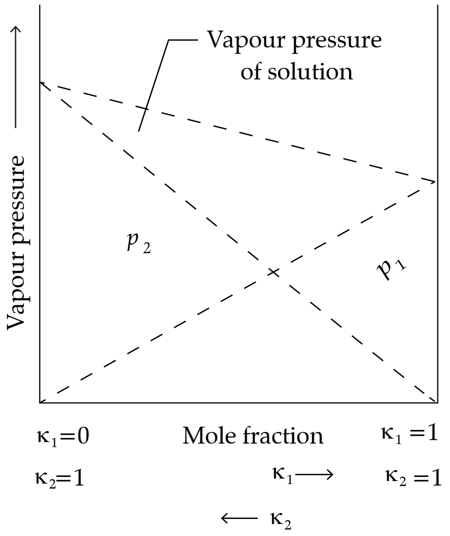
**OR**

**Correct option : (a)**

*Explanation :* Solubility of gases in liquids decreases with rise in temperature. As dissolution is an exothermic process, the solubility should decrease with increase of temperature. **[1]**

**Q. 2. Read the passage given below and answer the following questions : (1 × 4 = 4)**

Raoult's law states that for a solution of volatile liquids, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution. Dalton's law of partial pressure states that the total pressure ($p_{total}$) over the solution phase in the container will be the sum of the partial pressures of the components of the solution and is given as : $P_{total} = P_1 + P_2$



**(i)** **What type of deviation from Raoult's law does the above graph represent ?**

- **(a)** First positive then negative
- **(b)** Negative deviation
- **(c)** Positive deviation
- **(d)** First negative then positive

**(ii)** **In comparison to a 0.01 M solution of glucose, the depression in freezing point of a 0.01 M $MgCl_2$ solution is _____________.**

- **(a)** the same
- **(b)** about twice
- **(c)** about three times
- **(d)** about six times

**(iii) A solution of two liquids boils at a temperature more than the boiling point of either of them. What type of deviation will be shown by the solution formed in terms of Raoult's law ?**

**(a)** Negative deviation

**(b)** Positive deviation

**(c)** First positive then negative

**(d)** First negative then positive

**(iv) Which of the following aqueous solutions should have the highest boiling point ?**

**(a)** 1.0 M NaOH

**(b)** 1.0 M $Na_2SO_4$

**(c)** 1.0 M $NH_4NO_3$

**(d)** 1.0 M $KNO_3$

**Ans.**

**(i) Correct option : (b)**

Negative deviation **[1]**

**(ii) Correct option :** (c)

***Explanation :***

$\Delta T_f = iK_f\,m$, where $i=1$ for glucose.

$\Delta T_f^{glucose} = 1 \times K_f \times 0.01$

In case of $MgCl_2 \rightarrow Mg^{2+} + 2Cl^-$, where $i = 3$,

$\Delta T_f^{MgCl_2} = 3 \times 0.01 \times K_f$

$\Rightarrow \Delta T_f^{MgCl_2} = 3 \times \Delta T_f^{glucose}$

Hence, the depression in freezing point of $MgCl_2$ is three times that of glucose. **[1]**

**(iii) Correct option : (a)**

***Explanation :*** Since the Boiling point of the solution is more than the b.p. of the individual components in the solution, it indicates that the vapour pressure exerted by the solution is less than the expected, as boiling starts when vapour pressure equals the atmospheric pressure. Hence, the solution shows a negative deviation from the Raoult's law. **[1]**

**(iv) Correct option : (b)**

***Explanation :*** $Na_2SO_4$ will release 3 moles of ions/ moles of $Na_2SO_4$ in the aqueous solution, and b.p being a colligative property, the b.p of this solution will be the highest as other solutions release only 2 ions each. **[1]**

**Q. 3. Read the passage given below and answer the following questions:**

Boiling point or freezing point of liquid solution would be affected by the dissolved solids in the liquid phase. A soluble solid in solution has the effect of raising its boiling point and depressing its freezing point. The addition of non-volatile substances to a solvent decreases the vapor pressure and the added solute particles affect the formation of pure solvent crystals.

According to many researches the decrease in freezing point directly correlated to the concentration of solutes dissolved in the solvent. This phenomenon is expressed as freezing point depression and it is useful for several applications such as freeze concentration of liquid food and to find the molar mass of an unknown solute in the solution. Freeze concentration is a high quality liquid food concentration method where water is removed by forming ice crystals. This is done by cooling the liquid food below the freezing point of the solution. The freezing point depression is referred as a colligative property and it is proportional to the molar concentration of the solution (m), along with vapor pressure lowering, boiling point elevation, and osmotic pressure. These are physical characteristics of solutions that depend only on the identity of the solvent and the concentration of the solute. The characters are not depending on the solute's identity. (Jayawardena, J. A. E. C., Vanniarachchi, M. P. G., & Wansapala, M. A. J. (2017). Freezing point depression of different Sucrose solutions and coconut water.)

**(i) When a non volatile solid is added to pure water it will:**

**(a)** boil above 100°C and freeze above 0°C

**(b)** boil below 100°C and freeze above 0°C

**(c)** boil above 100°C and freeze below 0°C

**(d)** boil below 100°C and freeze below 0°C

**(ii) Colligative properties are:**

**(a)** dependent only on the concentration of the solute and independent of the solvent's and solute's identity.

**(b)** dependent only on the identity of the solute and the concentration of the solute and independent of the solvent's identity.

**(c)** dependent on the identity of the solvent and solute and thus on the concentration of the solute.

**(d)** dependent only on the identity of the solvent and the concentration of the solute and independent of the solute's identity.

**(iii) Assume three samples of juices A, B and C have glucose as the only sugar present in them.**

The concentration of sample A, B and C are 0.1M, .5M and 0.2 M respectively. Freezing point will be highest for the fruit juice:

**(a)** A

**(b)** B

**(c)** C

**(d)** All have same freezing point

**(iv) Identify which of the following is a colligative property :**

**(a)** freezing point

**(b)** boiling point

**(c)** osmotic pressure

**(d)** all of the above

**Ans.** 1. (b) 2. (d) 3. (a) 4. (c)

# Self-Asessment Test - 2

**Time : 1 Hour** **Max. Marks : 25**

1. **Read the passage given below and answer the following questions : (1 × 4 = 4)**

Most of the gases are soluble in water to some extent. The solubility of gas in water generally depends upon nature of the gas, temperature and pressure. In general, the gases which are easily liquefiable are more soluble in water. The dissolution of gas in water is exothermic process. Hence, the solubility of gas decreases with rise in temperature. The effect of pressure on the solubility of a gas is given by Henry's Law which states that mass of the gas dissolved per unit volume of a liquid at particular temperature is directly proportional to the pressure of the gas above liquid at equilibrium.

**(i) The solubility of gas in water depends upon:**

**(a)** Nature of the gas **(b)** Temperature

**(c)** Pressure **(d)** All of the above

**(ii) The dissolution of gas in water is:**

**(a)** Endothermic process

**(b)** Exothermic process

**(c)** Both (a) and (b)

**(d)** None of these

**(iii) The solubility of gas __________ with rise in temperature:**

**(a)** Increases

**(b)** Decreases

**(c)** Remains some

**(d)** First increases and then decreases

**(iv) The effect of pressure on the solubility of a gas given by:**

**(a)** Raoult's Law

**(b)** Henry's Law

**(c)** Boyle's Law

**(d)** Charle's Law

**The following questions (No. 2 to 5) are Multiple Choice Questions carrying 1 mark each.**

2. **Which of the following is not correct for an ideal solution?**

**(a)** It should obey Raoult's Law

**(b)** $\Delta H_{mix} = 0$

**(c)** $\Delta H_{mix} \neq 0$

**(d)** $\Delta V_{mix} = 0$

3. **Select the non-ideal solution showing positive deviation from Raoult's Law.**

**(a)** $CHCl_3 + C_6H_6$

**(b)** $(CH_3)_2CO + C_6H_5NH_2$

**(c)** $H_2O + HCl$

**(d)** $H_2O + C_2H_5OH$

4. **Which of the following is a colligative property?**

**(a)** Osmotic pressure

**(b)** Building point

**(c)** Vapour pressure

**(d)** Electrical conductivity

5. **The number of moles of solute present in 1000 g of the solvent is known as**

**(a)** Molarity **(b)** Molality

**(c)** Normality **(d)** Mole fraction

**In the following questions (no. 6 & 7), a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.**

**(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**

**(b) Assertion and reason both are correct statements but reason is not the correct explanation for assertion.**

**(c) Assertion is correct statement but reason is wrong statement.**

**(d) Assertion is wrong statement but reason is correct statement.**

6. **Assertion :** Cooking time is reduced in pressure cooker.

**Reason :** Boiling point of water inside the pressure cooker is elevated.

7. **Assertion :** Two solution having same osmotic pressures are called isotonic solutions.

**Reason :** Lowering of vapour pressure is not a colligative property.

**The following questions (No. 8 & 9), are Short Answer Type-I and carry 2 marks each.**

8. 10 g glucose is dissolved in 90 g of water then what will be the mass % of glucose?

9. The freezing point of solution of 0.1 g week monatomic acid dissolved in 22g water in 272.817 k. Calculate molar mass of acid. ($K_f$ = 1.86 k kg $mol^{-1}$)

**The following questions (No. 10 & 11) are Short Answer Type-II carrying 3 marks each.**

10. 10.8 g sucrose is dissolved in 100 g of water. At which temperature, this solution will boil at 1.013 bar pressure? The value of $K_b$ for water is 0.52 k kg $mol^{-1}$

**11.** A substance X (molecular mass = 94) associates as 2X $\rightleftharpoons$ $X_2$ when dissolved in $CCl_4$. If 10g of X is dissolved in 2 kg of $ccl_4$, the freezing point is lowered by 1.08°C, $K_f$ for $ccl_4$ is 31.8 k kg $mol^{-1}$. Calculate the degree of dissociation of X.

**Q.No 12 is a Long Answer Type Question carrying 5 marks each.**

**Q.12. (i)** Define the following terms :

**(a)** Molarity

**(b)** Molal elevation constant ($K_b$)

**(ii)** A solution containing 15 g urea (molar mass = 60 g $mol^{-1}$) per litre of solution in water has the same osmotic pressure (isotonic) as a solution of glucose (molar mass = 180 g $mol^{-1}$) in water. Calculate the mass of glucose present in one litre of its solution.

**OR**

**(a)** What will be the value of van't Hoff factor for dilute solution of $Al_2(SO_4)_3$ in water?

**(b)** Among 1 m glucose, 1m KCl and 1 m $K_2SO_4$, which will have minimum freezing point and why?

**(c)** A solution of glycerol ($C_3H_8O_3$) is formed by dissolving some glycerol in 500 g water. The boiling point of this solution is 100.42°C. How much quantity of glycerol was dissolved to form this solution? (For water, $K_b$ = 0.512 k kg $mol^{-1}$)

* * *