

## Very Short Answer Questions

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### Very Short Answer Questions (PYQ)

**Q.1. Define mole fraction.**

[CBSE Delhi 2012]

**Ans.** Mole fraction of a component in a solution may be defined as the ratio of moles of that component to the total number of moles of all the components present in the solution.

**Q.2. What is meant by 'reverse osmosis'?**

[CBSE (AI) 2011]

**Ans.** If a pressure larger than the osmotic pressure is applied on the solution side, the solvent starts to flow from the solution into the pure solvent through the semipermeable membrane. This phenomenon is called reverse osmosis.

**Q.3. What is the similarity between Raoult's law and Henry's law?**

[CBSE Delhi 2014]

**Ans.** The similarity between Raoult's law and Henry's law is that both state that the partial vapour pressure of the volatile component or gas is directly proportional to its mole fraction in the solution.

**Q.4. Out of two 0.1 molal solutions of glucose and of potassium chloride, which one will have a higher boiling point and why?**

[CBSE (F) 2013]

**Ans.** 0.1 M KCl solution will have higher boiling point as KCl dissociates in the solution

**Q.5. Define van't Hoff factor.**

[CBSE Delhi 2012]

**Ans.** van't Hoff factor may be defined as the ratio of normal molecular mass to observed molecular mass or the ratio of observed colligative property to normal colligative property.

**Q.6. What are isotonic solutions?**

[CBSE Delhi 2012, 2014]

**Ans.** The solutions of the same osmotic pressure at a given temperature are called isotonic solutions.

**Q.7. How is it that measurement of osmotic pressures is more widely used for determining molar masses of macromolecules than the elevation in boiling point or depression in freezing point of their solutions?**

**[CBSE (AI) 2009]**

**Ans.** The osmotic pressure method has the advantage over elevation in boiling point or depression in freezing point for determining molar masses of macromolecules because

**(i)** Osmotic pressure is measured at the room temperature and the molarity of solution is used instead of molality.

**(ii)** Compared to other colligative properties, its magnitude is large even for very dilute solutions.

### **Very Short Answer Questions (OIQ)**

**Q.1. Give an example of solution containing a solid solute in a solid solvent.**

**Ans.** Alloys like copper in gold.

**Q.2. Is smoke a homogeneous solution? If not, then what is it?**

**Ans.** No, it is a colloidal solution.

**Q.3. What do you mean by 10% aqueous solution of sodium carbonate?**

**Ans.** It means that 10 g of  $\text{Na}_2\text{CO}_3$  is present in 100 g of the solution

**Q.4. How does the molarity of a solution change with temperature?**

**Ans.** Molarity decreases with increase in temperature as volume of solution increases with increase in temperature.

**Q.5. When and why is molality preferred over molarity in handling solutions in chemistry?**

**Ans.** Molality is preferred in studies that involves changes in temperature as in some of the colligative properties of solutions. This is because molality depends on masses of solvent which do not change with temperature.

**Q.6. What do you understand by 'colligative properties'?**

**Ans.** Colligative properties are those properties which depend upon the number of moles of solute particle but not on the nature of solute particles.

**Q.7. Why is the vapour pressure of a solution of glucose in water lower than that of water?**

**[NCERT Exemplar]**

**Ans.** This is due to decrease in the escaping tendency of the water molecules from the surface of solution as some of the surface area is occupied by non-volatile solute, glucose particles.

**Q.8. State any two characteristics of ideal solutions.**

**Ans.** Ideal solutions (i) obey Raoult's Law (ii)  $\Delta_{\text{mix}} H = 0$ ,  $\Delta_{\text{mix}} V = 0$

**Q.9. What type of liquids form ideal solutions?**

**Ans.** Liquids that have similar structures and polarities form ideal solutions.

**Q.10. Under what condition do non-ideal solutions show negative deviations?**

**Ans.** When the new forces of interaction between the components are stronger than those in the pure components, then non-ideal solutions show negative deviations.

**Q.11. What are maximum boiling azeotropes? Give one example.**

**Ans.** Maximum boiling azeotropes are those which boil at higher temperature than boiling point of each component in pure state, e.g., 68% nitric acid and 32% water by mass.

**Q.12. What are minimum boiling azeotropes? Give one example.**

**Ans.** Minimum boiling azeotropes are those which boil at lower temperature than boiling point of each component in pure state, e.g., 95.5% ethyl alcohol and 4.5% water by mass.

**Q.13. Define molal elevation constant or ebullioscopic constant.**

**Ans.** Molal elevation constant is defined as the elevation in boiling point when one mole of non-volatile solute is added to one kilogram of solvent.

**Q.14. Define molal depression constant or cryoscopic constant.**

**Ans.** It is the depression in freezing point when 1 mole of non-volatile solute is dissolved in 1000 g of solvent.

**Q.15. What do you understand by the term that  $K_f$  for water is  $1.86 \text{ K kg mol}^{-1}$ ?**

**Ans.** It means that the freezing point of water is lowered by 1.86 K when 1 mole of non-volatile solute is dissolved in 1 kg of water.

**Q.16. What is an antifreeze?**

**Ans.** A substance such as ethylene glycol which is added to water to lower its freezing point is called an antifreeze. It is named so as it delays freezing.

**Q.17. What is de-icing agent? How does it work?**

**Ans.** Common salt is called de-icing agent as it lowers the freezing point of water to such an extent that it does not freeze to form ice. Thus, it is used to clear snow from roads.

**Q.18. What is 'reverse osmosis'?**

**Ans.** If the pressure applied on the solution is greater than the osmotic pressure then the solvent molecules start to move from solution into solvent through semipermeable membrane. This process is called reverse osmosis.

**Q.19. State how does osmotic pressure vary with temperature.**

**Ans.** Osmotic pressure increases with increase in temperature.

**Q.20. Why is osmotic pressure of 1 M KCl higher than 1 M urea solution?**

**Ans.** This is because KCl dissociates to give  $K^+$  and  $Cl^-$  ions while urea being a molecular solid does not dissociate into ions in the solution.

**Q.21. What is the van't Hoff factor for a compound which undergo dimerisation in an organic solvent?**

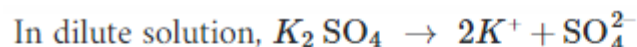
**Ans.**



$$i = \frac{\text{Number of moles of particles after association}}{\text{Number of moles of particles before association}} = \frac{1}{2}$$

**Q.22. What would be the value of van't Hoff factor for a dilute solution of  $K_2SO_4$  in water?**

**Ans.**



$$\text{van't Hoff factor, } i = \frac{\text{Number of moles of particles after dissociation}}{\text{Number of moles of particles before dissociation}} = \frac{3}{1} = 3$$

**Q.23. Why is glycol and water mixture used in car radiators in cold countries?**

[HOTS]

**Ans.** Ethylene glycol lowers the freezing point of water. Due to this, coolant in radiators will not freeze. Otherwise, radiator will burst due to freezing of coolant (water).

**Q.24. Why are the aquatic species more comfortable in cold water in comparison to warm water?**

[HOTS]

**Ans.** At a given pressure the solubility of oxygen in water increases with decrease in temperature. Presence of more oxygen at lower temperature makes the aquatic species more comfortable in cold water.

**Q.25. Why does the use of pressure cooker reduce cooking time?**

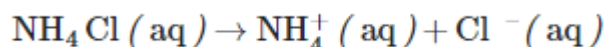
[HOTS]

**Ans.** The weight over the lid does not allow the steam to go out. As a result, pressure inside the cooker becomes high. Higher the pressure, higher is the boiling point and faster is the cooking.

**Q.26. The dissolution of ammonium chloride in water is an endothermic process but still it dissolves in water readily. Why?**

[HOTS]

**Ans.** This is because of entropy change. In this case,  $\Delta S$  is +ve.



The ions that were held together in crystalline solid are free and moving in all possible directions. Its entropy has increased and this makes  $T\Delta S > \Delta H$ , i.e.,  $\Delta G = -ve$ .

**Q.27. Which of the following solutions will have the highest boiling point:**

**(i) 1 M BaCl<sub>2</sub> (ii) 1 M Urea (iii) 1 M FeCl<sub>3</sub> (iv) 1 M NaCl.**

[HOTS]

**Ans.** FeCl<sub>3</sub> solution ( $T_b = T_b^0 + \Delta T_b$ ) As number of ions produced is maximum in FeCl<sub>3</sub> solution. The colligative property  $\Delta T_b$  will be maximum in case of FeCl<sub>3</sub>.

**Q.28. Which one of these has the highest freezing point?**

**(i) 1 M glucose (ii) 1 M NaCl (iii) 1 M CaCl<sub>2</sub>.**

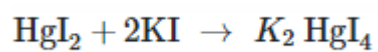
[HOTS]

**Ans.** 1 M glucose solution has the highest freezing point because it has lowest  $\Delta T_f$  ( $T_f = T_f^0 + \Delta T_f$ )

**Q.29. What will happen to freezing point of a potassium iodide aqueous solution when mercuric iodide is added to solution?**

[HOTS]

**Ans.**



Mercuric iodide forms a complex with potassium iodide, therefore, the number of solute particles (KI) in the solution decreases resulting in the decrease in the value of  $\Delta T_f$ , i.e., depression in the freezing point. As a result, the freezing

point  $\text{HgI}_2 + 2\text{KI} \rightarrow \text{K}_2\text{HgI}_4$  of the solution will increase.

## Short Answer Questions-I

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### Short Answer Questions-I (PYQ)

**Q.1. State Henry's law. Write its one application. What is the effect of temperature on solubility of gases in liquid?**

[CBSE (F) 2016]

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

$$p \propto x \text{ or } p = K_H x \quad \text{where } K_H \text{ is the Henry's constant.}$$

**Application of Henry's law:**

To increase the solubility of CO<sub>2</sub> in soft drinks and soda water, the bottle is sealed under high pressure.

**Effect of temperature on solubility:**

As dissolution is an exothermic process, therefore, according to Le Chatelier's principle solubility should decrease with rise in temperature.

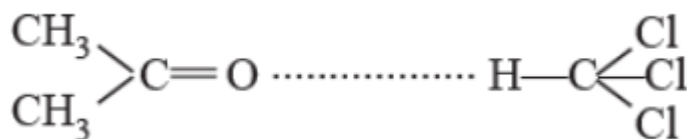
**Q.2. State Raoult's law for a solution containing non-volatile solute. What type of deviation from Raoult's law is shown by a solution of chloroform and acetone and why?**

[CBSE (F) 2017]

**Ans.** It states that the relative lowering of vapour pressure is equal to mole fraction of solute when solvent alone is volatile and is expressed as

$$\frac{P_A^{\circ} - P_{\text{Total}}}{P_A^{\circ}} = x_B$$

A solution of chloroform and acetone shows negative deviation from Raoult's law. This is because chloroform molecule is able to form H-bond with acetone molecule as shown below.



It decreases the escaping tendency of molecules of each component from the surface of solution and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law.

**Q.3. Answer the following question :**

**Q.** Why is an increase in temperature observed on mixing chloroform and acetone?

**Ans.** The bonds between chloroform molecules and molecules of acetone are dipole-dipole interactions but on mixing, the chloroform and acetone molecules, they start forming hydrogen bonds which are stronger bonds resulting in the release of energy. This gives rise to an increase in temperature.

**Q.** Why does sodium chloride solution freeze at a lower temperature than water?

[CBSE (F) 2013]

**Ans.** When a non-volatile solute is dissolved in a solvent, the vapour pressure decreases. As a result, the solvent freezes at a lower temperature.

**Q.4. Define an ideal solution and write one of its characteristics.**

[CBSE Delhi 2014]

**Ans.** A solution which obeys Raoult's law over the entire range of concentration is called ideal solution. The important characteristics of an ideal solution are

- i. The enthalpy of mixing of pure components to form the solution is zero *i.e.*,  
 $\Delta_{\text{mix}}H = 0$
- ii. The volume of mixing is zero *i.e.*,  $\Delta_{\text{mix}}V = 0$

**Q.5. Differentiate between molarity and molality of a solution. Explain how molarity value of a solution can be converted into its molality.**

[CBSE (F) 2011]

**Ans.** Molarity (M) is the number of moles of solute dissolved in one litre of solution whereas molality (m) is the number of moles of the solute per thousand grams of solvent.

If  $M_B$  is the molar mass of solute,  $d$  is the density of solution then molarity (M) value of a solution can be converted into its molality (m) by using the following formula.

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



**Q.6. Define azeotropes. What type of azeotrope is formed by negative deviation from Raoult's law? Give an example.**

[CBSE Delhi 2015]

**Ans.** Azeotropes are binary liquid mixtures having the same composition in liquid and vapour phase and boil at a constant temperature.

Maximum boiling azeotrope is formed by negative deviation from Raoult's law. A mixture of 68% nitric acid and 32% water by mass is an example of maximum boiling azeotrope.

**Q.7. Define the term osmotic pressure. Describe how the molecular mass of a substance can be determined by a method based on measurement of osmotic pressure.**

[CBSE Delhi 2012]

**Ans.** Osmotic pressure ( $\pi$ ) is defined as the extra pressure that must be applied to the solution side in order to prevent the flow of solvent molecules into it through a semipermeable membrane.

According to van't Hoff equation

$$\pi = \frac{n_B}{V} RT$$

where  $\pi$  is the osmotic pressure,  $R$  is the gas constant and  $V$  is the volume of solution in litres containing  $n_B$  moles of the solute.

If  $W_B$  grams of the solute of molar mass,  $M_B$  is present in the solution, then

$$n_B = \frac{W_B}{M_B} \text{ and we can write}$$

$$\pi = \frac{W_B \times R \times T}{M_B \times V} \quad \text{or} \quad M_B = \frac{W_B \times R \times T}{\pi \times V}$$

Thus, knowing  $W_B$ ,  $T$ ,  $\pi$  and  $V$ , the molecular mass of the solute,  $M_B$  can be calculated.

**Q.8. State Raoult's law for the solution containing volatile components. What is the similarity between Raoult's law and Henry's law?**

[CBSE Delhi 2014]

**Ans.** It states that for a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction. According to Raoult's law, for a volatile component, A of the solution

$P_A \propto x_A$  or  $P_A = P_A^0 x_A$ , where  $P_A^0$  is the vapour pressure of pure component A.

If one of the component is so volatile that it exist as a gas then according to Henry's law

$p = K_H x$ , where  $K_H$  is the Henry law constant *i.e.*, the partial vapour pressure of the volatile component (gas) is directly proportional to its mole fraction in the solution.

Thus the similarity between Raoult's law and Henry's law is that both state that the partial vapour pressure of the volatile component or gas is directly proportional to its mole fraction in the solution.

**Q.9. State the following:**

**Q.** Raoult's law in its general form in reference to solutions.

**Ans.** Raoult's law: It states that for any solution, the partial pressure of each volatile component in the solution is directly proportional to its mole fraction.

**Q.** Henry's law about partial pressure of a gas in a mixture.

[CBSE (AI) 2011]

**Ans.** Henry's law: It states that the partial pressure of a gas in vapour phase (P) is proportional to its mole fraction (x) in the solution.

**Q.10. Answer the following question :**

**Q.** 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?

**Ans.** According to Henry's law,  $p = K_H x$ , *i.e.*, higher the value of  $K_H$  lower is the solubility of the gas in the liquid. Therefore, Gas B will have higher value of  $K_H$  than gas A.

**Q.** In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes?

[CBSE Central 2016]

**Ans.** Negative deviation from Raoult's law.

**Q.11. Write two differences between a solution showing positive deviation and a solution showing negative deviation from Raoult's law.**

[CBSE East 2016]

**Ans.**

<b>Solutions showing positive deviation from Raoult's law</b>	<b>Solution showing negative deviation from Raoult's law</b>
<b>(i)</b> $P_A > P_0^A x_A$ and $P_B > P_0^B x_B$	<b>(i)</b> $P_A < P_0^A x_A$ and $P_B > P_0^B x_B$
<b>(ii)</b> $\Delta_{\text{mix}} H > 0$ , $\Delta_{\text{mix}} V > 0$	<b>(ii)</b> $\Delta_{\text{mix}} H < 0$ , $\Delta_{\text{mix}} V < 0$
<b>(iii)</b> Form minimum boiling azeotropes.	<b>(iii)</b> Form maximum boiling azeotropes.

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

**Q. Abnormal molar mass**

**Ans.** When the molar mass of a substance determined by using any of the colligative properties comes out to be different than the theoretically expected molar mass, the substance said to show abnormal molar mass.

**Q. van't Hoff factor (i)**

[CBSE Delhi 2017]

**Ans.** van't Hoff factor (i) gives the extent of association or dissociation of the solute particles in the solution. It may be defined as the ratio of observed colligative property to calculated colligative property.

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

**Q.13. What type of deviation is shown by a mixture of ethanol and acetone? What type of azeotrope is formed by mixing ethanol and acetone?**

[CBSE (F) 2013]

**Ans.** A mixture of ethanol and acetone shows positive deviation.

The azeotrope formed is minimum boiling azeotropes.

**Q.14. (i)** On mixing liquid X and liquid Y, volume of the resulting solution decreases. What type of deviation from Raoult's law is shown by the resulting solution? What change in temperature would you observe after mixing liquids X and Y?

**(ii)** What happens when we place the blood cell in water (hypotonic solution)? Give reason.

[CBSE Allahabad 2015]

**Ans. (i)** ♦ The solution will show negative deviation from Raoult's law.

♦ Temperature will rise.

**(ii)** Due to osmosis water enters into the cell and blood cell will swell.

**Q.15. State Raoult's law for the solution containing volatile components. Write two differences between an ideal solution and a non-ideal solution.**

[CBSE Panchkula 2015]

**Ans.** Raoult's law states that for a solution of volatile liquids the partial vapour pressure of each component is directly proportional to its mole fraction.

#### Differences between Ideal and non-Ideal solutions

S.No.	Ideal solution	Non-Ideal solution
(i)	Obeys Raoult's law over entire range of concentration <i>i.e.</i> , $P_A = P_A^\circ x_A; P_B = P_B^\circ x_B$	Does not obey Raoult's law over entire range of concentration, <i>i.e.</i> , $P_A \neq P_A^\circ x_A; P_B \neq P_B^\circ x_B$
(ii)	$\Delta_{\text{mix}} H = 0; \Delta_{\text{mix}} V = 0$	$\Delta_{\text{mix}} H \neq 0; \Delta_{\text{mix}} V \neq 0$
(ii)	Does not form azeotrope.	Forms azeotrope.

**Q.16. A solution prepared by dissolving 8.95 mg of a gene fragment in 35.0 mL of water has an osmotic pressure of 0.335 torr at 25°C. Assuming that the gene fragment is a non-electrolyte, calculate its molar mass.**

[CBSE (AI) 2011]

**Ans.**

$$M_B = \frac{W_B \times R \times T}{\pi \times V} \quad \dots (i)$$

Here,  $W_B = 8.95 \text{ mg} = 8.95 \times 10^{-3} \text{ g}$ ,  $R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$

$T = 25^\circ\text{C} = (25 + 273) \text{ K} = 298 \text{ K}$ ,  $\pi = 0.335 \text{ torr} = \frac{0.335}{760} \text{ atm}$

$V = 35 \text{ mL} = 35 \times 10^{-3} \text{ L}$

Substituting these values in the equation (i), we get

$$M_B = \frac{8.95 \times 10^{-3} \text{ g} \times 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1} \times 298 \text{ K} \times 760}{0.335 \text{ atm} \times 35 \times 10^{-3} \text{ L}} = 14193.3 \text{ g mol}^{-1}$$

**Q.17.** Henry's law constant ( $K_H$ ) for the solution of methane in benzene at 298 K is  $4.27 \times 10^5 \text{ mm Hg}$ . Calculate the solubility of methane in benzene at 298 K under 760 mm Hg.

[CBSE (F) 2013]

**Ans.**

Here,  $K_H = 4.27 \times 10^5 \text{ mm Hg}$

$p = 760 \text{ mm Hg}$

According to Henry's law,  $p = K_H x_{\text{CH}_4}$

$$x_{\text{CH}_4} = \frac{p}{K_H} = \frac{760 \text{ mm Hg}}{4.27 \times 10^5 \text{ mm Hg}} = 1.78 \times 10^{-3}$$

Mole fraction of methane in benzene,  $x_{\text{CH}_4} = 1.78 \times 10^{-3}$ .

**Q.18.** Derive the relationship between relative lowering of vapour pressure and molar mass of the solute.

[CBSE Chennai 2015]

**Ans.** From Raoult's law we have,  $P = P_A + P_B$

If solute B is non-volatile, then

$$P = P_A \quad \text{or} \quad P = P_A^0 x_A$$

$$P = P_A^0 (1 - x_B) = P_A^0 - P_A^0 x_B$$

$$P_A^0 x_B = P_A^0 - P$$

$$\frac{P_A^0 - P}{P_A^0} = x_B \quad \text{or} \quad \frac{\Delta P}{P_A^0} = \frac{n_B}{n_A + n_B}$$

For a dilute solution  $n_B \ll n_A$ , so  $n_B$  can be neglected in denominator in comparison to  $n_A$ .

$$\frac{\Delta P}{P_A^0} = \frac{n_B}{n_A} = \frac{W_B/M_B}{W_A/M_A} = \frac{W_B \times M_A}{M_B \times W_A}$$

$$M_B = \frac{P_A^0 \times W_B \times M_A}{\Delta P \times W_A}$$

**Q.19.** Calculate the freezing point depression expected for 0.0711 m aqueous solution of  $\text{Na}_2\text{SO}_4$ . If this solution actually freezes at  $-0.320^\circ\text{C}$ , what would be the value of van't Hoff factor?

( $K_f$  for water is  $1.86 \text{ K kg mol}^{-1}$ ).

[CBSE Delhi 2009; (F) 2009]

**Ans.**

$$\Delta T_f = [273.15 - (-0.320 + 273.15)] \text{ K} = 0.320 \text{ K}$$

$$\Delta T_f = K_f \cdot m = 1.86 \text{ K kg mol}^{-1} \times 0.0711 \text{ mol kg}^{-1} = 0.132 \text{ K}$$

$$i = \frac{\text{Observed value of } \Delta T_f}{\text{Calculated value of } \Delta T_f} = \frac{0.320 \text{ K}}{0.132 \text{ K}} = 2.42$$

**Q.20.** When 1.5 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point of benzene raised from 353.23 K to 353.93 K. Calculate the molar mass of the solute.

( $K_b$  for benzene =  $2.52 \text{ K kg mol}^{-1}$ )

[CBSE Chennai 2015]

**Ans.**

$$\Delta T_b = 353.93 \text{ K} - 353.23 \text{ K} = 0.7 \text{ K}$$

Substituting  $W_B = 1.5 \text{ g}$ ,  $W_A = 90 \text{ g}$ ,  $\Delta T_b = 0.7 \text{ K}$ ,  $K_b = 2.52 \text{ K kg mol}^{-1}$  in the expression

$$M_B = \frac{K_b \times W_B \times 1000}{\Delta T_b \times W_A}, \text{ we get}$$

$$M_B = \frac{2.52 \text{ K kg mol}^{-1} \times 1.5 \text{ g} \times 1000 \text{ g kg}^{-1}}{0.7 \text{ K} \times 90 \text{ g}}$$

$$M_B = 60 \text{ g mol}^{-1}$$

### Short Answer Questions-I (OIQ)

**Q.1. Explain the solubility rule “like dissolves like” in terms of intermolecular forces that exist in solutions.**

[NCERT Exemplar]

**Ans.** A substance (solute) dissolves in a solvent if the intermolecular interactions are similar in both the components; for example, polar solutes dissolve in polar solvents and non polar solutes in non polar solvents thus we can say “like dissolves like”.

**Q.2. CCl<sub>4</sub> and water are immiscible whereas ethanol and water are miscible in all proportions. Correlate this behaviour with molecular structure of these compounds.**

**Ans.** CCl<sub>4</sub> is a non-polar covalent compound, whereas water is a polar compound. CCl<sub>4</sub> can neither form hydrogen bonds with water molecules nor can it break hydrogen bonds between water molecule, therefore, it is insoluble in water.

Ethanol is a polar compound and can form hydrogen bonds with water, which is a polar solvent, therefore it is miscible with water in all proportions.

**Q.3. State Henry’s Law. What is the significance of  $K_H$ ?**

**Ans. Henry’s law:** It states that “the partial pressure of the gas in vapour phase ( $p$ ) is proportional to the mole fraction of the gas ( $x$ ) in the solution” and is expressed as:

$$p = K_H x$$

where,  $K_H$  is the Henry’s law constant.

**Significance of  $K_H$ :** Higher the value of Henry's law constant  $K_H$ , the lower is the solubility of the gas in the liquid.

**Q.4. State Raoult's law for a solution containing volatile components. How does Raoult's law become a special case of Henry's law?**

**Ans.** For a solution of volatile liquids, Raoult's law states that the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution, *i.e.*,

$$P_A \propto x_A, \quad \text{or} \quad P_A = P_A^0 x_A$$

According to Henry's law, the partial pressure of a gas in vapour phase ( $p$ ) is directly proportional to mole fraction ( $x$ ) of the gas in the solution.

$$p = K_H x$$

On comparing it with Raoult's law it can be seen that partial pressure of the volatile component or gas is directly proportional to its mole fraction in solution, only the proportionality constant  $K_H$  differs from  $P_A^0$

$$p_A \propto x$$

Thus, it becomes a special case of Henry's law in which  $K_H = P_A^0$

**Q.5. After removing the outer shell of two eggs in dil. HCl, one is placed in distilled water and the other in a saturated solution of NaCl. What will you observe and why?**

**Ans.** Egg in water will swell whereas in NaCl solution it will shrink. This is because due to osmosis, the net flow of solvent is from less concentrated to more concentrated solution.

**Q.6. When fruits and vegetables that have dried are placed in water, they slowly swell and return to the original form. Explain why. Would a temperature increase accelerate the process? Explain.**

**Ans.** The cell walls of the fruits and vegetables act as semipermeable membrane. When they are dried, concentration inside becomes higher. On placing in water, the process of osmosis takes place. So, they swell and return to their original form. The process will be accelerated with increase of temperature because osmosis becomes faster with increase in temperature.

**Q.7. Will the elevation in boiling point be same if 0.1 mol of sodium chloride or 0.1 mol of sugar is dissolved in 1 L of water? Explain.**

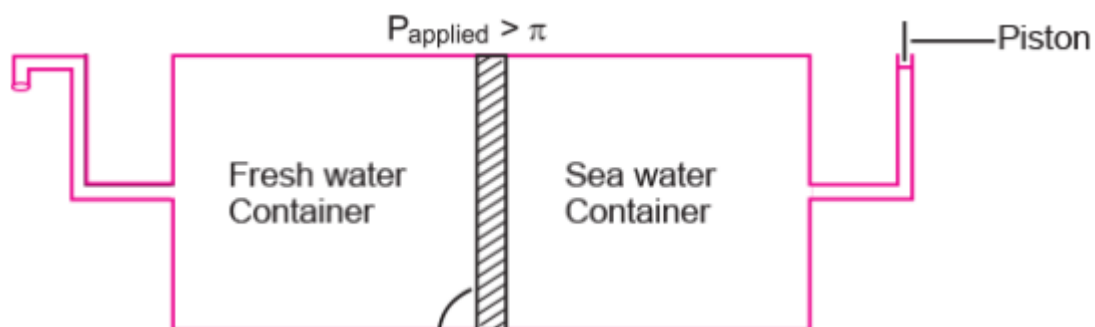


[CBSE Sample Paper 2016] [HOTS]

**Ans.** No, the elevation in boiling point is not the same. NaCl, being an electrolyte, dissociates almost completely to give  $\text{Na}^+$  and  $\text{Cl}^-$  ions whereas glucose, being non-electrolyte does not dissociate. Hence, the number of particles in 0.1 M NaCl solution is nearly double than 0.1 M glucose solution. Elevation in boiling point being a colligative property, is therefore, nearly twice for 0.1 M NaCl solution than for 0.1 M glucose solution.

**Q8.** Given alongside is the sketch of a plant for carrying out a process.

- i. Name the process occurring in the given plant.
- ii. To which container does the net flow of solvent take place?
- iii. Name one SPM which can be used in this plant.
- iv. Give one practical use of the plant.



**Ans.**

- i. Reverse osmosis.
- ii. Fresh water container.
- iii. Cellulose acetate placed on a suitable support.
- iv. Desalination of sea water.

## Short Answer Questions-II

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### Short Answer Questions-II (PYQ)

Q.1. A solution of glucose (molar mass =  $180 \text{ g mol}^{-1}$ ) in water is labelled as 10% (by mass). What would be the molality and molarity of the solution?

[CBSE (AI) 2014] [HOTS]

(Density of solution =  $1.2 \text{ g mL}^{-1}$ )

Ans.

Let the mass of solution = 100 g

$\therefore$  Mass of glucose = 10 g

Number of moles of glucose =  $\frac{\text{Mass of glucose}}{\text{Molar mass}}$

$$= \frac{10 \text{ g}}{180 \text{ g mol}^{-1}} = 0.056 \text{ mol}$$

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

$$= \frac{100 \text{ g}}{1.2 \text{ g mL}^{-1}} = 83.3 \text{ mL}$$

$$= \frac{83.3}{1000} \text{ L} = 0.083 \text{ L}$$

Molarity =  $\frac{\text{Moles of solute}}{\text{Volume of solution in litre}}$

$$= \frac{0.056 \text{ mol}}{0.083 \text{ L}} = 0.67 \text{ mol L}^{-1}$$

Mass of solvent, water =  $100 \text{ g} - 10 \text{ g} = 90 \text{ g}$

$$= \frac{90 \text{ g}}{1000 \text{ g kg}^{-1}} = 0.09 \text{ kg}$$

$$\text{Molality} = \frac{\text{Moles of glucose}}{\text{Mass of water in kg}}$$

$$= \frac{0.056 \text{ mol}}{0.09 \text{ kg}}$$

$$= 0.62 \text{ mol kg}^{-1}$$

**Q.2.** At 25°C the saturated vapour pressure of water is 3.165 kPa (23.75 mm Hg). Find the saturated vapour pressure of a 5% aqueous solution of urea (carbamide) at the same temperature. (Molar mass of urea = 60.05 g mol<sup>-1</sup>)

[CBSE (F) 2012]

**Ans.**

$$W_B = 5 \text{ g}, W_A = 95 \text{ g}, M_B = 60.05 \text{ g mol}^{-1}, M_A = 18 \text{ g mol}^{-1}, P_A^0 = 3.165 \text{ kPa}$$

Substituting the values in the expression

$$\frac{P_A^0 - p}{P_A^0} = \frac{W_B \times M_A}{M_B \times W_A}, \text{ we get}$$

$$\frac{3.165 \text{ kPa} - p}{3.165 \text{ kPa}} = \frac{5 \text{ g} \times 18 \text{ g mol}^{-1}}{60.05 \text{ g mol}^{-1} \times 95 \text{ g}} = 0.015$$

$$p = 3.165 \text{ kPa} - 0.015 \times 3.165 \text{ kPa}$$

$$p = 3.118 \text{ kPa}$$

**Q.3.** Calculate the freezing point of a solution when 3 g of CaCl<sub>2</sub> (M = 111 g mol<sup>-1</sup>) was dissolved in 100 g of water, assuming CaCl<sub>2</sub> undergoes complete ionisation. (*K<sub>f</sub>* for water = 1.86 K kg mol<sup>-1</sup>)

[CBSE East 2016]

**Ans.**

Here,  $W_B = 3 \text{ g}$ ,  $i = \frac{3}{1} = 3$  ( $\text{CaCl}_2 \rightarrow \text{Ca}^{2+} + 2 \text{Cl}^-$ ),  $W_A = 100 \text{ g}$ ,  $K_f = 1.86 \text{ K kg mol}^{-1}$ ,  $M_B = 111 \text{ g mol}^{-1}$

Substituting these values in the expression,

$$\Delta T_f = \frac{i \times K_f \times W_B \times 1000}{M_B \times W_A}, \text{ we get}$$

$$\Delta T_f = \frac{3 \times 1.86 \text{ K kg mol}^{-1} \times 3 \text{ g} \times 1000 \text{ g kg}^{-1}}{111 \text{ g mol}^{-1} \times 100 \text{ g}} = 1.508 \text{ K}$$

Freezing point of solution,

$$T_f = T_f^0 - \Delta T_f$$

$$= 273.15 \text{ K} - 1.508 \text{ K} = 271.642 \text{ K}$$

**Q.4. 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<sup>-1</sup>, K<sub>f</sub> for benzene = 4.9 K kg mol<sup>-1</sup>)**

**[CBSE Delhi 2015]**

**Ans.**

The given quantities are

$$W_B = 3.9 \text{ g}, W_A = 49 \text{ g}, \Delta T_f = 1.62 \text{ K}, M_B = 122 \text{ g mol}^{-1} \text{ and } K_f = 4.9 \text{ K kg mol}^{-1}$$

Substituting these values in the equation,  $M_B = \frac{K_f \times W_B \times 1000}{\Delta T_f \times W_A}$ , we get

$$M_B = \frac{4.9 \text{ K kg mol}^{-1} \times 3.9 \text{ g} \times 1000 \text{ g kg}^{-1}}{1.62 \text{ K} \times 49 \text{ g}}$$

$$M_B = 240.74 \text{ g mol}^{-1}$$

Thus, observed molecular mass of benzoic acid in benzene = 240.74 g mol<sup>-1</sup>

Normal molecular mass of benzoic acid = 122 g mol<sup>-1</sup>

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

$$i = \frac{122 \text{ g mol}^{-1}}{240.74 \text{ g mol}^{-1}} = 0.506$$

As  $i < 1$ , therefore, benzoic acid will undergo association in benzene.

**Q.5. A solution of glucose (Molar mass =  $180 \text{ g mol}^{-1}$ ) in water has a boiling point of  $100.20^\circ\text{C}$ . Calculate the freezing point of the same solution. Molal constants for water  $K_f$  and  $K_b$  are  $1.86 \text{ K kg mol}^{-1}$  and  $0.512 \text{ K kg mol}^{-1}$  respectively.**

[CBSE (F) 2017]

**Ans.**

$$\Delta T_b = 100.20^\circ\text{C} - 100^\circ\text{C} = 0.20^\circ\text{C} \text{ or } 0.20\text{K}$$

$$\Delta T_b = K_b \cdot m \quad \Rightarrow m = \Delta T_b / K_b$$

$$\Delta T_f = K_f m, \quad \Delta T_f = 1.86 \text{ K kg mol}^{-1} \times 0.39 \text{ mol kg}^{-1} = 0.725 \text{ K}$$

$$T_f = T_f^0 - \Delta T_f = 273.15 \text{ K} - 0.725 \text{ K} = 272.425 \text{ K}$$

**Q.6. Calculate the boiling point of solution when 2 g of  $\text{Na}_2\text{SO}_4$  ( $M = 142 \text{ g mol}^{-1}$ ) was dissolved in 50 g of water, assuming  $\text{Na}_2\text{SO}_4$  undergoes complete ionisation.**

( $K_b$  for water =  $0.52 \text{ K kg mol}^{-1}$ )

[CBSE North 2016]

**Ans.**

$$i = \frac{3}{1} = 3 \quad (\text{Na}_2\text{SO}_4 \rightarrow 2\text{Na}^+ + \text{SO}_4^{2-})$$

$$\text{Given, } W_B = 2 \text{ g, } W_A = 50 \text{ g, } M_B = 142 \text{ g mol}^{-1}, K_b = 0.52 \text{ K kg mol}^{-1}$$

$$\text{Substituting the values in the expression, } \Delta T_b = \frac{i \times K_b \times W_B \times 1000}{M_B \times W_A}$$

$$\Delta T_b = \frac{3 \times 0.52 \text{ K kg mol}^{-1} \times 2 \text{ g} \times 1000 \text{ g kg}^{-1}}{142 \text{ g mol}^{-1} \times 50 \text{ g}} = 0.439 \text{ K}$$

$$\text{So, boiling point of solution, } T_b = T_b^0 + \Delta T_b$$

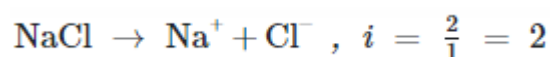
$$= 373.15 \text{ K} + 0.439 \text{ K} = 373.589 \text{ K}$$

**Q.7. Calculate the mass of NaCl (molar mass = 58.5 g mol<sup>-1</sup>) to be dissolved in 37.2 g of water to lower the freezing point by 2°C, assuming that NaCl undergoes complete dissociation.**

**(K<sub>f</sub> for water = 1.86 K kg mol<sup>-1</sup>)**

**[CBSE (F) 2015]**

**Ans.**



Substituting K<sub>f</sub> = 1.86 K kg mol<sup>-1</sup>, W<sub>A</sub> = 37.2 g, M<sub>B</sub> = 58.5 g mol<sup>-1</sup>, i = 2, ΔT<sub>f</sub> = 2°C or 2 K in the equation,

$$W_B = \frac{\Delta T_f \times M_B \times W_A}{i \times K_f \times 1000} , \text{ we get}$$

$$W_B = \frac{2\text{K} \times 58.5 \text{ g mol}^{-1} \times 37.2 \text{ g}}{12 \times 1.86 \text{ K kg mol}^{-1} \times 1000 \text{ g kg}^{-1}} = 1.17 \text{ g}$$

### Short Answer Questions-II (OIQ)

**Q.1 Which aqueous solution has higher concentration—1 molar or 1 molal solution of the same solute? Give reason.**

**[HOTS]**

**Ans.** Here density determines the relative concentrations of the solutions.

**Case (i):** When density of solvent is 1 g/mL: In aqueous solution, density of water is normally taken as 1. This means that 1 m solution has 1 mole of the solute dissolved in 1000 g or 1000 mL of the solvent. At the same time 1 M solution contains 1 mole of the solute in 1000 mL solution, which is the volume of both the solute and solvent present in the solution. This clearly shows that the solvent present in 1 M solution is less as compared to 1 m solution. Therefore, 1 M solution is more concentrated than 1 m solution.

**Case (ii):** When density of the solvent is less than 1 g/mL: This means that the volume of solvent (mass/density) will be more as compared to its mass. Thus, 1 M solution will be less concentrated than 1 m solution.

**Case (iii):** When density of the solvent is more than 1 g/mL: This means that the volume of solvent will be less than its mass. Under these circumstances, 1 M solution will be more concentrated than 1 m solution.

**Q.2. Calculate the boiling point of a 1 M aqueous solution (density 1.04 g mL<sup>-1</sup>) of potassium chloride**

( $K_b$  for water = 0.52 K kg mol<sup>-1</sup>, Atomic masses: K = 39 u, Cl = 35.5 u)

Assume, potassium chloride is completely dissociated in solution.

[CBSE Sample Paper 2016]

**Ans.** Mass of solution = Density of solution × Volume of solution

$$= 1.04 \text{ g mL}^{-1} \times 1000 \text{ mL} = 1040 \text{ g}$$

Molar mass of solute KCl,  $M_B = 39 + 35.5 = 74.5 \text{ g mol}^{-1}$

∴ Mass of solvent water,  $W_A = 1040 \text{ g} - 74.5 \text{ g} = 965.5 \text{ g}$

As KCl dissociates ( $\text{KCl} \rightarrow \text{K}^+ + \text{Cl}^-$ ) completely,  $i = \frac{2}{1} = 2$

For water,  $K_b = 0.52 \text{ K kg mol}^{-1}$ ,  $W_B = 74.5 \text{ g}$

Substituting these values in the expression  $\Delta T_b = \frac{i \times K_b \times W_B \times 1000}{M_B \times W_A}$ , we get

$$\Delta T_b = \frac{2 \times 0.52 \text{ K kg mol}^{-1} \times 74.5 \text{ g} \times 1000 \text{ g kg}^{-1}}{74.5 \text{ g mol}^{-1} \times 965.5 \text{ g}}$$

$$= 1.077 \text{ K}$$

Boiling point of solution,  $T_b = T_b^0 + \Delta T_b$

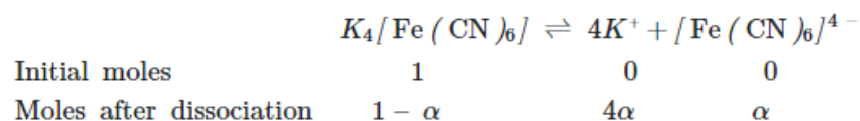
$$= 373.15 \text{ K} + 1.077 \text{ K}$$

$$= 374.227 \text{ K}$$

**Q.3. A decimolar solution of potassium ferrocyanide is 50% dissociated at 300 K. Calculate the osmotic pressure of the solution. ( $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ ).**

**Ans.**

Here,  $\alpha = 0.5$



Total moles of particles =  $1 - \alpha + 4\alpha + \alpha = 1 + 4\alpha$

$\therefore$  van't Hoff factor,  $i = \frac{1 + 4\alpha}{1}$

$$= 1 + 4 \times 0.5 = 3$$

Osmotic pressure,  $\pi = iCRT$

$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ , i.e., it is in SI units.

$$C = 0.1 \text{ M} = \frac{0.1}{10^{-3}} \text{ mol m}^{-3} = 10^2 \text{ mol m}^{-3}$$

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

$n$  = number of particles after dissociation

$$\frac{50}{100} = \frac{i - 1}{5 - 1}$$
$$i = 3$$

Hence, 
$$\pi = 3 \times 10^2 \times 8.314 \times 300$$

$$= 7.483 \times 10^5 \text{ Nm}^{-2}$$

$$= 7.483 \text{ atm}$$

**Q.4.** At 300 K, 36 g of glucose,  $C_6H_{12}O_6$  present per litre in its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of another glucose solution is 1.52 bar at the same temperature, calculate the concentration of the other solution.

[CBSE Sample Paper 2017]

Ans.

$$\pi = \frac{W_B \times R \times T}{M_B \times V} = CRT$$

$$4.98 = \frac{36 \times R \times 300}{180 \times 1} = 60R \quad \dots (i)$$

$$1.52 = C \times R \times 300 = 300CR \quad \dots (ii)$$



Dividing equation (ii) by (i), we get

$$\frac{300 CR}{60R} = \frac{1.52}{4.98}$$

$$\mathbf{C = 0.061 M}$$

## Long Answer Questions

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### Long Answer Questions (PYQ)

**Q.1. Define the following terms:**

**Q. Define the following terms:**

- a. Azeotrope
- b. Osmotic pressure
- c. Colligative properties

**Ans. (a)** The binary mixtures of liquids having same composition in liquid and vapour phase and boil at a constant temperature are called azeotropes.

**(b)** The excess of pressure which must be applied to the solution side to prevent the passage of solvent into it through a semipermeable membrane is called osmotic pressure.

**(c)** The properties of solutions which depend only on the number of solute particles in the solution but independent of their nature are called colligative properties.

**Q. Calculate the molarity of 9.8% (w/w) solution of  $\text{H}_2\text{SO}_4$  if the density of the solution is  $1.02 \text{ g mL}^{-1}$ .**

**(Molar mass of  $\text{H}_2\text{SO}_4 = 98 \text{ g mol}^{-1}$ )**

**[CBSE (F) 2014]**

**Ans.**

Let the mass of solution = 100 g

$\therefore$  Mass of  $\text{H}_2\text{SO}_4 = 9.8 \text{ g}$

Number of mole of  $\text{H}_2\text{SO}_4 = \frac{\text{Mass of } \text{H}_2\text{SO}_4}{\text{Molar Mass}}$

$= \frac{9.8 \text{ g}}{98 \text{ g mol}^{-1}} = 0.1 \text{ mol}$

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

$$= \frac{100 \text{ g}}{1.02 \text{ g mL}^{-1}} = \frac{100}{1.02} \text{ mL}$$

$$= \frac{100}{1.02} \text{ mL} \times \frac{1}{1000 \text{ mL L}^{-1}}$$

$$= \frac{1}{10.2} \text{ L}$$

$$\text{Molarity} = \frac{\text{Moles of solute, } H_2SO_4}{\text{Volume of solution (in L)}}$$

$$= \frac{0.1 \text{ mol}}{\frac{1 \text{ L}}{10.2}} = 1.02 \text{ mol L}^{-1} \text{ or } 1.02 \text{ M}]$$

**Q.2. Answer the following question :**

**Q. When 2.56 g of sulphur was dissolved in 100 g of CS<sub>2</sub>, the freezing point lowered by 0.383 K. Calculate the formula of sulphur (S<sub>x</sub>).**

**[K<sub>f</sub> for CS<sub>2</sub> = 3.83 K kg mol<sup>-1</sup>, Atomic mass of Sulphur = 32 g mol<sup>-1</sup>]**

**Ans.**

Here,  $W_B = 2.56 \text{ g}$ ,  $W_A = 100 \text{ g}$ ,  $\Delta T_f = 0.383 \text{ K}$

$$K_f = 3.83 \text{ K kg mol}^{-1}$$

Substituting these values in the expression, we get

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

$$M_B = \frac{3.83 \text{ K kg mol}^{-1} \times 2.56 \text{ g} \times 1000 \text{ g kg}^{-1}}{100 \text{ g} \times 0.383 \text{ K}} = 256 \text{ g mol}^{-1}$$

Now, molecular mass of S<sub>x</sub> =  $x \times 32 = 256$

$$x = \frac{256}{32} = 8$$

Therefore, formula of sulphur = S<sub>8</sub>

**Q. Blood cells are isotonic with 0.9 % sodium chloride solution. What happens if we place blood cells in a solution containing**

- a. 1.2% sodium chloride solution?
- b. 0.4% sodium chloride solution?

[CBSE Delhi 2016]

**Ans. (a)** Water will flow out of the cell and they would shrink.

**(b)** Water will flow into the cell and they would swell.

**Q.3. Answer the following question :**

**Q. Define the following terms:**

- a. Molarity
- b. Molal elevation constant ( $K_b$ )

**Ans. (a)** Molarity may be defined as number of moles of solute dissolved in one litre of solution.

$$\text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution (in litre)}}$$

**(b)** Molal elevation constant may be defined as the elevation in boiling point when one mole of solute is dissolved in 1000 grams of the solvent.

**Q. A solution containing 15 g urea (molar mass = 60 g mol<sup>-1</sup>) per litre of solution in water has the same osmotic pressure (isotonic) as a solution of glucose (molar mass = 180 g mol<sup>-1</sup>) in water. Calculate the mass of glucose present in one litre of its solution.**

[CBSE (AI) 2014]

**Ans.**

$$\text{Osmotic pressure, } \pi = \frac{W_B \times R \times T}{M_B \times V}$$

$$\text{Osmotic pressure of urea solution} = \frac{15 \times R \times T}{60 \times 1}$$

$$\text{Osmotic pressure of glucose solution} = \frac{W_B \times R \times T}{180 \times 1}$$

As, Osmotic pressure of urea solution = Osmotic pressure of glucose solution

$$\text{Therefore, } \frac{15 \times R \times T}{60 \times 1} = \frac{W_B \times R \times T}{180 \times 1}$$

$$\text{Mass of glucose, } W_B = \frac{15 \times 180}{60} = 45 \text{ g}$$

**Q.4. Answer the following question :**

**Q. Non-ideal solutions exhibit either positive or negative deviations from Raoult's law. What are these deviations and how are they caused?**

**Ans. Positive deviation from Raoult's law:** When the partial vapour pressure of each component (A and B) consequently the total vapour pressure is greater than the pressure expected on the basis of Raoult's law then the deviation is termed as positive deviation.

**Cause of positive deviation:** This type of deviation is observed by solution in which the forces of attraction between A–A molecules and between B–B molecules is greater than the forces of attraction between A–B molecules.

$$\gamma_{A-B} < \gamma_{A-A} \quad \text{OR} \quad \gamma_{B-B}$$

**Negative deviation from Raoult's law:** When the partial vapour pressure of each component of solution is less than the vapour pressure expected on the basis of Raoult's law then the deviation is called as negative deviation.

**Causes of negative deviation:** This type of deviation is shown by solutions in which the forces of attraction between A–A and B–B molecules is less than the forces of attraction between A and B molecules.

$$\gamma_{A-B} > \gamma_{A-A} \quad \text{OR} \quad \gamma_{B-B}$$

**Q. What mass of NaCl (molar mass = 58.5 g mol<sup>-1</sup>) must be dissolved in 65g of water to lower the freezing point by 7.50°C? The freezing point depression constant,  $K_f$  for water is 1.86 K kg mol<sup>-1</sup>. Assume van't Hoff factor for NaCl is 1.87.**

**[CBSE (F) 2010]**

**Ans.**

$$\text{Given: } M_B = 58.5 \text{ g mol}^{-1}$$

$$W_A = 65 \text{ g, } W_B = ?,$$

$$\Delta T_f = 7.5^\circ\text{C or } 7.5 \text{ K,}$$

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

$$i = 1.87$$

We know that,  $\Delta T_f = iK_f \times \frac{W_B}{M_B} \times \frac{1000}{W_A}$

$$\Rightarrow 7.5 = 1.87 \times 1.86 \times \frac{W_B}{58.5} \times \frac{1000}{65} = 8.199 \text{ g}$$

$$W_B = \frac{7.5 \times 58.5 \times 65}{1.87 \times 1.86 \times 1000} = 8.199 \text{ g}$$

**Q.5. Answer the following question :**

**Q. Explain why on addition of 1 mol glucose to 1 litre water the boiling point of water increases.**

**Ans.** On addition of glucose, a non-volatile solute to water (a volatile solvent) the vapour pressure of water decreases. In order to make the solution boil, its vapour pressure must be increased by raising the temperature above the boiling point of pure water. In other words, there is an increase in the boiling point of water.

**Q. Henry's law constant for CO<sub>2</sub> in water is  $1.67 \times 10^8$  Pa at 298 K. Calculate the number of moles of CO<sub>2</sub> in 500 ml of soda water when packed under  $2.53 \times 10^5$  Pa at the same temperature.**

[CBSE (AI) 2017C]

**Ans.**

According to Henry's law,  $P_{\text{CO}_2} = K_H \times x_{\text{CO}_2}$  or  $x_{\text{CO}_2} = \frac{P_{\text{CO}_2}}{K_H}$

$$\therefore x_{\text{CO}_2} = \frac{2.53 \times 10^5 \text{ Pa}}{1.67 \times 10^8 \text{ Pa}} = 1.51 \times 10^{-3}$$

Mass of water = Density of water  $\times$  volume of water

$$= 1 \text{ g mL}^{-1} \times 500 \text{ mL} = 500 \text{ g}$$

$$\text{Moles of water, } n = \frac{\text{Mass of water}}{\text{Molar mass}} = \frac{500 \text{ g}}{18 \text{ g mol}^{-1}} = 27.78 \text{ mol}$$

$$x_{\text{CO}_2} = \frac{n_{\text{CO}_2}}{n_{\text{H}_2\text{O}} + n_{\text{CO}_2}} = \frac{n_{\text{CO}_2}}{n_{\text{H}_2\text{O}}} \text{ or } n_{\text{CO}_2} = x_{\text{CO}_2} \times n_{\text{H}_2\text{O}}$$

$$n_{\text{CO}_2} = 1.51 \times 10^{-3} \times 27.78 \text{ mol} = 0.042 \text{ mol}$$

## Long Answer Questions (OIQ)

**Q.1. Discuss biological and industrial importance of osmosis.**

[NCERT Exemplar]

**Ans.** (i) The process of osmosis is of great biological and industrial importance as is evident from the following examples:

(ii) Movement of water from soil into plant roots and subsequently into upper portion of the plant occurs partly due to osmosis.

(iii) Preservation of meat against bacterial action by adding salt.

(iv) Preservation of fruits against bacterial action by adding sugar. Bacterium in canned fruit loses water through the process of osmosis, shrivels and dies.

(v) Reverse osmosis is used for desalination of water.

**Q.2. Answer the following question :**

**Q. Calculate the molality of a sulphuric acid solution in which the mole fraction of water is 0.85.**

**Ans.**

$$\frac{n_A}{n_A + n_B} = 0.85 \quad \dots (i)$$

$$\therefore \frac{n_B}{n_A + n_B} = 1 - 0.85 = 0.15 \quad \dots (ii)$$

Dividing (ii) by (i), we get

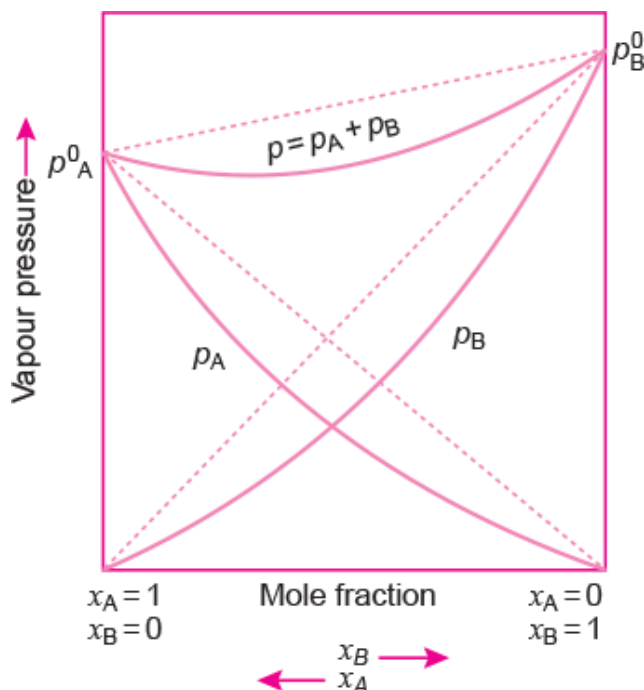
$$\frac{n_B}{n_A} = \frac{0.15}{0.85} \quad \text{or} \quad \frac{n_B}{1000/18} = \frac{0.15}{0.85}$$

$$\text{or} \quad n_B = \frac{0.15}{0.85} \times \frac{1000}{18} = 9.8 \text{ mol}$$

Hence, molality = **9.8 m**

**Q. The graphical representation of vapour pressures of two component system as a function of composition is given alongside. By graphic inspection, answer the following questions:**

- Are the A–B interactions weaker, stronger or of the same magnitude as A–A and B–B?
- Name the type of deviation shown by this system from Raoult's law.
- Predict the sign of  $\Delta_{\text{mix}}H$  for this system.
- Predict the sign of  $\Delta_{\text{mix}}V$  for this system.
- Give an example of such a system.
- What type of azeotrope will this system form, if possible?



Ans.

- Stronger
- Negative deviation
- ve
- ve
- A liquid mixture consisting of 20% acetone and 80% chloroform by mass.
- Maximum boiling azeotrope.

Q.3. Answer the following question :

Q. What is the freezing point of 0.4 molal solution of acetic acid in benzene in which it dimerises to the extent of 85%? Freezing point of benzene is 278.4 K and its molar heat of fusion is  $10.042 \text{ kJ mol}^{-1}$ .

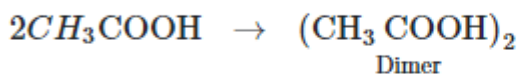
Ans.



Given,  $M = 78 \text{ g mol}^{-1}$ ,  $T_f^0 = 278.4 \text{ K}$ ,  $\Delta_{\text{fus}} H = 10.042 \text{ kJ mol}^{-1}$

$$K_f = \frac{R(T_f^0)^2 M}{1000 \times \Delta_{\text{fus}} H}$$

$$K_f = \frac{8.314 \times 10^{-3} \times (278.4)^2 \times 78}{1000 \times 10.042} = 5.0 \text{ K kg mol}^{-1}$$



$$\alpha = \frac{i-1}{\frac{1}{n}-1} \Rightarrow 0.85 = \frac{i-1}{\frac{1}{2}-1}$$

or  $i = 1 - 0.425 = 0.575$

$$\Delta T_f = iK_f m$$

$$= 0.575 \times 5 \times 0.4 = 1.15 \text{ K}$$

$$T_f = T_f^0 - \Delta T_f$$

$$= 278.4 \text{ K} - 1.15 \text{ K} = 277.25 \text{ K}$$

**Q. Explain the following:**

- Solution of chloroform and acetone is an example of maximum boiling azeotrope.**
- A doctor advised a person suffering from high blood pressure to take less quantity of common salt.**

**Ans.**

- This solution has lesser vapour pressure due to stronger interactions (hydrogen bonds) between chloroform and acetone molecules.
- Because higher quantity of NaCl will increase number of sodium and chloride ions in the body fluid which can increase the osmotic pressure of body fluid, i.e., blood pressure of a person.

**Q.4. Answer the following question :**

**Q. Why a person suffering from high blood pressure is advised to take minimum quantity of common salt?**

**Ans.** Osmotic pressure is directly proportional to the concentration of the solutes. Our body fluid contains a number of solutes. On taking large amount of common salt, Na<sup>+</sup> and Cl<sup>-</sup> ions enter into the body fluid thereby raising the concentration of the solutes. As a result, osmotic pressure increases which may rupture the blood cells.

**Q.** g of benzoic acid (C<sub>6</sub>H<sub>5</sub>COOH) dissolved in 25 g of benzene shows a depression in freezing point equal to 1.62 K. Molal depression constant for benzene is 4.9 K kg mol<sup>-1</sup>. What is the percentage association of acid if it forms dimer in solution?

**Ans.**

The given quantities are

$$W_B = 2 \text{ g}, W_A = 25 \text{ g}, \Delta T_f = 1.62 \text{ K}, K_f = 4.9 \text{ K kg mol}^{-1}$$

Substituting these values in equation  $M_B = \frac{K_f \times W_B \times 1000}{\Delta T_f \times W_A}$ , we get

$$M_B = \frac{4.9 \text{ K kg mol}^{-1} \times 2 \text{ g} \times 1000 \text{ g kg}^{-1}}{1.62 \text{ K} \times 25 \text{ g}} = 241.98 \text{ g mol}^{-1}$$

Thus, observed molecular mass of benzoic acid in benzene = 241.98 g mol<sup>-1</sup>

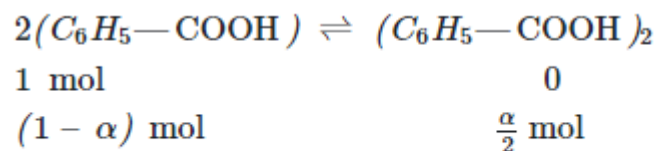
Normal molecular mass of C<sub>6</sub>H<sub>5</sub>COOH = 122 g mol<sup>-1</sup>

$$\therefore i = \frac{\text{Normal molecular mass}}{\text{Observed molecular mass}} = \frac{122 \text{ g mol}^{-1}}{241.98 \text{ g mol}^{-1}} = 0.504$$

$$i = 0.504 \quad \dots (i)$$

If  $\alpha$  represents the degree of association of solute then we would have  $(1 - \alpha)$  mole of benzoic acid left in unassociated form and corresponding  $\frac{\alpha}{2}$  as associated moles of benzoic acid at equilibrium.

**Now, consider the following equilibrium for the acid:**



Thus, total number of moles of particles at equilibrium

$$= 1 - \alpha + \frac{\alpha}{2} = 1 - \frac{\alpha}{2}$$

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

$$i = \frac{1 - \frac{\alpha}{2}}{1} = 1 - \frac{\alpha}{2} \quad \dots (ii)$$

From (i) and (ii), we have

$$0.504 = 1 - \frac{\alpha}{2}$$

$$\frac{\alpha}{2} = 1 - 0.504 = 0.496$$

$$\text{or } \alpha = 0.496 \times 2 = 0.992$$

Therefore, degree of association of benzoic acid in benzene is **99.2%**.

**Q. 5 . Answer the following question :**

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

- a. At higher altitudes, people suffer from a disease called anoxia. In this disease, they become weak and cannot think clearly.**
- b. When mercuric iodide is added to an aqueous solution of KI, the freezing point is raised.**

**Ans.**

- a. At higher altitudes, partial pressure of oxygen is less than that at ground level, so that oxygen concentration becomes less in blood or tissues. Hence, people suffer from anoxia.**
- b. Due to the formation of complex  $K_2[HgI_4]$ , number of particles in the solution decreases and hence the freezing point is raised.**

**Q. 0.6 mL of acetic acid ( $CH_3COOH$ ), having density  $1.06 \text{ g mL}^{-1}$ , is dissolved in 1 litre of water. The depression in freezing point observed for this strength of acid was  $0.0205^\circ\text{C}$ . Calculate the van't Hoff factor and the dissociation constant of acid.**

**Ans.**

Mass = Density  $\times$  Volume

$$\therefore \text{Mass of acetic acid} = 1.06 \text{ g mL}^{-1} \times 0.6 \text{ mL} = 0.636 \text{ g}$$

$$\text{Number of moles of acetic acid} = \frac{\text{Mass of acetic acid}}{\text{Molar mass}}$$

$$= \frac{0.636 \text{ g}}{60 \text{ g mol}^{-1}} = 0.0106 \text{ mol}$$

$$\text{Mass of water} = 1 \text{ g mL}^{-1} \times 1000 \text{ mL} = 100 \text{ g}$$

$$\text{Molality} = \frac{\text{Number of moles of acetic acid}}{\text{Mass of water in grams}} \times 1000$$

$$= \frac{0.0106}{1000} \times 1000 = 0.0106 \text{ mol kg}^{-1}$$

$$\Delta T_f = K_f \cdot m$$

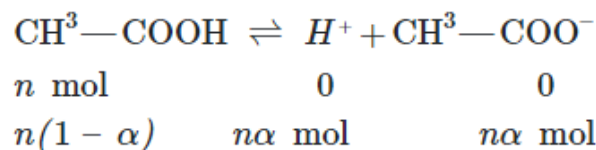
$$= 1.86 \text{ K kg mol}^{-1} \times 0.0106 \text{ mol kg}^{-1}$$

$$= 0.0197 \text{ K}$$

$$\text{van't Hoff Factor } (i) = \frac{\text{Observed freezing point}}{\text{Calculated freezing point}} = \frac{0.0205 \text{ K}}{0.0197 \text{ K}}$$

$$i = 1.041 \quad \dots (i)$$

If  $\alpha$  is the degree of dissociation of acetic acid, then we would have  $n(1 - \alpha)$  moles of undissociated acid,  $n\alpha$  moles of  $\text{CH}_3\text{COO}^-$  and  $n\alpha$  moles of  $\text{H}^+$  ions at equilibrium.



$$\text{Thus total moles of particles} = n - n\alpha + n\alpha + n\alpha = n(1 + \alpha)$$

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

$$i = \frac{n(1 + \alpha)}{n} = 1 + \alpha \quad \dots (ii)$$

From (i) and (ii), we have

$$1.041 = 1 + \alpha \Rightarrow \alpha = 1.041 - 1 = 0.041$$

$$K_a = \frac{[\text{CH}_3 - \text{COO}^-] [\text{H}^+]}{[\text{CH}_3 - \text{COOH}]}$$

$$[\text{CH}_3 - \text{COOH}] = n(1 - \alpha) = 0.0106 (1 - 0.041)$$

$$= 0.0106 \times 0.959$$

$$[\text{H}^+] = n\alpha = 0.0106 \times 0.041;$$

$$[\text{CH}_3 - \text{COO}^-] = n\alpha = 0.0106 \times 0.041$$

$$\therefore K_a = \frac{0.0106 \times 0.041 \times 0.0106 \times 0.041}{0.0106 \times 0.959}$$

$$= 1.86 \times 10^{-5}$$