

EXERCISE

Q.1 Chose the correct answer for the given ones:

- (i) Molarity of pure water is:
- (a) 1 (b) 18
(c) 55.5 (d) 6
- (ii) 18 g glucose is dissolved in 90 g of water. The relative lowering of vapour pressure is equal to:
- (a) $\frac{1}{5}$ (b) 5.1
(c) $\frac{1}{51}$ (d) 6
- (iii) A solution of glucose is 10 percent. The volume in which 1 g mole of it is dissolved will be:
- (a) 1 dm^3 (b) 1.8 dm^3
(c) 200 Cm^3 (d) 900 Cm^3
- (iv) An aqueous solution of ethanol in water may have vapour pressure:
- (a) Equal to that of water (b) Equal to that of ethanol
(c) More than that of water (d) Less than that of water
- (v) An azeotropic mixture of two liquids boils at a lower temperature than either of them when:
- (a) It is saturated
(b) It shows positive deviation from Raoult's law
(c) It shows negative deviation from Raoult's law
(d) It is metastable.
- (vi) An azeotropic mixture showing positive deviation from Raoult's law, the volume of the mixture is:
- (a) Slightly more than the total volume of the components
(b) Slightly less than the total volume of the components
(c) Equal to the total volume of the components
(d) None of these



- (vii) Which of the following solutions has the highest boiling point:
- 5.85 percent solution of sodium chloride
 - 18.0 percent solution of glucose
 - 6.0 percent solution of urea
 - All have the same boiling point
- (viii) Two solutions of NaCl and KCl are prepared separately by dissolving same amount of the solute in water. Which of the following statements is true for these solutions:
- KCl solution will have higher boiling point than NaCl solution
 - Both of the solutions have different boiling points
 - KCl and NaCl solution possess same vapour pressure
 - KCl solution possesses lower freezing point than NaCl solution
- (ix) The molal boiling constant is the ratio of the elevation in boiling point to:
- Molarity
 - Molality
 - Mole fraction of solvent
 - Mole fraction of solute
- (x) Colligative properties are the properties of:
- Dilute solution which behave as nearly ideal solutions
 - Concentrated solutions which behave as nearly non-ideal solutions
 - Both (a) and (b)
 - Neither (a) nor (b)

ANSWERS

Answers	Reasons
(i) (c)	Molarity is the number of moles per litre (1 dm^3). And density of water is g/cm^3 $1 \text{ g} = 1 \text{ cm}^3$ $1000 \text{ g} = 1000 \text{ cm}^3 = 1 \text{ dm}^3$ The mass of 1 dm^3 is 1000 g. We can calculate the no. of moles in 1000 g (1 dm^3) of pure water $n = \frac{m}{M} = \frac{1000}{18} = 55.5 \text{ moles}$



- (ii) (b) The relative lowering of vapour pressure is equal to mole fraction of solute
- $$\frac{\Delta P}{P^0} = x_2$$
- Mole fraction of solute (x_2) can be calculated by knowing the no. of moles of solute and solvent. No. of moles of glucose in 18 g = $\frac{18}{180} = \frac{1}{10} = 0.1$ moles.
- No. of moles of water in 90 g = $\frac{90}{18} = 5$ moles. Hence, mole fraction of solute (x_2) is the ratio of no. of moles of solute to the total no. of moles
- $$x_2 = \frac{0.1}{0.1 + 5} = \frac{0.1}{5.1} = \frac{1}{51}$$
- and $\boxed{\frac{\Delta P}{P^0} = \frac{1}{51}}$
- (iii) (b) 10% w/v glucose solution means
 10 g of glucose = 100 cm³ of solution
 1 g of glucose = $\frac{100}{10}$ cm³ of solution
 and 180 g (1 g mole) of glucose = $\frac{100}{10} \times 180$ cm³ of solution
 = 1800 cm³
 = 1.8 dm³ of solution
 (1 dm³ = 1000 cm³)
- Hence, the volume of solution in which 1 g mole (180 g) of glucose is present is 1800 cm³ (1.8 dm³)
- (iv) (c) The solution ethanol in water shows positive deviation from Raoult's Law. It means that vapour pressure of solution is greater and boiling point is lesser than either of the two component.
- Boiling point of water = 100°C
 Boiling point of ethanol = 78.5°C
 Boiling point of solution = 78.1°C
- (v) (b) An azeotropic mixture of two liquids that boils at lower temperature than either of them, then its vapour pressure is higher than either of them. And a solution whose vapour pressure is greater than either of two components.
- (vi) (a) When azeotropic mixture shows positive deviation from Raoult's law, then its vapour pressure is greater than either of the two components. Increase of vapour pressure is only possible when there is decrease of intermolecular force between solute and solvent molecules. The decrease of forces leads to increase of volume of two components.



- (vii) (a) 5.85% NaCl solution means 5.85 g (0.1 mole) of NaCl in 100 g of solution.
18.0% glucose solution means 1.8 g (0.1 mole) of glucose in 100 g of solution.
6.0% urea solution means 6 g (0.1 mole) of urea 100 g of solution.
- All the solutions contains 0.1 moles of respective species per 100 g of solution. 0.1 moles of both glucose and urea produces 6.02×10^{23} particles in solution whereas 0.1 moles of NaCl produces $2 \times 6.02 \times 10^{23}$ particles in solution because NaCl ionizes and produces twice the no. of ions than formula. Unit 5.85% NaCl solution will have highest boiling point than other two species because it contain twice no. of particles than other two.
- (viii) (b) The molar mass of NaCl is 58.5 g/mole and that of KCl is 74.5 g/mole. 1 formula unit of both the species produces two ions in the solution. If we consider the same amount (mass) i.e., 58.5 g of both the species, then 58.5 g of NaCl (equal to its 1 mole) produces twice the Avogadro's number of particles (ions). Whereas 58.5 g KCl (less than its one mole) produce less than twice the N_A of ions. Hence, the 58.5 g of NaCl solution containing greater number of particles (ions) have higher boiling point than KCl solution. In other words, both have different boiling point.
- Note: (For this case only)
1. The boiling point of NaCl solution is higher and its freezing point is lesser than KCl solution.
 2. The vapour pressure of NaCl solution is lower than KCl solution.
- (ix) (b) The boiling point elevation of a solution is directly proportional to molality of the solution.
- $$\Delta T_b \propto m$$
- $$\Delta T_b = K_b m$$
- $$K_b = \frac{\Delta T_b}{m}$$
- Hence, molal boiling point constant is the ratio of boiling point elevation to molality of the solution.
- (x) (a) Dilute solutions are usually ideal. Colligative properties are the properties of dilute solutions. For concentrated solutions, there are large numbers of solute particles very close to each other. Due to which attraction starts and particles associate. As a result, no. of particles reduces and effect on the property is also less. Hence concentrated solution do not behave ideally.



Q.2 Fill in the blanks with suitable words:

- (i) Number of molecules of sugar in 1 dm^3 of 1 M sugar solution is _____.
- (ii) 100 g of a 10% aqueous solution of NaOH contains 10 g of NaOH in _____ g of water.
- (iii) When an azeotropic mixture is distilled, it _____ remains constant.
- (iv) The molal freezing point constant is also known as _____ constant.
- (v) The boiling point of an azeotropic solution of two liquids is lower than either of them because the solution show _____ from Raoult's law.
- (vi) Among equimolal aqueous solutions of NaCl, BaCl_2 and FeCl_3 , the maximum depression in freezing point is shown by _____ solution.
- (vii) A solution of ethanol in water shows _____ deviation and show azeotropic solution with _____ boiling point than other components.
- (viii) Colligative properties are used to calculate _____ of compound.
- (ix) The hydration energy of Br^- ion is _____ than that of F^- ion.
- (x) The aqueous solution of NH_4Cl is _____ while that of Na_2SO_4 is _____.

ANSWERS

Answers	Explanation
(i) 6.02×10^{23}	1 dm^3 of 1M sugar solution contains 1 mole of sugar. And there 6.02×10^{23} molecules of sugar in the solution.
(ii) 90 g	10% NaOH solution means 10 g of NaOH and 90 g of water to make total 100 g of solution.
(iii) Composition	Azeotropic mixture (corresponding to specific composition distil without change in composition and have constant boiling point.
(iv) Cryoscopic	
(v) Positive deviation	When Azeotropic solution have boiling point less than either of the component, then its vapour pressure will be higher than either of two components and is said to show positive deviation from Raoult's law.
(vi) FeCl_3	Freezing point depression is a colligative property and depends upon number of solute particles. 1 molal solution of NaCl have twice the Avogadro's no. of ions, and 1 molal solution of BaCl_2 have thrice the Avogadro's no. of ions and 1 molal solution of FeCl_3 have, four times the Avogadro's no. of ions when dissolved in water. Amongst the equimolal. (1 molal) solutions of all the three species, FeCl_3 produced greatest no. of ions in the solution. Hence, it has maximum depression in freezing point.



(vii)	Less	Ethanol solution in water shows positive deviation i.e., have higher vapour pressure and low boiling point than component.
(viii)	Molar mass	Mathematical form at the end of each colligative property gives us basis for molar mass calculation of unknown compound e.g., mathematical equation for lowering of vapour pressure. $\frac{\Delta P}{P^\circ} = \frac{W_2}{M_2} \times \frac{M_1}{W_1}$ $M_2 = \frac{P^\circ}{\Delta P} \times \frac{W_2}{W_1} M_1$ M_2 is a molar mass of unknown compound.
(ix)	Lesser	The value of hydration energy depends upon charge to size ratio or charge density of ions. Greater the charge density, greater will be the Hydration energy. The charge on Br^- and F^- ion is same but the size of Br^- ion larger. Hence, Br^- ion will have low charge density and less hydration energy.
(x)	Acidic, neutral	NH_4Cl undergo hydrolytic reaction as $\text{NH}_4\text{Cl} + \text{H}_2\text{O} \longrightarrow \text{NH}_4\text{OH} + \text{H}^+ + \text{Cl}^-$ This produces weak base NH_4OH and Cl^- ion which is not hydrolysed. As a result H^+ ions are set free and solution becomes acidic. Na_2SO_4 ionizes as: $\text{Na}_2\text{SO}_4 + \text{H}_2\text{O} \rightleftharpoons 2\text{Na}^+ + \text{SO}_4^{2-} + \text{H}^+ + \text{OH}^-$ Na^+ ion and SO_4^{2-} are not hydrolysed by water. As a result, H^+ ion and OH^- concentration remains same and solution remains neutral.

Q.3 Indicate True or False from the given statement:

- (i) At a definite temperature the amount of solute in a given saturated solution is fixed.
- (ii) Polar solvents readily dissolve non-polar covalent compounds.
- (iii) The solubility of substance decreases with increases in temperature if the heat of solution in negative.
- (iv) The rate of evaporation of liquid is inversely proportional to the intermolecular forces of attraction.
- (v) The molecular mass of an electrolyte determined by lowering of vapour pressure is less than the theoretical molecular mass.

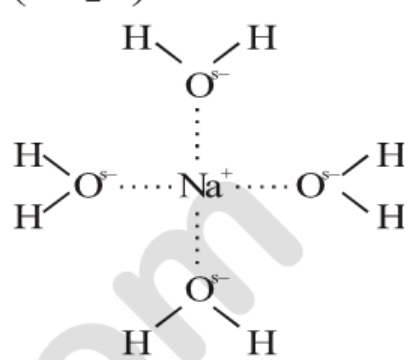


- (vi) Boiling point elevation is directly proportional to the molality of the solution and inversely proportional to boiling point of solvent.
- (vii) All solutions containing 1 g of non-volatile non-electrolyte solutes in same solvent will have same freezing point.
- (viii) The freezing point of a 0.05 molal solution of a non-volatile non-electrolyte solute in water is -0.93°C .
- (ix) Hydration and hydrolysis are different process for Na_2SO_4 .
- (x) The hydration energy of an ion only depends upon its charge.

ANSWERS

Answers	Explanation
(i) True	
(ii) False	Polar solvents readily dissolve polar covalent compounds.
(iii) True	The principle of dissolution is, like dissolve like i.e. Polar compounds are soluble in polar solvents whereas non-polar compounds are soluble in non-polar solvents. e.g., Sugar is soluble in water and I_2 is soluble in CCl_4 .
(iv) True	If the dissolution of a compound is exothermic (heat of solution is negative), then rise of temperature will favour its crystallization which is endothermic. Hence, solubility decreases.
(v) True	If intermolecular forces of attraction between the molecules of liquid are stronger, then there are less chances for the molecules to escape from the surface. Hence, evaporation and intermolecular forces are inversely proportional.
(vi) False	Boiling point elevation is directly proportional to molality of the solution and is independent of boiling point of solvent.
	$\Delta T_b \propto m$
	In this relationship, boiling point elevation has no relation with the boiling point of solvent.
(vii) False	All the solutions containing 1 g of non-volatile, non-electrolyte solutes in same solvent will have different freezing point.
	1g of all the electrolytes have different number of moles and molecules, since their molar masses are different.
	For example: 1 g of glucose will have moles = $\frac{1}{180}$
	and 1 g of sucrose will have moles = $\frac{1}{342}$
	Hence their no. of molecules will be different and freezing points also be different because it depends upon no. of solute particles.



(viii)	False	The freezing point of a 0.05 molal solution of a non-volatile and non-electrolyte solute in water is -0.093°C. The molal freezing point of non-electrolyte solute in water is -1.86°C. Mean: Freezing point of 1 molal solution = -1.86°C Freezing point of 0.1 molal solution = -0.186°C Freezing point of $0.05 \left(\frac{0.1}{2}\right)$ molal solution = $\left(-\frac{0.186}{2}\right) = -0.093^{\circ}\text{C}$
(ix)	True	Hydration is the surrounding of ions by water molecules with their oppositely charged ends whereas hydrolysis is the interaction of salt and water as a result of which salt dissociates in ions. $\text{Na}_2\text{SO}_4 \xrightleftharpoons{\text{H}_2\text{O}} 2\text{Na}^+ + \text{SO}_4^{-2}$ 
(x)	False	Hydration energy of an ion depends upon charge / size ratio (charge density) of ions. Greater the charge density of ion, greater will be its hydration energy.

Q.4 Define and explain the following with examples:

- | | |
|------------------------------------|------------------------------|
| (a) A homogeneous phase | (b) A concentrated solution |
| (c) A solution of solid in a solid | (d) A consolute temperature |
| (e) A non-ideal solution | (f) Zeotropic solution |
| (g) Heat of hydration | (h) Water of crystallization |
| (i) Azeotropic solution | (j) Conjugate solution |

Ans.

- (a) **A Homogeneous Phase:** A mixture of two or more substances with uniform composition and properties throughout the sample is called homogeneous phase.

Example: Sugar solution.

Note: If small amount of sugar is added to water, sugar is dissolved and the whole mixture is in liquid state with sweet taste. These properties remain uniform throughout the sample. Hence, sugar solution is said to be homogeneous phase.

- (b) **A Concentrated Solution:** A solution containing relatively large amount of solute dissolved in solvent is called concentrated solution.

Example: 1 dm³ solution containing 50 g dissolved sugar is concentrated than 1 dm³ solution containing 20 g dissolved sugar.



- (c) **A Solution of Solid in Solid:** A solution in which both solute and solvent are in solid phase is called solution of solid in solid.
Example: Metal alloys (homogeneous mixture of two or more metals).
- (d) **A Consolute Temperature:** The temperature at which two conjugate solutions completely merge into each other is called consolute temperature or upper consolute temperature. It is also called critical solution temperature. OR
 The temperature at which two polarity miscible liquids forms homogeneous mixture (a true solution) is called consolute temperature.
Example: The consolute temperature for phenol-water system is 65.9°C.
- (e) **A Non-ideal Solution:** The solution that shows deviations from Raoult's law due to differences in molecular structures (i.e., size, shape, and intermolecular forces) of the components are called non-ideal solutions.
Example: Solution of ethanol in water, solution of HCl in water.
- (f) **Zeotropic Solution:** A solution that distill with the change in composition and do not have constant boiling point is called zeotropic solution. Its components can be separated by fractional distillation. It is ideal solution that obeys Raoult's law.
- (g) **Heat of Hydration:** The amount of heat evolved or absorbed when one mole of gaseous ions or solute particles dissolve in water to form an infinite dilute solution.
 For Ex; When 1 mole of gaseous hydrogen ions are dissolve in water forming an infinitely dilute solution, a large amount of heat is evolved.
- $$\text{H}_{(\text{g})}^{+} + \text{Water} \longrightarrow \text{H}_{(\text{aq})}^{+} \quad \Delta\text{H} = -1075 \text{ kJ/mol}$$
- Heat of hydration depends upon the charge to size ration. In IA, heat of hydration decreases. In this group size of ions increases but charge remains the same.
 In the VII A, heat of hydration decreases due to decrease in the ratio of charge to size.
- (h) **Water of Crystallization:** The water molecules which combine with the compounds as they are crystallized from aqueous solution are called water molecules of crystallization or simply water of crystallization or water of hydration.
Example: $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.
- (i) **Azeotropic Solution:** A solution that distills without change in composition and have constant boiling point is called azeotropic solution. Its components cannot be separated by fractional distillation. It is non-ideal solution that shows either positive or negative deviation from Raoult's law.
Example: Solution of HCl in water or solution of ethanol in water.
- (j) **Conjugate Solution:** Two partially miscible liquids remain as separate layers but small quantities of these layers dissolve into each other forming solution of one another called conjugate solutions or two layers of partially miscible liquids which are solution of each other are called conjugate solutions.

Q.5

- (a) What are the concentration units of solutions. Compare molar and molal solutions.
 (b) One has one molal solution of NaCl and one molal solution of glucose:
 (i) Which solution has greater number of particles of solute?
 (ii) Which solution has greater amount of solvent?
 (iii) How do we convert these concentration into weight by weight percentage?

Ans.

- (a) **Concentration Units of Solution:** The units used to measure the concentration of solutions are called concentration units of solutions which are listed below:
 (i) Percentage composition (%) (ii) Molarity (M)
 (iii) Molality (m) (iv) Mole-fraction (X)
 (v) Parts per million (ppm)



Comparison of Molar and Molal Solution:

Molar Solution	Molar Solution
(i) The solution having no. of moles of solute per dm^3 of the solution.	(i) The solution having no. of moles of solute per kg of the solvent.
(ii) Molar solution of a substance (say sugar) is concentrated.	(ii) Molal solution of a substance (say sugar) is dilute.
(iii) The concentration of molar solution vary with the temperature because volume of solution is considered which depends upon temperature.	(iii) The concentration of molal solution do not vary with the temperature because masses of solute and solvent are considered which do not depend upon temperature.
(iv) The concentration of molar solution is calculated by formula.	(iv) The concentration of molal solution is calculated by formula.
Molarity (M) = $\frac{\text{No. of moles of solute}}{\text{Volume of solution in dm}^3}$	Molality (m) = $\frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}}$

- (b) (i) 1 molal NaCl solution has greater number of particles than 1 molal glucose solution.

1 molal solution means that the solutions contain one mole of solute per kg of the solvent. 1 mole of NaCl has Avogadro's no. of formula units and twice the Avogadro's no. of particles (ions) and 1 mole of glucose has Avogadro's no. of molecules. Avogadro's no. of formula unit of NaCl (being electrolyte) produces twice the Avogadro's no. of ions (particles) in solution. Avogadro's no. of molecules of glucose (1 mole) being non-electrolyte do not dissociate or ionize in solution and as a result its no. of molecules (particles) remains the same i.e., Avogadro's no.

Hence, 1 molal NaCl solution has greater number of particles than 1 molal glucose solution.

- (ii) Both the solutions are molal and for molal solution we consider 1 kg of the solvent. So, both the solutions have equal amount of solvent.
- (iii) For weight by weight percentage, we need mass of solute and total mass of solution and formula used is:

$$\text{Percentage of solution} = \frac{\text{Mass of solute}}{\text{Total mass of solution}} \times 100$$

- (a) w/w % of 1 molal NaCl solution:

$$\text{Mass of NaCl (solute)} = 58.5 \text{ g (1 mole)}$$

$$\text{Mass of water (solvent)} = 1000 \text{ g (1 kg)}$$

$$\text{Total mass of solution} = 1000 + 58.5 = 1058.5 \text{ g}$$

$$\text{Percentage of NaCl solution} = \frac{\text{Mass of NaCl}}{\text{Total mass of solution}} \times 100$$

$$= \frac{58.5 \text{ g}}{1058.5 \text{ g}} \times 100 = 5.52\%$$



(b) w/w % of 1 molal solution of glucose:

Mass of glucose (solute) = 180 g (1 mole)

Mass of water (solvent) = 1000 g (1 kg)

Total mass of solution = 1000 + 180 = 1180 g

$$\begin{aligned}\text{Percentage of glucose solution} &= \frac{\text{Mass of glucose}}{\text{Total mass of solution}} \times 100 \\ &= \frac{180}{1180} \times 100 = 15.2\%\end{aligned}$$

Q.6 Explain the following with reason?

- (i) The concentration in terms of molality is independent of temperature but molarity depends upon temperature.
- (ii) The sum of mole fractions of all the components is always equal to unity for any solution.
- (iii) 100 g of 98% H_2SO_4 has volume of 54.34 cm^3 of H_2SO_4 because its density is 1.84 gcm^{-3} .
- (iv) Relative lowering of vapour pressure is independent of the temperature.
- (v) Colligative properties are obeyed when the solute is non-electrolyte and also when the solutions are dilute.
- (vi) The total volume of the solution by mixing 100 cm^3 of water with 100 cm^3 of alcohol may not be equal to 200 cm^3 . Justify it.
- (vii) One molal solution of urea, in water is dilute as compared to one molar solution of urea. But the number of particles of the solute is same. Justify it.
- (viii) Non-ideal solution don't obey the Raoult's law.

Ans.

- (i) In case of molarity, we consider masses of solute and solvent. Mass is a temperature independent quantity. Hence, molality is also a temperature independent quantity.

Whereas, for molarity volume of the solution is taken and volume is a temperature dependent quantity. Hence molarity also depends upon temperature.

Note: Molar solution of a substance is concentrated at higher temperature than at lower temperature.

- (ii) We have solution with two components i.e., A = solvent and B = solute. For example:

No. of moles of solvent (A) = n_A = 98 moles

No. of moles of solute (B) = n_B = 2 moles

Total no. of moles of solution = $n_A + n_B = n_t = 100 \text{ mole}$



Mole fraction of a component = No. of moles of that components ÷ Total no. of moles

$$\begin{aligned}\text{Mole fraction of solvent (A)} &= X_A \\ &= \frac{n_A}{n_A + n_B} \\ &= \frac{98}{100} = 0.98\end{aligned}$$

$$\begin{aligned}\text{Mole fraction of solute (B)} &= X_B \\ &= \frac{n_B}{n_A + n_B} \\ &= \frac{2}{100} = 0.02\end{aligned}$$

$$\begin{aligned}\text{Sum of mole fraction 'A' and 'B'} &= X_A + X_B \\ &= 0.98 + 0.02 \\ &= X_A + X_B \\ &= 1.00\end{aligned}$$

- Note:**
- (i) The mole fraction of one component in a mixture is always less than unity.
 - (ii) The sum of mole fractions of all the components is always equal to unity.
 - (iii) The mole fraction multiplied by 100 gives mole percent.
 - (iv) The mole percent of one component in a mixture is always less than 100.
 - (v) The sum of mole percents of all the components in a mixture is always equal to 100.

- (iii) Mass of H_2SO_4 solution = 100 g
 Density of H_2SO_4 solution = 1.84 g cm^{-3}
 Volume of H_2SO_4 solution = ?

We know that:

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

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

$$\text{Volume} = \frac{100}{1.84}$$

$$\boxed{\text{Volume} = 54.34 \text{ cm}^3}$$

- (iv) The relative lowering of vapour pressure is equal to mole fraction of solute.

$$\frac{\Delta P}{P^\circ} = X_2$$

Mole fraction of the solute is a temperature independent quantity. Mole fraction of a solute is ratio of no. of moles of solute to the total no. of moles of solute and solvent. And no. of moles does not depend upon temperature. Hence, relative lowering of vapour pressure does not depend upon temperature.



- (v) **Colligative properties when solute is non-electrolyte:** Colligative properties depends upon number of solute particles in solution. Non-electrolyte solute do not ionize in solution and its number of particles remain the same. e.g., 1 mole of urea-produces 6.02×10^{23} particles in solution.

When solute is electrolyte, it ionizes in the solution and its no. of particles increases. As a result of that Raoult's law and colligative properties are not obeyed e.g., 1 mole of NaCl produces $2(6.02 \times 10^{23})$ particles (6.02×10^{23} Na^+ ions and 6.02×10^{23} Cl^- ions) in the solution.

Colligative properties when solution is dilute: When solution is dilute, less number of solute particles far away from each other and they behave independently. And colligative properties are obeyed.

For a concentrated solution, there are greater number of solute particles which are closer to each other. Due to which attraction dominate and particles may associate. As a result of which lowering of vapour pressure is less than the ideal value.

Hence colligative properties are not obeyed for concentrated solution.

- (vi) When 100 cm^3 of water and 100 cm^3 of alcohol are mixed together, the volume of the solution is slightly more than 200 cm^3 . This is because forces of attraction between water-alcohol in mixture are weaker than that between water and alcohol in their pure state. Also, that is the reason why this solution shows deviation from Raoult's law.

This solution is not ideal and shows positive deviation from Raoult's law.

- (vii) In one molal solution of urea, 60 g of urea is dissolved in 1000 g of water. 1000 g of water is approximately equal to its 1000 cm^3 . In 1 molal solution, volume of solvent (H_2O) will be 1000 cm^3 whereas, 1 molar solution contains 60 g urea dissolved per 1000 cm^3 of solution. Means in the later solution the volume of water is less than 1000 cm^3 , because solute is also included in 1000 cm^3 of solution.

Hence, number of solute particles are same in both the solutions but molal solution of urea containing greater amount of solvent (water) is dilute as compared to its molar solution.

- (viii) During the formation of non-ideal solution, there is either decrease or increase of attraction between solute and solvent particles. As a result, of which the values of vapour pressure of the individual components are not proportional to their mole fraction. This is against the Raoult's law. Therefore, we say that non-ideal solutions do not obey Raoult's law.

Q.7 What are non-ideal solution? Discuss their types and give three examples of each.

Ans. Descriptive question, consult text book.

- Q.8** (a) Explain fractional distillation. Justify the two curves when composition is plotted against boiling point of solutions.
(b) The solutions showing positive and negative deviations cannot be fractionally distilled at their specific compositions. Explain it.

Ans.

- (a) Descriptive question, consult text book.
(b) Descriptive question, consult text book.

- Q.9** (a) What are azeotropic mixtures? Explain them with the help of graphs.
(b) Explain the effect of temperature on phenol- water system.

Ans.

- (a) Descriptive question, consult text book.
(b) Descriptive question, consult text book.



- Q.10** (a) What are the colligative properties? Why are they called so?
 (b) What is the physical significant of K_b and K_f values of solvents?

Ans.

- (a) Descriptive question, consult text book.
 (b) **Molal Boiling Point Constant (K_b):** If we have one molal solution of different non-volatile and non-electrolyte solutes in H_2O , then the boiling point elevation for all the solutions will be same i.e., $0.52^\circ C$. This is called molal boiling point constant. Its value is different for different solvents but is independent of nature of solute. Its units are $^\circ C \text{ kg mol}^{-1}$.

Molal Freezing Point Constant (K_f): Freezing point depression for 1 molal solution of non-volatile and non-electrolyte solute in H_2O is same i.e., $1.86^\circ C$ and is called molal freezing point constant. Its value depends upon the nature of solvent and is independent of nature of solute. Its units are $^\circ C \text{ kg mol}^{-1}$.

- (b) Descriptive question, consult text book.

- Q.11** How do you explain that the lowering of vapour pressure is a colligative property? How do we measure the molar mass of a non-volatile, non-electrolyte solute in a volatile solvent?

Ans.

Descriptive question, consult text book.

- Q.12** How do you justify that?

- (a) Boiling points of the solvents increase due to the presence of solutes.
 (b) Freezing points are depressed due to the presence of solutes.
 (c) The boiling point of one molal urea solution is $100.52^\circ C$ but the boiling point of two molal urea solution is less than $101.04^\circ C$.
 (d) Beckmann's thermometer is used to note the depression in freezing point.
 (e) In summer the antifreeze solutions protect the liquid of the radiator from boiling over.
 (f) $NaCl$ and KNO_3 are used to lower the melting point of ice.

Ans.

- (a) When solute is added to solvent, some of the solute molecules come to lie on the surface of solvent as well. They do not allow the solvent molecules to escape from the surface as quickly as in pure state. As a result of that vapour pressure decreases and boiling point increases.

Increase in boiling point depends upon the concentration of solute. Greater the amount of solute, greater will be the increase of boiling temperature.

- (b) When solute is added into a solvent solute particles come to lie in between solvent molecules and solution. As a result of that, distance between solvent molecules increases and forces of attraction between solvent molecules decreases. Hence solvent in solution freeze at lower temperature than pure solvent and freezing point decreases.

Therefore, we can easily say that the freezing point is depressed due to presence of solute.



- (c) Two molal urea solution is concentrated than one molal urea solution. No. of molecules in two molal urea solution is twice the Avogadro's no. Due to high concentration, molecules are closer together and there are dominant forces of attraction between them and molecules may associate. Due to which number of molecules which are free to move are less than twice the Avogadro's no. Hence, elevation in boiling is not doubled (101.4°C).
- (d) Beckmann's thermometer can measure upto $\frac{1}{100}$ th of a degree i.e., 0.01 K . Since depression in freezing point for a dilute solution is small. Hence, Beckmann's thermometer can read very small changes of temperature during depression in freezing point.
- (e) Ethylene glycol is an anti-freeze solutions in the water of car radiator. Due to the addition of ethylene glycol in water, its freezing point decreases and boiling point increases. In winter, it prevents water from freezing and in summer, it prevents water from boiling over.
- (f) NaCl and KNO_3 being electrolytes and highly soluble in water. They dissolve and produces double the number of ions than formula units. Due to which freezing point is depressed to greater extent. This mixture is also used to melt the ice from roads in winter.

Q.13 What is Raoult's law? Give its three statements. How this law can help us to understand the ideality of a solution.

Ans. Descriptive question, consult text book.

Q.14 Give graphical explanation for elevation of boiling point of a solution. Describe one method to determine the boiling point elevation of a solution.

Ans. Descriptive question, consult text book.

Q.15 Freezing points of solutions are depressed when non-volatile solutes present in volatile solvents. Justify it. Plot a graph to elaborate your answer. Also give one method to record the depression of freezing point of a solution.

Ans. Detailed question. For answer, consult text book.

Q.16 Discuss the energetics of solution. Justify the heats of solutions as exothermic or endothermic properties.

Ans. Descriptive question, consult text book.

- Q.17**
- Calculate the molarity of glucose solution when 9g of it is dissolved in 250 cm^3 of solution.
 - Calculate the mass of urea in 100 g of water in 0.3 molal solution.
 - Calculate the concentration of solution in molality kg^{-1} which is obtained by mixing 250 g of 20% solution of NaCl with 200 g of 40% solution of NaCl .

Ans.

- (a) The volume of solution has to be taken in dm^3 .

$$\text{Mass of glucose dissolved (W}_2\text{)} = 9.0\text{ g}$$

$$\begin{aligned}\text{Volume of solution} &= 250\text{ cm}^3 \\ &= 0.25\text{ dm}^3\end{aligned}$$

$$\text{Molar mass of glucose} = 180.0\text{ g mol}^{-1}$$

$$\text{Molarity of solution} = ?$$

$$\text{Molarity (M)} = \frac{\text{Mass of solute}}{\text{Molar mass of solute}} \times \frac{1}{\text{Volume of solution in dm}^3}$$

Substituting the values:

$$\text{Molarity (M)} = \frac{9.00 \text{ g}}{180.0 \text{ g/mol}} \times \frac{1}{0.25 \text{ dm}^3}$$

$$\text{Molarity (M)} = \frac{9}{180 \times 0.25} \text{ moles dm}^{-3}$$

$$\text{Molarity (M)} = 0.2 \text{ M}$$

(b) We need the mass of solvent in kg.

$$\text{Mass of water as a solvent} = 100.00 \text{ g}$$

$$\text{Mass of solvent in kg} = \frac{100}{1000} = 0.1 \text{ kg}$$

$$\text{Molality of solution (m)} = 0.3 \text{ m}$$

$$\text{Molar mass of urea} = 60.0 \text{ g mol}^{-1}$$

$$\text{Mass of urea dissolved} = ?$$

$$\text{Molality (m)} = \frac{\text{Mass of urea}}{\text{Molar mass of solute}} \times \frac{1}{\text{Mass of solvent in (kg)}}$$

Putting values:

$$0.3 \text{ mol kg}^{-1} = \frac{\text{Mass of urea}}{60.00 \text{ g mol}^{-1}} \times \frac{1}{0.1 \text{ kg}}$$

$$\text{Mass of urea} = 0.3 \times 60.00 \times 0.1$$

$$\text{Mass of urea} = 1.8 \text{ g}$$

(c) 1st solution:

$$\% \text{ of NaCl solution} = 20\%$$

$$\text{Mass of 20\% solution} = 250 \text{ g}$$

$$\text{Concentration of solution} = ?$$

20% of NaCl solution means that:

$$100 \text{ g of solution has NaCl} = 20 \text{ g}$$

$$1 \text{ g of solution has NaCl} = \frac{20}{100} \text{ g}$$

$$= \frac{20}{100} \times 250 \text{ g}$$

$$250 \text{ g of solution has NaCl} = 50 \text{ g}$$

2nd solution:

$$\% \text{ of NaCl solution} = 40$$

$$\text{Mass of 40\% NaCl solution} = 200 \text{ g}$$

$$100 \text{ g of solution has NaCl} = 40 \text{ g}$$

$$1 \text{ g of solution has NaCl} = \frac{40}{100} \text{ g}$$

$$200 \text{ g of solution has NaCl} = \frac{40}{100} \times 200$$

$$= 80 \text{ g}$$



$$\begin{aligned}
 \text{Mass of NaCl in both solutions} &= 50 + 80 = 130 \text{ g} \\
 \text{Total mass of both the solutions} &= 200 + 250 = 450 \text{ g} \\
 \text{Mass of solvent} &= 450 - 130 = 320 \text{ g} = 0.32 \text{ kg}
 \end{aligned}$$

$$\text{Molality} = \frac{\text{Mass of solute}}{\text{Molar mass}} \times \frac{1}{\text{Mass of solvent in kg}}$$

Putting the values:

$$\text{Molality} = \frac{130}{58.5} \times \frac{1}{0.32} = 0.71 \text{ m}$$

- Q.18** (a) An aqueous solution of sucrose has been labeled as one molal. Find the mole fraction of the solute and the solvent.
- (b) You are provided with 80 % H_2SO_4 w/w having density 1.8 g cm^{-3} . How much volume of this sulphuric acid sample is required to obtain 1 dm^3 of 20% w/w H_2SO_4 whose density is 1.25 g cm^{-3} .

Ans.

(a) Name of compound = Sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$)

Molar mass of sucrose = 342 g mol^{-1}

Since, the solution is 1 molal, so 342 g is dissolved in 1000 g of H_2O .

Hence Mass of sucrose dissolved = 342 g

Mass of H_2O taken = 1000 g

Number of moles of sucrose = 1

Mole fraction of solvent = ?

Mole fraction of solute = ?

First of all calculate no. of moles of water.

$$\text{Number of moles of } \text{H}_2\text{O} = \frac{\text{Mass of water taken}}{\text{Molar mass of water}}$$

Putting values:

$$\text{No. of moles of } \text{H}_2\text{O} = \frac{1000}{18} = 55.55$$

And no. of moles of sucrose is 1.

Now we calculate mole fraction of sucrose.

$$\text{Mole fraction of sucrose } (X_{\text{sucrose}}) = \frac{\text{No. of moles of sucrose}}{\text{Total no. of moles}}$$

Putting the values:

$$\text{Mole fraction of sucrose } (X_{\text{sucrose}}) = \frac{1}{55.51 + 1} = \boxed{0.0176}$$

Similarly calculate mole fraction of H_2O .

$$\text{Mole fraction of water } (X_{\text{H}_2\text{O}}) = \frac{\text{Number of moles of } \text{H}_2\text{O}}{\text{Total no. of moles}}$$

Putting the values:

$$\text{Mole fraction of water } (X_{\text{H}_2\text{O}}) = \frac{55.55}{55.55 + 1} = \boxed{0.9823}$$



(b) The solution of this numerical is to be done in two stages:

(i) Conversion of 80% H_2SO_4 to molarity:

$$\% \text{ of concentrated } \text{H}_2\text{SO}_4 = 80.00$$

$$\text{Density of concentrated } \text{H}_2\text{SO}_4 = 1.8 \text{ g cm}^{-3}$$

It means:

$$1 \text{ cm}^3 \text{ of } \text{H}_2\text{SO}_4 \text{ has mass} = 1.8 \text{ g}$$

$$1000 \text{ cm}^3 \text{ of } \text{H}_2\text{SO}_4 \text{ has mass} = 1.8 \times 1000 = 1800 \text{ g}$$

1800 g of concentrated H_2SO_4 is 80% of H_2SO_4 .

$$100 \text{ g of concentrated solution of } \text{H}_2\text{SO}_4 \text{ contains } \text{H}_2\text{SO}_4 = \frac{80}{100} \times 1800 = 1440 \text{ g}$$

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

Putting the values:

$$\text{Number of moles of } \text{H}_2\text{SO}_4 = \frac{1440 \text{ g}}{98 \text{ g mol}^{-1}} = 14.7 \text{ mole}$$

It means 14.7 moles of H_2SO_4 is present in 1000 cm^3 of solution, hence, it is 14.7 molar H_2SO_4 .

Conversion of 20% H_2SO_4 in molarity:

$$\% \text{ of dilute } \text{H}_2\text{SO}_4 = 20$$

$$\text{Density of dilute } \text{H}_2\text{SO}_4 = 1.25 \text{ g cm}^{-3}$$

It means:

$$1 \text{ cm}^3 \text{ of } \text{H}_2\text{SO}_4 \text{ has mass} = 1.25 \text{ g}$$

$$1000 \text{ g cm}^3 \text{ of } \text{H}_2\text{SO}_4 \text{ has mass} = 1.25 \times 1000 = 1250 \text{ g}$$

1250 g of dilute H_2SO_4 is 20% H_2SO_4 .

$$100 \text{ g of dilute solution contains } \text{H}_2\text{SO}_4 = 20 \text{ g}$$

$$1 \text{ g of dilute solution of } \text{H}_2\text{SO}_4 \text{ has } \text{H}_2\text{SO}_4 = \frac{20}{100} \text{ g}$$

$$1250 \text{ g of dilute solution of } \text{H}_2\text{SO}_4 \text{ has } \text{H}_2\text{SO}_4 = \frac{20}{100} \times 1250 = 250 \text{ g}$$

$$\text{No. of moles of } \text{H}_2\text{SO}_4 = \frac{\text{Mass of } \text{H}_2\text{SO}_4}{\text{Molar mass}}$$

Putting the values:

$$\text{No. of moles of } \text{H}_2\text{SO}_4 = \frac{250 \text{ g}}{98 \text{ g mol}^{-1}} = 2.55 \text{ mol}$$

Now, we have to dilute 14.7 M solution to 2.55 M H_2SO_4 . For this purpose, use the dilution formula.



$$\begin{aligned} \text{(ii)} \quad \text{Conc. H}_2\text{SO}_4 &= \text{Dil. H}_2\text{SO}_4 \\ M_1 V_1 &= M_2 V_2 \end{aligned}$$

Putting the values:

$$14.7 \times V_1 = 2.55 \times 1000$$

$$V_1 = \frac{2.55 \times 1000}{14.7}$$

$$V_1 = 173.5 \text{ cm}^3$$

So, 173.5 cm^3 of conc. H_2SO_4 is diluted up to 1000 cm^3 to get the solution of required molarity. In this way $14.7 \text{ M H}_2\text{SO}_4$ is converted to $2.55 \text{ M H}_2\text{SO}_4$.

Q.19 250 cm^3 of $0.2 \text{ molar K}_2\text{SO}_4$ solution is mixed with 250 cm^3 of 0.2 molar KCl solution. Calculate the molar concentration of K^+ ions in the solution.

Ans. 250 cm^3 of $0.2 \text{ molar K}_2\text{SO}_4$ solution has 0.4 moles K^+ ion. Because each formula unit of K_2SO_4 has two K^+ ions.

250 cm^3 of 0.2 molar KCl solution has 0.2 moles K^+ ion.

Because one formula unit of KCl has one K^+ ion.

When two solutions are mixed then 0.6 moles K^+ ions may be present if the volume remains 250 cm^3 . Since after mixing 500 cm^3 volume is obtained, so the conc. of K^+ ions become half of 0.6 molar i.e., 0.3 molar .

Q.20 5 g of NaCl is dissolved in 1000 g of water, the density of resulting solution is 0.997 g cm^{-3} . Calculate the Molarity and mole fractions of this solution. Assume that the volume of the solution is equal to that of solvent.

Ans.

(i) Calculation of molality (m):

$$\text{Mass of NaCl} = 5 \text{ g}$$

$$\text{Mass of H}_2\text{O} = 1000 \text{ g} = 1 \text{ kg}$$

$$\text{Molality of NaCl (m)} = \frac{\text{Mass of NaCl}}{\text{Molar mass of NaCl}} \times \frac{1}{\text{Mass of solvent in (kg)}}$$

$$\text{Molality of NaCl (m)} = \frac{5}{58.5} \times \frac{1}{1 \text{ kg}} = 0.0854 \text{ molal}$$

(ii) Calculations of molarity (M):

$$\text{Density of solution} = 0.997 \text{ g cm}^{-3}$$

$$\text{Total mass of solution} = 1005 \text{ g}$$

$$d = \frac{m}{V}$$

$$V = \frac{m}{d}$$



Putting the values:

$$V = \frac{1005}{0.997} = 1008.02 \text{ cm}^3$$

$$\text{Volume of solution in dm}^3 = 1.00802 \text{ dm}^3$$

$$\text{Molarity (M)} = \frac{\text{Mass of NaCl}}{\text{Molar mass}} \times \frac{1}{1.00802}$$

$$\text{Molar mass of NaCl} = 58.5 \text{ mol}^{-1}$$

Putting the values:

$$\text{Molarity (M)} = \frac{5}{58.5} \times \frac{1}{1.00802} = \boxed{0.084}$$

(iii) Calculation of Mole Fraction:

$$\text{No. of moles of NaCl} = \frac{5}{58.5} = 0.0854$$

$$\text{No. of moles of H}_2\text{O} = \frac{1000}{18} = 55.55$$

$$X_{\text{NaCl}} = \frac{\text{No. of moles of NaCl}}{\text{No. of moles of NaCl} + \text{No. of moles of H}_2\text{O}}$$

Putting the values:

$$\begin{aligned} X_{\text{NaCl}} &= \frac{0.0854}{0.0854 + 55.5} \\ &= \frac{0.0854}{55.5854} = \boxed{0.000153} \end{aligned}$$

$$X_{\text{H}_2\text{O}} = \frac{55.55}{55.5854} = \boxed{0.999}$$

Q.21 4.675 g of a compound with empirical formula $\text{C}_3\text{H}_3\text{O}$, was dissolved in 212.5 g of pure benzene. The freezing point of the solution was found 1.02°C less than that of pure benzene. The molal freezing point constant of benzene is 5.1°C . Calculate:

- the relative molar mass
- the molecular formula of the compound

Ans. Mass of solute dissolved (W_2) = 4.675 g
 Mass of solvent benzene (W_1) = 212.5 g
 Depression of F.P. of solution (ΔT_f) = 1.02°C
 Molar F.P constant of solvent (K_f) = 5.1°C



(i) Relative molar mass of solute (M_2):

$$\begin{aligned}
 M_2 &= \frac{K_f}{\Delta T_f} \cdot \frac{1000 W_2}{W_1} \\
 &= \frac{5.1^\circ\text{C} \times 1000 \times 4.675 \text{ g}}{1.02^\circ\text{C} \times 212.5 \text{ g}} \\
 &= \frac{5.1 \times 1000 \times 4.675}{1.02 \times 212.5} \\
 M_2 &= \frac{23842.5}{216.75} = 110 \text{ g mol}^{-1}
 \end{aligned}$$

(ii) Empirical formula = $\text{C}_3\text{H}_3\text{O}$

$$\text{Empirical formula mass} = 36 + 3 + 16 = 55$$

$$\text{Molar mass} = n(\text{E.F. mass})$$

$$110 = n(55)$$

$$n = \frac{110}{55} = 2$$

$$\text{Molecular formula of the compound} = 2(\text{E.F.})$$

$$= 2(\text{C}_3\text{H}_3\text{O})$$

$$\text{Hence, the molecular formula of the compound} = \boxed{\text{C}_6\text{H}_6\text{O}_2}$$

Q.22 The boiling point of a solution containing 0.2 g of a substance 'A' in 20 g of ether (molar mass = 74) is 0.17 K higher than that of pure ether. Calculate the molar mass of 'A'. Molal boiling point constant of ether is 2.16 K.

Ans. Mass of the solute A (W_2) = 0.2 g

Mass of the solvent ether (W_1) = 20.0 g

Elevation of B.P. of solution (ΔT_b) = 0.17 K

Molal B.P. constant of ether (K_b) = 2.16 K

Molar mass of A (M_2) = ?

$$\begin{aligned}
 M_2 &= \frac{K_b}{\Delta T_b} \cdot \frac{1000 W_2}{W_1} \\
 &= \frac{2.16 \text{ K} \times 1000 \times 0.2 \text{ g}}{0.17 \text{ K} \times 20 \text{ g}} \\
 M_2 &= \frac{132}{3.4} = \boxed{127.0 \text{ g mol}^{-1}}
 \end{aligned}$$



Q.23 3 g of a non-volatile, non-electrolyte solute 'X' is dissolved in 50 g of ether (molar mass 74) at 293 K. The vapour pressure of ether falls from 442 torr to 426 torr under these conditions. Calculate the molecular mass of the solute X.

Ans. Mass of solute 'X' dissolved (W_2) = 3.00 g

Mass of solvent ether (W_1) = 50.00 g

Molar mass of ether (M_1) = 74.00 g mol⁻¹

Vapour pressure of pure ether (P°) = 442 torr

Vapour pressure of solution (P°) = 426 torr

Lowering of vapour pressure (ΔP) = 442 – 426 = 16 torr

Molar mass of 'X' (M_2) = ?

$$\frac{\Delta P}{P^\circ} = \frac{W_2}{M_2} \times \frac{M_1}{W_1}$$

$$M_2 = \frac{W_2 \times M_1 \times P^\circ}{\Delta P \times W_1}$$

$$= \frac{3.0 \text{ g} \times 74 \text{ g mol}^{-1} \times 442 \text{ torr}}{16 \text{ torr} \times 50.0 \text{ g}}$$

$$= \frac{3 \times 74 \times 442}{16 \times 50} \text{ g mol}^{-1}$$

$$= \frac{98124}{800} \text{ g mol}^{-1}$$

$$M_2 = \boxed{122.6 \text{ g mol}^{-1}}$$



DO YOU KNOW?

1. Any mixture having uniform composition and single phase is called solution.
2. The solution which contains two components is called Binary solution.
3. The substance which is present in large quantity in solution is called solvent and the substance present in small quantity is called solute.
4. The number of moles of solute dissolved per dm^3 of solution is called molarity.
5. The number of moles of solute dissolved per kg of solvent is called molality.
6. One molar solution of sugar is sweeter than one molal solution.
7. The sum of the mole fraction of all components of a solution must be equal to one (unity).
8. The number of parts by mass or volume of solute per million parts by mass or volume of solution is called ppm.
9. Phenol and water are partially miscible whereas alcohol and water are completely miscible.
10. Benzene and water are immiscible.
11. Raoult's law is obeyed in case of dilute solutions.
12. The temperature at which two conjugate solutions merge into one another is called critical solution temperature or consolute temperature.
13. The liquid mixture which distills with a change in composition is called zeotropic mixture.
14. The liquid mixture which boils at constant temperature and distills over without change in composition at any pressure like a chemical compound is called azeotropic mixture.
15. The elevation of the boiling point when 1 mole of solute is dissolved in one kg of solvent is called molal boiling point constant or Ebullioscopic constant.
16. Equimolal solution of different non-electrolytes increase the boiling point equally.
17. The amount of heat evolved when one mole of vapours are condensed to a liquid at constant temperature is called latent heat of condensation.
18. The depression in the freezing point when 1 mole of solute is dissolved in one kg of solvent is called molal freezing point constant or cryoscopic constant.
19. Units of $K_b = \text{C}^\circ \text{kg mol}^{-1}$.



20. Units of $K_f = C^\circ \text{ kg mol}^{-1}$.
21. The process in which solvent molecules surround and interact with the solute particles is called solvation.
22. The process in which water molecules surround and interact with the solute particles is called hydration.
23. Copper sulphate is penta hydrated.
24. Washing soda is deca hydrated.
25. Epsom salt is hepta hydrated.

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