

- Q1. State Raoult's law for a solution of volatile liquids.
- Q2. State the following: Raoult's law in its general form in reference to solutions.
- Q3. Define Raoult's law.
- Q4. State the following: Henry's law about partial pressure of a gas in a mixture.
- Q5. Explain the following: Henry's law about dissolution of a gas in a liquid.
- Q6. 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?
- Q7. State the main advantage of molality over molarity as the unit of concentration.
- Q8. What is meant by molality of a solution?
- Q9. Define the following term: Mole fraction.
- Q10. Define the following term: Molarity.
- Q11. How is it that alcohol and water are miscible in all proportions?
- Q12. Define the following term: Ideal solution.
- Q13. Define the following term: Azeotrope.
- Q14. Some liquids on mixing form 'azeotropes'. What are 'azeotropes'?
- Q15. In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes?
- Q16. Define the following term: Van't Hoff factor.
- Q17. State the condition resulting in reverse osmosis.
- Q18. What is meant by colligative properties?
- Q19. Explain the following: Boiling point elevation constant for a solvent.
- Q20. Define the following term: Isotonic solutions.
- Q21. Define the following term: Osmotic pressure.
- Q22. How is the vapour pressure of a solvent affected when a non-volatile solute is dissolved in it?
- Q23. Define the following term: Molal elevation constant (K_b).
- Q24. What are isotonic solutions?
- Q25. Define the term, 'molarity of a solution'. State one disadvantage in using the molarity as the unit of concentration.

- Q26. Differentiate between molarity and molality of a solution. Explain how molarity value of a solution can be converted into its molality?
- Q27. Differentiate between molarity and molality in a solution. What is the effect of temperature change on molarity and molality in a solution?
- Q28. A solution of glucose ($C_6H_{12}O_6$) in water is labelled as 10% by weight. What would be the molality of the solution? (Molar mass of glucose = 180 g mol^{-1})
- Q29. Define: (a) Mole fraction, (b) Molality.
- Q30. Differentiate between molarity and molality of a solution.
- Q31. Calculate the molarity of 9.8% (w/W) solution of H_2SO_4 if the density of the solution is 1.02 g mL^{-1} . (Molar mass of $H_2SO_4 = 98 \text{ g mol}^{-1}$)
- Q32. An antifreeze solution is prepared from 222.6 g of ethylene glycol ($C_2H_4(OH)_2$) and 200 g of water. Calculate the molality of the solution. If the density of this solution be 1.072 g mL^{-1} , what will be the molality of the solution?
- Q33. State Henry's law and mention two of its important applications.
- Q34. Explain why aquatic species are more comfortable in cold water rather than in warm water.
- Q35. What is meant by positive deviations from Raoult's law? Give an example. What is the sign of $\Delta_{\text{mix}} H$ for positive deviation?
- Q36. State Raoult's law. How is it formulated for solutions of non-volatile solutes?
- Q37. State Raoult's law for a solution containing volatile components. Name the solution which follows Raoult's law at all concentrations and temperatures.
- Q38. State Raoult's law for the solution containing volatile components. What is the similarity between Raoult's law and Henry's law?
- Q39. State Henry's law correlating the pressure of a gas and its solubility in a solvent and mention two applications for the law.
- Q40. Non-ideal solutions exhibit either positive or negative deviations from Raoult's law. What are these deviations and why are they caused? Explain with one example for each type.
- Q41. Explain why a solution of chloroform and acetone shows negative deviation from Raoult's law.
- Q42. What is meant by positive and negative deviations from Raoult's law and how is the sign of $\Delta_{\text{mix}} H$ related to positive and negative deviations from Raoult's law?
- Q43. What type of deviation is shown by a mixture of ethanol and acetone? Give reason.
- Q44. Define azeotropes. What type of azeotrope is formed by negative deviation from Raoult's law? Give an example.
- Q45. Define azeotropes. What type of azeotrope is formed by positive deviation from Raoult's law? Give an example.
- Q46. What is meant by negative deviation from Raoult's law? Give an example. What is the sign of $\Delta_{\text{mix}} H$ for negative deviation?

- Q47. (a) Out of 1 M glucose and 2 M glucose, which one has a higher boiling point and why?
(b) What happens when the external pressure applied becomes more than the osmotic pressure of solution?
- Q48. What is meant by negative deviation from Raoult's law? Draw a diagram to illustrate the relationship between vapour pressure and mole fractions of components in a solution to represent negative deviation.
- Q49. State Raoult's law for solutions of volatile liquids. Taking suitable examples explain the meaning of positive and negative deviations from Raoult's law.
- Q50. What type of intermolecular attraction exists in each of the following pairs of compounds:
(a) *n*-hexane and *n*-octane. (b) methanol and acetone.
- Q51. Outer hard shells of two eggs are removed. One of the egg is placed in pure water and the other is placed in saturated solution of sodium chloride. What will be observed and why?
- Q52. Define the terms, 'osmosis' and 'osmotic pressure'. What is the advantage of using osmotic pressure as compared to other colligative properties for the determination of molar masses of solutes in solutions?
- Q53. List any four factors on which the colligative properties of a solution depend.
- Q54. Define the terms osmosis and osmotic pressure. Is the osmotic pressure of a solution a colligative property? Explain.
- Q55. An aqueous solution of sodium chloride freezes below 273 K. Explain the lowering in freezing point of water with the help of a suitable diagram.
- Q56. 18 g of glucose, $C_6H_{12}O_6$ (Molar mass = 180 g mol^{-1}) is dissolved in 1 kg of water in a sauce pan. At what temperature will this solution boil?
(K_b for water = $0.52 \text{ K kg mol}^{-1}$, boiling point of pure water = 373.15 K)
- Q57. Calculate the mass of compound (molar mass = 256 g mol^{-1}) to be dissolved in 75 g of benzene to lower its freezing point by 0.48 K , ($K_f = 5.12 \text{ K kg mol}^{-1}$).
- Q58. Why does a solution containing non-volatile solute have higher boiling point than the pure solvent? Why is elevation of boiling point a colligative property?
- Q59. 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?
- Q60. A 1.00 molal aqueous solution of trichloroacetic acid (CCl_3COOH) is heated to its boiling point. The solution has the boiling point of 100.18°C . Determine the van't Hoff factor for trichloroacetic acid. (K_b for water = $0.512 \text{ K kg mol}^{-1}$)
- Q61. Assuming complete dissociation, calculate the expected freezing point of a solution prepared by dissolving 6.00 g of Glauber's salt, $Na_2SO_4 \cdot 10H_2O$ in 0.100 kg of water.
(K_f for water = $1.86 \text{ K kg mol}^{-1}$, Atomic masses : Na = 23, S = 32, O = 16, H = 1)
- Q62. What is van't Hoff factor? What types of values can it have if in forming the solution the solute molecules undergo (a) dissociation, (b) Association?

- Q79. What mass of NaCl must be dissolved in 65.0 g of water to lower the freezing point of water by 7.50°C? The freezing point depression constant (K_f) for water is 1.86°C/m. Assume van't Hoff factor for NaCl is 1.87. (Molar mass of NaCl = 58.5 g mol⁻¹)
- Q80. What would be the molar mass of a compound if 6.21 g of it dissolved in 24.0 g of chloroform to form a solution that has a boiling point of 68.04°C. The boiling point of pure chloroform is 61.7°C and the boiling point elevation constant, K_b for chloroform is 3.63°C/m.
- Q81. 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 the gene fragment is a non-electrolyte, determine its molar mass.
- Q82. Calculate the boiling point of a solution prepared by adding 15.00 g of NaCl to 250.00 g of water. (K_b for water = 0.512 K kg mol⁻¹), (Molar mass of NaCl = 58.44 g)
- Q83. A solution containing 30 g of non-volatile solute exactly in 90 g of water has a vapour pressure of 2.9 kPa at 298 K. Further 18 g of water is added to this solution. The new vapour pressure becomes 2.9 kPa at 298 K. Calculate (a) the molecular mass of solute and (b) vapour pressure of water at 298 K.
- Q84. 15.0 g of an unknown molecular material was dissolved in 450 g of water. The resulting solution was found to freeze at - 0.34°C. What is the molar mass of this material? (K_f for water = 1.86 K kg mol⁻¹)
- Q85. What mass of ethylene glycol (molar mass = 62.0 g mol⁻¹) must be added to 5.50 kg of water to lower the freezing point of water from 0°C to - 10.0°C? (K_f for water 1.86 K kg mol⁻¹)
- Q86. A solution prepared by dissolving 1.25 g of oil of winter green (methyl salicylate) in 99.0 g of benzene has a boiling point of 80.31°C. Determine the molar mass of this compound. (B.pt of pure benzene = 80.10°C and K_b for benzene = 2.53°C kg mol⁻¹)
- Q87. Calculate the boiling point of one molar aqueous solution (density 1.06 g mol⁻¹) of KBr. (Given : K_b for H₂O = 0.52 K kg mol⁻¹, atomic mass : K = 39, Br = 80]
- Q88. The molecular masses of polymers are determined by osmotic pressure method and not by measuring other colligative properties. Give two reasons.
- Q89. Calculate the amount of sodium chloride which must be added to one kilogram of water so that the freezing point of water is depressed by 3 K.
[Given: K_f = 1.86 K kg mol⁻¹, atomic mass : Na = 23.0, Cl = 35.5]
- Q90. 100 mg of a protein is dissolved in just enough water to make 10.0 mL of solution. If this solution has an osmotic pressure of 13.3 mm Hg at 25°C, what is the molar mass of the protein? (R = 0.0821 L atm mol⁻¹ K⁻¹ and 760 mm Hg = 1 atm)
- Q91. A 0.1539 molal aqueous solution of cane sugar (mol. mass = 342 g mol⁻¹) has a freezing point of 271 K while the freezing point of pure water is 273.15 K. What will be the freezing point of an aqueous solution containing 5 g of glucose (mol. mass = 180 g mol⁻¹) per 100 g of solution.
- Q92. A solution containing 8 g of a substance in 100 g of diethyl ether boils at 36.86°C, whereas pure ether boils at 35.60°C. Determine the molecular mass of the solute.
(For ether K_b = 2.02 K kg mol⁻¹)
- Q93. Calculate the temperature at which a solution containing 54 g of glucose, (C₆H₁₂O₆), in 250 g of water will freeze. (K_f for water = 1.86 K mol⁻¹ kg)

- Q94. Calculate the freezing point of a solution containing 18 g glucose, $C_6H_{12}O_6$ and 68.4 g sucrose, $C_{12}H_{22}O_{11}$ in 200 g of water. The freezing point of pure water is 273 K and K_f for water is 1.86 K m^{-1} .
- Q95. x g of a non-electrolytic compound (molar mass = 200) is dissolved in 1.0 L of 0.05 M NaCl aqueous solution. The osmotic pressure of this solution is found to be 4.92 atm at 27°C . Calculate the value of x . Assume complete dissociation of NaCl and ideal behaviour of the solution. ($R = 0.082 \text{ L atm mol}^{-1} \text{ K}^{-1}$)
- Q96. Calculate the boiling point of solution when 4 g of $MgSO_4$ ($M = 120 \text{ g mol}^{-1}$) was dissolved in 100 g of water, assuming $MgSO_4$ undergoes complete ionization. [K_b for water = $0.52 \text{ K kg mol}^{-1}$]
- Q97. When 2.56 g of sulphur was dissolved in 100 g of CS_2 , the freezing point lowered by 0.383 K. Calculate the formula of sulphur.
(K_f the $CS_2 = 3.83 \text{ K kg mol}^{-1}$, atomic mass of sulphur = 32 g mol^{-1})
- Q98. Calculate the freezing point of solution when 1.9 g of $MgCl_2$ ($M = 95 \text{ g mol}^{-1}$) was dissolved in 50 g of water, assuming $MgCl_2$ undergoes complete ionization.
(K_f for water $1.86 \text{ K kg mol}^{-1}$)
- Q99. A 0.561 m solution of an unknown electrolyte depresses the freezing point of water by 2.93°C . What is van't Hoff factor for this electrolyte? The freezing point depression constant (K_f) for water is $1.86^\circ\text{C Kg mol}^{-1}$.
- Q100 Calculate the freezing point of an aqueous solution containing 10.50 g of $MgBr_2$ in 200 g of water. (Molar mass of $MgBr_2 = 184 \text{ g mol}^{-1}$) (K_f for water = $1.86 \text{ K kg mol}^{-1}$)
- Q101 Calculate the amount of KCl which must be added to 1 kg of water so that the freezing point is depressed by 2 K (the K_f for water = $1.86 \text{ K kg mol}^{-1}$).
- Q102 Determine the osmotic pressure of a solution prepared by dissolving 2.5×10^{-2} g of K_2SO_4 in 2 L of water at 25°C , assuming that it is completely dissociated.
($R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$, molar mass of $K_2SO_4 = 174 \text{ g mol}^{-1}$)
- Q103 Calculate the mass of NaCl (molar mass = 58.5 g mol^{-1}) to be dissolved in 37.2 g of water to lower the freezing point by 2°C , Assuming that NaCl undergoes complete dissociation. (K_f for water = $1.86 \text{ K kg mol}^{-1}$)
- Q104 3.9 g of benzoic acid dissolved in 49 g of benzene shows a depression in freezing point of 1.62 K. Calculate the van't Hoff factor and predict the nature of solute (associated or dissociated).
(Given: Molar mass of benzoic acid = 122 g mol^{-1} , K_f for benzene = $4.9 \text{ K kg mol}^{-1}$)
- Q105 The boiling point elevation of 0.30 g acetic acid in 100 g benzene is 0.0633 K. Calculate the molar mass of acetic acid from this data. What conclusion can you draw about the molecular state of the solute in the solution? (Given, K_b for benzene = $2.53 \text{ K kg mol}^{-1}$)
- Q106 An aqueous solution containing 12.48 g of barium chloride in 1.0 kg of water boils at 373.0832 K. Calculate the degree of dissociation of barium chloride.
(Given, K_b for $H_2O = 0.52 \text{ K m}^{-1}$; Molar mass of $BaCl_2 = 208.34 \text{ g mol}^{-1}$)
- Q107 Phenol associates in benzene to a certain extent to form a dimer. A solution containing 20 g of phenol in 1.0 kg of benzene has its freezing point lowered by 0.69 K. Calculate the fraction of phenol that has dimerised (Given, K_f for benzene = 5.1 K m^{-1}).

Q108A decimolar solution of potassium ferrocyanide $K_4[Fe(CN)_6]$ is 50% dissociated at 300 K. Calculate the value of van't Hoff factor for potassium ferrocyanide.

Q109The freezing point of a solution containing 0.2 g of acetic acid in 20.0 g of benzene is lowered by 0.45°C . Calculate.

- (a) the molar mass of acetic acid from this data.
- (b) van't Hoff factor (for benzene, $K_f = 5.12 \text{ K kg mol}^{-1}$). What conclusion can you draw from the value of van't factor obtained?

Q110(a) The depression in freezing point of water observed for the same molar concentration of acetic acid, trichloroacetic acid and trifluoroacetic acid increases in the order as stated above. Explain.

- (b) Calculate the depression in freezing point of water when 20.0 g of $\text{CH}_3\text{CH}_2\text{CHClCOOH}$ is added to 500 g of water. (Given, $K_a = 1.4 \times 10^{-3}$, $K_f = 1.96 \text{ K kg mol}^{-1}$)

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S1. Raoult's law: For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ \cdot x$

where p° = Vapour pressure of pure component
 x = mole fraction of that component.

S2. Raoult's law: For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ \cdot x$

where p° = Vapour pressure of pure component
 x = mole fraction of that component.

S3. Raoult's law: For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ \cdot x$

where p° = Vapour pressure of pure component
 x = mole fraction of that component.

S4. Henry's law state that, the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.

$p = K_H \cdot x$ where, K_H = Henry's law constant. Different gases have different K_H values at the same temperature.

S5. Henry's law state that, the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.

$p = K_H \cdot x$ where, K_H = Henry's law constant. Different gases have different K_H values at the same temperature.

S6. According to Henry's law, the solubility of a gas is inversely proportional to the Henry's law constant (K_H) for that gas. Hence, gas (B) being less soluble, would have a higher K_H value.

S7. Molality is independent of temperature, whereas molarity is a function of temperature.

S8. Molality of a solution can be defined as the number of moles of solute dissolved in one kg solvent. It is denoted by m .

$$m = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}} = \frac{n_2}{W_1}$$

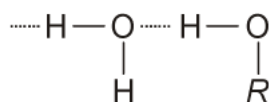
S9. Mole fraction is the ratio of number of moles of solute or solvent and total number of moles of solution. It is denoted by x .

$$x_{\text{solute}} = \frac{n_2}{n_1 + n_2}, \quad x_{\text{solvent}} = \frac{n_1}{n_1 + n_2}.$$

S10. Number of moles of solute dissolved in one litre solution is called molarity. It is denoted by M .

$$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litre}}.$$

S11. Both alcohol and water are polar in nature hence, they are miscible in all proportions. Water and ethanol molecules attract each other because of the formation of H-bonds. This property also makes them miscible.



S12. A solution which obeys Raoult's law at all concentrations and temperatures is called an ideal solution.

S13. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phases and that have constant boiling points.

It is not possible to separate the components of azeotropes by fractional distillation.

S14. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phases and that have constant boiling points.

It is not possible to separate the components of azeotropes by fractional distillation.

S15. Non-ideal solutions that show negative deviation from Raoult's law form maximum boiling azeotropes.

S16. Van't Hoff factor: It is defined as the ratio of the experimental value of colligative property to the calculated value of the colligative property and is used to find out the extent of dissociation or association. Mathematically, it is represented as

$$i = \frac{\text{Experimental (or observed value) of colligative property}}{\text{Calculated (or normal value) of colligative property}}$$

S17. Reverse osmosis occurs when a pressure larger than the osmotic pressure is applied to the solution side.

S18. Colligative properties are the properties of solution which depend upon the number of solute particles and not upon the nature of the solute.

S19. Ebullioscopic constant is the boiling point elevation constant when one mole of solute is dissolved in 1000 g of solvent. It is denoted by K_b .

S20. Two solutions having same osmotic pressure at a given temperature are called isotonic solutions.

S21. Osmotic pressure is the extra pressure which is applied on the solution to just prevent the flow of solvent into the solution through a semi-permeable membrane.

S22. When a non-volatile solute is added to a solvent, the vapour pressure of the solvent (above the resulting solution) is lower than the vapour pressure above the pure solvent.

S23. Molal elevation constant may be defined as the elevation in boiling point when the molality of the solution is unit (*i.e.*, 1 mole of the solute is dissolved in 1 kg (1000 g) of the solvent). The units of K_b are therefore, degree/molality *i.e.*, K/m or °C/m or K kg mol⁻¹.

S24. Two solutions having same osmotic pressure at a given temperature are called isotonic solutions.

S25. Number of moles of solute dissolved in one litre solution is called molarity. It is denoted by M .

$$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litre}}$$

Disadvantage in using molarity as the unit of concentration is that it depends upon temperature.

S26.	Molarity	Molality
	Number of moles of solute dissolved in one litre solution is called molarity.	Number of moles of solute dissolved in one kg solvent is called molality.
	$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litre}}$	$m = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}}$
	Molarity depends on temperature as volume depends on temperature. Molarity decreases with rise in temperature.	Molality is independent of temperature as mass does not change with temperature.

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,

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

S27.	Molarity	Molality
	Number of moles of solute dissolved in one litre solution is called molarity.	Number of moles of solute dissolved in one kg solvent is called molality.
	$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litre}}$	$m = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}}$
	Molarity depends on temperature as volume depends on temperature. Molarity decreases with rise in temperature.	Molality is independent of temperature as mass does not change with temperature.

S28.

Mass of solution = 100 g

Mass of solute = 10 g

Mass of solvent = 100 - 10 = 90 g = $\frac{90}{1000}$ kg = 0.09 kg

Number of moles of solute, $n = \frac{10}{180} = 0.055$ mol

$$m = \frac{0.055 \text{ mol}}{0.09 \text{ kg}} = 0.61 \text{ m.}$$

- S29.** (a) Mole fraction is the ratio of number of moles of solute or solvent and total number of moles of solution. It is denoted by x .

$$x_{\text{solute}} = \frac{n_2}{n_1 + n_2}, \quad x_{\text{solvent}} = \frac{n_1}{n_1 + n_2}.$$

- (b) Molality of a solution can be defined as the number of moles of solute dissolved in one kg solvent. It is denoted by m .

$$m = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}} = \frac{n_2}{W_1}.$$

S30.	Molarity	Molality
	Number of moles of solute dissolved in one litre solution is called molarity.	Number of moles of solute dissolved in one kg solvent is called molality.
	$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litre}}$	$m = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}}$
	Molarity depends on temperature as volume depends on temperature. Molarity decreases with rise in temperature.	Molality is independent of temperature as mass does not change with temperature.

- S31.** Given, Mass of solute = 9.8 g
 Mass of solution = 100 g
 Density of solution = 1.02 g mL⁻¹

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

$$= \frac{100 \text{ g}}{1.02 \text{ g mL}^{-1}} = 98.039 \text{ mL} = 0.098 \text{ L}$$

Number of moles solute, $n = \frac{9.8 \text{ g}}{98 \text{ g}} = 0.1 \text{ mol}$

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

$$= \frac{0.1 \text{ mol}}{0.098 \text{ L}} = 1.02 \text{ M.}$$

- S32.** Mass of the solute, $\text{C}_2\text{H}_4(\text{OH})_2 = 222.6 \text{ g}$
 Molar mass of solute, $\text{C}_2\text{H}_4(\text{OH})_2 = 62 \text{ g mol}^{-1}$

$$\therefore \text{Moles of the solute} = \frac{222.6 \text{ g}}{62 \text{ g mol}^{-1}} = 3.59$$

Mass of the solvent = 200 g = 0.200 kg

$$\begin{aligned}\text{Volume of solution} &= \frac{422.6 \text{ g}}{1.072 \text{ g mL}^{-1}} = 394.2 \text{ mL} \\ &= 0.3942 \text{ L}\end{aligned}$$

$$\begin{aligned}\text{Molality} &= \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}} \\ &= \frac{3.59}{0.2} = 17.95 \text{ m}\end{aligned}$$

$$\text{Molarity} = \frac{3.59 \text{ moles}}{0.3942 \text{ L}} = 9.11 \text{ mol L}^{-1}.$$

S33. Henry's law 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.

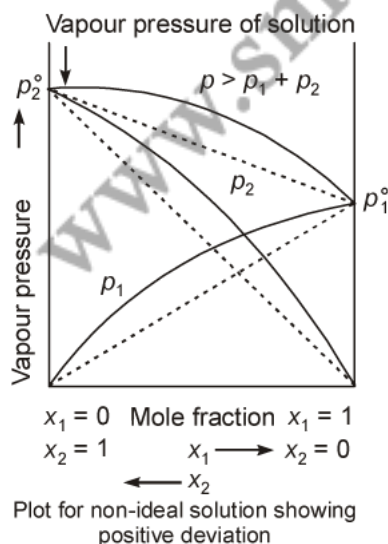
$p = K_H \cdot x$ where, K_H = Henry's law constant. Different gases have different K_H values at the same temperature.

Application of Henry's law:

- To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.
- To minimise the painful effects of decompression sickness in deep sea divers, oxygen diluted with less soluble helium gas is used as breathing gas.

S34. Increase in temperature decreases the solubility of oxygen in water. As a result, amount of dissolved oxygen decreases. It becomes more difficult to breathe as oxygen is less. Hence, the aquatic species are not comfortable in warm water.

S35. Positive deviation: For non-ideal solutions, if the vapour pressure is higher, then it is said to exhibit positive deviation. $A-B$ interactions are weaker than $A-A$ or $B-B$ interactions. Due to this vapour pressure increases which results in positive deviation. In positive deviation, intermolecular force decreases, volume increases, vapour pressures increase, enthalpy increases. Therefore, $\Delta H_{\text{mix}} = +ve$, $\Delta V_{\text{mix}} = +ve$. e.g., ethanol + acetone and carbon disulphide + acetone show positive deviation.



S36. Raoult's law: For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ \cdot x$

where $p^\circ =$ Vapour pressure of pure component
 $x =$ mole fraction of that component.

Raoult's law for solution containing non-volatile solute: It states that partial vapour pressure of a solution of non-volatile solute, p_{solution} is directly proportional to the mole fraction of the solvent in the solution.

Mathematically, $p_{\text{solution}} = p^\circ_{\text{solvent}} \times x_{\text{solvent}}$

where $p^\circ_{\text{solvent}} =$ vapour pressure of the pure solvent at the given temperature.

or $\frac{p^\circ - p_{\text{sol}}}{p^\circ} = x_2$.

S37. Raoult's law: For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ \cdot x$

where $p^\circ =$ Vapour pressure of pure component
 $x =$ mole fraction of that component.

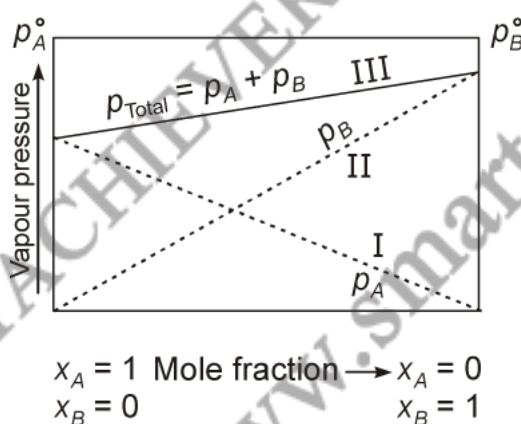
Let a solution consists of two volatile liquids A and B with their mole fraction x_A and x_B respectively. If p_A and p_B are their partial vapour pressures, then

$$p_A \propto x_A \Rightarrow p_A = p^\circ_A x_A \quad \text{and} \quad p_B \propto x_B \Rightarrow p_B = p^\circ_B x_B$$

where p°_A and p°_B represent the vapour pressures of pure liquid components A and B.

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

A plot of p_A or p_B against x_A or x_B for a solution will be a straight line.



Ideal solutions obey Raoult law at all concentrations and temperature.

S38. Raoult's law: For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ \cdot x$

where $p^\circ =$ Vapour pressure of pure component
 $x =$ mole fraction of that component.

Henry's law: If gas is the solute and liquid is the solvent, then according to Henry's law,

$$p = K_H \cdot x$$

i.e., partial pressure of the volatile component (gas) is directly proportional to the mole fraction of that component (gas) in the solution.

Hence, Raoult's law and Henry's law has been identical except that their proportionality constant are different. It is equal to p° for Raoult's law and K_H for Henry's law.

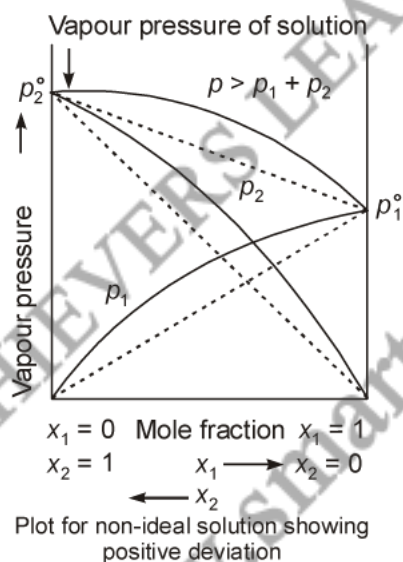
Therefore, Raoult's law becomes a special case of Henry's law in which K_H becomes equal to vapour pressure of pure component p° .

S39. Henry's law states that at a constant temperature, the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of liquid or solution.

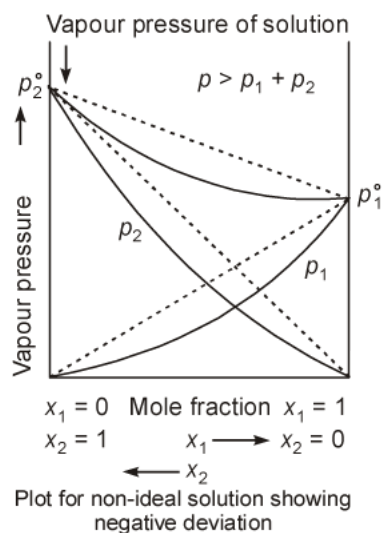
Application of Henry's law:

- (a) To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.
- (b) To minimise the painful effects of decompression sickness in deep sea divers, oxygen diluted with less soluble helium gas is used as breathing gas.

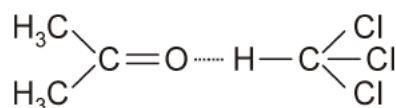
S40. Positive deviation: For non-ideal solutions, if the vapour pressure is higher, then it is said to exhibit positive deviation. $A - B$ interactions are weaker than $A - A$ or $B - B$ interactions. Due to this vapour pressure increases which results in positive deviation. In positive deviation, intermolecular force decreases, volume increases, vapour pressures increases, enthalpy increases. Therefore, $\Delta H_{\text{mix}} = +ve$, $\Delta V_{\text{mix}} = +ve$. e.g., ethanol + acetone and carbon disulphide + acetone show positive deviation.



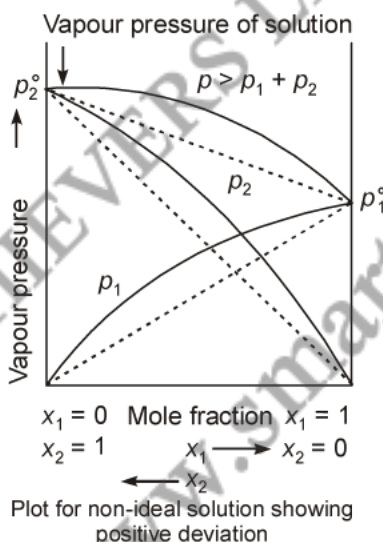
Negative deviation: For non-ideal solution, if the vapour pressure is lower, then it is said to exhibit negative deviation. $A - B$ interactions are stronger than $A - A$ and $B - B$ interactions. Due to this, vapour pressure decreases which results in negative deviation. In negative deviation, intermolecular force increases, volume decreases, vapour pressure decreases and heat is released. Therefore, $\Delta H_{\text{mix}} = -ve$, $\Delta V_{\text{mix}} = -ve$. Example, phenol + aniline and chloroform + acetone show negative deviation.



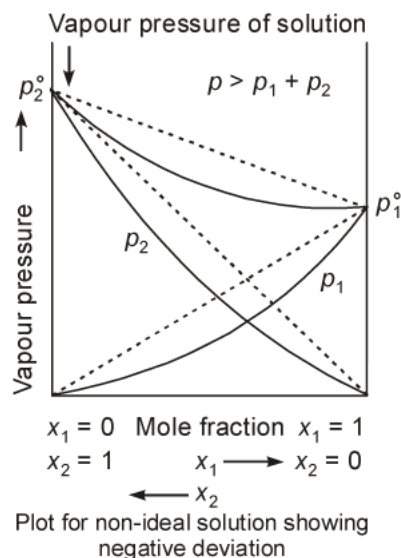
S41. A mixture of chloroform and acetone shows negative deviation from Raoult's law because chloroform molecule forms H-bonding with acetone molecule. As a result of this A — B interaction becomes stronger than A — A and B — B interactions. This leads to the decrease in vapour pressure and resulting in negative deviation.



S42. Positive deviation: For non-ideal solutions, if the vapour pressure is higher, then it is said to exhibit positive deviation. A — B interactions are weaker than A — A or B — B interactions. Due to this vapour pressure increases which results in positive deviation. In positive deviation, intermolecular force decreases, volume increases, vapour pressures increases, enthalpy increases. Therefore, $\Delta H_{\text{mix}} = +ve$, $\Delta V_{\text{mix}} = +ve$. e.g., ethanol + acetone and carbon disulphide + acetone show positive deviation.



Negative deviation: For non-ideal solution, if the vapour pressure is lower, then it is said to exhibit negative deviation. A — B interactions are stronger than A — A and B — B interactions. Due to this, vapour pressure decreases which results in negative deviation. In negative deviation, intermolecular force increases, volume decreases, vapour pressure decreases and heat is released. Therefore, $\Delta H_{\text{mix}} = -ve$, $\Delta V_{\text{mix}} = -ve$. Example, phenol + aniline and chloroform + acetone show negative deviation.



S43. A mixture of ethanol and acetone shows positive deviation from Raoult's law. Pure ethanol possesses hydrogen bonding. Introduction of acetone between the molecules of ethanol results in breaking of some of these hydrogen bonds. Due to weakening of interactions, the solution shows positive deviation from Raoult's law.

S44. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phases and that have constant boiling points.

It is not possible to separate the components of azeotropes by fractional distillation.

A maximum boiling azeotrope is formed by solutions showing a large negative deviation from Raoult's law at a specific composition.

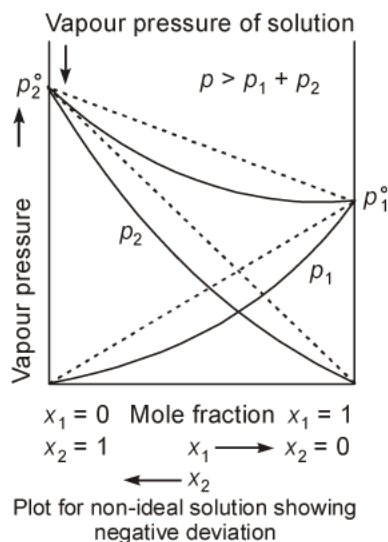
For example Chloroform – acetone mixture.

S45. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phases and that have constant boiling points.

It is not possible to separate the components of azeotropes by fractional distillation.

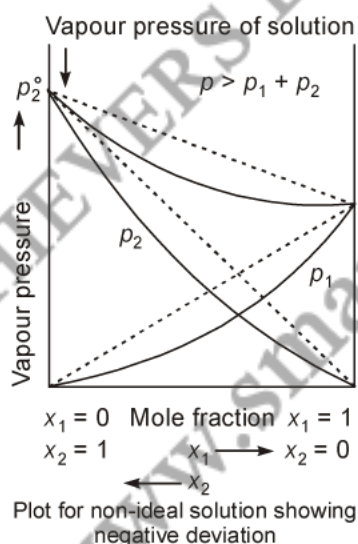
A minimum boiling azeotrope is formed by solutions showing a large positive deviation from Raoult's law at a specific composition. For example an ethanol-water mixture containing approximately 95% ethanol by volume.

S46. Negative deviation: For non-ideal solution, if the vapour pressure is lower, then it is said to exhibit negative deviation. $A-B$ interactions are stronger than $A-A$ and $B-B$ interactions. Due to this, vapour pressure decreases which results in negative deviation. In negative deviation, intermolecular force increases, volume decreases, vapour pressure decreases and heat is released. Therefore, $\Delta H_{\text{mix}} = -ve$, $\Delta V_{\text{mix}} = -ve$. Example, phenol + aniline and chloroform + acetone show negative deviation.



- S47.** (a) The elevation in boiling point of a solution is a colligative property which depends on the number of moles of solute added. Higher the concentration of solute added, higher will be the elevation in boiling point. Thus, 2 M glucose has higher boiling point than 1 M glucose solution.
- (b) When the external pressure applied becomes more than the osmotic pressure of solution then the solvent molecules from the solution pass through the semipermeable membrane to the solvent side and the process is called reverse osmosis.

S48. Negative deviation: For non-ideal solution, if the vapour pressure is lower, then it is said to exhibit negative deviation. $A - B$ interactions are stronger than $A - A$ and $B - B$ interactions. Due to this, vapour pressure decreases which results in negative deviation. In negative deviation, intermolecular force increases, volume decreases, vapour pressure decreases and heat is released. Therefore, $\Delta H_{\text{mix}} = -ve$, $\Delta V_{\text{mix}} = -ve$. Example, phenol + aniline and chloroform + acetone show negative deviation.



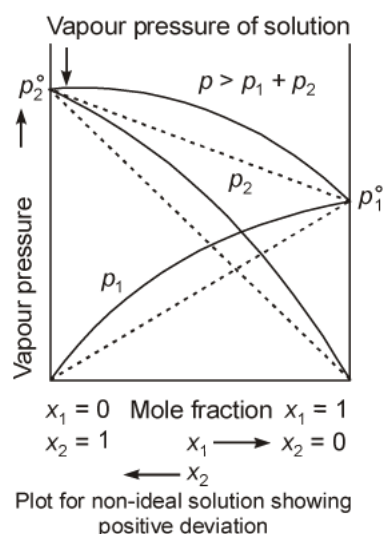
S49. Raoult's law: For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ \cdot x$

where

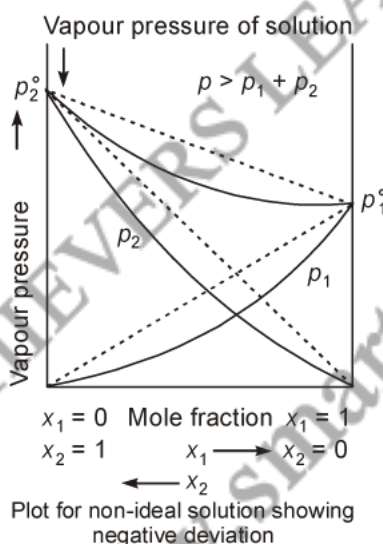
p° = Vapour pressure of pure component

x = mole fraction of that component.

Positive deviation: For non-ideal solutions, if the vapour pressure is higher, then it is said to exhibit positive deviation. $A - B$ interactions are weaker than $A - A$ or $B - B$ interactions. Due to this vapour pressure increases which results in positive deviation. In positive deviation, intermolecular force decreases, volume increases, vapour pressures increases, enthalpy increases. Therefore, $\Delta H_{\text{mix}} = +ve$, $\Delta V_{\text{mix}} = +ve$. e.g., ethanol + acetone and carbon disulphide + acetone show positive deviation.



Negative deviation: For non-ideal solution, if the vapour pressure is lower, then it is said to exhibit negative deviation. $A - B$ interactions are stronger than $A - A$ and $B - B$ interactions. Due to this, vapour pressure decreases which results in negative deviation. In negative deviation, intermolecular force increases, volume decreases, vapour pressure decreases and heat is released. Therefore, $\Delta H_{\text{mix}} = -ve$, $\Delta V_{\text{mix}} = -ve$. Example, phenol + aniline and chloroform + acetone show negative deviation.



- S50.** (a) ***n*-Hexane and *n*-octane:** London dispersion forces as both the molecules are non-polar.
 (b) **Methanol and acetone:** Dipole-dipole interactions as both the molecules are polar.

S51. The egg placed in pure water will swell because the concentration of proteins is high inside the egg as compare to water. Therefore, endosmosis occurs and water diffuses through the semipermeable membrane. The egg which is placed in sodium chloride solution will shrink due to osmosis of water out of the egg.

S52. Osmosis: The spontaneous movement of the solvent molecules from the pure solvent or from a dilute solution to a concentrated solution through a semi-permeable membrane is called osmosis.

Osmotic pressure: The minimum excess pressure that has to be applied on the solution to prevent the passage of solvent molecules into it through semipermeable membrane is called osmotic pressure.

Osmotic pressure is a colligative property because it depends on the number of solute particles and not on their nature.

The osmotic pressure method has the advantage over other methods because

- (i) osmotic pressure can be measured at room temperature and the molarity of the solution is used instead of molality.
- (ii) its magnitude is large as compared to other colligative properties even for very dilute solutions.

S53. (i) Number of particles of solute. (ii) Association or dissociation of solute.
(iii) Concentration of solute. (iv) Temperature.

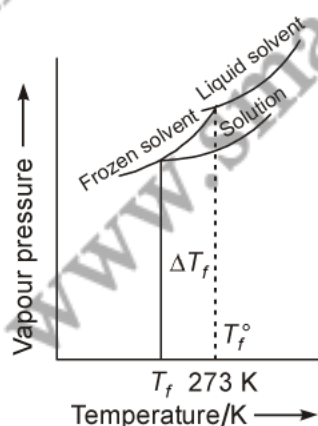
S54. Osmosis: The spontaneous movement of the solvent molecules from the pure solvent or from a dilute solution to a concentrated solution through a semi-permeable membrane is called osmosis.

Osmotic pressure: The minimum excess pressure that has to be applied on the solution to prevent the passage of solvent molecules into it through semipermeable membrane is called osmotic pressure.

Osmotic pressure is a colligative property because it depends on the number of solute particles and not on their nature.

S55. When a non-volatile solute is added to a solvent, the freezing point of the solution is always lower than that of pure solvent as the vapour pressure of the solvent decreases in the presence of non-volatile solute.

Plot for the lowering in freezing point of water when NaCl is added to it is shown as:



S56. Given, $W_1 = 1 \text{ kg} = 1000 \text{ g}$, $W_2 = 18 \text{ g}$, $M_2 = 180 \text{ g mol}^{-1}$
 $T_b^{\circ} = 373.15 \text{ K}$, $K_b = 0.52 \text{ K kg mol}^{-1}$, $T_b = ?$

Using formula,

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

$$\Delta T_b = \frac{0.52 \text{ K} \times 18 \times 1000}{180 \times 1000} = 0.052 \text{ K}$$

$$\Delta T_b = T_b - T_b^\circ$$

$$0.052 = T_b - 373.15$$

$$T_b = 373.15 + 0.052 = 373.202 \text{ K.}$$

S57. Given, $W_2 = ?$, $M_2 = 256 \text{ g mol}^{-1}$, $\Delta T_f = 0.48 \text{ K}$, $W_1 = 75 \text{ g}$, $K_f = 5.12 \text{ K kg mol}^{-1}$

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

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

$$= \frac{0.48 \times 256 \times 75}{5.12 \times 1000} = 1.8 \text{ g}$$

S58. The boiling point of the solution is always higher than that of the pure solvent. As the vapour pressure of the solution is lower than that of the pure solvent and vapour pressure increases with increase in temperature. Hence, the solution has to be heated more to make the vapour pressure equal to the atmospheric pressure.

Elevation of boiling point is a colligative property because it depends on number of solute particles present in a solution.

S59. (a) 1.2% sodium chloride solution is hypertonic with respect to 0.9% sodium chloride solution or blood cells thus, on placing blood cells in this solution exosmosis takes place that results in shrinking of cells.

(b) 0.4% sodium chloride solution is hypotonic with respect to 0.9% sodium chloride solution or blood cells thus, on placing blood cells in this solution endosmosis takes place that results in swelling of cells.

S60. Molality of solution, $m = 1.00 \text{ m}$

Boiling point of solution, $T_b = 100.18^\circ\text{C} = 373.18 \text{ K}$

Boiling point of water (solvent), $T_b^\circ = 100.00^\circ\text{C} = 373 \text{ K}$

$$\Delta T_b = T_b - T_b^\circ = 373.18 \text{ K} - 373 \text{ K} = 0.18 \text{ K}$$

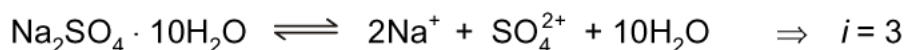
$$\Delta T_b = i K_f \cdot m$$

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

$$i = \frac{0.18 \text{ K}}{0.512 \text{ K kg mol}^{-1} \times 1 \text{ mol kg}^{-1}} = 0.35.$$

S61. Molecular mass of $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O} = [2 \times 23 + 32 + 16 \times 4 + 10 \times (2 \times 1 + 16)]$
 $= (46 + 32 + 64 + 180) \text{ g mol}^{-1} = 322 \text{ g mol}^{-1}$

$\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ionises as:



$$m = \frac{n_B}{W_A} = \frac{W_B}{M_B \times W_A} = \frac{6.00 \text{ g}}{322 \text{ g mol}^{-1} \times 0.1 \text{ kg}}$$

$$= 0.186 \text{ mol kg}^{-1} = 0.186 \text{ m}$$

Also,

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

$$= 3 \times 1.86 \text{ K m}^{-1} \times 0.186 \text{ m} = 1.04 \text{ K}$$

$$\Rightarrow T_f = T_f^\circ - \Delta T_f = (273 - 1.04) \text{ K} = 271.96 \text{ K}.$$

S62. Van't Hoff factor: It is defined as the ratio of the experimental value of colligative property to the calculated value of the colligative property and is used to find out the extent of dissociation or association. Mathematically, it is represented as

$$i = \frac{\text{Experimental (or observed value) of colligative property}}{\text{Calculated (or normal value) of colligative property}}$$

(a) van't Hoff factor (i) > 1 for solutes undergoing dissociation.

(b) van't Hoff factor (i) < 1 for solutes undergoing association.

S63. Osmotic pressure is the extra pressure which is applied on the solution to just prevent the flow of solvent into the solution through a semi-permeable membrane.

Relation between osmotic pressure and molar mass,

$$\pi V = n_2 RT$$

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

$$\left[\because n_2 = \frac{W_2}{M_2} \right]$$

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

where π is osmotic pressure and M_2 is molar mass of solute.

S64. Given,

$$W_2 = 0.520 \text{ g}$$

$$W_1 = 80.2 \text{ g}, K_b = 0.52 \text{ K m}^{-1}$$

$$M_2 \text{ of } \text{C}_6\text{H}_{12}\text{O}_6 = 6 \times 12 + 12 \times 1 + 6 \times 16 = 180 \text{ g mol}^{-1}$$

$$\Delta T_b = \frac{K_b \times W_2 \times 1000}{M_2 \times W_1} = \frac{0.52 \times 0.520 \times 1000}{180 \times 80.2} = 0.019 \text{ K}$$

Boiling point of solution,

$$T_b = T_b^\circ + \Delta T_b$$

$$= 373 \text{ K} + 0.019 \text{ K} = 373.019 \text{ K}.$$

S65. van't Hoff factor: It is defined as the ratio of the experimental value of colligative property to the calculated value of the colligative property and is used to find out the extent of dissociation or association. Mathematically, it is represented as

$$i = \frac{\text{Experimental (or observed value) of colligative property}}{\text{Calculated (or normal value) of colligative property}}$$

(a) van't Hoff factor (i) > 1 for solutes undergoing dissociation.

S66. Given, Mass of solute, $W_2 = 10$ g
 Mass of solvent, $W_1 = 90$ g
 Molar mass of solute, $M_2 = 180$ g mol⁻¹
 Density of solution = 1.3 g mL⁻¹

(i) Molality = $\frac{W_2 \times 1000}{M_2 \times W_1} = \frac{10 \times 1000}{180 \times 90} = 0.62$ mol kg⁻¹

(ii) Volume of solution = $\frac{\text{Mass}}{\text{Density}} = \frac{100 \text{ g}}{1.2 \text{ g mL}^{-1}}$

$$\text{Molarity} = \frac{w_2 \times 1000}{M_2 \times V}$$

$$M = \frac{10 \times 1000}{180 \times \frac{100}{1.2}} = \frac{10 \times 1000 \times 1.2}{180 \times 100} = 0.66 \text{ mol L}^{-1}$$

S67. Applying the relationship, $m = K_H \times p$

In the first case,

$$6.56 \times 10^{-2} \text{ g} = K_H \times 1 \text{ bar}$$

or, $K_H = 6.56 \times 10^{-2} \text{ g bar}^{-1}$

In the second case,

$$5.0 \times 10^{-2} \text{ g} = (6.56 \times 10^{-2} \text{ g bar}^{-1}) \times p$$

$$p = \frac{5.0 \times 10^{-2} \text{ g}}{6.56 \times 10^{-2} \text{ g bar}^{-1}} = 0.762 \text{ bar}$$

S68. Given, Temperature (T) = 25°C + 273 = 298 K

Total pressure (P_{total}) = 1 atm

$$p_{\text{N}_2} = \text{mole fraction of N}_2 \text{ in air} \times P_{\text{total}} = 0.78 \times 1 \text{ atm} = 0.78 \text{ atm} = 0.78 \times 760 \text{ mm} = 592.8 \text{ mm}$$

As K_H is in the units of M (mm)⁻¹, Henry's law is applied in the form:

$$\begin{aligned} \text{Conc. in solution} &= K_H p_{\text{N}_2} = 8.42 \times 10^{-7} \text{ M (mm)}^{-1} \times 592.8 \text{ mm} \\ &= 4.99 \times 10^{-4} \text{ M} \end{aligned}$$

S69. According to Henry's law, $p_{N_2} = K_H \times x_{N_2}$

$$x_{N_2} = \frac{p_{N_2}}{K_H} = \frac{0.987 \text{ bar}}{76480 \text{ bar}} = 1.29 \times 10^{-5}$$

If n moles of N_2 are present in 1 L (i.e., 55.55 moles),

$$x_{N_2} = \frac{n}{n + 55.55} = \frac{n}{55.55} \text{ of water}$$

$$\therefore \frac{n}{55.55} = 1.29 \times 10^{-5}$$

$$\begin{aligned} \text{or } n &= 1.29 \times 10^{-5} \times 55.55 \text{ moles} \\ &= 71.659 \times 10^{-5} \text{ moles} = 0.716 \text{ millimoles.} \end{aligned}$$

S70. Given: $p_A^\circ = 450 \text{ mm Hg}$, $p_B^\circ = 700 \text{ mm Hg}$, $p_{\text{Total}} = 600 \text{ mm Hg}$, $x_A = ?$

Applying Raoult's law,

$$p_A = x_A \times p_A^\circ$$

$$p_B = x_B \times p_B^\circ = (1 - x_A) p_B^\circ$$

$$\begin{aligned} p_{\text{Total}} &= p_A + p_B = x_A \times p_A^\circ + (1 - x_A) p_B^\circ \\ &= p_B^\circ + (p_A^\circ - p_B^\circ) x_A \end{aligned}$$

Substituting the given values, we get

$$600 = 700 + (450 - 700)x_A \quad \text{or} \quad 250x_A = 100$$

$$\text{or } x_A = \frac{100}{250} = 0.40$$

Thus, composition of the liquid mixture will be

$$x_A = 0.40$$

$$x_B = 1 - 0.40 = 0.60$$

Calculation of composition in the vapour phase,

$$p_A = x_A \times p_A^\circ = 0.40 \times 450 \text{ mm Hg} = 180 \text{ mm Hg}$$

$$p_B = x_B \times p_B^\circ = 0.60 \times 700 \text{ mm Hg} = 420 \text{ mm Hg}$$

Mole fraction of A in the vapour phase

$$= \frac{p_A}{p_A + p_B} = \frac{180}{180 + 420} = 0.30$$

Mole fraction of B in vapour phase = $1 - 0.30 = 0.70$

S71. Given, Mass of urea = 15 g

Molar mass of urea = 60 g mol^{-1}

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

Mass of glucose = ?

For isotonic solution, osmotic pressure, $\pi_1 = \pi_2$

$$n_1 = n_2 \quad (\text{when volume is same})$$

or
$$\frac{W_1}{M_1} = \frac{W_2}{M_2} \Rightarrow \frac{15}{60} = \frac{W_2}{180}$$

$$\Rightarrow W_2 = \frac{15 \times 180}{60} = 45 \text{ g.}$$

S72. Mass of ethylene glycol ($\text{C}_2\text{H}_6\text{O}_2$), $W_2 = 31 \text{ g}$

Mass of water, $W_1 = 500 \text{ g}$

M_2 (Mol. mass of $\text{C}_2\text{H}_6\text{O}_2$) = 62 g mol^{-1} ,

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

Using formula,

$$\begin{aligned} \Delta T_f &= K_f \times \frac{W_2 \times 1000}{M_2 \times W_1} \\ &= 1.86 \times \frac{31 \times 1000}{62 \times 500} = 1.86 \text{ K} \end{aligned}$$

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

or

$$T_f = T_f^\circ - \Delta T_f = 273 - 1.86 = 271.14 \text{ K.}$$

S73. Given, Mass of CaCl_2 (W_2) = 10 g

Mass of water (W_1) = 200 g

Molar mass of CaCl_2 (M_2) = 111 g mol^{-1}

Molal Elevation constant = $0.512 \text{ K kg mol}^{-1}$

$$m = \frac{W_2 \times 1000}{M_2 \times W_1}$$

$$m = \frac{10}{111} \times \frac{1000}{200} = 0.450 \text{ m}$$

$$\Delta T_b = K_b \cdot m = 0.512 \times 0.450 = 0.2306 \text{ K.}$$

S74.

$W_1 = 500 \text{ g}$

Boiling point of solution (T_b) = 100.42°C

K_b for water = $0.512 \text{ K kg mol}^{-1}$

$$\begin{aligned} M_2 (\text{C}_6\text{H}_8\text{O}_3) &= (3 \times 12) + (8 \times 1) + (3 \times 16) \\ &= 92 \text{ g mol}^{-1} \end{aligned}$$

$$\Delta T_b = T_b - T_b^\circ = 373.42 \text{ K} - 373 \text{ K} = 0.42 \text{ K}$$

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

$$W_2 = \frac{\Delta T_b \times M_2 \times W_1}{K_b \times 1000} = \frac{0.42 \times 92 \times 500}{0.512 \times 1000} = 37.73 \text{ g.}$$

S75. Given, Molality of sugar solution = $\frac{W_2 \times 1000}{M_2 \times W_1} = \frac{5}{342} \times \frac{1000}{95} = 0.154 \text{ m}$

$$\Delta T_f = T_f^\circ - T_f = 273.15 - 271 = 2.15 \text{ K}$$

$$\Delta T_f = K_f \times m \quad \therefore K_f = \frac{\Delta T_f}{m} = \frac{2.15}{0.154}$$

Molality of glucose solution = $\frac{W_2 \times 1000}{M_2 \times W_1} = \frac{5}{180} \times \frac{1000}{95} = 0.292 \text{ m}$

$$\therefore \Delta T_f(\text{Glucose}) = K_f \times m = \frac{2.15}{0.154} \times 0.292 = 4.08$$

$$\therefore \text{Freezing point of glucose solution} = 273.15 - 4.08 = 269.07 \text{ K.}$$

S76. Give,

$$W_2 = 1.00 \text{ g}, \quad W_1 = 50 \text{ g},$$

$$K_f = 5.12 \text{ K kg mol}^{-1}, \quad \Delta T_f = 0.40 \text{ K}$$

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

$$M_2 = \frac{K_f \times W_2 \times 1000}{W_1 \times \Delta T_f} = \frac{5.12 \times 1 \times 1000}{50 \times 0.40}$$

$$= 256 \text{ g mol}^{-1}.$$

S77.

$$T_f = -15^\circ\text{C}, \quad K_f = 1.86 \text{ K kg mol}^{-1}$$

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

$$= 0 - (-15^\circ\text{C}) = 15^\circ\text{C} = 288 \text{ K}$$

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

$$288 = 1.86 \times \frac{W_2}{0.062 \times 5}$$

$$W_2 = 48 \text{ g}$$

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

$$\Delta T_b = 0.52 \times \frac{48}{0.062 \times 5}$$

$$\Delta T_b = 80.51 \text{ K}$$

$$\Delta T_b = T_b - T_b^\circ$$

$$80.51 = T_b - 373$$

$$T_b = 80.51 + 373 = 453.51 \text{ K.}$$

S78. (a) Osmotic pressure: The minimum excess pressure that has to be applied on the solution to prevent the passage of solvent molecules into it through semipermeable membrane is called osmotic pressure.

Osmotic pressure is a colligative property because it depends on the number of solute particles and not on their nature.

- (i) Number of particles of solute. (ii) Association or dissociation of solute.
(iii) Concentration of solute. (iv) Temperature.

(b) Colligative properties are the properties of solution which depend upon the number of solute particles and not upon the nature of the solute.

S79. Given, $W_1 = 65.0 \text{ g}$, $\Delta T_f = 7.50^\circ\text{C}$

$$K_f = 1.86^\circ\text{C/m}, \quad i = 1.87$$

and

$$M_2 = 58.5 \text{ g mol}^{-1}$$

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

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

$$\begin{aligned} &= \frac{7.50^\circ\text{C} \times 58.5 \text{ g mol}^{-1} \times 65 \text{ g}}{1.87 \times 1.86^\circ\text{C/m} \times 1000} \\ &= 8.199 \text{ g.} \end{aligned}$$

S80. Given,

$$W_2 = 6.21 \text{ g}, \quad W_1 = 24.0 \text{ g}$$

$$T_b = 68.04^\circ\text{C}, \quad T_b^\circ = 61.7^\circ\text{C}$$

and

$$K_b = 3.63^\circ\text{C/m}$$

$$\Delta T_b = T_b - T_b^\circ = 68.04^\circ\text{C} - 61.7^\circ\text{C} = 6.34^\circ\text{C}$$

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

or

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

$$\begin{aligned} M_2 &= \frac{3.63^\circ\text{C m}^{-1} \times 6.21 \text{ g} \times 1000}{6.34^\circ\text{C} \times 24.0 \text{ g}} \\ &= 148.15 \text{ g mol}^{-1}. \end{aligned}$$

S81.

$$W_B = 8.95 \text{ mg} = 8.95 \times 10^{-3} \text{ g},$$

$$R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}, \quad V = 35 \times 10^{-3} \text{ L}$$

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

Substituting these values in the equation,

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

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

$$M_B = 14193.29 \text{ g mol}^{-1}.$$

S82. $i = 2$, $K_b = 0.512 \text{ K kg mol}^{-1}$, $W_B = 15 \text{ g}$, $M_B = 58.44 \text{ g mol}^{-1}$, $W_A = 250 \text{ g}$

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

$$\Delta T_b = \frac{2 \times 0.512 \times 15 \times 1000}{58.44 \times 250} = 1.05 \text{ K}$$

Therefore, boiling point of aqueous solution.

$$T_b = T_b^\circ + \Delta T_b = 372.15 \text{ K} + 1.05 \text{ K} = 374.40 \text{ K}.$$

S83. The relative lowering of vapour pressure is given by the following expression,

$$(p_{\text{solvent}}^\circ - p_{\text{solution}})/p_{\text{solvent}}^\circ = n_2/(n_1 + n_2)$$

for dilute solutions, $n_2 \ll n_1$, therefore

$$(p_{\text{solvent}}^\circ - p_{\text{solution}})/p_{\text{solvent}}^\circ = n_2/n_1$$

$$= (W_2 \times M_1)/(M_2 \times W_1)$$

$$(p_{\text{solvent}}^\circ - 2.8)/p_{\text{solvent}}^\circ = (30 \times 18)/(M_2 \times 90)$$

$$(p_{\text{solvent}}^\circ - 2.8)/p_{\text{solvent}}^\circ = 6/M_2$$

... (i)

Similarly for second case we get,

$$(p_{\text{solvent}}^\circ - 2.9)/p_{\text{solvent}}^\circ = (30 \times 18)/(M_2 \times 108)$$

$$(p_{\text{solvent}}^\circ - 2.9)/p_{\text{solvent}}^\circ = 5/M_2$$

... (ii)

On solving Eq. (i) and (ii), we get

$$(p_{\text{solvent}}^\circ - 2.8)/p_{\text{solvent}}^\circ = 6/5$$

$$\therefore p_{\text{solvent}}^\circ = 3.4 \text{ kPa}$$

i.e., vapour pressure of water at 298 K is 3.4 kPa

Substituting the value of p_{solvent}° in (i) we get,

$$(3.4 - 2.8) = 6/M_2$$

$$\text{or } 0.6/3.4 = 6/M_2$$

$$\therefore M_2 = 34 \text{ g}.$$

S84.

$$W_1 = 450 \text{ g}, \quad W_2 = 15.0 \text{ g}$$

$$\Delta T_f = T_f^\circ - T_f = 273 \text{ K} - 272.66 \text{ K} = 0.34 \text{ K}$$

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

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

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

$$M_2 = \frac{1.86 \times 15 \times 1000}{0.34 \times 450} = 182.35 \text{ g mol}^{-1}.$$

S85.

$$M_2 \text{ (ethylene glycol)} = 1.86 \text{ K kg mol}^{-1}$$

$$W_1 = 5.50 \text{ kg} = 5500 \text{ g}$$

$$\Delta T_f = T_f^\circ - T_f = 0^\circ\text{C} - (-10^\circ\text{C}) = 10^\circ\text{C} = 10 \text{ K}$$

and

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

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

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

$$= \frac{10 \times 62 \times 5500}{1.86 \times 1000} = 1833.33 \text{ g} = 1.833 \text{ kg}.$$

S86. Given,

$$W_2 = 1.25 \text{ g}, \quad W_1 = 99.0 \text{ g}$$

$$\Delta T_b = T_b - T_b^\circ = (80.31 - 80.10)^\circ\text{C} = 0.21^\circ\text{C} = 0.21 \text{ K}$$

$$\Delta T_b = K_b \cdot m$$

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

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

$$= \frac{2.53 \times 1.25 \times 1000}{0.21 \times 99} = \frac{3162.5}{20.79}$$

$$= 152.11 \text{ g} = 152 \text{ g mol}^{-1}.$$

S87.

Concentration of the solution = 1 molar

Density of the solution = 1.06 g mL^{-1}

M_2 , Molar mass of KBr = $39 + 80 = 119 \text{ g mol}^{-1}$

$$K_b \text{ for H}_2\text{O} = 0.52 \text{ K kg mol}^{-1}$$

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

$$m = \frac{1 \times 1000}{1000 \times 1.06 - 1 \times 119} = 1.0626 \text{ mol kg}^{-1}$$

$$\Delta T_b = K_b \cdot m = 0.52 \text{ K kg mol}^{-1} \times 1.0626 \text{ mol kg}^{-1}$$

$$\Delta T_b = 0.5525 \text{ K} = 0.553 \text{ K}$$

$$T_b = T_b^\circ + \Delta T_b = 373 \text{ K} + 0.553 \text{ K} = 373.553 \text{ K}.$$

S88. The egg placed in pure water will swell because the compared to water. Therefore, endosmosis occurs and water diffuses through the semipermeable membrane. The egg which is placed in sodium chloride solution will shrink due to osmosis of water out of the egg.

S89. Given,

$$W_1 = 1 \text{ kg} = 1000 \text{ g}, \quad \Delta T_f = 3 \text{ K}, \quad K_f = 1.86 \text{ K kg mol}^{-1}$$

$$M_2 (\text{NaCl}) = 23 + 35.5 = 58.5 \text{ g mol}^{-1}$$

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

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

[For NaCl, $i = 2$ because 1 mole of NaCl on dissociation give 2 moles of ions]

$$W_2 = \frac{3 \times 58.5 \times 1000}{2 \times 1.86 \times 1000} = 47.18 \text{ g}.$$

S90. Given,

$$W_2 = 100 \text{ mg} = 0.1 \text{ g}, \quad V = 10.0 \text{ mL} = 0.01 \text{ L}.$$

$$\pi = 13.4 \text{ mm Hg} = \frac{13.3}{760} \text{ atm}$$

$$T = 25^\circ\text{C} = 273 + 25 = 298 \text{ K}$$

$$R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$$

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

$$M_2 (\text{Protein}) = \frac{W_2 RT}{\pi V} = \frac{0.1 \text{ g} \times 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1} \times 298 \text{ K}}{\frac{13.3}{760} \text{ atm} \times 0.01 \text{ L}}$$

$$M_2 = 13980.45 \text{ g mol}^{-1}.$$

S91. Here,

$$\text{Molality} = 0.1539 \text{ m},$$

$$\Delta T_f = T_f^\circ - T_f = 273.15 - 271 = 2.15 \text{ K}$$

$$\therefore \Delta T_f = K_f \cdot m \quad \text{or} \quad K_f = \frac{\Delta T_f}{m} = \frac{2.15}{0.1539}$$

Again mass of solute, $W_2 = 5 \text{ g}$

Molar mass of solute, $M_2 = 180 \text{ g mol}^{-1}$

Mass of solution = 100 g

\therefore Mass of solvent, $W_1 = 95 \text{ g}$

Using,

$$\Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 \times W_1}$$
$$= \frac{2.15 \times 5 \times 1000}{0.1539 \times 180 \times 95} = 4.08 \text{ K}$$

\therefore Freezing point of solution, $T_f = T_f^\circ - \Delta T_f$

$$= 273.15 - 4.08 = 269.07 \text{ K.}$$

S92. Here,

$$T_b = 36.86^\circ\text{C}, \quad T_b^\circ = 35.60^\circ\text{C}$$

$$\Delta T_b = T_b - T_b^\circ = 36.86 - 35.60 = 1.26^\circ\text{C}$$

$$m = \frac{W_2}{M_2} \times \frac{1000}{W_1} = \frac{8}{M_2} \times \frac{1000}{100} = \frac{80}{M_2}$$

$$\Delta T_b = K_b \cdot m$$

$$1.26 = 2.02 \times \frac{80}{M_2}$$

$$M_2 = \frac{80 \times 2.02}{1.26} = 128.25 \text{ g mol}^{-1}.$$

S93. Here,

$$M_2 (\text{glucose, } \text{C}_6\text{H}_{12}\text{O}_6) = 180 \text{ g mol}^{-1}$$

$$W_2 = 54 \text{ g}, \quad W_1 = 250 \text{ g}, \quad K_f = 1.86 \text{ K kg mol}^{-1}$$

$$\Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 \times W_1}$$
$$= \frac{1.86 \times 54 \times 1000}{180 \times 250} = 2.23 \text{ K}$$

Freezing point of solution, $T_f = T_f^\circ - \Delta T_f$

$$= 273 \text{ K} - 2.23 \text{ K} = 270.77 \text{ K.}$$

S94. Molar mass of glucose, $\text{C}_6\text{H}_{12}\text{O}_6 = 6 \times 12 + 12 \times 1 + 6 \times 16 = 180 \text{ g mol}^{-1}$

Molar mass of sucrose, $\text{C}_{12}\text{H}_{22}\text{O}_{11} = 12 \times 12 + 22 \times 1 + 11 \times 16 = 342 \text{ g mol}^{-1}$

$$n_{\text{glucose}} = \frac{18}{180} = 0.1, \quad n_{\text{sucrose}} = \frac{68.4}{342} = 0.2$$

Total moles of solute,

$$n_2 = 0.1 + 0.2 = 0.3$$

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

$$\Delta T_f = \frac{K_f \times n_2 \times 1000}{W_1}$$

$$= \frac{1.86 \text{ K m}^{-1} \times 0.3 \text{ mol} \times 1000}{200 \text{ g}} = 2.79 \text{ K}$$

Freezing point of aqueous solution,

$$T_f = T_f^\circ - \Delta T_f = 273 - 2.79 = 270.21 \text{ K.}$$

S95. Given, Total moles in solution = $\frac{x}{200} + 0.05 \times 2 = \frac{x}{200} + 0.1$ ($\because i = 2$ for NaCl)

$$\pi V = nRT$$

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

$$\frac{x}{200} + 0.1 = \frac{4.92 \text{ atm} \times 1 \text{ L}}{0.082 \text{ L atm K}^{-1} \text{ mol}^{-1} \times 300 \text{ K}} = 0.20$$

$$\frac{x}{200} = 0.20 - 0.1 = 0.1$$

$$x = 0.1 \times 200 = 20 \text{ g.}$$

S96. Given,

$$W_2 = 4 \text{ g, } M_2 = 120 \text{ g mol}^{-1}$$

$$W_1 = 100 \text{ g, } K_b = 0.52 \text{ K kg mol}^{-1}$$

For complete dissociation,

$$i = 2$$

Using formula,

$$\Delta T_b = i K_b m$$

or

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

$$= 2 \times 0.52 \times \frac{4 \times 1000}{120 \times 100} = 0.34 \text{ K}$$

\therefore

$$T_b = T_b^\circ + \Delta T_b = 100 + 0.34 = 100.34^\circ \text{C.}$$

S97. Given,

$$W_2 = 2.56 \text{ g, } W_1 = 100 \text{ g, } \Delta T_f = 0.283 \text{ K}$$

$$K_f = 3.83 \text{ K kg mol}^{-1}, \Delta T_f = K_f \cdot m$$

\Rightarrow

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

\Rightarrow

$$M_2 = \frac{W_2 \times 1000}{\Delta T_f \times W_1} \times K_f = \frac{2.56 \times 1000}{0.283 \times 100} \times 3.83$$
$$= 256 \text{ g mol}^{-1}$$

$$\therefore i = \frac{\text{Normal atomic mass}}{\text{Observed atomic mass}} = \frac{32}{256} = \frac{1}{8}$$

Sulphur exists as S_8 .

S98.

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

i for $MgCl_2 = 3$

Molality, $m = \frac{W_2 \times 1000}{M_2 \times W_1} = \frac{1.9 \times 1000}{95 \times 50} = 0.4 \text{ m}$

$$\Delta T_f = 3 \times 1.86 \times 0.4 = 2.232 \text{ K}$$

Freezing point of solution, $T_f = T_f^\circ - \Delta T_f$

$$= 273 - 2.232 \text{ K} = 270.77 \text{ K}.$$

S99. Given, $m = 0.561 \text{ m}$, $\Delta T_f = 2.93^\circ\text{C}$

and $K_f = 1.86^\circ\text{C kg mol}^{-1}$

$$\Delta T_f = i K_f m$$

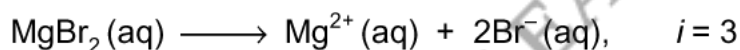
$$i = \frac{\Delta T_f}{K_f m} = \frac{2.93^\circ\text{C}}{1.86^\circ\text{C kg mol}^{-1} \times 0.561 \text{ m}} = 2.807.$$

S100 Given,

$$W_2 = 10.50 \text{ g}, \quad W_1 = 200 \text{ g}$$

$$M_2 (\text{MgBr}_2) = 184 \text{ g mol}^{-1}$$

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



$$\Delta T_f = i K_f m$$

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

$$\Delta T_f = \frac{3 \times 1.86 \times 10.50 \times 1000}{184 \times 200} = 1.592 \text{ K}$$

Freezing point of solution, $T_f = T_f^\circ - \Delta T_f = 273 - 1.592 = 271.408 \text{ K}.$

S101 $\Delta T_f = 2 \text{ K}$, $K_f = 1.86 \text{ K kg mol}^{-1}$, $W_1 = 1 \text{ kg}$, $\Delta T_f = i K_f m$, $M_2 (\text{KCl}) = 74.5 \text{ g mol}^{-1}$

$i = 2$ for KCl

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

$$2 = \frac{2 \times 1.86 \times W_2 \times 1000}{74.5 \times 1000}$$

$\Rightarrow W_2 = 40.05 \text{ g}.$

S102 Mass of K_2SO_4 ,

$$W_2 = 2.5 \times 10^{-2} \text{ g}$$

Molar mass of K_2SO_4 ,

$$M_2 = 174 \text{ g mol}^{-1}$$

$$V = 2 \text{ L}, \quad T = 25^\circ\text{C} = 298 \text{ K}$$

$$R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$$

We know, osmotic pressure, $\pi = \frac{W_2 RT}{M_2 V}$

$$\pi = \frac{2.5 \times 10^{-2} \times 0.0821 \times 298}{174 \times 2}$$

$$= \frac{61.1645 \times 10^{-2}}{348}$$

$$= 0.1758 \times 10^{-2} \text{ atm.}$$

S103 Here,

$$\Delta T_f = i K_f m = \frac{i \times K_f \times W_2 \times 1000}{M_2 \times W_1}$$

$$2 = \frac{2 \times 1.86 \times W_2 \times 1000}{58.5 \times 37.2}$$

\Rightarrow

$$W_2 = 1.17 \text{ g.}$$

S104 Given,

$$W_2 = 3.9 \text{ g}, \quad W_1 = 49 \text{ g,}$$

$$\Delta T_f = 1.62 \text{ K}, \quad M_2 = 122 \text{ g mol}^{-1}$$

$$K_f = 4.9 \text{ K kg mol}^{-1}$$

$$\Delta T_f = i K_f m = i \times K_f \times \frac{W_2 \times 1000}{M_2 \times W_1}$$

\Rightarrow

$$1.62 = \frac{i \times 4.9 \times 3.9 \times 1000}{122 \times 49} = 0.34 \text{ K}$$

\Rightarrow

$$i = \frac{1.62 \times 122 \times 49}{4.9 \times 3.9 \times 1000} = 0.506$$

As $i < 1$, solute is associated.

S105.

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

$$= \frac{2.53 \times 0.30 \times 1000}{0.0633 \times 100} = 120 \text{ g mol}^{-1}$$

∴ Molar mass of $\text{CH}_3\text{COOH} = 60 \text{ g/mol}$

Here, $i < 1$, therefore, the solute acetic acid is associated in benzene.

S106 Here, $n = 3$ because 2 molecule of BaCl_2 on dissociation gives three ions.

$$W_2 = 12.48 \text{ g}, \quad W_1 = 1.0 \text{ kg} = 1000 \text{ g}$$

$$T_b = 373.0832 \text{ K}, \quad K_b \text{ for } \text{H}_2\text{O} = 0.52 \text{ K m}^{-1}$$

and

$$M_2(\text{BaCl}_2) = 208.34 \text{ g mol}^{-1}$$

$$\Delta T_b = T_b - T_b^\circ = 373.0832 \text{ K} - 373 \text{ K} = 0.0832 \text{ K}$$

$$M_{2(\text{observed})} = \frac{K_b \times W_2 \times 1000}{\Delta T_b \times W_1}$$

$$M_{2(\text{observed})} = \frac{0.52 \times 12.48 \times 1000}{0.0832 \times 1000} = 78$$

$$M_{2(\text{observed})} = 78 \text{ g mol}^{-1}$$

$$i = \frac{M_{2(\text{calculated})}}{M_{2(\text{observed})}} = \frac{208.34 \text{ g mol}^{-1}}{78 \text{ g mol}^{-1}} = 2.67$$

$$\alpha = \frac{i - 1}{n - 1} = \frac{2.67 - 1}{3 - 1} = \frac{1.67}{2} = 0.835 = 83.5\%$$

S107 Here, $n = 2$ because phenol forms dimer on association.

$$W_2 = 20 \text{ g}, \quad W_1 = 1 \text{ kg} = 1000 \text{ g}$$

$$\Delta T_f = 0.69 \text{ K}, \quad K_f = 5.1 \text{ K m}^{-1}$$

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

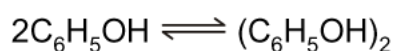
$$M_2 = \frac{K_f \times W_2 \times 1000}{\Delta T_f \times W_1}$$

$$= \frac{5.1 \times 20 \times 1000}{0.69 \times 1000} = 147.82$$

$$M_{2(\text{observed})} = 147.82$$

$$M_{2(\text{observed})} \text{ C}_6\text{H}_5\text{OH} = 6 \times 12 + 6 \times 1 + 16 = 94 \text{ g mol}^{-1}$$

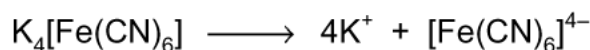
$$i = \frac{M_{2(\text{calculated})}}{M_{2(\text{observed})}} = \frac{94}{147.82} = 0.635$$



$$\alpha = \frac{i - 1}{\left(\frac{1}{n} - 1\right)} = \frac{0.635 - 1}{\left(\frac{1}{2} - 1\right)} = \frac{0.365}{0.5} = 0.73 = 73\%$$

S108.

$$C = \frac{1}{10} \text{ M}$$



∴

$$n = 5$$

Degree of dissociation,

$$\alpha = \frac{50}{100} = 0.5$$

$$\alpha = \frac{i-1}{n-1}, \quad 0.5 = \frac{i-1}{5-1}, \quad 0.5 = \frac{i-1}{4}$$

⇒

$$i-1 = 2 \quad \therefore \quad i = 3.$$

S109(a)

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

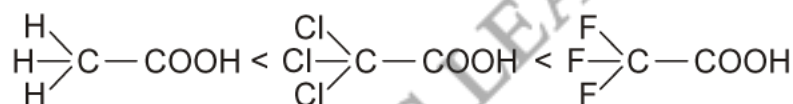
$$= \frac{5.12 \times 0.2 \times 1000}{0.45 \times 20} = 113.77 \text{ g mol}^{-1}$$

(b) Molar mass of acetic acid = 60 g/mol

$$i = \frac{M_{2(\text{calculated})}}{M_{2(\text{observed})}} = \frac{60}{113.77} = 0.52$$

Here, $i < 1$, therefore, the solute acetic acid is associated in benzene.**S110**(a) The depression in freezing point is in the order:

Acetic acid < trichloroacetic < trifluoroacetic acid



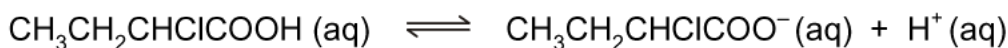
Fluorine has the highest electron withdrawing inductive effect ($-I$ effect) so trifluoroacetic acid is the strongest acid and acetic acid is the weakest acid. Therefore, trifluoroacetic acid ionises to the greater extent and acetic acid ionises to the minimum extent. Greater the number of ions produced, greater is the depression in freezing point.

(b) Molar mass of $\text{CH}_3\text{CH}_2\text{CHClCOOH} = 4 \times 12 + 7 \times 1 + 35.5 + 2 \times 16 = 122.5 \text{ g mol}^{-1}$

$$\text{Number of moles of } \text{CH}_3\text{CH}_2\text{CHClCOOH} = \frac{20}{122.5} = 0.1632 \text{ mol}$$

$$\text{Molality of solution} = \frac{\text{Moles of solute} \times 1000}{\text{Mass of solvent (g)}}$$

$$m = \frac{0.1632 \times 1000}{500} = 0.3264 \text{ m}$$

where, α is the degree of dissociation of acid.

$$K_a = \frac{(C\alpha)^2}{C(1-\alpha)} = C\alpha^2 \quad (\because 1 \gg \alpha)$$

$$\alpha = \sqrt{\frac{K_a}{C}} = \sqrt{\frac{1.4 \times 10^{-3}}{0.3264}} = 0.065$$

$$\alpha = \frac{i-1}{n-1} \Rightarrow 0.065 = \frac{i-1}{2-1}$$

[\because For the given acid $n=2$ because 1 molecule gives 2 particles on dissociation]

$$i = 1 + 0.065 = 1.065$$

$$\Delta T_f = i K_f m$$

$$= 1.065 \times 1.86 \times 0.3264$$

$$\Delta T_f = 0.6465 = 0.65 \text{ K.}$$

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