CHAPTER

2

Solutions

2.2 Expressing Concentration of Solutions

1. Which of the following is dependent on temperature?
   (a) Molarity
   (b) Mole fraction
   (c) Weight percentage *(NEET 2017)*

2. What is the mole fraction of the solute in a 1.00 m aqueous solution? (b) 0.0354
   (c) 0.0177 (d) 0.177 *(2015, 2011)*

3. How many grams of concentrated nitric acid solution should be used to prepare 250 mL of 2.0 M HNO_3? The concentrated acid is 70% HNO_3.
   (a) 70.0 g conc. HNO_3
   (b) 54.0 g conc. HNO_3
   (c) 45.0 g conc. HNO_3
   (d) 90.0 g conc. HNO_3 *(NEET 2013)*

4. Which of the following compounds can be used as antifreeze in automobile radiators?
   (a) Methyl alcohol (b) Glycol
   (c) Nitrophenol (d) Ethyl alcohol
   (2012)

5. Concentrated aqueous sulphuric acid is 98% H_2SO_4 by mass and has a density of 1.80 g mL^{-1}. Volume of acid required to make one litre of 0.1 M H_2SO_4 solution is
   (a) 16.65 mL (b) 22.20 mL
   (c) 5.55 mL (d) 11.10 mL *(2007)*

6. The mole fraction of the solute in one molal aqueous solution is
   (a) 0.009 (b) 0.018
   (c) 0.027 (d) 0.036 *(2005)*

7. 2.5 litre of 1 M NaOH solution is mixed with another 3 litre of 0.5 M NaOH solution. Then find out molarity of resultant solution.
   (a) 0.80 M (b) 1.0 M
   (c) 0.73 M (d) 0.50 M *(2002)*

8. How many g of dibasic acid (mol. weight 200) should be present in 100 mL of the aqueous solution to give strength of 0.1 N?
   (a) 10 g (b) 2 g
   (c) 1 g (d) 20 g *(1999)*

9. What is the molarity of H_2SO_4 solution, that has a density 1.84 g/cc at 35°C and contains 98% by weight?
   (a) 18.4 M (b) 18 M
   (c) 4.18 M (d) 8.14 M *(1996)*

10. The concentration unit, independent of temperature, would be
    (a) normality (b) weight volume percent
    (c) molality (d) molarity. *(1995, 1992)*

11. How many grams of CH_3OH should be added to water to prepare 150 mL solution of 2 M CH_3OH?
    (a) 9.6×10^3 (b) 2.4×10^3
    (c) 9.6 (d) 2.4 *(1994)*

2.4 Vapour Pressure of Liquid Solutions

12. In water saturated air, the mole fraction of water vapour is 0.02. If the total pressure of the saturated air is 1.2 atm, the partial pressure of dry air is (b) 1.76 atm
    (c) 1.176 atm (d) 0.98 atm.
    (Odisha NEET 2019)

13. p_A and p_B are the vapour pressures of pure liquid components, A and B, respectively of an ideal binary solution. If x_A represents the mole fraction of component A, the total pressure of the solution will be
    (a) $p_A + x_A(p_B - p_A)$ (b) $p_A + x_A(p_A - p_B)$
    (c) $p_B + x_A(p_B - p_A)$ (d) $p_B + x_A(p_A - p_B)$
    (2012)

14. Vapour pressure of chloroform ($CHCl_3$) and dichloromethane (CH_2Cl_2) at 25°C are 200 mm Hg and 41.5 mm Hg respectively. Vapour pressure of the solution obtained by mixing 25.5 g of $CHCl_3$ and 40 g of CH_2Cl_2 at the same temperature will be

(Molecular mass of $CHCl_3$ = 119.5 u and molecular mass of CH_2Cl_2 = 85 u)

(a) 173.9 mm Hg (b) 615.0 mm Hg
(c) 347.9 mm Hg (d) 285.5 mm Hg
(Mains 2012)

15. A solution has a 1 : 4 mole ratio of pentane to hexane. The vapour pressures of the pure hydrocarbons at 20 °C are 440 mm Hg for pentane and 120 mm Hg for hexane. The mole fraction of pentane in the vapour phase would be

(a) 0.200 (b) 0.549
(c) 0.786 (d) 0.478 *(2005)*

16. The vapour pressure of two liquids P and Q are 80 and 60 torr, respectively. The total vapour pressure of solution obtained by mixing 3 mole of P and 2 mol of Q would be

(a) 72 torr (b) 140 torr
(c) 68 torr (d) 20 torr *(2005)*

2.5 Ideal and Non-Ideal Solutions

17. The mixture which shows positive deviation from Raoult's law is

(a) ethanol + acetone (b) benzene + toluene
(c) acetone + chloroform
(d) chloroethane + bromoethane. *(NEET 2020)*

18. For an ideal solution, the correct option is

(a) $\Delta_{mix}G = 0$ at constant T and P
(b) $\Delta_{mix}S = 0$ at constant T and P
(c) $\Delta_{mix}V \neq 0$ at constant T and P
(d) $\Delta_{mix}H = 0$ at constant T and P. *(NEET 2019)*

19. The mixture that forms maximum boiling azeotrope is

(a) heptane + octane (b) water + nitric acid
(c) ethanol + water
(d) acetone + carbon disulphide. *(NEET 2019)*

20. Which of the following statements is correct regarding a solution of two components A and B exhibiting positive deviation from ideal behaviour?

(a) Intermolecular attractive forces between A-A and B-B are stronger than those between A-B.
(b) $\Delta_{mix} H = 0$ at constant T and P.
(c) $\Delta_{mix} V = 0$ at constant T and P.
(d) Intermolecular attractive forces between A-A and B-B are equal to those between A-B.
(Odisha NEET 2019)

21. Which one of the following is incorrect for ideal solution?

(a) $\Delta H_{mix} = 0$ (b) $\Delta U_{mix} = 0$
(c) $\Delta P = P_{obs} - P_{\text{calculated by Raoult's law}} = 0$
(d) $\Delta G_{mix} = 0$ *(NEET-II 2016)*

22. Which of the following statements about the composition of the vapour over an ideal 1 : 1 molar mixture of benzene and toluene is correct? Assume that the temperature is constant at 25°C. (Given, vapour pressure data at 25°C, benzene = 12.8 kPa, toluene = 3.85 kPa)

(a) The vapour will contain equal amounts of benzene and toluene.
(b) Not enough information is given to make a prediction.
(c) The vapour will contain a higher percentage of benzene.
(d) The vapour will contain a higher percentage of toluene. *(NEET-I 2016)*

23. Which condition is not satisfied by an ideal solution?

(a) $\Delta_{mix}V = 0$ (b) $\Delta_{mix}S = 0$
(c) Obeyance to Raoult's Law
(d) $\Delta_{mix}H = 0$ *(Karnataka NEET 2013)*

24. A solution of acetone in ethanol

(a) obeys Raoult's law
(b) shows a negative deviation from Raoult's law
(c) shows a positive deviation from Raoult's law
(d) behaves like a near ideal solution. *(2006)*

25. A solution containing components A and B follows Raoult's law

(a) A - B attraction force is greater than A - A and B - B
(b) A - B attraction force is less than A - A and B - B
(c) A - B attraction force remains same as A - A and B - B
(d) volume of solution is different from sum of volume of solute and solvent. *(2002)*

26. All form ideal solution except

(a) C_6H_6 and $C_6H_5CH_3$ (b) C_2H_6 and C_2H_5I
(c) C_6H_5Cl and C_6H_5Br (d) C_2H_5I and C_2H_5OH
(1988)

27. An ideal solution is formed when its components

(a) have no volume change on mixing
(b) have no enthalpy change on mixing
(c) have both the above characteristics
(d) have high solubility. *(1988)*

2.6 Colligative Properties and Determination of Molar Mass

28. The freezing point depression constant (K_f) of benzene is 5.12 K kg mol^{-1}. The freezing point depression for the solution of molality 0.078 m containing a non-electrolyte solute in benzene is (rounded off upto two decimal places)

(a) 0.20 K (b) 0.80 K
(c) 0.40 K (d) 0.60 K *(NEET 2020)*

29. If molality of the dilute solution is doubled, the value of molal depression constant (K_f) will be

(a) halved (b) tripled

(c) unchanged (d) doubled. *(NEET 2017)*

30. At 100°C the vapour pressure of a solution of 6.5 g of a solute in 100 g water is 732 mm. If $K_b = 0.52$, the boiling point of this solution will be

(a) 102 °C (b) 103 °C

(c) 101 °C (d) 100 °C

(NEET-I 2016)

31. 200 mL of an aqueous solution of a protein contains its 1.26 g. The osmotic pressure of this solution at 300 K is found to be 2.57×10^{-3} bar. The molar mass of protein will be ($R = 0.083$ L bar mol^{-1} K^{-1})

(a) 51022 g mol^{-1} (b) 122044 g mol^{-1}

(c) 31011 g mol^{-1} (d) 61038 g mol^{-1}

(Mains 2011)

32. A solution of sucrose (molar mass = 342 g mol^{-1}) has been prepared by dissolving 68.5 g of sucrose in 1000 g of water. The freezing point of the solution obtained will be (K_f for water = 1.86 K kg mol^{-1})

(a) –0.372 °C (b) – 0.520 °C

(c) + 0.372 °C (d) – 0.570 °C *(2010)*

33. During osmosis, flow of water through a semipermeable membrane is

(a) from solution having lower concentration only

(b) from solution having higher concentration only

(c) from both sides of semipermeable membrane with equal flow rates

(d) from both sides of semipermeable membrane with unequal flow rates. *(2006)*

34. 1.00 g of a non-electrolyte solute (molar mass 250 g mol^{-1}) was dissolved in 51.2 g of benzene. If the freezing point constant, K_f of benzene is 5.12 K kg mol^{-1}, the freezing point of benzene will be lowered by

(a) 0.2 K (b) 0.4 K

(c) 0.3 K (d) 0.5 K *(2006)*

35. A solution containing 10 g per dm^3 of urea (molecular mass = 60 g mol^{-1}) is isotonic with a 5% solution of a non-volatile solute. The molecular mass of this non-volatile solute is

(a) 200 g mol^{-1} (b) 250 g mol^{-1}

(c) 300 g mol^{-1} (d) 350 g mol^{-1} *(2006)*

36. A solution of urea (mol. mass 56 g mol^{-1}) boils at 100.18°C at the atmospheric pressure. If K_f and K_b for water are 1.86 and 0.512 K kg mol^{-1} respectively, the above solution will freeze at

(a) 0.654°C (b) –0.654°C

(c) 6.54°C (d) – 6.54°C *(2005)*

37. A solution contains non-volatile solute of molecular mass M_2. Which of the following can be used to calculate the molecular mass of solute in terms of osmotic pressure?

(a) $M_2 = \left(\frac{m_2}{V}\right) VRT$ *(b)* $M_2 = \left(\frac{m_2}{V}\right) \frac{RT}{\pi}$

(c) $M_2 = \left(\frac{m_2}{V}\right) \pi RT$ *(d)* $M_2 = \left(\frac{m_2}{V}\right) \frac{\pi}{RT}$

(m_2 = mass of solute, V = volume of solution, π = osmotic pressure) *(2002)*

38. Pure water can be obtained from sea water by

(a) centrifugation (b) plasmolysis

(c) reverse osmosis (d) sedimentation.

(2001)

39. From the colligative properties of solution, which one is the best method for the determination of molecular weight of proteins and polymers?

(a) Osmotic pressure

(b) Lowering in vapour pressure

(c) Lowering in freezing point

(d) Elevation in boiling point *(2000)*

40. The vapour pressure of benzene at a certain temperature is 640 mm of Hg. A non-volatile and non-electrolyte solid, weighing 2.175 g is added to 39.08 of benzene. The vapour pressure of the solution is 600 mm of Hg. What is the molecular weight of solid substance?

(a) 69.5 (b) 59.6

(c) 49.50 (d) 79.8 *(1999)*

41. If 0.15 g of a solute, dissolved in 15 g of solvent, is boiled at a temperature higher by 0.216°C, than that of the pure solvent. The molecular weight of the substance (Molal elevation constant for the solvent is 2.16°C) is

(a) 10.1 (b) 100

(c) 1.01 (d) 1000 *(1999)*

42. A 5% solution of cane sugar (mol. wt. = 342) is isotonic with 1% solution of a substance X. The molecular weight of X is

(a) 68.4 (b) 171.2

(c) 34.2 (d) 136.8 *(1998)*

43. The vapour pressure of a solvent decreased by 10 mm of mercury when a non-volatile solute was added to the solvent. The mole fraction of the solute in the solution is 0.2. What should be the mole fraction of the solvent if the decrease in the vapour pressure is to be 20 mm of mercury?

(a) 0.4 (b) 0.6

(c) 0.8 (d) 0.2 *(1998)*

44. The vapour pressure of CCl_4 at 25°C is 143 mm Hg. If 0.5 g of a non-volatile solute (mol. weight = 65) is dissolved in 100 g CCl_4, the vapour pressure of the solution will be

(a) 199.34 mm Hg (b) 143.99 mm Hg

(c) 141.43 mm Hg (d) 94.39 mm Hg. *(1996)*

45. The relationship between osmotic pressure at 273 K when 10 g glucose (p_1), 10 g urea (p_2), and 10 g sucrose (p_3) are dissolved in 250 mL of water is

(a) $p_2 > p_1 > p_3$ (b) $p_2 > p_3 > p_1$

(c) $p_1 > p_2 > p_3$ (d) $p_3 > p_1 > p_2$ *(1996)*

46. According to Raoult's law, the relative lowering of vapour pressure for a solution is equal to

(a) mole fraction of solute

(b) mole fraction of solvent

(c) moles of solute (d) moles of solvent.

(1995)

47. If 0.1 M solution of glucose and 0.1 M solution of urea are placed on two sides of the semipermeable membrane to equal heights, then it will be correct to say that

(a) there will be no net movement across the membrane

(b) glucose will flow towards glucose solution

(c) urea will flow towards glucose solution

(d) water will flow from urea solution to glucose.

(1992)

48. Which one is a colligative property?

(a) Boiling point (b) Vapour pressure

(c) Osmotic pressure (d) Freezing point *(1992)*

49. Blood cells retain their normal shape in solution which are

(a) hypotonic to blood (b) isotonic to blood

(c) hypertonic to blood (d) equinormal to blood.

(1991)

50. The relative lowering of the vapour pressure is equal to the ratio between the number of

(a) solute molecules to the solvent molecules

(b) solute molecules to the total molecules in the solution

(c) solvent molecules to the total molecules in the solution

(d) solvent molecules to the total number of ions of the solute. *(1991)*

2.7 Abnormal Molar Masses

51. The van't Hoff factor (i) for a dilute aqueous solution of the strong electrolyte barium hydroxide is

(a) 0 (b) 1 (c) 2 (d) 3

(NEET-II 2016)

52. The boiling point of 0.2 mol kg^{-1} solution of X in water is greater than equimolal solution of Y in water. Which one of the following statements is true in this case?

(a) Molecular mass of X is less than the molecular mass of Y.

(b) Y is undergoing dissociation in water while X undergoes no change.

(c) X is undergoing dissociation in water.

(d) Molecular mass of X is greater than the molecular mass of Y. *(2015, Cancelled)*

53. Of the following 0.10 m aqueous solutions, which one will exhibit the largest freezing point depression?

(a) KCl (b) $C_6H_{12}O_6$

(c) $Al_2(SO_4)_3$ (d) K_2SO_4 *(2014)*

54. The van't Hoff factor i for a compound which undergoes dissociation in one solvent and association in other solvent is respectively

(a) less than one and greater than one

(b) less than one and less than one

(c) greater than one and less than one

(d) greater than one and greater than one. *(2011)*

55. The freezing point depression constant for water is –1.86 °C m^{-1}. If 5.00 g Na_2SO_4 is dissolved in 45.0 g H_2O, the freezing point is changed by –3.82 °C. Calculate the van't Hoff factor for Na_2SO_4.

(a) 2.05 (b) 2.63

(c) 3.11 (d) 0.381 *(2011)*

56. A 0.1 molal aqueous solution of a weak acid is 30% ionized. If K_f for water is 1.86°C/m, the freezing point of the solution will be

(a) –0.18 °C (b) – 0.54 °C

(c) –0.36 °C (d) – 0.24 °C

(Mains 2011)

57. An aqueous solution is 1.00 molal in KI. Which change will cause the vapour pressure of the solution to increase?

(a) Addition of NaCl (b) Addition of Na_2SO_4

(c) Addition of 1.00 molal KI

(d) Addition of water *(2010)*

58. A 0.0020 m aqueous solution of an ionic compound $[Co(NH_3)_5(NO_2)]Cl$ freezes at –0.00732 °C. Number of moles of ions which 1 mol of ionic compound produces on being dissolved in water will be (K_f = –1.86 °C/m)

(a) 3 (b) 4 (c) 1 (d) 2 *(2009)*

59. 0.5 molal aqueous solution of a weak acid (HX) is 20% ionised. If K_f for water is 1.86 K kg mol^{-1}, the lowering in freezing point of the solution is

(a) 0.56 K (b) 1.12 K

(c) –0.56 K (d) –1.12 K *(2007)*

60. Which of the following 0.10 m aqueous solution will have the lowest freezing point?
(a) KI (b) $C_{12}H_{22}O_{11}$
(c) $Al_2(SO_4)_3$ (d) $C_5H_{10}O_5$ *(1997)*

61. Which of the following salts has the same value of van't Hoff factor (*i*) as that of $K_3[Fe(CN)_6]$?
(a) Na_2SO_4 (b) $Al(NO_3)_3$
(c) $Al_2(SO_4)_3$ (d) NaCl *(1994)*

62. At 25°C, the highest osmotic pressure is exhibited by 0.1 M solution of
(a) glucose (b) urea
(c) $CaCl_2$ (d) KCl. *(1994)*

63. Which of the following aqueous solution has minimum freezing point?
(a) 0.01 m NaCl (b) 0.005 m C_2H_5OH
(c) 0.005 m MgI_2 (d) 0.005 m $MgSO_4$ *(1991)*

ANSWER KEY

1.	(a)	**2.**	(c)	**3.**	(c)	**4.**	(b)	**5.**	(c)	**6.**	(b)	**7.**	(c)	**8.**	(c)	**9.**	(a)	**10.**	(c)
11.	(c)	**12.**	(c)	**13.**	(d)	**14.**	None	**15.**	(d)	**16.**	(a)	**17.**	(a)	**18.**	(d)	**19.**	(b)	**20.**	(a)
21.	(d)	**22.**	(c)	**23.**	(b)	**24.**	(c)	**25.**	(c)	**26.**	(d)	**27.**	(c)	**28.**	(c)	**29.**	(c)	**30.**	(c)
31.	(d)	**32.**	(a)	**33.**	(a)	**34.**	(b)	**35.**	(c)	**36.**	(b)	**37.**	(b)	**38.**	(c)	**39.**	(a)	**40.**	(a)
41.	(b)	**42.**	(a)	**43.**	(b)	**44.**	(c)	**45.**	(a)	**46.**	(a)	**47.**	(a)	**48.**	(c)	**49.**	(b)	**50.**	(b)
51.	(d)	**52.**	(c)	**53.**	(c)	**54.**	(c)	**55.**	(b)	**56.**	(d)	**57.**	(d)	**58.**	(d)	**59.**	(b)	**60.**	(c)
61.	(b)	**62.**	(c)	**63.**	(a)														

Hints & Explanations

1. (a) : Molarity is a function of temperature as volume depends on temperarure.

2. (c) : 1 molal aqueous solution means 1 mole of solute is present in 1000 g of water.

$$\therefore\ x_{solute} = \frac{1}{1+\frac{1000}{18}} = \frac{1}{56.5} = 0.0177$$

3. (c) : Molarity $= \dfrac{w_{HNO_3} \times 1000}{M_{HNO_3} \times V_{sol(mL)}}$

$$\text{or } 2 = \frac{w_{HNO_3}}{63} \times \frac{1000}{250} \Rightarrow w_{HNO_3} = \frac{63}{2}\text{ g}$$

$$\text{Mass of acid} \times \frac{70}{100} = \frac{63}{2}$$

Mass of acid = 45 g

4. (b) : A 35% (*V*/*V*) solution of ethylene glycol is used as an antifreeze in cars for cooling the engine. At this concentration, the antifreeze lowers the freezing point of water to 255.4 K (–17.6°C).

5. (c) : H_2SO_4 is 98% by weight.
Weight of H_2SO_4 = 98 g, Weight of solution = 100 g

$$\therefore \text{ Volume of solution} = \frac{\text{mass}}{\text{density}} = \frac{100}{1.80}\text{ mL}$$

$$= 55.55\text{ mL} = 0.0555\text{ L}$$

$$\text{Molarity of solution} = \frac{98}{98 \times 0.0555} = 18.02\text{ M}$$

Let *V* mL of this H_2SO_4 is used to prepare 1 litre of 0.1 M H_2SO_4.
∴ mM of concentrated H_2SO_4 = mM of dilute H_2SO_4
or, $V \times 18.02 = 1000 \times 0.1$

$$\Rightarrow V = \frac{1000 \times 0.1}{18.02} = 5.55\text{ mL}$$

6. (b) : 1 molal aqueous solution means 1 mole of solute present in 1 kg of H_2O.

1 mole of solute present in $\frac{1000}{18}$ mole of H_2O

$$x_{solute} = \frac{1}{\frac{1000}{18}+1} = \frac{18}{1018} = 0.01768 \approx 0.018$$

7. (c) : Molecular weight of NaOH = 40 g mol^{-1}
2.5 litre of 1 M NaOH solution contain
40 g mol^{-1} × 1 mol L^{-1} × 2.5 L
= 40 × 2.5 g of NaOH
3 litre of 0.5 M NaOH solution contain
40 g mol^{-1} × 0.5 mol L^{-1} × 3 L
= 40 × 0.5 × 3 g of NaOH
If these two solutions are mixed, the volume of the resultant solution = (2.5 + 3) = 5.5 litre.
5.5 litre of the resultant solution contain
= 40(2.5 + 1.5) g of NaOH
1 litre of the resultant solution contain

$$\frac{40 \times 4}{5.5}\text{ g of NaOH} = \frac{40 \times 4}{5.5 \times 40}\text{ mole of NaOH}$$

The molarity of the resultant solution = 0.727 ≈ 0.73 M

8. (c) : The strength of the solution is 0.1 N.

$\frac{w}{E} = \frac{V \times N}{1000}$ (Equivalent weight = $\frac{200}{2}$ = 100)

$\Rightarrow w = \frac{100 \times 0.1 \times 100}{1000} = 1$ g

9. (a) : We know that 98% H_2SO_4 by weight means 98 g of H_2SO_4 is present in 100 g of solution.
Therefore, its weight is 98 and moles of H_2SO_4

$= \frac{\text{Weight of } H_2SO_4}{\text{Molecular weight}} = \frac{98}{98} = 1$

and volume of solution $= \frac{\text{Mass}}{\text{Density}}$

$= \frac{100}{1.84} = 54.35 \text{ mL} = \frac{54.35}{1000}$ L

Therefore, molarity of H_2SO_4

$= \frac{\text{Moles of } H_2SO_4}{\text{Volume (in litres)}} = \frac{1 \times 1000}{54.35} = 18.4$ M

10. (c) : The molality involves weights of the solute and the solvent. Since the weight does not change with the temperature, therefore molality does not depend upon the temperature.

11. (c) : Since the molecular mass of CH_3OH is 32, therefore quantity of CH_3OH to prepare 150 mL solution of 2 M $CH_3OH = \left(\frac{2}{1000}\right) \times 150 \times 32 = 9.6$ g

12. (c) : $p_{\text{water vapour}} = x_{\text{water vapour}} \times P_{\text{total}}$

$= 0.02 \times 1.2 = 0.024$ atm

$P_{\text{total}} = p_{\text{water vapour}} + p_{\text{dry air}}$

$1.2 = 0.024 + p_{\text{dry air}}$

$p_{\text{dry air}} = 1.2 - 0.024 = 1.176$ atm

Partial vapour pressure is directly proportional to mole fraction, $p \propto x$.

13. (d) : According to Raoult's law,

$P = x_A p_A + x_B p_B$ ... (i)

For binary solutions,

$x_A + x_B = 1, \ x_B = 1 - x_A$ ... (ii)

Putting value of x_B from eqn. (ii) to eqn. (i)

$P = x_A p_A + (1 - x_A) p_B = x_A p_A + p_B - x_A p_B$

$P = p_B + x_A(p_A - p_B)$

14. (None) :

$p°_{CHCl_3} = 200$ mm Hg, $p°_{CH_2Cl_2} = 41.5$ mm Hg

Moles of $CHCl_3$

$= \frac{\text{Weight}}{\text{Molecular weight}} = \frac{25.5}{119.5} = 0.213$

Moles of $CH_2Cl_2 = \frac{40}{85} = 0.470$

$x_{CHCl_3} = \frac{0.213}{0.213 + 0.470} = 0.31$

$x_{CH_2Cl_2} = \frac{0.470}{0.213 + 0.470} = 0.69$

$P_{\text{total}} = p°_{CHCl_3} x_{CHCl_3} + p°_{CH_2Cl_2} x_{CH_2Cl_2}$

$= 200 \times 0.31 + 41.5 \times 0.69 = 62 + 28.63 = 90.63$ mm Hg

15. (d) : $\frac{n_{C_5H_{12}}}{n_{C_6H_{14}}} = \frac{1}{4}$

$\Rightarrow x_{C_5H_{12}} = \frac{1}{5}$ and $x_{C_6H_{14}} = \frac{4}{5}$

$p°_{C_5H_{12}} = 440$ mm Hg; $p°_{C_6H_{14}} = 120$ mm Hg

$P_{\text{total}} = p°_{C_5H_{12}} x_{C_5H_{12}} + p°_{C_6H_{14}} x_{C_6H_{14}}$

$= 440 \times \frac{1}{5} + 120 \times \frac{4}{5} = 88 + 96 = 184$ mm of Hg

By Raoult's law, $p_{C_5H_{12}} = p°_{C_5H_{12}} x_{C_5H_{12}}$ ...(1)

$x_{C_5H_{12}} \rightarrow$ mole fraction of pentane in solution.

By Dalton's law, $p_{C_5H_{12}} = x'_{C_5H_{12}} P_{\text{total}}$ ...(2)

$x'_{C_5H_{12}} \rightarrow$ mole fraction of pentane above the solution.

From (1) and (2),

$p_{C_5H_{12}} = 440 \times \frac{1}{5} = 88$ mm of Hg

$\Rightarrow 88 = x'_{C_5H_{12}} \times 184$

$x'_{C_5H_{12}} = \frac{88}{184} = 0.478$

16. (a) : By Raoult's Law, $P_T = p°_P x_P + p°_Q x_Q$
where $p°_P = 80$ torr, $p°_Q = 60$ torr, $x_P = \frac{3}{5}$; $x_Q = \frac{2}{5}$

$P_T = 80 \times \frac{3}{5} + 60 \times \frac{2}{5} = 48 + 24 = 72$ torr

17. (a) : Mixture of ethanol and acetone shows positive deviation from Raoult's law.

In pure ethanol, molecules are hydrogen bonded. On adding acetone, its molecules get in between the host molecules and break some of the hydrogen bonds between them. Due to weakening of interactions, the solution shows positive deviation from Raoult's law.

18. (d) : For an ideal solution, $\Delta_{\text{mix}}H = 0$ and $\Delta_{\text{mix}}V = 0$ at constant T and P.

19. (b) : Maximum boiling azeotropes are formed by those solutions which show negative deviations from Raoult's law. H_2O and HNO_3 mixture shows negative deviations.

20. (a) : In case of positive deviation from Raoult's law, *A*-*B* interactions are weaker than those between *A*-*A* or *B*-*B*, *i.e.*, in this case the intermolecular attractive forces between the solute-solvent molecules are weaker than those between the solute-solute and solvent-solvent molecules. This means that in such solution, molecules of *A* (or *B*) will find it easier to escape than in pure state. This will increase the vapour pressure and result in positive deviation.

21. (d) : For an ideal solution,

$\Delta H_{mix} = 0$, $\Delta V_{mix} = 0$,

Now, $\Delta U_{mix} = \Delta H_{mix} - P\Delta V_{mix}$

$\therefore \quad \Delta U_{mix} = 0$

Also, for an ideal solution,

$p_A = x_A p_A^\circ$, $p_B = x_B p_B^\circ$

$\therefore \quad \Delta P = P_{\text{obs}} - P_{\text{calculated by Raoult's law}} = 0$

$\Delta G_{mix} = \Delta H_{mix} - T\Delta S_{mix}$

For an ideal solution, $\Delta S_{mix} \neq 0$

$\therefore \quad \Delta G_{mix} \neq 0$

22. (c) : $p_{\text{Benzene}} = x_{\text{Benzene}}\, p^\circ_{\text{Benzene}}$

$p_{\text{Toluene}} = x_{\text{Toluene}}\, p^\circ_{\text{Toluene}}$

For an ideal 1 : 1 molar mixture of benzene and toluene, $x_{\text{Benzene}} = \frac{1}{2}$ and $x_{\text{Toluene}} = \frac{1}{2}$

$$p_{\text{Benzene}} = \frac{1}{2} p^\circ_{\text{Benzene}} = \frac{1}{2} \times 12.8 \text{ kPa} = 6.4 \text{ kPa}$$

$$p_{\text{Toluene}} = \frac{1}{2} p^\circ_{\text{Toluene}} = \frac{1}{2} \times 3.85 \text{ kPa} = 1.925 \text{ kPa}$$

Thus, the vapour will contain a high percentage of benzene as the partial vapour pressure of benzene is higher as compared to that of toluene.

23. (b) : For an ideal solution :

- Volume change (ΔV) on mixing should be zero.
- Heat change (ΔH) on mixing should be zero.
- Obeys Raoult's law at every range of concentration.
- Entropy change (ΔS) on mixing $\neq 0$.

24. (c) : Both the components escape easily showing higher vapour pressure than the expected value. This is due to breaking of some hydrogen bonds between ethanol molecules.

25. (c) : Raoult's law is valid for ideal solutions only. The element of non-ideality enters into the picture when the molecules of the solute and solvent affect each others intermolecular forces. A solution containing components of A and B behaves as ideal solution when $A - B$ attraction force remains same as $A - A$ and $B - B$ attraction forces.

26. (d) : Because C_2H_5I and C_2H_5OH are dissimilar liquids.

27. (c) : For ideal solution,

$\Delta V_{\text{mixing}} = 0$ and $\Delta H_{\text{mixing}} = 0$.

28. (c) : Given : $K_f = 5.12$ K kg mol^{-1}, $m = 0.078$ m

$\Delta T_f = K_f \times m = 5.12 \times 0.078 = 0.39936 \approx 0.40$ K

29. (c) : The value of molal depression constant, K_f is constant for a particular solvent, thus, it will be unchanged when molality of the dilute solution is doubled.

30. (c) : Given : $W_B = 6.5$ g, $W_A = 100$ g, $p_s = 732$ mm, $K_b = 0.52$, $T_b^\circ = 100°C$, $p^\circ = 760$ mm

$$\frac{p^\circ - p_s}{p^\circ} = \frac{n_2}{n_1} \Rightarrow \frac{760 - 732}{760} = \frac{n_2}{100/18}$$

$$\Rightarrow n_2 = \frac{28 \times 100}{760 \times 18} = 0.2046 \text{ mol}$$

$\Delta T_b = K_b \times m$

$$T_b - T_b^\circ = K_b \times \frac{n_2 \times 1000}{W_A\,(\text{g})}$$

$$T_b - 100°\text{C} = \frac{0.52 \times 0.2046 \times 1000}{100} = 1.06$$

$T_b = 100 + 1.06 = 101.06$ °C

31. (d) : We know that $pV = nRT$, where $n = \frac{w}{M}$

$$\pi V = \frac{w}{M} RT$$

$$M = \frac{wRT}{\pi V} = \frac{1.26 \times 0.083 \times 300}{2.57 \times 10^{-3} \times \frac{200}{1000}}$$

$$= \frac{1.26 \times 0.083 \times 300}{2.57 \times 10^{-3} \times 0.2} = 61038 \text{ g mol}^{-1}$$

32. (a) : We know, $\Delta T_f = K_f\, m$

$$m = \frac{w_B}{M_B} \times \frac{1000}{W_A} = \frac{68.5 \times 1000}{342 \times 1000} = \frac{68.5}{342}$$

$$\Delta T_f = 1.86 \times \frac{68.5}{342} = 0.372°\text{C}$$

$\therefore \quad T_f = 0 - 0.372°\text{C} = -0.372°\text{C}$

33. (a)

$$\textbf{34. (b) :}\ M_B = \frac{1000 \times K_f \times w_B}{W_A \times \Delta T_f}$$

$$\text{or, } 250 = \frac{1000 \times 5.12 \times 1}{51.2 \times \Delta T_f}$$

$$\therefore \Delta T_f = \frac{1000 \times 5.12 \times 1}{51.2 \times 250} = 0.4 \text{ K}$$

35. (c) : Molar concentration of urea $= \frac{10}{60}$ dm^{-3}

Molar concentration of non-volatile solution

$$= \frac{50}{M_B} \text{L}^{-1} = \frac{50}{M_B} \text{dm}^{-3}$$

For isotonic solutions, $\frac{10}{60} = \frac{50}{M_B}$

$\Rightarrow \quad M_B = 300$ g mol^{-1}

36. (b) : $\Delta T_f = K_f\, m$ ...(1)

$\Delta T_b = K_b\, m$ ...(2)

$$\Rightarrow \frac{\Delta T_f}{\Delta T_b} = \frac{K_f}{K_b} \quad \text{...(3)}$$

$\Delta T_f \rightarrow$ depression in freezing point

$\Delta T_b \rightarrow$ elevation in boiling point

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

$K_b = 0.512$ K kg mol^{-1}, $\Delta T_b = 100.18 - 100 = 0.18$

$\Rightarrow$ From eq. (3), $\dfrac{\Delta T_f}{0.18} = \dfrac{1.86}{0.512}$

$\Rightarrow \Delta T_f = 0.654 = T^\circ_f - T_f = 0 - T_f \Rightarrow T_f = -0.654°\text{C}$

$\Rightarrow$ Freezing point of urea in water = –0.654°C

37. (b) : For dilute solution, $\pi = \dfrac{n}{V}RT$

$$\Rightarrow \pi V = \frac{m_2}{M_2}RT \quad \Rightarrow M_2 = \frac{m_2 RT}{\pi V}$$

38. (c) **39. (a)**

40. (a) : $p^\circ = 640$ mm Hg, $p_s = 600$ mm Hg,

$w_B = 2.175$ g, $W_A = 39.08$ g

From Raoult's law

$$\frac{p^\circ - p_s}{p^\circ} = \frac{w_B \times M_A}{W_A \times M_B} \Rightarrow \frac{640 - 600}{640} = \frac{2.175 \times 78}{39.08 \times M_B}$$

$\Rightarrow M_B = 69.5$

41. (b) : $w_B = 0.15$ g, $W_A = 15$ g, $\Delta T_b = 0.216°\text{C}$

$K_b = 2.16$, $m = ?$

As $\Delta T_b = \dfrac{1000 \times K_b \times w_B}{M_B \times W_A}$

$$\Rightarrow M_B = \frac{1000 \times 2.16 \times 0.15}{0.216 \times 15} = 100$$

42. (a) : Cane Sugar *X*

Cane Sugar	X
$W_1 = 5$ g	$W_2 = 1$ g
$V_1 = 100$ mL $= 0.1$ L	$V_2 = 100$ mL $= 0.1$ L
$M_1 = 342$	$M_2 = ?$

For isotonic solutions, $C_1 = C_2$

$$\frac{W_1}{M_1V_1} = \frac{W_2}{M_2V_2} \Rightarrow \frac{5}{342 \times 0.1} = \frac{1}{M_2 \times 0.1}$$

$$\Rightarrow M_2 = \frac{342}{5} = 68.4$$

43. (b) : x_2 (mole fraction of solute) = 0.2

From Raoult's law,

$$\frac{p^\circ - p_s}{p^\circ} = x_2 \quad \Rightarrow \frac{10}{p^\circ} = 0.2 \quad \Rightarrow p^\circ = 50 \text{ mm Hg}$$

Again, when $p^\circ - p_s = 20$ mm Hg, then

$$\frac{p^\circ - p_s}{p^\circ} = \text{mole fraction of solute} = \frac{20}{50} = 0.4$$

$\Rightarrow$ mole fraction of solvent = 1 – 0.4 = 0.6

44. (c) : Vapour pressure of pure solvent (p°_A) = 143 mm Hg, weight of solute (w_B) = 0.5 g, weight of solvent (W_A) = 100 g, molecular weight of solute (M_B) = 65 and molecular weight of solvent (M_A) = 154.

$$\frac{p^\circ_A - p_s}{p^\circ_A} = \frac{w_B M_A}{M_B W_A} \quad \text{or} \quad \frac{143 - p_s}{143} = \frac{0.5 \times 154}{65 \times 100}$$

or $p_s = 141.31$ mm Hg

45. (a) : Weight of glucose = 10 g,

Weight of urea = 10 g and weight of sucrose = 10 g

The number of moles of glucose

$$(n_1) = \frac{\text{Weight}}{\text{Molecular weight}} = \frac{10}{180} = 0.05$$

Similarly, number of moles of urea $(n_2) = \dfrac{10}{60} = 0.16$ and the number of moles of sucrose $(n_3) = \dfrac{10}{342} = 0.03$

The osmotic pressure is a colligative property and it depends upon the number of moles of a solute.

Since $n_2 > n_1 > n_3$, therefore $p_2 > p_1 > p_3$.

46. (a)

47. (a) : There is no net movement of the solvent through the semipermeable membrane between two solutions of equal concentration.

48. (c) : The properties which depend only upon the number of solute particles present in the solution irrespective of their nature are called colligative properties. Lowering in vapour pressure, elevation in boiling point, depression in freezing point and osmotic pressure are colligative properties.

49. (b) : Blood cells neither swell nor shrink in isotonic solution. The solutions having same osmotic pressure are called isotonic solutions.

50. (b) : Relative lowering of vapour pressure is equal to mole fraction of solute which is the ratio of solute molecules to the total molecules in solution.

51. (d) : Being a strong electrolyte, $Ba(OH)_2$ undergoes 100% dissociation in a dilute aqueous solution,

$$Ba(OH)_{2(aq)} \rightarrow Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$$

Thus, van't Hoff factor $i = 3$.

52. (c) : $\Delta T_b = iK_b m$

For equimolal solutions, elevation in boiling point will be higher if solution undergoes dissociation *i.e.*, $i > 1$.

53. (c) : $\Delta T_f = i \times K_f \times m$

So, $\Delta T_f \propto i$ (van't Hoff factor)

Salt	i
KCl	2
$C_6H_{12}O_6$	1
$Al_2(SO_4)_3$	5
K_2SO_4	3

Hence, i is maximum *i.e.*, 5 for $Al_2(SO_4)_3$.

54. (c) : From the value of van't Hoff factor i it is possible to determine the degree of dissociation or association. In case of dissociation, i is greater than 1 and in case of association i is less than 1.

55. (b) : We know that

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

Given : $\Delta T_f = 3.82$, $K_f = 1.86$,
$w_B = 5$, $M_B = 142$, $W_A = 45$

$$i = \frac{\Delta T_f \times M_B \times W_A}{K_f \times w_B \times 1000} = \frac{3.82 \times 142 \times 45}{1.86 \times 5 \times 1000} = 2.63$$

56. (d) : We know that $\Delta T_f = i \times K_f \times m$
Here i is van't Hoff factor.
i for weak acid is $1 + \alpha$.
Here α is degree of dissociation *i.e.*, 30/100 = 0.3
$\therefore \quad i = 1 + \alpha = 1 + 0.3 = 1.3$
$\Delta T_f = i \times K_f \times m = 1.3 \times 1.86 \times 0.1 = 0.24$
$\therefore$ Freezing point of solution, $T_f = T^\circ_f - \Delta T_f$
$= 0 - 0.24 = -0.24°C$

57. (d) : Addition of water to an aqueous solution of KI causes the concentration of the solution to decrease thereby increasing the vapour pressure. In the other three options, the electrolytes undergo ionization, which leads to lowering of vapour pressure.

58. (d) : The number of moles of ions produced by 1 mol of ionic compound = i
Applying, $\Delta T_f = i \times K_f \times m$
$0.00732 = i \times 1.86 \times 0.002$

$$\Rightarrow i = \frac{0.00732}{1.86 \times 0.002} = 1.96 \approx 2$$

59. (b) : HX □ $H^+ + X^-$
$1 - \alpha \quad \alpha \quad \alpha$
Total = $1 + \alpha$
$\therefore \quad i = 1 + \alpha = 1 + 0.2 = 1.2$
$\Delta T_f = i \times K_f \times m = 1.2 \times 1.86 \times 0.5 = 1.116\ K \approx 1.12\ K$

60. (c) : Since $Al_2(SO_4)_3$ gives maximum number of ions on dissociation, therefore it will have the lowest freezing point.

$\Delta T_f = iK_f \cdot m$

61. (b) : $K_3[Fe(CN)_6]$ □ $3K^+ + [Fe(CN)_6]^{3-}$ and
$Al(NO_3)_3$ □ $Al^{3+} + 3NO_3^-$
Since both $Al(NO_3)_3$ and $K_3[Fe(CN)_6]$ give the same number of ions, therefore they have the same van't Hoff factor.

62. (c) : In solution, $CaCl_2$ gives three ions, KCl gives two ions while glucose and urea are covalent molecules so they do not undergo ionisation. Since osmotic pressure is a colligative property and it depends upon the number of solute particles (ions), therefore, 0.1 M solution of $CaCl_2$ exhibits the highest osmotic pressure.

63. (a) : Here, $\Delta T_f = i \times K_f \times m$
van't Hoff factor, $i = 2$ for NaCl, so conc. = 0.02, which is maximum in the present case.
Hence, ΔT_f is maximum or freezing point is minimum in 0.01 m NaCl.