CHAPTER 16

Solutions

1. Freezing point of an aqueous solution is (–0.186)°C. Elevation of boiling point of the same solution is $K_b = 0.512$°C, $K_f = 1.86$°C, find the increase in boiling point. **[2002]**
(a) 0.186°C (b) 0.0512°C
(c) 0.092°C (d) 0.2372°C.

2. In mixture A and B components show -ve deviation as
(a) $\Delta V_{mix} > 0$ **[2002]**
(b) $\Delta H_{mix} < 0$
(c) $A-B$ interaction is weaker than $A-A$ and $B-B$ interaction
(d) $A-B$ interaction is stronger than $A-A$ and $B-B$ interaction.

3. If liquids A and B form an ideal solution **[2003]**
(a) the entropy of mixing is zero
(b) the free energy of mixing is zero
(c) the free energy as well as the entropy of mixing are each zero
(d) the enthalpy of mixing is zero

4. In a 0.2 molal aqueous solution of a weak acid HX the degree of ionization is 0.3. Taking k_f for water as 1.85, the freezing point of the solution will be nearest to **[2003]**
(a) $-0.360^\circ C$ (b) $-0.260^\circ C$
(c) $+0.480^\circ C$ (d) $-0.480^\circ C$

5. A pressure cooker reduces cooking time for food because **[2003]**
(a) boiling point of water involved in cooking is increased
(b) the higher pressure inside the cooker crushes the food material
(c) cooking involves chemical changes helped by a rise in temperature
(d) heat is more evenly distributed in the cooking space

6. Which one of the following aqueous solutions will exihibit highest boiling point ? **[2004]**
(a) 0.015 M urea (b) 0.01 M KNO_3
(c) 0.01 M Na_2SO_4 (d) 0.015 M glucose

7. For which of the following parameters the structural isomers C_2H_5OH and CH_3OCH_3 would be expected to have the same values?(Assume ideal behaviour) **[2004]**
(a) Boiling points
(b) Vapour pressure at the same temperature
(c) Heat of vaporization
(d) Gaseous densities at the same temperature and pressure

8. Which of the following liquid pairs shows a positive deviation from Raoult's law ? **[2004]**
(a) Water - nitric acid
(b) Benzene - methanol
(c) Water - hydrochloric acid
(d) Acetone - chloroform

9. Which one of the following statements is **FALSE?** **[2004]**
(a) The correct order of osmotic pressure for 0.01 M aqueous solution of each compound is
$BaCl_2 > KCl > CH_3COOH >$ sucrose
(b) The osmotic pressure (π) of a solution is given by the equation $\pi = MRT$, where M is the molarity of the solution
(c) Raoult's law states that the vapour pressure of a component over a solution is proportional to its mole fraction
(d) Two sucrose solutions of same molality prepared in different solvents will have the same freezing point depression

10. Benzene and toluene form nearly ideal solution. At 20°C, the vapour pressure of benzene is 75 torr and that of toluene is 22 torr. The partial

vapour pressure of benzene at 20°C for a solution containing 78 g of benzene and 46 g of toluene in torr is **[2005]**

(a) 53.5 (b) 37.5

(c) 25 (d) 50

11. Equimolar solutions in the same solvent have **[2005]**

(a) Different boiling and different freezing points

(b) Same boiling and same freezing points

(c) Same freezing point but different boiling points

(d) Same boiling point but different freezing points

12. Among the following mixtures, dipole-dipole as the major interaction, is present in **[2006]**

(a) KCl and water

(b) benzene and carbon tetrachloride

(c) benzene and ethanol

(d) acetonitrile and acetone

13. 18 g of glucose ($C_6H_{12}O_6$) is added to 178.2 g of water. The vapour pressure of water for this aqueous solution at 100ºC is **[2006]**

(a) 76.00 Torr (b) 752.40 Torr

(c) 759.00 Torr (d) 7.60 Torr

14. A mixture of ethyl alcohol and propyl alcohol has a vapour pressure of 290 mm at 300 K. The vapour pressure of propyl alcohol is 200 mm. If the mole fraction of ethyl alcohol is 0.6, its vapour pressure (in mm) at the same temperature will be **[2007]**

(a) 360 (b) 350

(c) 300 (d) 700

15. Equal masses of methane and oxygen are mixed in an empty container at 25°C. The fraction of the total pressure exerted by oxygen is **[2007]**

(a) 1/2 (b) 2/3

(c) $\frac{1}{3}\times\frac{273}{298}$ (d) 1/3.

16. A 5.25% solution of a substance is isotonic with a 1.5% solution of urea (molar mass = 60 g mol^{-1}) in the same solvent. If the densities of both the solutions are assumed to be equal to 1.0 g cm^{-3}, molar mass of the substance will be **[2007]**

(a) 210.0 g mol^{-1} (b) 90.0 g mol^{-1}

(c) 115.0 g mol^{-1} (d) 105.0 g mol^{-1}.

17. At 80° C, the vapour pressure of pure liquid 'A' is 520 mm Hg and that of pure liquid 'B' is 1000 mm Hg. If a mixture solution of 'A' and 'B' boils at 80° C and 1 atm pressure, the amount of 'A' in the mixture is (1 atm = 760 mm Hg) **[2008]**

(a) 52 mol percent (b) 34 mol percent

(c) 48 mol percent (d) 50 mol percent

18. The vapour pressure of water at 20° C is 17.5 mm Hg. If 18 g of glucose ($C_6H_{12}O_6$) is added to 178.2 g of water at 20° C, the vapour pressure of the resulting solution will be **[2008]**

(a) 17.325 mm Hg (b) 15.750 mm Hg

(c) 16.500 mm Hg (d) 17.500 mm Hg

19. A binary liquid solution is prepared by mixing *n*-heptane and ethanol. Which one of the following statements is correct regarding the behaviour of the solution? **[2009]**

(a) The solution is non-ideal, showing – ve deviation from Raoult's Law.

(b) The solution is non-ideal, showing + ve deviation from Raoult's Law.

(c) n-heptane shows + ve deviation while ethanol shows – ve deviation from Raoult's Law.

(d) The solution formed is an ideal solution.

20. Two liquids *X* and *Y* form an ideal solution. At 300 K, vapour pressure of the solution containing 1 mol of *X* and 3 mol of *Y* is 550 *mm*Hg. At the same temperature, if 1 mol of *Y* is further added to this solution, vapour pressure of the solution increases by 10 *mm*Hg. Vapour pressure (in *mm*Hg) of *X* and *Y* in their pure states will be, respectively: **[2009]**

(a) 300 and 400 (b) 400 and 600

(c) 500 and 600 (d) 200 and 300

21. If sodium sulphate is considered to be completely dissociated into cations and anions in aqueous solution, the change in freezing point of water (ΔT_f), when 0.01 mol of sodium sulphate is dissolved in 1 kg of water, is (K_f = 1.86 K kg mol^{-1}) **[2010]**

(a) 0.372 K (b) 0.0558 K

(c) 0.0744 K (d) 0.0186 K

22. On mixing, heptane and octane form an ideal solution. At 373 K, the vapour pressures of the two liquid components (heptane and octane) are 105 kPa and 45 kPa respectively. Vapour pressure of the solution obtained by mixing 25.0 g of heptane and 35 g of octane will be
(molar mass of heptane = 100 g mol^{-1} and of octane = 114 g mol^{-1}) **[2010]**
(a) 72.0 kPa (b) 36.1 kPa
(c) 96.2 kPa (d) 144.5 kPa

23. A 5% solution of cane sugar (molar mass 342) is isotonic with 1% of a solution of an unknown solute. The molar mass of unknown solute in g/mol is : **[2011RS]**
(a) 171.2 (b) 68.4
(c) 34.2 (d) 136.2

24. The density of a solution prepared by dissolving 120 g of urea (mol. mass = 60 u) in 1000 g of water is 1.15 g/mL. The molarity of this solution is : **[2012]**
(a) 0.50 M (b) 1.78 M
(c) 1.02 M (d) 2.05 M

25. K_f for water is 1.86 K kg mol^{-1}. If your automobile radiator holds 1.0 kg of water, how many grams of ethylene glycol ($C_2H_6O_2$) must you add to get the freezing point of the solution lowered to –2.8ºC ? **[2012]**
(a) 72 g (b) 93 g
(c) 39 g (d) 27 g

26. The molarity of a solution obtained by mixing 750 mL of 0.5(M) HCl with 250 mL of 2(M) HCl will be : **[2013]**
(a) 0.875 M (b) 1.00 M
(c) 1.75 M (d) 0.975 M

27. Consider separate solutions of 0.500 M $C_2H_5OH(aq)$, 0.100 M $Mg_3(PO_4)_2(aq)$, 0.250 M KBr(aq) and 0.125 M $Na_3PO_4(aq)$ at 25°C. Which statement is **true** about these solutions, assuming all salts to be strong electrolytes? **[2014]**
(a) They all have the same osmotic pressure.
(b) 0.100 M $Mg_3(PO_4)_2$(aq) has the highest osmotic pressure.
(c) 0.125 M Na_3PO_4(aq) has the highest osmotic pressure.
(d) 0.500 M C_2H_5OH(aq) has the highest osmotic pressure.

28. The vapour pressure of acetone at 20°C is 185 torr. When 1.2 g of a non-volatile substance was dissolved in 100 g of acetone at 20°C, its vapour pressure was 183 torr. The molar mass (g mol^{-1}) of the substance is : **[JEE M 2015]**
(a) 128 (b) 488
(c) 32 (d) 64

29. The freezing point of benzene decreases by 0.45°C when 0.2g of acetic acid is added to 20 g of benzene. If acetic acid associates to form a dimer in benzene, percentage association of acetic acid in benzene will be : **[JEE M 2017]**
(K_f for benzene = 5.12 K kg mol^{-1})
(a) 64.6% (b) 80.4%
(c) 74.6% (d) 94.6%

Answer Key

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(b)	(d)	(d)	(d)	(a)	(c)	(d)	(b)	(d)	(d)	(d)	(d)	(b)	(b)	(d)
16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	
(a)	(d)	(a)	(b)	(b)	(b)	(a)	(b)	(d)	(b)	(a)	(a)	(d)	(d)	

SOLUTIONS

1. **(b)** $\Delta T_b = K_b \frac{W_B}{M_B \times W_A} \times 1000$;

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

$\frac{\Delta T_b}{\Delta T_f} = \frac{K_b}{K_f} = \frac{\Delta T_b}{-0.186}$

$= \frac{0.512}{1.86} = 0.0512°C.$

2. **(d)** In solution containing A and B component showing negative deviation A–A and B–B interactions are weaker than that of A–B interactions. For such solutions.
$\Delta H = -ve$ and $\Delta V = -ve$

3. **(d)** When A and B form an ideal solution, $\Delta H_{mix} = 0$

4. **(d)** $\Delta T_f = K_f \times m \times i$;
$\Delta T_f = 1.85 \times 0.2 \times 1.3 = 0.480^\circ C$
$\therefore$ $T_f = 0 - 0.480^\circ C = -0.480^\circ C$

$$(\underset{1-0.3}{HX} \rightleftharpoons \underset{0.3}{\overset{+}{H}} + \underset{0.3}{X^-}, i = 1.3)$$

5. **(a)** **NOTE** On increasing pressure, the temperature is also increased. Thus in pressure cooker due to increase in pressure the b.p. of water increases.

6. **(c)** $\because \Delta T_b^\circ = T_b - T_b^\circ$
Where T_b = b.pt of solution
T_b° = b.pt of solvent or $T_b = T_b^\circ + \Delta T_b$

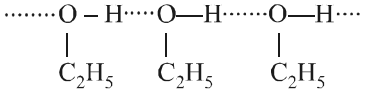
NOTE Elevation in boiling point is a colligative property, which depends upon the no. of particles.Thus greater the number of particles, greater is it elevation and hence greater will be its boiling point.

$$Na_2SO_4 \rightleftharpoons 2Na + SO_4$$

Since Na_2SO_4 has maximum number of particles (3) hence has maximum boiling point.

7. **(d)** Gaseous densities of ethanol and dimethyl ether would be same at same temperature and pressure. The heat of vaporisation, V.P. and b.pts will differ due to H-bonding in ethanol.

8. **(b)** **NOTE** Positive deviations are shown by such solutions in which solvent-solvent and solute-solute interactions are stronger than the solvent interactions. In such solution, the intcractions among molecules becomes weaker. Therefore their escaping tendency increases which results in the increase in their partial vapour pressures.
In a solutions of benzene and methanol there exists inter molecular H– bonding.



In this solution benzene molecules come between ethanol molecules which weaken intermolecular forces. This results in increase in vapour pressure.

9. **(d)** $\Delta T_f = K_f \times m \times i$. Since K_f has different values for different solvents, hence even if the m is the same ΔT_f will be different

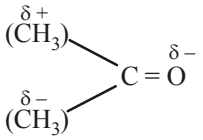
10. **(d)** Given, Vapour pressure of benzene = 75 torr
Vapour pressure of benezene = 22 torr
mass of benzene in = 78g
hence moles of benzene $= \frac{78}{78} = 1$mole
(mol.wt of benzene = 78)
mass of toluence in solution = 46g
hence moles of toluene $= \frac{46}{92} = 0.5$ mole
now partial pressure of benezene

$$= P^o_b . X_b = 75 \times \frac{1}{1+0.5} = 50 \text{ torr} = 75 \times \frac{1}{1.5}$$

$$= 75 \times \frac{2}{3} = 50$$

11. **(d)** Equimolar solutions of normal solutes in the same solvent will have the same b. pts and same f. pts.

12. **(d)** Acetonitrile $(\overset{\delta+}{C}H_3 - C \equiv \overset{\delta-}{N})$ and acetone



both are polar molecules, hence dipole-dipole interaction exist between them. Between KCl and water ion-dipole interaction is found and in Benzene ethanol and Benzene–Carbon tetra chloride dispersion force is present

13. **(b)** Moles of glucose $= \frac{18}{180} = 0.1$

Moles of water $= \frac{178.2}{18} = 9.9$

Total moles = 0.1 + 9.9 = 10

p_{H_2O} = Mole fraction × Total pressure

$$= \frac{9.9}{10} \times 760$$

$$= 752.4 \text{ Torr}$$

14. **(b)** $P_A^o = ?$, Given $P_B^o = 200\text{mm}$, $x_A = 0.6$, $x_B = 1 - 0.6 = 0.4$, $P = 290$

$P = P_A + P_B = P_A^o x_A + P_B^o x_B$

$\Rightarrow 290 = P_A^o \times 0.6 + 200 \times 0.4 \quad \therefore \; P_A^o = 350\text{mm}$

15. **(d)** Let the mass of methane and oxygen = m gm.

Mole fraction of O_2

$$= \frac{\text{Moles of } O_2}{\text{Moles of } O_2 + \text{Moles of } CH_4}$$

$$= \frac{m/32}{m/32 + m/16} = \frac{m/32}{3m/32} = \frac{1}{3}$$

Partial pressure of O_2 = Total pressure × mole fraction of O_2, $P_{O_2} = P \times \frac{1}{3} = \frac{1}{3}P$

16. **(a)** **TIPS / Formulae**

Osmotic pressure (π) of isotonic solutions are equal. For solution of unknown substance $(\pi = CRT)$

$$C_1 = \frac{5.25/M}{V}$$

For solution of urea, C_2 (concentration) = $\frac{1.5/60}{V}$

Given, $\pi_1 = \pi_2$

$\because \pi = CRT$

$\therefore \; C_1RT = C_2RT$ or $C_1 = C_2$

or $\frac{5.25/M}{V} = \frac{1.8/60}{V}$

$\therefore M = 210\text{ g/mol}$

17. **(d)** At 1 atmospheric pressure the boiling point of mixture is 80°C.

At boiling point the vapour pressure of mixture, P_T = 1 atmosphere = 760 mm Hg.

Using the relation,

$P_T = P_A^o X_A + P_B^o X_B$, we get

$P_T = 520X_A + 1000(1 - X_A)$

$\{\because P_A^o = 520\text{mm Hg}, \; P_B^o = 1000\text{ mm Hg}, \; X_A + X_B = 1\}$

or $760 = 520X_A + 1000 - 1000X_A$

or $480X_A = 240$

or $X_A = \frac{240}{480} = \frac{1}{2}$ or 50 mol. percent

i.e., The correct answer is (d)

18. **(a)** **NOTE** On addition of glucose to water, vapour pressure of water will decrease. The vapour pressure of a solution of glucose in water can be calculated using the relation

$$\frac{P^o - P_s}{P_s} = \frac{\text{Moles of glucose in solution}}{\text{moles of water in solution}}$$

or $\frac{17.5 - P_s}{P_s} = \frac{18/180}{178.2/18} \quad [\because P^o = 17.5]$

or $17.5 - P_s = \frac{0.1 \times P_s}{9.9}$ or $P_s = 17.325$ mm Hg.

Hence (a) is correct answer.

19. **(b)** For this solution intermolecular interactions between *n*-heptane and ethanol aare weaker than *n*-heptane - *n*-heptane & ethanol-ethanol interactions hence the solution of *n*-heptane and ethanol is non-ideal and shows positive deviation from Raoult's law.

20. **(b)** $P_{total} = P_A^\circ X_A + P_B^\circ X_B$

$550 = P_A^\circ \times \frac{1}{4} + P_B^\circ \times \frac{3}{4}$

$P_A^\circ + 3P_B^\circ = 550 \times 4 \quad \ldots(i)$

In second case

$P_{total} = P_A^\circ \times \frac{1}{5} + P_B^\circ \times \frac{4}{5}$

$P_A^\circ + 4P_B^\circ = 560 \times 5 \quad \ldots(ii)$

Subtract (i) from (ii)

$\therefore P_B^\circ = 560 \times 5 - 550 \times 4 = 600$

$\because P_A^\circ = 400$

21. **(b)** Sodium sulphate dissociates as

$Na_2SO_4(s) \longrightarrow 2Na^+ + SO_4^{--}$

hence van't hoff factor $i = 3$

Now $\Delta T_f = i k_f . m$

$= 3 \times 1.86 \times 0.01 = 0.0558\text{ K}$

22. **(a)** $P_{Total=} = P°_A x_A + P°_B X_B$

$= P°_{\text{Heptane}}\ X_{\text{Heptane}} + P°_{\text{Octane}}\ X_{\text{Octane}}$

$= 105 \times \frac{25/100}{\frac{25}{100}+\frac{35}{114}} + 45 \times \frac{35/114}{\frac{25}{100}+\frac{35}{114}}$

$= 105 \times \frac{0.25}{0.25+0.3} + 45 \times \frac{0.3}{0.25+0.3}$

$= \frac{105 \times 0.25}{0.55} + \frac{45 \times 0.3}{0.55} = \frac{26.25+13.5}{0.55}$

$= 72$ kPa

23. **(b)** For isotonic solutions

$\pi_1 = \pi_2$

$C_1 = C_2$

$\frac{5/342}{0.1} = \frac{1/M}{0.1}$

$\frac{5}{342} = \frac{1}{M}$

$\Rightarrow \quad M = \frac{342}{5} = 68.4$ gm/mol

24. **(d)** $\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution}(\ell)}$

Mass of solution = 1000 + 120 = 1120

$d = \frac{M}{v}; v = \frac{M}{d} = \frac{1120}{1.15}$ mL

$= \frac{120 \times 1.15}{60 \times 1120} \times 1000 = 2.05$ M

25. **(b)** $\Delta T_f = i \times K_f \times m$

Given $\Delta T_f = 2.8$, $K_f = 1.86$ K kg mol^{-1} $i = 1$

(ethylene glygol is a non- electrolyte)

wt. of solvent = 1 kg

Let of wt of solute = x

Mol. wt of ethylene glycol = 62

$2.8 = 1 \times 1.86 \times \frac{x}{62 \times 1}$

or $\quad x = \frac{2.8 \times 62}{1.86} = 93$ gm

26. **(a)** From molarity equation :

$M_1V_1 + M_2V_2 = M \times V$

$M = \frac{M_1V_1 + M_2V_2}{V}$ where V = total volume

$= \frac{750 \times 0.5 + 250 \times 2}{1000}$

$= 0.875$ M

27. **(a)** $\pi = i\,CRT$

$\pi_{C_2H_5OH} = 1 \times 0.500 \times R \times T = 0.5\,RT$

$\pi_{Mg_3(PO_4)_2}$

$= 5 \times 0.100 \times R \times T = 0.5\,RT$

$\pi_{KBr} = 2 \times 0.250 \times R \times T = 0.5\,RT$

$\pi_{Na_3PO_4} = 4 \times 0.125 \times RT = 0.5\,RT$

Since the osmotic pressure of all the given solutions is equal. Hence all are isotonic solution.

28. **(d)** Using relation,

$\frac{p° - p_s}{p_s} = \frac{w_2 M_1}{w_1 M_2}$

where w_1, M_1 = mass in g and mol. mass of solvent

w_2, M_2 = mass in g and mol. mass of solute

Let $M_2 = x$

$p° = 185$ torr

$p_s = 183$ torr

$\frac{185-183}{183} =$

(Mol. mass of acetone = 58)

$x = 64$

$\therefore$ Molar mass of substance = 64

29. **(d)** In benzene

$2CH_3COOH \rightleftharpoons (CH_3COOH)_2$

$1-\alpha \qquad \alpha/2$

$i = 1 - \alpha + \alpha/2 = 1 - \alpha/2$

Here α is degree of association

$\Delta T_f = iK_f m$

$0.45 = \left(1 - \frac{\alpha}{2}\right)(5.12)\frac{\left(\frac{0.2}{60}\right)}{\frac{20}{1000}}$

$1 - \frac{\alpha}{2} = 0.527$

$\alpha = 0.945$

% degree of association = 94.6%