16

Solutions

TOPIC 1 Solubility and Concentration of Solutions

1. The mole fraction of a solvent in aqueous solution of a solute is 0.8. The molality (in mol kg^{-1}) of the aqueous solution is : **[April 12, 2019 (I)]**
(a) 13.88×10^{-2} (b) 13.88×10^{-1}
(c) 13.88 (d) 13.88×10^{-3}

2. What would be the molality of 20% (mass/mass) aqueous solution of KI? (molar mass of KI = 166 g mol^{-1}) **[April 9, 2019 (II)]**
(a) 1.08 (b) 1.35 (c) 1.48 (d) 1.51

3. A solution of sodium sulfate contains 92 g of Na^+ ions per kilogram of water. The molality of Na^+ ions in that solution in mol kg^{-1} is: **[Jan. 9, 2019 (I)]**
(a) 12 (b) 4 (c) 8 (d) 16

4. The solubility of N_2 in water at 300 K and 500 torr partial pressure is 0.01 g L^{-1}. The solubility (in g L^{-1}) at 750 torr partial pressure is : **[Online April 9, 2016]**
(a) 0.0075 (b) 0.005 (c) 0.02 (d) 0.015

5. 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

6. 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

TOPIC 2 Vapour Pressure, Laws of Solutions and Ideal, Non-ideal Solutions

7. A set of solutions is prepared using 180g of water as a solvent and 10g of different non-volatile solutes A, B and C. The relative lowering of vapour pressure in the presence of these solutes are in the order [Given, molar mass of A = 100g mol^{-1}; B = 200g mol^{-1}; C = 10,000g mol^{-1}] **[Sep. 06, 2020 (II)]**
(a) B > C > A (b) C > B > A
(c) A > B > C (d) A > C > B

8. At 300 K, the vapour pressure of a solution containing 1 mole of *n*-hexane and 3 moles of *n*-heptane is 550 mm of Hg. At the same temperature, if one more mole of *n*-heptane is added to this solution, the vapour pressure of the solution increases by 10 mm of Hg. What is the vapour pressure in mm Hg of *n*-heptane in its pure state ________? **[NV, Sep. 04, 2020 (I)]**

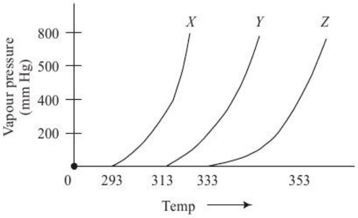
9. Henry's constant (in kbar) for four gases α, β, γ and δ in water at 298 K is given below : **[Sep. 03, 2020 (I)]**

	α	β	γ	δ
K_H	50	2	2×10^{-5}	0.5

(density of water = 10^3 kg m^{-3} at 298 K)
This table implies that :
(a) α has the highest solubility in water at a given pressure
(b) solubility of γ at 308 K is lower than at 298 K
(c) The pressure of a 55.5 molal solution of γ is 1 bar
(d) The pressure of a 55.5 molal solution of δ is 250 bar

10. An open beaker of water in equilibrium with water vapour is in a sealed container. When a few grams of glucose are added to the beaker of water, the rate at which water molecules : **[Sep. 02, 2020 (I)]**
(a) leaves the vapour increases
(b) leaves the solution increases
(c) leaves the solution decreases
(d) leaves the vapour decreases

11. A graph of vapour pressure and temperature for three different liquids *X*, *Y*, and *Z* is shown below:



The following inferences are made: **[Jan. 08, 2020 (I)]**

(A) *X* has higher intermolecular interactions compared to Y.

(B) *X* has lower intermolecular interactions compared to Y.

(C) *Z* has lower intermolecular interactions compared to Y.

The correct inference(s) is/are:

(a) (A) and (C) (b) (A)

(c) (B) (d) (C)

12. At 35 °C, the vapour pressure of CS_2 is 512 mm Hg and that of acetone is 344 mm Hg. A solution of CS_2 in acetone has a total vapour pressure of 600 mm Hg. The false statement amongst the following is: **[Jan. 07, 2020 (I)]**

(a) Raoult's law is not obeyed by this system

(b) a mixture of 100 mL CS_2 and 100 mL acetone has a volume < 200 mL

(c) CS_2 and acetone are less attracted to each other than to themselves

(d) heat must be absorbed in order to produce the solution at 35 °C

13. Two open beakers one containing a solvent and the other containing a mixture of that solvent with a non volatile solute are together sealed in a container. Over time: **[Jan. 07, 2020 (II)]**

(a) the volume of the solution increases and the volume of the solvent decreases

(b) the volume of the solution decreases and the volume of the solvent increases

(c) the volume of the solution and the solvent does not change

(d) the volume of the solution does not change and the volume of the solvent decreases

14. Liquid 'M' and liquid 'N' form an ideal solution. The vapour pressures of pure liquids 'M' and 'N' are 450 and 700 mmHg, respectively, at the same temperature. Then correct statement is: **[April 9, 2019 (I)]**

(x_M = Mole fraction of 'M' in solution;
x_N = Mole fraction of 'N' in solution;
y_M = Mole fraction of 'M' in vapour phase;
y_N = Mole fraction of 'N' in vapour phase)

(a) $\frac{x_M}{x_N} = \frac{y_M}{y_N}$ (b) $(x_M - y_M) < (x_N - y_N)$

(c) $\frac{x_M}{x_N} < \frac{y_M}{y_N}$ (d) $\frac{x_M}{x_N} > \frac{y_M}{y_N}$

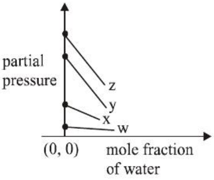
15. The vapour pressures of pure liquids A and B are 400 and 600 mmHg, respectively at 298K. On mixing the two liquids, the sum of their initial volumes is equal to the volume of the final mixture. The mole fraction of liquid B is 0.5 in the mixture. The vapour pressure of the final solution, the mole fractions of components A and B in vapour phase, respectively are: **[April 8, 2019 (I)]**

(a) 450 mmHg, 0.4, 0.6 (b) 500 mmHg, 0.5, 0.5

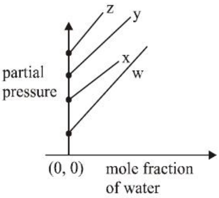
(c) 450 mmHg, 0.5, 0.5 (d) 500 mmHg, 0.4, 06

16. For the solution of the gases *w*, *x*, *y* and *z* in water at 298K, the Henrys law constants (K_H) are 0.5, 2, 35 and 40 kbar, respectively. The correct plot for the given data is : **[April 8, 2019 (II)]**

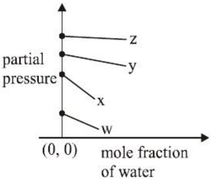
(a)



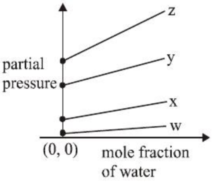
(b)



(c)



(d)



17. Liquids A and B form an ideal solution in the entire composition range. At 350 K, the vapor pressures of pure A and pure B are 7×10^3 Pa and 12×10^3 Pa, respectively. The composition of the vapour is in equilibrium with a solution containing 40 mole percent of A at this temperature is: **[Jan. 10, 2019 (I)]**

(a) $x_A = 0.37; x_B = 0.63$ (b) $x_A = 0.28; x_B = 0.72$

(c) $x_A = 0.4; x_B = 0.6$ (d) $x_A = 0.76; x_B = 0.24$

18. Which one of the following statements regarding Henry's law is not correct? **[Jan. 9, 2019 (I)]**

(a) Higher the value of K_H at a given pressure, higher is the solubility of the gas in liquids.

(b) Different gases have different K_H (Henry's law constant) values at the same temperature.

(c) The partial pressure of the gas in vapour phase is proportional to the mole fraction of the gas in the solution.

(d) The value of K_H increases with increase of temperature and K_H is function of the nature of the gas.

19. A solution is prepared by mixing 8.5 g of CH_2Cl_2 and 11.95 g of $CHCl_3$. If vapour pressure of CH_2Cl_2 and $CHCl_3$ at 298 K are 415 and 200 mmHg respectively, the mole fraction of $CHCl_3$ in vapour form is : **[Online April 9, 2017]**

(Molar mass of Cl = 35.5 g mol^{-1})

(a) 0.162 (b) 0.675 (c) 0.325 (d) 0.486

20. A solution at 20 °C is composed of 1.5 mol of benzene and 3.5 mol of toluene. If the vapour pressure of pure benzene and pure toluene at this temperature are 74.7 torr and 22.3 torr, respectively, then the total vapour pressure of the solution and the benzene mole fraction in equilibrium with it will be, respectively : **[Online April 10, 2015]**

(a) 35.8 torr and 0.280 (b) 38.0 torr and 0.589

(c) 30.5 torr and 0.389 (d) 30.5 torr and 0.480

21. Choose the correct statement with respect to the vapour pressure of a liquid among the following: **[Online April 19, 2014]**

(a) Increases linearly with increasing temperature

(b) Increases non-linearly with increasing temperature

(c) Decreases linearly with increasing temperature

(d) Decreases non-linearly with increasing temperature

22. For an ideal solution of two components A and B, which of the following is true? **[Online April 19, 2014]**

(a) $\Delta H_{mixing} < 0$ (zero)

(b) $\Delta H_{mixing} > 0$ (zero)

(c) A – B interaction is stronger than A – A and B – B interactions

(d) A– A, B – B and A – B interactions are identical.

23. Vapour pressure of pure benzene is 119 torr and that of toluene is 37.0 torr at the same temperature. Mole fraction of toluene in vapour phase which is in equilibrium with a solution of benzene and toluene having a mole fraction of toluene 0.50, will be : **[Online April 23, 2013]**

(a) 0.137 (b) 0.237 (c) 0.435 (d) 0.205

24. Liquids A and B form an ideal solution. At 30 °C, the total vapour pressure of a solution containing 1 mol of A and 2 mol of B is 250 mm Hg. The total vapour pressure becomes 300 mm Hg when 1 more mol of A is added to the first solution. The vapour pressures of pure A and B at the same temperature are **[Online May 19, 2012]**

(a) 150, 450 mm Hg (b) 125, 150 mm Hg

(c) 450, 150 mm Hg (d) 250, 300 mm Hg

25. 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

26. 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 mmHg. At the same temperature, if 1 mol of *Y* is further added to this solution, vapour pressure of the solution increases by 10 mmHg. Vapour pressure (in mmHg) 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

27. 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.

28. 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 at 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

29. 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

30. 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

31. 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

32. 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

33. 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

34. 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

35. 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

36. 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 is zero
(d) the enthalpy of mixing is zero

37. 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

38. 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.

TOPIC 3 Colligative Properties and Abnormal Molecular Masses

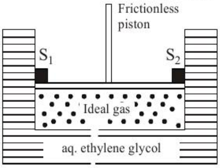
39. The elevation of boiling point of 0.10 m aqueous $CrCl_3.xNH_3$ solution is two times that of 0.05 m aqueous $CaCl_2$ solution. The value of *x* is ______.
[Assume 100% ionisation of the complex and $CaCl_2$, coordination number of Cr as 6, and that all NH_3 molecules are present inside the coordination sphere]
[NV, Sep. 06, 2020 (I)]

40. The osmotic pressure of a solution of NaCl is 0.10 atm and that of a glucose solution is 0.20 atm. The osmotic pressure of a solution formed by mixing 1 L of the sodium chloride solution with 2 L of the glucose solution is $x \times 10^{-3}$ atm. *x* is __________. (nearest integer) **[NV, Sep. 04, 2020 (II)]**

41. If 250 cm^3 of an aqueous solution containing 0.73 g of a protein A is isotonic with one litre of another aqueous solution containing 1.65 g of a protein B, at 298 K, the ratio of the molecular masses of A and B is _________ $\times 10^{-2}$ (to the nearest integer). **[NV, Sep. 03, 2020 (II)]**

42. How much amount of NaCl should be added to 600 g of water ($\rho = 1.00$ g/mL) to decrease the freezing point of water to –0.2°C? _______. (The freezing point depression constant for water = 2 K kg mol^{-1}) **[NV, Jan. 09, 2020 (I)]**

43. A cylinder containing an ideal gas (0.1 mol of 1.0 dm^3) is in thermal equilibrium with a large volume of 0.5 molal aqueous solution of ethylene glycol at its freezing point. If the stoppers S_1 and S_2 (as shown in the figure) are suddenly withdrawn, the volume of the gas in litres after equilibrium is achieved will be _______.
(Given, K_f (water) = 2.0 K kgmol^{-1}, R = 0.08 dm^3 atm K^{-1} mol^{-1})
[NV, Jan. 09, 2020 (II)]



44. A solution is prepared by dissolving 0.6 g of urea (molar mass = 60 g mol^{-1}) and 1.8 g of glucose (molar mass = 180 g mol^{-1}) in 100 mL, of water at 27 °C. The osmotic pressure of the solution is : **[April 12, 2019 (II)]**
(R = 0.08206 L atm K^{-1} mol^{-1})
(a) 8.2 atm (b) 2.46 atm (c) 4.92 atm (d) 1.64 atm

45. At room temperature, a dilute solution of urea is prepared by dissolving 0.60 g of urea in 360 g of water. If the vapour pressure of pure water at this temperature is 35 mmHg, lowering of vapour pressure will be : **[April 10, 2019 (I)]**
(molar mass of urea = 60 g mol^{-1})
(a) 0.027 mmHg (b) 0.028 mmHg
(c) 0.017 mmHg (d) 0.031 mmHg

46. 1 g of a non-volatile non-electrolyte solute is dissolved in 100 g of two different solvents A and B whose ebullioscopic constants are in the ratio of 1 : 5. The ratio of the elevation in their boiling points, $\frac{\Delta T_b(A)}{\Delta T_b(B)}$, is :
[April 10, 2019 (II)]
(a) 5 : 1 (b) 10 : 1 (c) 1 : 5 (d) 1 : 0.2

47. The osmotic pressure of a dilute solution of an ionic compound XY in water is four times that of a solution of 0.01 M $BaCl_2$ in water. Assuming complete dissociation of the given ionic compounds in water, the concentration of XY (in mol L^{-1}) in solution is: **[April 9, 2019 (I)]**
(a) 4×10^{-2} (b) 6×10^{-2} (c) 4×10^{-4} (d) 16×10^{-4}

48. Molal depression constant for a solvent is 4.0 K kg mol^{-1}. The depression in the freezing point of the solvent for 0.03 mol kg^{-1} solution K_2SO_4 is: **[April 9, 2019 (II)]**
(Assume complete dissociation of the electrolyte)
(a) 0.18 K (b) 0.24 K
(c) 0.12 K (d) 0.36 K

49. Freezing point of a 4% aqueous solution of X is equal to freezing point of 12% aqueous salution of Y. If molecular weight of X is A, then molecular weight of Y is: **[Jan. 12, 2019 (I)]**
(a) 3A (b) 2A (c) A (d) 4A

50. Molecules of benzoic acid (C_6H_5COOH) dimerise in benzene. 'w' g of the acid dissolved in 30 g of benzene shows a depression in freezing point equal to 2 K. If the percentage association of the acid to form dimer in the solution is 80, then w is :
(Given that $K_f = 5$ K kg mol^{-1}, Molar mass of benzoic acid = 122 g mol^{-1}) **[Jan. 12, 2019 (II)]**
(a) 2.4 g (b) 1.0 g (c) 1.5 g (d) 1.8 g

51. The freezing point of a diluted milk sample is found to be – 0.2°C, while it should have been – 0.5°C for pure milk. How much water has been added to pure milk to make the diluted sample? **[Jan. 11, 2019 (I)]**
(a) 1 cup of water to 2 cups of pure milk
(b) 3 cups of water to 2 cups of pure milk
(c) 1 cup of water to 3 cups of pure milk
(d) 2 cups of water to 3 cups of pure milk

52. K_2HgI_4 is 40% ionised in aqueous solution. The value of its van't Hoff factor (i) is : **[Jan. 11, 2019 (II)]**
(a) 1.6 (b) 1.8 (c) 2.0 (d) 2.2

53. Elevation in the boiling point for 1 molal solution of glucose is 2 K. The depression in the freezing point for 2 molal solution of glucose in the same solvent is 2 K. The relation between K_b and K_f is: **[Jan. 10, 2019 (II)]**
(a) $K_b = 1.5 K_f$ (b) $K_b = K_f$
(c) $K_b = 0.5 K_f$ (d) $K_b = 2 K_f$

54. A solution containing 62 g ethylene glycol in 250 g water is cooled to – 10 °C. If K_f for water is 1.86 K kg mol^{-1}, the amount of water (in g) separated as ice is: **[Jan. 9, 2019 (II)]**
(a) 48 (b) 32 (c) 64 (d) 16

55. For 1 molal aqueous solution of the following compounds, which one will show the highest freezing point? **[2018]**
(a) $[Co(H_2O)_6]Cl_3$ (b) $[Co(H_2O)_5Cl]Cl_2.H_2O$
(c) $[Co(H_2O)_4Cl_2]Cl. 2H_2O$ (d) $[Co(H_2O)_3Cl_3].3H_2O$

56. The mass of non-volatile, non-elctrolyte solute (molar mass = 50 g mol^{-1}) needed to be dissolved in 114 g octane to reduce its vapour pressure to 75%, is ___________. **[Online April 16, 2018]**
(a) 37.5 g (b) 75 g (c) 150 g (d) 50 g

57. Two 5 molal solutions are prepared by dissolving a non-electrolyte, non-volatile solute separately in the solvents X and Y. The molecular weights of the solvents are M_X and M_Y, respectively where $M_X = \frac{3}{4} M_Y$. The relative lowering of vapour pressure of the solution in X is "m" times that of the solution in Y. Given that the number of moles of solute is very small in comparison to that of solvent, the value of "m" is: **[Online April 15, 2018 (II)]**
(a) $\frac{3}{4}$ (b) $\frac{1}{2}$ (c) $\frac{1}{4}$ (d) $\frac{4}{3}$

58. 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 : **[2017]**
(K_f for benzene = 5.12 K kg mol^{-1})
(a) 64.6% (b) 80.4% (c) 74.6% (d) 94.6%

59. 5 g of Na_2SO_4 was dissolved in *x* g of H_2O. The change in freezing point was found to be 3.82°C. If Na_2SO_4 is 81.5% ionised, the value of *x* **[Online April 8, 2017]**
(K_f for water = 1.86°C kg mol^{-1}) is approximately :
(molar mass of S = 32 g mol^{-1} and that of Na = 23 g mol^{-1})
(a) 15 g (b) 25 g (c) 45 g (d) 65 g

60. 18 g glucose ($C_6H_{12}O_6$) is added to 178.2 g water. The vapour pressure of water (in torr) for this aqueous solution is: **[2016, 2006]**
(a) 752.4 (b) 759.0 (c) 7.6 (d) 76.0

61. An aqueous solution of a salt MX_2 at certain temperature has a van't Hoff factor of 2. The degree of dissociation for this solution of the salt is : **[Online April 10, 2016]**
(a) 0.50 (b) 0.33 (c) 0.67 (d) 0.80

62. 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 : **[2015]**
(a) 128 (b) 488 (c) 32 (d) 64

63. Determination of the molar mass of acetic acid in benzene using freezing point depression is affected by : **[Online April 11, 2015]**
(a) partial ionization (b) dissociation
(c) complex formation (d) association

64. 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.

65. The observed osmotic pressure for a 0.10 M solution of $Fe(NH_4)_2(SO_4)_2$ at 25 °C is 10.8 atm. The expected and experimental (observed) values of van't Hoff factor (i) will be respectively:
(R = 0.082 L atm K^{-1} mol^{-1}) **[Online April 19, 2014]**

(a) 5 and 4.42 (b) 4 and 4.00
(c) 5 and 3.42 (d) 3 and 5.42

66. 12 g of a nonvolatile solute dissolved in 108 g of water produces the relative lowering of vapour pressure of 0.1. The molecular mass of the solute is : **[Online April 9, 2013]**

(a) 80 (b) 60 (c) 20 (d) 40

67. A molecule M associates in a given solvent according to the equation $M \rightleftharpoons (M)_n$. For a certain concentration of M, the van't Hoff factor was found to be 0.9 and the fraction of associated molecules was 0.2. The value of n is: **[Online April 22, 2013]**

(a) 3 (b) 5 (c) 2 (d) 4

68. How many grams of methyl alcohol should be added to 10 litre tank of water to prevent its freezing at 268 K ? (K_f for water is 1.86 K kg mol^{-1}) **[Online April 25, 2013]**

(a) 880.07 g (b) 899.04 g (c) 886.02 g (d) 868.06 g

69. 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 –2.8 °C ? **[2012]**

(a) 72 g (b) 93 g (c) 39 g (d) 27 g

70. A solution containing 0.85 g of $ZnCl_2$ in 125.0 g of water freezes at –0.23 °C. The apparent degree of dissociation of the salt is (K_f for water = 1.86 K kg mol^{-1}, atomic mass: Zn = 65.3 and Cl = 35.5) **[Online May 12, 2012]**

(a) 1.36% (b) 73.5% (c) 7.35% (d) 2.47%

71. The freezing point of a 1.00 m aqueous solution of HF is found to be –1.91°C. The freezing point constant of water, K_f is 1.86 K kg mol^{-1}. The percentage dissociation of HF at this concentration is **[Online May 26, 2012]**

(a) 30% (b) 10% (c) 5.2% (d) 2.7%

72. 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

73. 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

74. 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

75. 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}.

76. 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

77. 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

$$BaCl_2 > KCl > CH_3COOH > \text{sucrose}$$

(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 same freezing point depression

78. 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 °C (b) –0.260 °C
(c) +0.480 °C (d) –0.480 °C

79. 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.

Hints & Solutions

1. **(c)** Let, 1 mole be present in the solution,

$n_{solute} = 0.2$ mol

$n_{solvent} = 0.8$ mol

$= 0.8 \times 18$ g

$$\text{molality} = \frac{\text{Moles of solute}}{\text{Kilogram of solvent}}$$

$$\therefore \quad m = \frac{0.2 \times 1000}{0.8 \times 18} = \frac{1000}{4 \times 18} \approx 13.88$$

2. **(d)** 20% W/W KI solution (Given)

i.e. 100 g solution contains 20 g KI

$\therefore$ Mass of solvent = 100 – 20 = 80 g

$$\text{No. of moles of KI is } \frac{20}{166} = 0.121 \text{ mol}$$

$$\therefore \text{ Molality} = \frac{0.121 \times 1000}{80} = 1.51 \text{ m}$$

3. **(b)** Number of moles in 92 g of $Na^+ = \frac{92}{23} = 4$ mol

$$\text{Molality } (m) = \frac{\text{Number of moles}}{\text{Mass of solvent (in kg)}}$$

$$\therefore \quad m = \frac{4}{1} = 4 \text{ mol kg}^{-1}$$

4. **(d)** According to Henry's law

$$\frac{P_1}{P_2} = \frac{S_1}{S_2}$$

$$\frac{500}{750} = \frac{0.01}{S_2}$$

$$\therefore S_2 = \frac{750 \times 0.01}{500} = 0.015 \text{ g/L}$$

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

$M_1V_1 + M_2V_2 = M \times V$

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

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

$= 0.875$ M

6. **(d)** $\text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution}(\ell)}$

Mass of solution = 1000 + 120 = 1120

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

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

7. **(c)** Relative lowering in vapour pressure (RLVP)

$$= \frac{P - P_s}{P} = \frac{n}{n + N}$$

$n \rightarrow$ moles of solute

$N \rightarrow$ moles of solvent

$$n_A = \frac{10}{100}, n_B = \frac{10}{200}, n_C = \frac{10}{10000}$$

$$\text{Moles of solvent } (H_2O) = \frac{180}{18} = 10 \text{ mol}$$

$$RLVP_A = \frac{0.1}{10.1} = \frac{1}{101}$$

$$RLVP_B = \frac{0.05}{10.05} = \frac{1}{201}$$

$$RLVP_C = \frac{10^{-3}}{10} = 10^{-4}$$

From the above relation

RLVP(A) > RLVP(B) > RLVP(C)

8. **(600)**

$$P_{total} = P^o_{hexane} \cdot X_{hexane} + P^o_{heptane} \cdot X_{heptane}$$

$$550 = [P^o_{hexane}] \times \frac{1}{4} + [P^o_{heptane}] \times \frac{3}{4}$$

$$\Rightarrow 2200 = P^o_{hexane} + 3P^o_{heptane} \qquad \text{...(i)}$$

$$560 = [P^o_{hexane}] \times \frac{1}{5} + [P^o_{heptane}] \times \frac{4}{5}$$

$$\Rightarrow 2800 = P^o_{hexane} + 4P^o_{heptane} \qquad \text{...(ii)}$$

From equation (i) and (ii),

$P^o_{heptane} = 600$ mm of Hg

9. **(d)** (a) From Henry's law $p = K_H(x)$

Higher the value of K_H smaller will be the solubility of the gas, so γ is more soluble.

(b) Though solubility of gases will decrease with increase in temperature but this conclusion can not be drawn from the given table.

(c) For γ

$(p)_\gamma = (K_H)_\gamma \cdot (x)_\gamma$

$$= 2\times10^{-5}\left[\frac{55.5}{55.5+\frac{1000}{18}}\right] = 10^{-5}\text{ k bar} = 10^{-2}\text{bar}$$

(d) For $\delta \Rightarrow$

$p_\delta = (K_H)_\delta \cdot (x)_\delta$

$$= 0.5\left[\frac{55.5}{55.5+\frac{1000}{18}}\right]$$

$= 0.5 \times 0.5 = 0.25\,k\text{ bar} = 250$ bar.

10. **(a)** The vapour pressure of solution will be less than the vapour pressure of pure solvent, so some vapour molecules will get condensed to maintain new equilibrium.

11. **(c)** At a particular temperature as intermolecular force of attraction increases vapour pressure decreases. Thus, intermolecular forces are inversely proportional to vapour pressure and directly proportional to temperature. Therefore X has lower intermolecular interactions compared to Y.

12. **(b)** Mixture of carbon disulphide and acetone will show positive deviation from Raoult's Law. The dipolar interaction between solute (CS_2) solvent (acetone) molecules in solution are weaker. So the vapour pressure of solution will be greater than the individual vapoure pressure of pure components.

13. **(a)** There will be lowering in vapour pressure in second beaker.

14. **(d)** $P_M^o = 450$ mmHg, $P_N^o = 700$ mmHg

$P_M = P_M^o x_M = y_M P_T$

$\Rightarrow P^\circ_M = \frac{y_M}{x_M}(P_T)$

Similarly, $P_N^o = \frac{y_N}{x_N}(P_T)$

Given, $P_M^o < P_N^o$

$\Rightarrow \frac{y_M}{x_M} < \frac{y_N}{x_N}$

$\Rightarrow \frac{y_M}{y_N} < \frac{x_M}{x_N}$

15. **(d)** $P = x_B p_B^\circ + x_A p_A^\circ$

$= 0.5 \times 600 + 0.5 \times 400 = 300 + 200 = 500$

Using the relation $p_i = y_i P_{\text{Total}}$, we can calculate the mole fractions of the components in vapour phase.

$p_B = y_B P_{\text{total}}$

$y_B = \frac{p_B}{P_{\text{Total}}} = \frac{300}{500} = \frac{3}{5} = 0.6$

$y_A = \frac{p_A}{P_{\text{Total}}} = \frac{200}{500} = \frac{2}{5} = 0.4$

16. **(a)** According to Henry's law

$P = K_H \cdot X_{gas}$

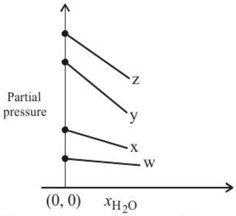
$\because X_{gas} + X_{H_2O} = 1$

$\therefore X_{gas} = 1 - X_{H_2O}$

$\therefore P = K_H(1 - X_{H_2O})$

$\therefore P = K_H - K_H \cdot X_{H_2O}$

$y = c + mx$; $m = - K_H \Rightarrow$ slope is negative.



Gas	K_H
w	0.5
x	2
y	35
z	50

17. **(b)** $P^\circ_A = 7 \times 10^3$

$P_B^\circ = 12 \times 10^3$

$x'_A = 0.4; x'_B = 1 - 0.4$

$x'_B = 0.6$

$P_{\text{total}} = P^\circ_A x'_A + P^\circ_B x'_B$

$= 7 \times 10^3 \times 0.4 + 12 \times 10^3 \times 0.6$

$= (7 \times 0.4 + 12 \infty \times 0.6) \times 10^3 = 10^4$

$$x_A = \frac{P_A^\circ x'_A}{P_{\text{total}}} = \frac{7\times10^3\times0.4}{10^4}$$

$\therefore\ x_A = 0.28, x_B = 1 - 0.28 = 0.72$

18. **(a)** The solubility of the gas in liquids decreases with the increase in value of K_H at a given pressure.

19. **(c)** Molar mass of $CHCl_3 = 119.5$ g/mol

Molar mass of $CH_2Cl_2 = 85$ g/mol

Moles of $CHCl_3 = \frac{11.95}{119.5} = 0.1$ mol

Moles of $CH_2Cl_2 = \frac{8.5}{85} = 0.1$ mol

Mole fraction of $CHCl_3 = \frac{0.1}{0.2} = 0.5$ mol

Mole fraction of $CH_2Cl_2 = \frac{0.1}{0.2} = 0.5$ mol

(Given -
Vapour pressure of $CHCl_3 = 200$ mm Hg $= 0.263$ atm.
Vapour pressure of $CH_2Cl_2 = 415$ mm Hg $= 0.546$ atm.)
(1 atm = 760 mm Hg)

$\therefore P_{(total)} =$ Mole fraction of $CHCl_3 \times$ (Vapour pressure of $CHCl_3$) + Mole fraction of CH_2Cl_2 $\times$ (Vapour pressure of CH_2Cl_2)

$= 0.5 \times 0.263 + 0.5 \times 0.546 = 0.4045$

Mole fraction of $CHCl_3$ in vapour form

$$= \frac{\text{vapour pressure}}{P_{total}} = \frac{0.1315}{0.4045} = 0.325.$$

20. **(b)** Total V.P. of solution $= P_A^\circ X_A + P_B^\circ X_B$

Given, $P_A^\circ = 74.7$ torr, $P_B^\circ = 22.3$ torr
$n_{benzene} = 1.5$ mol, $n_{toluene} = 3.5$ mol
$n_{solution} = 1.5 + 3.5 = 5$ mol

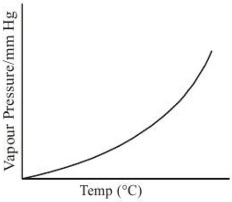
$$x_A = \frac{n_{benzene}}{n_{solution}} = \frac{1.5}{5} = 0.3$$

$$x_B = \frac{n_{toluene}}{n_{solution}} = \frac{3.5}{3} = 0.7$$

Total V.P. of solution $= (0.3 \times 74.7 + 0.5 \times 22.3)$ torr
$= (22.4 + 15.6)$ torr $= 38$ torr

Mole fraction of benzene in vapour form $= \frac{22.4}{38} = 0.589$

21. **(b)** If we plot a graph between the vapour pressure and the temperature. We would get a curve that rises faster as T increases, giving a curved line.



22. **(d)** Solutions in which solute - solute and solvent-solvent interactions are almost similar to solute solvent interactions are known as ideal solution.

23. **(b)** $P_A = P_A^\circ \times X_A =$ total pressure $\times y_A$
$P_B = P_B^\circ \times X_B =$ total pressure $\times y_B$

where x and y represents mole fraction in liquid and vapour phase respectively.

$$\frac{P_B^\circ X_B}{P_A^\circ X_A} = \frac{y_B}{y_A}; \frac{P_B^\circ(1-X_A)}{P_A^\circ X_A} = \frac{1-y_A}{y_A}$$

on putting values $\frac{119(1-0.50)}{37 \times 0.50} = \frac{1-y_A}{y_A}$

on solving $y_A = 0.237$

24. **(c)** Let vapour pressure of $A = P_A^\circ$
Vapour pressure of $B = P_B^\circ$
In first solution,

Mole fraction of $A(X_A) = \frac{1}{1+2} = \frac{1}{3}$

Mole fraction of $B(X_B) = \frac{2}{1+2} = \frac{2}{3}$

According to Raoult's law,

Total vapour pressure $= 250 = P_A^\circ X_A + P_B^\circ X_B$

$$250 = \frac{1}{3}P_A^\circ + \frac{2}{3}P_B^\circ \qquad \text{...(i)}$$

In second solution

Mole fraction of $A(X_A) = \frac{2}{2+2} = \frac{2}{4} = \frac{1}{2}$

Mole fraction of $B(X_B) = \frac{2}{4} = \frac{1}{2}$

$\therefore$ Total vapour pressure $= 300 = P_A^\circ X_A + P_B^\circ X_B$

$$300 = \frac{1}{2}P_A^\circ + \frac{1}{2}P_B^\circ \qquad \text{...(ii)}$$

Multiplying equation (i) by $\frac{1}{2}$ and equation (ii) by $\frac{1}{3}$

$$\frac{1}{6}P_A^\circ + \frac{2}{6}P_B^\circ = 125$$

$$\frac{\frac{1}{6}P_A^\circ + \frac{1}{6}P_B^\circ = 100}{\frac{1}{6}P_B^\circ = 25}$$

$P_B^\circ = 25 \times 6 = 150$ mm Hg
On substituting value of P_B° in equation (ii) we get

$$300 = P_A^\circ \times \frac{1}{2} + 150 \times \frac{1}{2}$$

$P_A^\circ = 450$ mm Hg

25. **(a)** $P_{Total} = P^\circ_A X_A + P^\circ_B X_B$

$$= P^\circ_{Heptane} X_{Heptane} + P^\circ_{Octane} X_{Octane}$$

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

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

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

$= 72\,\text{kPa}$

26. **(b)** $P_{total} = P_x^\circ X_x + P_y^\circ X_y$

$$550 = P_x^\circ \times \frac{1}{4} + P_y^\circ \times \frac{3}{4}$$

$$P_x^\circ + 3P_y^\circ = 550 \times 4 \qquad \text{...(i)}$$

In second case,

$$P_{total} = P_x^\circ \times \frac{1}{5} + P_y^\circ \times \frac{4}{5}$$

$$P_x^\circ + 4P_y^\circ = 560\,'\,5 \qquad \text{...(ii)}$$

Subtract (i) from (ii)

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

$\because P_x^\circ = 400$

27. **(b)** For this solution intermolecular interactions between *n*-heptane and ethanol are 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.

28. **(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,

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

$P_B^\circ = 1000$ 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

29. **(b)** $P_A^\circ = ?$, Given $P_B^\circ = 200\,\text{mm}$, $X_A = 0.6$,

$X_B = 1 - 0.6 = 0.4$, $P = 290$

$P = P_A + P_B = P_A^\circ X_A + P_B^\circ X_B$

$290 = P_A^\circ \times 0.6 + 200 \times 0.4$

$\therefore P_A^\circ = 350\,\text{mm}$

30. **(d)** Let the mass of methane and oxygen = mg.

Mole fraction of O_2

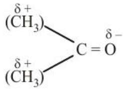
$$= \frac{\text{Moles of } O_2}{\text{Moles of } O_2 + \text{Moles of } CH_4}$$

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

Partial pressure of O_2 = Total pressure × mole fraction of O_2,

$$p_{O_2} = P \times \frac{1}{3} = \frac{1}{3}P$$

31. **(d)** Acetonitrile $(\overset{\delta+}{CH_3} - C \equiv \overset{\delta-}{N})$ and acetone



both are polar molecules, hence dipole-dipole interaction exists between them. Between KCl and water, ion-dipole interaction is found and in benzene-ethanol and benzene–carbon tetrachloride dispersion force is present.

32. **(d)** Vapour pressure of benzene = 75 torr

Vapour pressure of toluene = 22 torr

mass of benzene in = 78g

$$\text{Moles of benzene} = \frac{78}{78} = 1\text{mol}$$

$\therefore$ (Mol.wt of benzene = 78)

Mass of toluene in solution = 46g

$$\text{Hence moles of toluene} = \frac{46}{92} = 0.5\text{ mol}$$

Now partial pressure of benzene

$$= P^o{}_b \cdot X_b = 75 \times \frac{1}{1 + 0.5} = 75 \times \frac{1}{1.5}$$

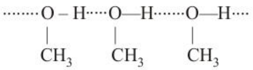
$$= 75 \times \frac{2}{3} = 50$$

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

34. **(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.

35. **(b)** **Note:** Positive deviations are shown by such solutions in which solvent-solvent and solute-solute interactions are stronger than the solvent-solute interactions. In such solutions, the interactions among molecules becomes weaker. Therefore, their escaping tendency increases which results in the increase in their partial vapour pressure.

In a solution of methanol there exists intermolecular H–bonding.



$$\cdots\cdots\underset{CH_3}{\underset{|}{O}}-H\cdots\cdots\underset{CH_3}{\underset{|}{O}}-H\cdots\cdots\underset{CH_3}{\underset{|}{O}}-H\cdots$$

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

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

37. **(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.

38. **(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 $\Delta V = -ve$

39. **(5.0)**

Molality of $CaCl_2$ solution = 0.05 m

$$\Delta T_b = iK_b m = 3 \times K_b \times 0.05 = 0.15 K_b$$

Molality of $CrCl_3.xNH_3 = 0.10$ m

$$\Delta T_b' = iK_b \times 0.10 \Rightarrow \Delta T_b' = 2\Delta T_b$$

$$iK_b \times 0.10 = 2 \times 0.15 K_b \Rightarrow i = 3$$

Since, co-ordination number of Cr is 6.

$\therefore$ The complex is $[Cr(NH_3)_5Cl]Cl_2$.

$\therefore x = 5$.

40. **(167)**

For NaCl : $\pi_1 = iC_1RT \Rightarrow C_1 = \dfrac{0.10}{2RT}$

For Glucose : $\pi_2 = C_2RT \Rightarrow C_2 = \dfrac{0.20}{RT}$

When 1 L of NaCl solution and 2 L glucose solution are mixed.

$$\therefore C'_1 = \frac{0.10}{6RT} \text{ and } C'_2 = \frac{0.20 \times 2}{3RT} = \frac{0.40}{3RT}$$

$$\therefore \pi_{Total} = iC'_1 RT + C'_2 RT = \frac{0.10}{3} + \frac{0.40}{3} = \frac{0.50}{3}$$

$$\pi_{Total} = 167 \times 10^{-3} \text{ atm}$$

41. **(177)**

$$\pi_A = iC_ART,\ \pi_B = iC_BRT$$

For isotonic solution, $\pi_A = \pi_B$

$i_1C_1 = i_2C_2$ (For protein $i = 1$)

$$\Rightarrow C_1 = C_2$$

$$\Rightarrow \frac{0.73 \times 1000}{M_A \times 250} = \frac{1.65}{M_B \times 1}$$

$$\therefore \frac{M_A}{M_B} = \frac{0.73 \times 4}{1.65} = 1.77 = 177 \times 10^{-2}$$

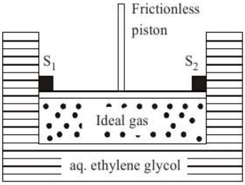
42. **(1.75)**

$$\Delta T_f = iK_f m$$

$$0.2 = 2 \times 2 \times \frac{w}{58.5} \times \frac{1000}{600}$$

$$w = \frac{0.2 \times 58.5 \times 600}{1000 \times 4} = \frac{1.2 \times 58.5}{40} = 1.75 \text{ g}$$

43. **(2.18)**



$K_f = 2.0$ K kg mol^{-1}; m = 0.5

$\Delta T_f = K_f m = 0.5 \times 2$

$T_{initial} = 272$ K

$n = 0.1$ mol

$V = 1$ dm^3

$$P_{gas} = \frac{nRT}{V} = \frac{0.1 \times 0.08 \times 272}{1} = 2.176 \text{ atm}$$

After releasing piston $P_1V_1 = P_2V_2$

$2.176 \times 1 = 1 \times V_2$

$V_2 = 2.18$ dm^3

44. **(c)** Osmotic pressure $(\pi) = CRT$

Since, there are two solutes i.e. urea and glucose.

$\therefore \pi = (C_1 + C_1)RT$

$$= \left(\frac{0.6}{60 \times 0.1} + \frac{1.8}{180 \times 0.1}\right) \times 0.0821 \times 300$$

$$= 0.2 \times 0.0821 \times 300 = 4.926 \text{ atm}$$

45. **(c)** Relative lowering of vapour pressure, is given by,

$$\frac{p^\circ - p}{p^\circ} = x_A = \frac{n_A}{n_A + n_B} \simeq \frac{n_A}{n_B}$$

Given, $p^\circ = 35\,\text{mm Hg}, n_{\text{urea}} = \frac{0.60}{60}, n_{\text{water}} = \frac{360}{18}$

$$\frac{p^\circ - p}{35} = \frac{0.6 \times 18}{60 \times 360} = \frac{1}{2000}$$

$$\Delta p = p^\circ - p = 0.017$$

46. **(c)** Ebullioscopic constant (molal devation const.) is given by,

$$k_b = \frac{\Delta T_b}{m} \Rightarrow \frac{(k_b)_A}{(k_b)_B} = \frac{1}{5}$$

$$\therefore \frac{(\Delta T_b)_A}{(\Delta T_b)_B} = \frac{(k_b)_A}{(k_b)_B} = \frac{1}{5}$$

47. **(b)** We know, $\pi = iCRT$; $\pi_{xy} = 4\pi_{BaCl_2}$

Since both are ionic solute, i.e.,

$XY \rightarrow X^+ + Y^- \Rightarrow i = 2$

$BaCl_2 \rightarrow B^2a^+ + 2Cl^- \Rightarrow i = 3$

Now,

$2[XY] = 4 \times 3 \times [0.01]$

$[XY] = 0.06$

$= 6 \times 10^{-2}$ mol/L

48. **(d)** Dissociation of Potassium Sulphate (K_2SO_4),

$$K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}$$

i (Van't Hoff factor) = 3

We know that, $\Delta T_f = iK_f m$

where, K_f is molal depression constant and m is molality.

$= 3 \times 4 \times 0.03 = 0.36$ K

49. **(a)** $(\Delta T_f)_x = (\Delta T_f)_y$

$$K_f.m_x = K_f.m_y$$

$$m_x = m_y$$

$$\frac{\text{No. of moles of x}}{\text{wt. of solvent in kg}} = \frac{\text{No. of moles of y}}{\text{wt. of solvent in kg}}$$

Given, 4% aqueous solution of x = 4g of solute, x present in 100g of H_2O

12% aqueous solution of y = 12g of solute, y present in 100g of H_2O.

$$\text{Now, } \frac{4g}{m_1} \times \frac{1000}{100} = \frac{12g}{m_2} \times \frac{1000}{100}$$

$$\frac{4g}{A} = \frac{12g}{m_2} \quad [m_1 = A]$$

$$m_2 = 3A$$

50. **(a)**

$$\underset{\text{w g}}{2C_6H_5COOH} \longrightarrow \underset{\text{Dimer}}{(C_6H_5COOH)_2}$$

$$\begin{array}{lll} t = 0 & 1 & 0 \\ t = t_{eq} & 1 - \alpha & \frac{\alpha}{2} \end{array}$$

$$\text{Moles at equilibrium} = 1 - \alpha + \frac{\alpha}{2} = 1 - \frac{\alpha}{2}$$

$$i = \frac{\text{Total moles at equilibrium}}{\text{Initial moles}} = \frac{1 - \frac{\alpha}{2}}{1}$$

$$i = \frac{1 - \frac{0.8}{2}}{1} = 0.6$$

$$\Delta T_f = iK_f m$$

$$2 = 0.6 \times 5 \times \left(\frac{\frac{w}{122}}{30} \right) \times 1000$$

$$w = 2.4 \text{ g}$$

51. **(b)** Freezing point of diluted milk = –0.2 °C

$\Delta T'_f = 0.2$ °C

Freezing point of pure milk = –0.5 °C

$\Delta T_f = 0.5$ °C

$$\frac{\Delta T_f}{\Delta T'_f} = \frac{K_f \times m}{K_f \times m'}; \quad m = \frac{\text{mole of solute}}{\text{mass of solvent (kg)}}$$

Moles of solute are same in both samples.

$$\therefore \frac{0.5}{0.2} = \frac{W'}{W}$$

$$\frac{W'}{W} = \frac{5}{2}; \quad W' = \frac{5}{2} W$$

2 cups of pure milk is mixed with 3 cups of water to make 5 cups of diluted milk.

52. **(b)** $K_2HgI_4 \rightleftharpoons 2K^+ + [HgI_4]^{2-}; n = 3$

$$\because \quad \alpha = \frac{i-1}{n-1};\ 0.4 = \frac{i-1}{3-1}$$

$i = 1.8$

53. **(d)** According to the question we can write

$\Delta T_b = K_b m \Rightarrow K_b(1) = 2 \Rightarrow K_b = 2\ \text{Km}^{-1}$

$\Delta T_f = K_f m \Rightarrow K_f(2) = 2 \Rightarrow K_f = 1\ \text{Km}^{-1}$

$$\text{So, } \frac{K_b}{K_f} = \frac{2}{1}$$

$\therefore K_b = 2K_f$

54. **(c)** As we know,

$\Delta T_f = K_f \cdot m$

$$\Rightarrow 10 = 1.86 \times \frac{62 \times 1000}{62 \times w}$$

$$\Rightarrow w = = \frac{1.86 \times 1000}{10} = 186\ \text{g}$$

Total amount of water = 250 g

$\therefore$ The amount of water separated as ice

$= 250 - 186 = 64$ g

55. **(d)**

		Number of particles (i)
(a)	$[Co(H_2O)_6]Cl_3$	4
(b)	$[Co(H_2O)_5Cl]Cl_2{\cdot}H_2O$	3
(c)	$[Co(H_2O)_4Cl_2]Cl{\cdot}2H_2O$	2
(d)	$[Co(H_2O)_3Cl_3]{\cdot}3H_2O$	1

z ; where $\Delta T_f = (T_f - T_f')$

Remember, greater the no. of particles, lower will be the freezing point. Compound (d) will have the highest freezing point due to least number of particles.

56. **(c)** Molar mass of octane = 114 g/mol

From the lowering of vapour pressure we have,

$$\frac{\Delta P}{P} = \frac{\dfrac{W_2}{M_2}}{\dfrac{W_2}{M_2} + \dfrac{W_1}{M_1}}$$

$$\frac{75}{100} = \frac{\dfrac{W_2}{50\ \text{g/mol}}}{\dfrac{W_2}{50\ \text{g/mol}} + \dfrac{114\ \text{g}}{114\ \text{g/mol}}}$$

$$0.75 = \frac{\dfrac{W_2}{50}}{\dfrac{W_2}{50} + 1}$$

$$.\frac{W_2}{50} + 1 = \frac{W_2}{50 \times 0.75}$$

$W_2 = 150$ g

Note : W_2 and M_2 are mass and molar mass of solute whereas W_1 and M_1 are mass and molar mass of octane.

57. **(a)** The relationship between molar masses of the two solvents is

$$M_X = \frac{3}{4} M_Y \ \ldots\text{(i)}$$

The relative lowering of vapour pressure of the two solutions is

$$\left(\frac{\Delta P}{P}\right)_X = m\left(\frac{\Delta P}{P}\right)_Y$$

But, the relative lowering of vapour pressure of solutions is directly proportional to the mole fraction of solute.

Given 5 molal solution, means 5 moles of solute are dissolved in 1 kg (or 1000 g) of solvent.

$$\text{The number of moles of solvent} = \frac{1000\ \text{g}}{M}$$

$$\text{The mole fraction of solute} = \frac{5}{1000/M}$$

$$= M \times \frac{5}{1000}$$

$$\text{Hence, } M_X \times \frac{5}{1000} = m \times M_Y \times \frac{5}{1000} \quad \ldots\text{(ii)}$$

Substitute equation (i) in equation (ii)

$$\frac{3}{4} \times M_Y \times \frac{5}{1000} = m \times M_Y \times \frac{5}{1000}$$

$$m = \frac{3}{4}$$

58. **(d)** In benzene,

$$\underset{1-\alpha}{2CH_3COOH} \rightleftharpoons \underset{\alpha/2}{(CH_3COOH)_2}$$

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

Here α is degree of association

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

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

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

$$\alpha=0.945$$

% degree of association = 94.6%

59. **(c)** Molality (experimental)

$$=\frac{\Delta T_f}{K_f}=\frac{3.82}{1.86}=2.054\text{ mol/1000 g solvent}$$

$$\text{Molality (theortical)}=\frac{\text{moles of solute}}{\text{wt. of solvent(g)}}\times 1000$$

$$=\frac{5\text{ g}/142\text{ g / mole}}{x}\times 1000$$

	$Na_2SO_4 \longrightarrow$	$2Na^+$	$+SO_4^{2-}$
Moles before dissociation	1	0	0
Moles after dissociation	$1-\alpha$	2α	α

$$\text{Von't Hoff factor }(i)=\frac{\text{Moles after dissociation}}{\text{Moles before dissociation}}$$

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

Na_2SO_4 is ionised 81.5% means $\alpha=0.815$

$$=\frac{(1-0.815)+2\times 0.815+0.815}{1}$$

$$=2.63.$$

$$i=\frac{\text{Observed molality}}{\text{Calculated molality}}$$

$$2.63=\frac{2.054}{\frac{0.0352}{x}\times 1000}$$

$$x=45.07\text{ g}$$

60. **(a)** According to Raoult's Law

$$\frac{P^\circ-P_s}{P_s^\circ}=\frac{W_B\times M_A}{M_B\times W_A} \qquad \ldots\text{(i)}$$

Here P° = Vapour pressure of pure solvent,

P_s = Vapour pressure of solution

W_B = Mass of solute, W_A = Mass of solvent

M_B = Molar mass of solute, M_A = Molar Mass of solvent

Vapour pressure of pure water at 100 °C (by assumption = 760 torr)

By substituting values in equation (i) we get,

$$\frac{760-P_s}{P_s^\circ}=\frac{18\times 18}{180\times 178.2} \qquad \ldots\text{(ii)}$$

On solving (ii) we get

$P_s = 752.4$ torr

61. **(a)** Van't Hoff factor (i)

$$=\frac{\text{No. of particles after association or dissociation}}{\text{No. of particles before association or dissociation}}$$

For	$MX_2 \rightleftharpoons$	M^{2+}	$+2X^-$
$t=0$	1	0	0
at eq.	$1-\alpha$	α	2α

Total no. of particles $=1-\alpha+\alpha+2\alpha=1+2\alpha$

$$\therefore\ i=\frac{1+2\alpha}{1}=2.$$

$\therefore\ \alpha=0.50$ or 50%.

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

$$\frac{P^\circ-P_s}{P^\circ}=\frac{w_2M_1}{w_1M_2}$$

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

$P^\circ = 185$ torr, $P_s = 183$ torr

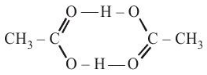
$$\frac{185-183}{185}=\frac{1.2\times 58}{100\times M_2}$$

(Mol. mass of acetone = 58)

$M_2 = 64.68 \approx 64$

$\therefore$ Molar mass of substance = 64

63. **(d)** Acetic acid contain carboxylic group – COOH which can form H-bonding so acetic acid dimerises.



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

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

$$\pi_{Mg_3(PO_4)_2}=5\times 0.100\times R\times T=0.5RT$$

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

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

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

65. **(a)** Given, $\pi_{ob} = 10.8$ atm

$\pi_{nor} = CRT = 0.10 \times 0.0821 \times 298 = 2.446$

Now experimental value of (i)

$$= \frac{\text{Observed osmotic pressure}}{\text{Normal osmotic pressure}} = \frac{10.8}{2.446} = 4.42$$

66. **(c)** $\frac{P^\circ - P_s}{P^\circ} = \frac{W_B \times M_A}{M_B \times W_A}$

$$0.1 = \frac{12}{M_B} \times \frac{18}{108}$$

$$m_B = \frac{12 \times 18}{0.1 \times 108} = 20$$

67. **(c)** van't Hoff factor (i) and the degree of association are related as below :

$$i = 1 - \alpha\left(1 - \frac{1}{n}\right)$$

$$0.9 = 1 - 0.2\left(1 - \frac{1}{n}\right)$$

On solving,

$$\left(1 - \frac{1}{n}\right) = \frac{1}{2}$$

$$\frac{1}{n} = 1 - \frac{1}{2} = \frac{1}{2}$$

$\therefore\ n = 2$

68. **(d)** $\Delta T_f = K_f m$

where m = molality

$$273 - 268 = 1.86 \times \frac{w}{M \times V}$$

$$5 = 1.86 \times \frac{w}{32 \times 10}$$

$$w = \frac{5 \times 32 \times 10}{1.86} = 860.2 \approx 868.06\text{ g}$$

69. **(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

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

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

70. **(b)** $\text{Mol.wt.}(M_B) = \frac{K_f \times W_B \times 1000}{\Delta T_f \times W_A}$

$$= \frac{1.86 \times 0.85 \times 1000}{0.23 \times 125} \approx 55\text{ g}$$

Where,

$W_B = 0.85$ g

$W_A = 125$ g

$\Delta T_f = 0°C - (-23°C) = 23°C$

$$\text{Now, } i = \frac{M_{normal}}{M_{observed}} = \frac{136.3}{55} = 2.47$$

$$\underset{1-\alpha}{ZnCl_2} \rightleftharpoons \underset{\alpha}{Zn^{2+}} + \underset{2\alpha}{2Cl^-}$$

$$\text{Van't Hoff factor } (i) = \frac{1 - \alpha + \alpha + 2\alpha}{1} = 2.47$$

$\therefore\ \alpha = 0.735 = 73.5\%$

71. **(d)** $\Delta T_f = i \times K_f \times m$

$$i = \frac{\Delta T_f}{K_f \times m} = \frac{1.91}{1.86 \times 1} = 1.02$$

$$\text{For}\ \underset{(1-\alpha)}{HI} \rightleftharpoons \underset{\alpha}{H^+} + \underset{\alpha}{I^-}$$

$1 - \alpha + \alpha + \alpha = i = 1.027$

$1 + \alpha = 1.027$

$\alpha = 0.027$ or 2.7%

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

$\pi_1 = \pi_2$

$C_1 = C_2$

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

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

$$\Rightarrow\ M = \frac{342}{5} = 68.4\text{ g/mol}$$

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

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

Hence van't Hoff factor, i = 3

Now $\Delta T_f = i K_f .m$

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

74. **(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

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

$$\text{or } \frac{17.5 - P_s}{17.5} = \frac{18/180}{178.2/18} \qquad [\because P^\circ = 17.5]$$

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

75. **(a)** 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,

$$C_2 \text{ (concentration)} = \frac{1.5/60}{V}$$

Given, $\pi_1 = \pi_2$ $\qquad \because \pi = CRT$

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

$$\text{or } \frac{5.25/M}{V} = \frac{1.5/60}{V}$$

$\therefore$ $M = 210$ g/mol

76. **(c)** $\because \Delta T_b = T_b - T^o$

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.

$$Na_2SO_4 \rightleftharpoons 2Na^+ + SO_4^{2-}$$

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

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

78. **(d)** $\Delta T_f = i \times K_f \times m$;

$\Delta T_f = 1.85 \times 0.2 \times 1.3 = 0.480$ °C

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

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

$\therefore$ $T_f = 0 - 0.480\,°C = -0.480\,°C$

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

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

$$\frac{\Delta T_b}{\Delta T_f} = \frac{K_b}{K_f}; \frac{\Delta T_b}{0.186} = \frac{0.512}{1.86}$$

$$= 0.0512\,°C.$$