CHAPTER

10

Liquid Solution

EXERCISE I (JEE MAIN)

Solution of Gas in Liquid

1. Low concentration of oxygen in blood and tissues of people living at high altitude is due to

(a) low temperature.

(b) low atmospheric pressure.

(c) high atmospheric pressure.

(d) both low temperature and high pressure.

2. Which of the following statement is correct regarding the solubility of gas in water?

(a) Solubility increases with increase in temperature.

(b) A more polar gas will be less soluble.

(c) Solubility increases with increase in pressure.

(d) Solubility is always an endothermic process.

3. The only incorrect statement regarding Henry's law for a gas dissolving in water is

(a) The value of K_H (Henry's constant) is greater for O_2 than H_2 at same temperature.

(b) The value of K_H increases with increase in temperature.

(c) Henry's law is not applicable for HCl(g).

(d) Henry's law is applicable when the solubility of gas is very low.

4. Henry's law constant for CO_2 in water is 1.6×10^8 Pa at 298 K. The quantity of CO_2 in 500 g of soda water when packed under 3.2 bar pressure at 298 K is

(a) 2.44 g (b) 24.4 g

(c) 0.244 g (d) 0.61 g

5. H_2S, a toxic gas with rotten egg like smell, is used for the quantitative analysis. If the solubility of H_2S in water at STP is 0.2 m, then Henry's law constant for H_2S in water at 273 K is

(a) 3.6×10^8 Pa (b) 5.0×10^8 Pa

(c) 5.0×10^5 Pa (d) 2.78×10^7 Pa

Vapour Pressure

6. On increasing the altitude at constant temperature, the vapour pressure of a liquid

(a) increases

(b) decreases

(c) remains the same.

(d) depends upon climate.

7. The boiling points of C_6H_6, CH_3OH, $C_6H_5NH_2$ and $C_6H_5NO_2$ are 80°C, 65°C, 184°C and 212°C, respectively. Which of the following will have the highest vapour pressure at room temperature?

(a) C_6H_6 (b) CH_3OH

(c) $C_6H_5NH_2$ (d) $C_6H_5NO_2$

8. Which of the following is not a characteristic property of the polar liquids?

(a) They have high boiling points.
(b) They have high heat of vaporization.
(c) They have low viscosity.
(d) They have low vapour pressure.

9. Vapour pressure of the liquid

(a) increases with increase in temperature.
(b) decreases with increase in temperature.
(c) is independent of temperature.
(d) either increases or decreases with increase in temperature, depending on the nature of liquid.

10. The vapour pressure of water at 300 K in a closed container is 0.4 atm. If the volume of the container is doubled, then its vapour pressure at 300 K will be

(a) 0·8 atm (b) 0·2 atm
(c) 0·4 atm (d) 0·6 atm

Solution of Liquid in Liquid

11. Which of the following behaviour is true about the ideal binary liquid solution of liquids 'A' and 'B', if $P_A^o < P_B^o$?

(a) Plot of P_{total} vs X_A is non-linear.
(b) Plot of P_{total} vs X_B is linear with +ve slope.
(c) Plot of P_{total} vs X_B is linear with slope = 0.
(d) Plot of P_{total} vs X_B is linear with –ve slope.

12. For an ideal solution of A and B, Y_A is the mole fraction of A in the vapour phase at equilibrium. Which of the following plot should be linear?

(a) P_{total} vs Y_A (b) Ptotal vs YB
(c) $\frac{1}{P_{total}}$ vs YA (d) $\frac{1}{P_{total}}$ *vs* $\frac{1}{Y_A}$

13. At 323 K, the vapour pressure (in mm Hg) of a methanol–ethanol solution is represented as

$$P = 120X + 140,$$

where X is the mole fraction of methanol in liquid solution at equilibrium. The value of P_{EtOH}^o is

(a) 120 mm (b) 140 mm
(c) 260 mm (d) 20 mm

14. The vapour pressure of pure benzene at 88°C is 960 mm and that of toluene at the same temperature is 380 mm of benzene. At what mole fraction of benzene, the mixture will boil at 88°C?

(a) 0.655 (b) 0.345
(c) 0.05 (d) 0.25

15. Heptane and octane form ideal solution. At 373 K, the vapour pressures of the pure liquids are 106 kPa and 46 kPa, respectively. What will be the vapour pressure, in bar, of a mixture of 30.0 g of heptane and 34.2 g of octane?

(a) 76 bar (b) 152 bar
(c) 1.52 bar (d) 0.76 bar

16. Benzene and toluene form an ideal solution. The vapour pressures of benzene and toluene are 75 mm and 25 mm, respectively, at 20°C. If the mole fractions of benzene and toluene in vapour are 0.75 and 0.25, respectively, then the vapour pressure of the ideal solution is

(a) 62.5 mm (b) 50 mm
(c) 30 mm (d) 40 mm

17. For which of the following pair, the heat of mixing, ΔH_{mix}, is approximately zero?

(a) $CH_3COOCH_3 + CHCl_3$
(b) $CH_3COOH + H_2O$
(c) $C_2H_5OH + CH_3OH$
(d) $CH_3COCH_3 + C_6H_6$

18. Each of the following pair shows a positive deviation from the Raoult's law except

(a) $(C_2H_5)O + HCl$
(b) $CCl_4 + CH_3OH$
(c) $CHCl_3 + C_2H_5OH$
(d) $C_2H_5OH + H_2O$

19. The vapour pressure of a solution of two liquids, A (P^o = 80 mm, X = 0.4) and B (P^o = 120 mm, X = 0.6) is found to be 100 mm. It shows that the solution exhibits

(a) negative deviation from ideal behaviour.
(b) positive deviation from ideal behaviour.
(c) ideal behaviour.
(d) positive deviation at lower concentration

20. When 25 ml of CCl_4 and 25 ml of toluene is mixed, the total volume of the solution will be

(a) 50 ml (b) > 50 ml
(c) < 50 ml (d) indefinite

21. The immiscible liquid system containing aniline-water boils at 98°C under a pressure of 760 mm. At this temperature, the vapour pressure of water is 700 mm. If aniline is distilled in steam at 98°C, then what percent of total weight of the distillate will be aniline?

(a) 7.89 (b) 8.57
(c) 30.7 (d) 44.3

22. Azeotropic mixture of liquids can only be separated by

(a) simple distillation.
(b) fractional distillation.
(c) distillation under reduced pressure.
(d) chemical means.

23. The boiling point of an azeotropic mixture of water and ethanol is less than that of water and ethanol, separately. The mixture shows

(a) no deviation from Raoult's law.
(b) positive deviation from Raoult's law.
(c) negative deviation from Raoult's law.
(d) that the solution is unsaturated.

24. Which of the following can be separated into its pure components by fractional distillation?

(a) $C_6H_6 + C_7H_8$ (b) $H_2O + HCl$
(c) $H_2O + HNO_3$ (d) $H_2O + C_2H_5OH$

25. Pure water boils at 373 K and nitric acid at 359 K. The azeotropic mixture of water and nitric acid boils at 393.5 K. On distillation of the azeotropic mixture,

(a) pure nitric acid will distil over first.
(b) pure water will distil over first.
(c) one of them will distil over with small amount of the other.
(d) both of them will distil over in the same composition as they are in the mixture.

Lowering of Vapour Pressure

26. The ratio between lowering of vapour pressure of solution and mole fraction of solute is equal to

(a) relative lowering of vapour pressure.
(b) vapour pressure of pure solvent.
(c) vapour pressure of solution.
(d) molar mass of solvent.

27. The vapour pressure of a dilute solution of a non-volatile solute is not influenced by the

(a) temperature of the solution
(b) melting point of the solute
(c) mole fraction of the solute
(d) degree of dissociation of solute

28. Addition of 4.0 g of a non-volatile solute to 54.0 g water results in a lowering of vapour pressure by 1.0%. What is the molar mass of the non-volatile solute?

(a) 132 (b) 66
(c) 133.33 (d) 333

29. An aqueous solution of sucrose is 0.5 molal. What is the vapour pressure of water above this solution? The vapour pressure of pure water is 25.0 mm Hg at this temperature.

(a) 24.8 mm Hg (b) 0.45 mm Hg
(c) 2.22 mm Hg (d) 20.3 mm Hg

30. When mass fraction of solute in a very dilute solution is doubled, its mole fraction is

(a) doubled (b) halved
(c) increased (d) remains constant

31. The vapour pressure of a solution of non-volatile solute is

(a) less than that of solvent.
(b) equal to that of solvent.
(c) more than that of solvent.
(d) equal to or more than that of solvent.

32. Addition of solute to a given solvent in a closed container

(a) decreases the rate of condensation.
(b) decreases the rate of evaporation.
(c) increases the rate of evaporation.
(d) decreases both the rate of evaporation and condensation.

33. The mass of a non-volatile solute (molecular mass = 40) which should be dissolved in 114 g octane to reduce its vapour pressure to 80% is

(a) 8 g (b) 12 g
(c) 4 g (d) 10 g

34. The vapour pressure of water at room temperature is lowered by 5% on dissolving a non-volatile solute in it. The molality of the solution is

(a) 2.0 (b) 1.4
(c) 2.78 (d) 2.92

35. How many grams of glucose ($C_6H_{12}O_6$) should be dissolved in 0.5 kg of water at 25°C to reduce the vapour pressure of the water by 1.0%?

(a) 50.5 g (b) 50.0 g
(c) 18.0 g (d) 18.2 g

36. An ideal solution is obtained by dissolving *n* moles of non-volatile, non-electrolyte solute in *N* moles of solvent. If the vapour pressure of solution is *P* and the vapour pressure of pure solvent is 'P^o', then

(a) $\frac{P^o - P}{P} = \frac{n}{N}$ (b) $\frac{P^o - P}{P^o} = \frac{n}{N}$
(c) $\frac{P^o - P}{P^o} = \frac{N}{n}$ (d) $\frac{P^o - P}{P} = \frac{N}{n}$

37. Dry air was passed successively through a solution of 5 g of a solute in 80 g of water and then through pure water. The loss in mass of solution was 2.5 g and that of pure solvent was 0.04 g. What is the molecular mass of the solute?

(a) 70.3 (b) 71.43
(c) 14.28 (d) 14.06

38. An ideal solution was obtained by mixing methanol and ethanol. If the partial vapour pressures of methanol and ethanol are 2.8 and 4.2 kPa respectively, the mole fraction of methanol in the vapour at equilibrium is

(a) 0.67 (b) 0.4
(c) 0.6 (d) 0.33

39. For an ideal solution containing two liquid components A and B, the Gibb's free energy of mixing is minimum, when the molar ratio of the liquids is

(a) 1 : 1 (b) 1 : 2
(c) 1 : 10 (d) 1 : 1000

40. Liquids A and B form an ideal solution. A certain solution of A and B contains 25 mole percent of A, whereas the vapours in the equilibrium with the solution at 298 K contains 50 mole percent of A. The ratio of vapour pressures of pure A to that of pure B at 298 K, is

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

Osmotic Pressure

41. Which of the following serves best as a semipermeable membrane?

(a) Copper ferrocyanide
(b) Vegetable membrane
(c) Animal membrane
(d) Cellophane

42. Two aqueous solutions S_2 and S_2 are separated by a semipermeable membrane. S_1 has lower vapour pressure than S_2. Which of the following statement is correct?

(a) More solvent will flow from S_2 to S_2.
(b) More solute will flow from S_2 to S_1.
(c) Solvent from S_1 to S_2 and S_2 to S_1 will flow at equal rates.
(d) No flow of solvent will take place.

43. After removing the hard shell of an egg by dissolving in dilute HCl, a semipermeable membrane can be visible. If such an egg is kept in a saturated solution of common salt, the size of egg will

(a) shrink
(b) grow
(c) remain unchanged.
(d) first shrink, then grow.

44. The process of getting fresh water from sea water is known as

(a) osmosis (b) filtration
(c) pressure distillation (d) reverse osmosis

45. Blood is isotonic with

(a) 0.9% (w/v) – NaCl solution
(b) 0.9 M – NaCl solution
(c) 0.9 M – NaCl solution
(d) 9.0% (w/v) – NaCl solution

46. The solution containing 4.0 g of PVC in 1 L of dioxane was found to have osmotic pressure of 0.006 atm at 300 K. The molecular mass of the polymer PVC is

(a) 16,420 (b) 1642
(c) 1,64,200 (d) 4105

47. A semipermeable membrane separates a solution which is 0.012 M in glucose from one that is 0.250 M in glucose. On which of these solutions must pressure be applied to prevent a net flow of water through the membrane?

(a) On the 0.012 M solution.
(b) On the 0.250 M solution.
(c) Equal pressure on both the solutions.
(d) The pressure on 0.012 M solution should be double the pressure on 0.250 M solution.

48. If 0.1 molar solution of glucose is separated from 0.1 molar solution of cane sugar by a semipermeable membrane, then which one of the following statements is correct?

(a) Water will flow from glucose solution into cane sugar solution.
(b) Cane sugar will flow across the membrane into glucose solution.
(c) Glucose will flow across the membrane into cane sugar solution.
(d) There will be no net movement across the semipermeable membrane.

49. Five percent solution of a solute (X) is isotonic with 0.855% solution of sucrose (molecular weight = 342). What is the molecular mass of solute (X)?

(a) 200 (b) 58.482
(c) 400 (d) 2000

50. What will be the osmotic pressure of decimolar solution of glucose at 30°C?

(a) 2.48 atm (b) 8.24 atm
(c) 3.48 atm (d) 0.241 atm

51. The solution having higher osmotic pressure than the reference solution is called

(a) hypertonic solution (b) isotonic solution
(c) hypotonic solution (d) ideal solution

52. Due to osmosis, the volume of concentrated solution

(a) decreases slowly (b) increases slowly
(c) increases rapidly (d) decreases rapidly

53. The osmotic pressure of a solution may be increased by

(a) decreasing the temperature of solution.
(b) diluting the solution.
(c) increasing the moles of solute.
(d) increasing the moles of solvent.

54. The relationship between osmotic pressure at 273 K when 10 g glucose (π_1), 10 g urea (π_2) and 10 g sucrose (π_3) are dissolved in 250 ml of water, is

(a) $\pi_1 > \pi_2 > \pi_3$ (b) $\pi_3 > \pi_1 > \pi_2$
(c) $\pi_2 > \pi_1 > \pi_3$ (d) $\pi_2 > \pi_3 > \pi_1$

55. A solution having 54 g of glucose per litre has an osmotic pressure of 4.56 bar. If the osmotic pressure of a urea solution is 1.52 bar at the same temperature, then what would be its concentration?

(a) 1.0 M (b) 0.5 M
(c) 0.3 M (d) 0.1 M

Elevation in Boiling Point

56. Which of the following will cook food more easily?

(a) Saline water (b) Pure water
(c) Alcoholic water (d) All in the same rate

57. The elevation in boiling point method is used for the determination of molecular masses of

(a) non-volatile and soluble solute.
(b) non-volatile and insoluble solute.
(c) volatile and soluble solute.
(d) volatile and insoluble solute.

58. The ebullioscopic constant of a liquid solvent is the elevation of boiling point of

(a) one molar solution of non-volatile and non-electrolyte solute in it.
(b) one normal solution of non-volatile and non-electrolyte solute in it.
(c) one formal solution of non-volatile and non-electrolyte solute in it.
(d) one molal solution of non-volatile and non-electrolyte solute in it.

59. A solution containing 2.60 g of a non-volatile and non-electrolyte solute in 200 g of water boils at 100.130°C at 1 atm. What is the molar mass of the solute? [K_b (H_2O) = 0.52 K-kg/mol]

(a) 52.0 g mol^{-1} (b) 152.0 g mol^{-1}
(c) 104 g mol^{-1} (d) 204 g mol^{-1}

60. Water should boil at 90°C at pressure

(a) 1 atm (b) > 1 atm

(c) < 1 atm (d) Any of these

61. The latent heat of vaporization of a liquid of molar mass, 80 g/mol and boiling point, 127°C is 8 kcal/mol. The ebullioscopic constant of the liquid is

(a) 3.2 K-kg/mol (b) 0.04 K-kg/mol

(c) 0.32 K-kg/mol (d) 0.52 K-kg/mol

62. Which of the following aqueous solution will have the highest boiling point?

(a) 34.2%(w/w) Sugar (b) 18%(w/w) Glucose

(c) 6.00%(w/w) Urea (d) All the same

63. The molal boiling point elevation constant of water is 0.513°C kg mol^{-1}. When 0.1 mole of sugar is dissolved in 200 g of water, the solution boils under a pressure of 1 atm at

(a) 100.513°C (b) 102.565°C

(c) 100.256°C (d) 101.025°C

64. The rise in the boiling point of a solution containing 1.8 g of glucose in 100 g of a solvent is 0.1°C. The molal elevation constant of the solvent is

(a) 1 K/m (b) 10 K/m

(c) 0.01 K/m (d) 2731 K/m

65. An aqueous solution of a non-volatile and non-electrolyte solute (molecular mass = 150) boils at 373.26 K. The composition of solution, in terms of mass percent of the solute, is (K_b of water = 0.52)

(a) 50% (b) 7.5%

(c) 6.98% (d) 75%

Depression in Freezing Point

66. An aqueous solution of 10% NaCl (consider ideal behaviour of the solution) is cooled. It will allow some

(a) NaCl to crystallize.

(b) water to freeze.

(c) water to solidify along with some NaCl.

(d) precipitation of NaCl.

67. If 1 mole of a non-volatile and non-electrolyte solute in 1000 g of water depresses the freezing point by 1.86°C, then what will be the freezing point of a solution of 1 mole of the solute in 500 g of water?

(a) −0.93°C (b) −1.86°C

(c) 3.72°C (d) −3.72 °C

68. What is the molecular mass of a non-ionizing solid if 10 g of this solid, when dissolved in 100 g of water forms a solution which freezes at −1.24°C? $K_f(H_2O) = 1.86°C$ kg mol^{-1}.

(a) 250 (b) 150

(c) 120 (d) 75

69. It is more convenient to obtain the molecular mass of an unknown solute by measuring the freezing point depression than by measuring the boiling point elevation because

(a) freezing point depression is a colligative property, whereas boiling point elevation is not.

(b) freezing point depressions are larger than boiling point elevations for the same solution.

(c) freezing point depressions are smaller than boiling point elevations for the same solution.

(d) freezing point depressions depends more on the amount of solute than boiling point elevation.

70. When the depression in freezing point is carried out, the equilibrium exist between

(a) liquid solvent and solid solvent.

(b) liquid solute and solid solvent.

(c) liquid solute and solid solute.

(d) liquid solvent and solid solute.

71. The molal depression constant for four liquids P, Q, R and S, respectively, are 1.84, 2.20, 3.15 and 3.92. If 0.1 m urea solution is made in all the solvents, then the solution in which solvent will show maximum depression in freezing point is

(a) P (b) Q

(c) R (d) S

72. Among the colligative properties of solution, which one is the best method for the determination of molecular masses of proteins and polymers?

(a) Osmotic pressure

(b) Lowering in vapour pressure

(c) Lowering in freezing point

(d) Elevation in boiling point

73. 5 g of urea is dissolved in one kg of water. Up to what temperature, the solution may be cooled before ice starts crystallizing out? (K_f of water = 1.86)

(a) –0.310°C
(b) –0.240°C
(c) –0.195°C
(d) –0.155°C

74. In the above problem, if the solution is cooled to –0.200°C, then how many grams of ice would separate?

(a) 200
(b) 225
(c) 325
(d) 175

75. Of the following measurements, the one most suitable for the determination of the molecular mass of oxyhaemoglobin, a molecule with a molecular mass of many thousands, is

(a) the elevation of the boiling point.
(b) the depression of the freezing point.
(c) the osmotic pressure.
(d) any of the previous three, as they are all equally good.

Abnormal Colligative Properties

76. Phenol dimerizes in benzene. If the observed molecular mass of phenol in solution is 120, then its degree of dimerization is

(a) 0.600
(b) 0.433
(c) 0.277
(d) 0.866

77. The van't Hoff factor for a dilute solution of $K_3[Fe(CN)_6]$ is

(a) 4.0
(b) 0.25
(c) 5.0
(d) 3.0

78. The molecular mass of NaCl as determined by osmotic pressure measurement is

(a) 58.5
(b) less than 58.5
(c) more than 58.5
(d) unpredictable

79. The limiting value of van't Hoff factor for Na_2SO_4 is

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

80. The ratio of the elevation in boiling points of NaCl solution to that of glucose solution of same molality is nearly

(a) 1 : 2
(b) 1 : 1
(c) 2 : 1
(d) 58.5 : 180

81. The mass of KCl required to depress the freezing point of 500 g water by 2 K is (K_f = 1.86, K = 39)

(a) 10.01 g
(b) 40.05 g
(c) 7.45 g
(d) 20.03 g

82. For each of the following dilute solutions, van't Hoff factor is equal of 3, except

(a) Na_2SO_4
(b) CaF_2
(c) K_3PO_4
(d) $(NH_4)_2CO_3$

83. Which of the following aqueous solution will have the lowest freezing point?

(a) 0.10 m-sucrose
(b) 0.10 m-$NiCl_2$
(c) 0.10 m-$CuSO_4$
(d) 0.10 m-NH_4NO_3

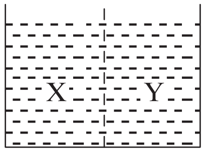
84. At the same temperature, each of the following solution has the same osmotic pressure except

(a) 0.140 M-sucrose
(b) 0.07 M-KCl
(c) 0.070 M-$Ca(NO_2)_2$
(d) 0.140 M-urea

85. The 0.1 m aqueous solutions, each of urea, common salt and sodium sulphate, are taken. The ratio of their elevation in boiling points is

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

86. $FeCl_3$ solution (side X) on reaction with $K_4[Fe(CN)_6]$ (side Y) in aqueous solution gives blue colour. These are separated by a semipermeable membrane as shown. Due to osmosis, there is



(a) blue colour formation in the side X.
(b) blue colour formation in the side Y.
(c) blue colour formation in both sides of X and Y.
(d) no blue colour formation.

87. Which one of the following pairs of solution can we expect to be isotonic at the same temperature?

(a) 0.1 M-urea and 0.1 M-NaCl
(b) 0.1 M-urea and 0.1 M-$MgCl_2$
(c) 0.1 M-Na_2SO_4 and 0.1 M-NaCl
(d) 0.1 M – Na_2SO_4 and 0.1 M – $Ca(NO_3)_2$

88. Aqueous solutions of 0.004 M-Na_2SO_4 and 0.01 M-Glucose are isotonic. The percentage dissociation of Na_2SO_4 is

(a) 25% (b) 60%
(c) 75% (d) 40%

89. Under the condition of similar temperature, which of the following solution will have minimum vapour pressure?

(a) 0.1 M-sugar (b) 0.1 M-NaCl
(c) 0.1 M-$BaCl_2$ (d) 0.1 M-$Al_2(SO_4)_3$

90. Maximum osmotic pressure will be shown by which of the following solution (all 90% ionized)?

(a) 0.1 M-$AlCl_3$ (b) 0.1 M-$BaCl_2$
(c) 0.1 M-NaCl (d) 0.1 M-sugar

91. If 0.1 molal aqueous solution of sodium bromide freezes at –0.3348°C at one atmospheric pressure, then the percent dissociation of salt in the solution is ($K_f = 1.86$)

(a) 90 (b) 80
(c) 60 (d) 20

92. An aqueous solution containing 0.25 moles of a non-volatile but strong electrolyte solute 'X' in 500 g water freezes at –2.79°C. The number of ions furnished in water per formula unit of 'X' is ($K_f = 1.86$)

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

93. An aqueous solution (0.85%) of $NaNO_3$ is apparently 90% dissociated at 27°C. The osmotic pressure of solution is

(a) 2.463 atm (b) 4.68 atm
(c) 24.63 atm (d) 46.8 atm

94. The van't Hoff factor for $Ba(NO_3)_2$ solution is 2.74. The degree of dissociation of salt is

(a) 0.913 (b) 0.87
(c) 1.00 (d) 0.74

95. The elevation in boiling point, when 13.44 g of freshly prepared $CuCl_2$ is added to one kg of water, is (Some useful data: K_b of water = 0.52 K – kg/mol and molecular weight of $CuCl_2$ = 134.4)

(a) 0.052 (b) 0.104
(c) 0.156 (d) 0.208

96. When 20 g of naphtholic acid ($C_{11}H_8O_2$) is dissolved in 50 g of benzene (K_f = 1.72 K kg mol^{-1}), a freezing point depression of 2 K is observed. The van't Hoff factor (i) is

(a) 0.5 (b) 1
(c) 2 (d) 3

97. The degree of dissociation (α) of a weak electrolyte, A_xB_y, is related to van't Hoff factor (i) by the expression

(a) $\alpha = \frac{i-1}{x+y-1}$ (b) $\alpha = \frac{i-1}{x+y+1}$

(c) $\alpha = \frac{x+y-1}{i-1}$ (d) $\alpha = \frac{x+y+1}{i-1}$

98. The amino acid alanine has two isomers, such as α-alanine and β-alanine. When equal masses of these two compounds are dissolved in equal mass of a solvent, the solution of α-alanine freezes at relatively lower temperature. Which forms of α-alanine or β-alanine, has the larger equilibrium constant for ionization?

(a) α-alanine (b) β-alanine
(c) Same for both (d) Unpredictable

EXERCISE II (JEE ADVANCED)

Section A (Only one Correct)

1. The Henry's law constant for the solubility of N_2 gas in water at 298 K is 1.0×10^5 atm. The mole fraction of N_2 in air is 0.8. The number of moles of N_2 from air dissolved in 10 moles of water at 298 K and 5 atm pressure is

   (a) 4.0×10^{-4} (b) 4.0×10^{-5}
   (c) 5.0×10^{-4} (d) 5.0×10^{-5}

2. At a particular temperature and at a pressure of 1 atm, the mass and volume of O_3 that can be dissolved in 1 L of H_2O is 'm' gram and 'V' ml, respectively. Assuming that the solution obeys Henry's law, the mass and volume of O_3 dissolved in 2 L of water at the same temperature and at 5 atm will be

   (a) 5 *m* gram, 5*V* ml
   (b) 10 *m* gram, 10*V* ml
   (c) 10 *m* gram, 2*V* ml
   (d) 10 *m* gram, 5*V* ml

3. The vapour pressure of a substance of low volatility can be measured by passing an unreactive gas over a sample of the substance and analysing the composition of the resulting gas mixture. When nitrogen was passed over mercury at 23°C, the mixture was analysed to 0.8 mg of Hg, 50.4 g of nitrogen at a total pressure of 720 torr. The vapour pressure of mercury at this temperature is (Hg = 200)

   (a) 8×10^{-4} torr (b) 1.6×10^{-3} torr
   (c) 3.2×10^{-3} torr (d) 1.6×10^{-4} torr

4. A beaker (A) contains 20 g sugar in 100 g water. Another beaker (B) contains 10 g of sugar in 100 g water. Both the beakers are placed under a bell jar and allowed to stand until equilibrium is reached. How much water will be transferred from one beaker to the other? Neglect the mass of water vapour present at equilibrium.

   (a) 0
   (b) 33.33 g water will transfer from beaker–A to beaker–B.
   (c) 33.33 g water will transfer from beaker–B to beaker–A.
   (d) 50.00 g water will transfer from beaker–B to beaker–A.

5. Liquids A and B form an ideal solution. The plot of $\frac{1}{X_A}$ (*Y*-axis) versus $\frac{1}{Y_A}$ (*X*-axis) (where X_A and Y_A are the mole fractions of A in liquid and vapour phases at equilibrium, respectively) is linear whose slope and intercept, respectively, are given as

   (a) $\frac{P_A^o}{P_B^o}, \frac{(P_A^o - P_B^o)}{P_B^o}$ (b) $\frac{P_A^o}{P_B^o}, \frac{(P_B^o - P_A^o)}{P_B^o}$

   (c) $\frac{P_B^o}{P_A^o}, \frac{(P_A^o - P_B^o)}{P_B^o}$ (d) $\frac{P_B^o}{P_A^o}, \frac{(P_B^o - P_A^o)}{P_B^o}$

6. Liquids P and Q form an ideal solution. The vapour pressures of pure liquids P and Q at 80°C are 300 mm and 100 mm of Hg, respectively. Suppose that the vapour above a solution composed of 1.0 mole of P and 1.0 mole of Q at 80°C is collected and condensed. This condensate is then heated to 80°C and vapour is again condensed to form a liquid R. What is the mole fraction of P in R?

   (a) 0.5 (b) 0.75
   (c) 0.90 (d) 0.10

7. A mixture contains 1 mole of volatile liquid A ($P_A{}^o = 100$ mm Hg) and 3 moles of volatile liquid B ($P_B{}^o = 80$ mm Hg). If the solution behaves ideally, the total vapour pressure of the distillate is

   (a) 85 mm Hg (b) 85.88 mm Hg
   (c) 90 mm Hg (d) 92 mm Hg

8. Pressure over an ideal binary liquid solution containing 10 moles each of liquid A and B is gradually decreased isothermally. At what pressure, half of the total amount of liquid will get converted into vapour? ($P_A^o = 200$ torr, $P_B^o = 100$ torr)

   (a) 150 torr (b) 166.5 torr
   (c) 133.3 torr (d) 141.4 torr

9. A liquid mixture of 'A' and 'B' (assume ideal solution) is placed in a cylinder and piston arrangement. The piston is slowly pulled out isothermally so that the volume of liquid decreases and that of the vapour increases. At the instant when the quantity of the liquid still remaining is negligibly small, the mole fraction of 'A' in the vapour is 0.4. If $P_A° = 0.4$ atm and $P_B° = 1.2$ atm at this temperature, then the total pressure at which the liquid has almost evaporated is

(a) 0.667 atm (b) 1.5 atm
(c) 0.8 atm (d) 0.545 atm

10. A liquid solution is formed by mixing 10 moles of aniline and 20 moles of phenol at a temperature where the vapour pressures of pure liquid aniline and phenol are 90 and 87 mm Hg, respectively. The possible vapour pressure of solution at that temperature is

(a) 82 mm Hg (b) 88 mm Hg
(c) 90 mm Hg (d) 94 mm Hg

11. At 35°C, the vapour pressure of CS_2 is 512 mm Hg and that of acetone CH_3COCH_3 is 344 mm Hg. A solution of CS_2 and acetone, in which the mole fraction of CS_2 is 0.25 has a total vapour pressure of 600 mmHg. Which the following statement about the solution of acetone and CS_2 is true?

(a) A mixture of 100 ml of acetone and 100 ml of CS_2 has a total volume of 200 ml.
(b) When acetone and CS_2 are mixed at 35°C, heat is released.
(c) When acetone and CS_2 are mixed at 35°C, heat is absorbed.
(d) Raoult's law is obeyed by both CS_2 and acetone for the solution in which the mole fraction of CS_2 is 0.25.

12. Mixing of the components in which of the following pair rises the temperature?

(a) Trichloromethane and ethanol.
(b) Tetrachloroethane and methanol.
(c) Trichloromethane and ethoxy ethane.
(d) Trichloroethane and ethoxy ethane.

13. Water and chlorobenzene are immiscible liquids. Their mixture boils at 90°C under a reduced pressure of 9.031×10^4 Pa. The vapour pressure of pure water at 90°C is 7.031×10^4 Pa and the molecular mass of chlorobenzene is 112.5. On mass percent basis, chlorobenzene in the distillate is equal to

(a) 50 (b) 22.2
(c) 64 (d) 36

14. A liquid solvent is in equilibrium with its vapour. When a non-volatile solute is added to this liquid, the instant effect is the rate at which the solvent molecules leaves the

(a) vapour phase and decreases.
(b) vapour phase and increases.
(c) solution and increases.
(d) solution and decreases.

15. The vapour pressure of a solution of a non-volatile and non-electrolyte solute in a solvent is 95% of the vapour pressure of the pure solvent at the same temperature. If the molecular mass of the solvent is 0.3 times that of solute, then the mass ratio of solvent and solute is

(a) 3 : 20 (b) 57 : 10
(c) 1 : 5 (d) 4 : 1

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

(a) 0.8 (b) 0.6
(c) 0.4 (d) 0.7

17. Vapour pressure of a solution of 5 g of non-electrolyte in 100 g of water at a particular temperature is 2985 N/m^2. If the vapour pressure of pure water at this temperature is 3000 N/m^2, then the molecular mass of the solute is

(a) 60 (b) 120
(c) 180 (d) 360

18. The vapour pressure of pure benzene at a certain temperature is 0.85 bar. A non-volatile, non-electrolyte solid weighing 0.5 g is added to 39.0 g of benzene. The vapour pressure of the solution then is 0.845 bar. Molar mass of the solid substance is

(a) 169 g/mol (b) 170 g/mol
(c) 85 g/mol (d) 39 g/mol

19. The vapour pressure of water is 12.3 kPa at 300 K. What is the vapour pressure of 1 molal aqueous solution of a non-volatile solute at 300 K?

(a) 1.208 kPa (b) 12.08 kPa
(c) 0.22 kPa (d) 12.13 kPa

20. A solution containing 30 g of a non-volatile solute exactly in 90 g water has a vapour pressure of 2.8 kPa at 298 K. On adding 18 g of water in the solution, the new vapour pressure becomes 2.9 kPa at 298 K. The molecular mass of the solute is

(a) 23
(b) 69
(c) 34
(d) 43

21. Lowering of vapour pressure in 1 molal aqueous solution at 100°C is

(a) 13.44 mm Hg
(b) 14.12 mm Hg
(c) 31.2 mm Hg
(d) 35.2 mm Hg

22. When 2 g non-volatile hydrocarbon containing 94.4% carbon by mass is dissolved in 100 g of benzene, the vapour pressure of benzene at 30°C is lowered from 89.78 mm to 89.0 mm. The molecular formula of the hydrocarbon is

(a) $C_{12}H_{34}$
(b) $C_{13}H_{22}$
(c) $C_{14}H_{12}$
(d) $C_{14}H_{10}$

23. Air was drawn through a solution containing 40 g of solute (non-volatile and non-electrolyte) in 100 g of water and then through water. The loss of mass of water was 0.05 g and the total mass of water absorbed in sulphuric acid tube was 2.05 g. The molecular mass of the solute is

(a) 267.86
(b) 288.0
(c) 295.2
(d) 302.4

24. A quantity of 10 g of solute 'A' and 20 g of solute 'B' is dissolved in 500 ml water. The solution is isotonic with the solution obtained by dissolving 6.67 g of 'A' and 30 g of 'B' in 500 ml water at the same temperature. The ratio of molar masses, $M_A : M_B$, is

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

25. Equal volumes of $M/20$ glucose solution at 300 K and $M/20$ sucrose solution at 300 K are mixed without change in temperature. If the osmotic pressure of glucose solution, sucrose solution and the mixture of two solutions are π_1, π_2 and π_3, respectively, then

(a) $\pi_1 = \pi_2 = \pi_3$
(b) $\pi_1 > \pi_2 > \pi_3$
(c) $\pi_1 < \pi_2 < \pi_3$
(d) $\pi_1 = \pi_2 < \pi_3$

26. A glucose solution is isopiestic with blood. What is the osmolarity of glucose solution?

(a) 0.31 M
(b) 5.5 M
(c) 3.1 M
(d) 0.154 M

27. Based upon the technique of reverse osmosis, the approximate minimum pressure required to desalinate sea water containing 2.5% (w/v) NaCl at 27°C should be

(a) 10.5 atm
(b) 21 atm
(c) 2.1 atm
(d) 1.05 atm

28. A liquid is in equilibrium with its vapour at its boiling point. On average, the molecules in the two phases have equal

(a) potential energy
(b) intermolecular force
(c) kinetic energy
(d) total energy

29. The boiling point of a 2% (w/w) aqueous solution of a non-volatile and non-electrolyte solute is 0.102°C higher than that of pure water. If K_b for water is 0.52 K-kg/mol, the molecular mass of the solute is

(a) 180
(b) 102
(c) 40
(d) 104

30. Which one of the following statement is incorrect about a liquid solution containing a non-volatile solute?

(a) The fraction of total molecules in solution that has sufficient kinetic energy to overcome the binding forces of the liquid decreases as more solute molecules are added.
(b) The boiling point of the solution increases as we add more solute.
(c) The higher the concentration of the solute, the lower the vapour pressure of the solvent.
(d) Addition of a non-volatile solute increases the vapour pressure of the solvent.

31. The molar latent heat of vaporization of a certain liquid is 4.9 kcal/mol. The normal boiling point of the liquid is 77°C. The change in boiling point per atm increase in pressure at the normal boiling point of the liquid is

(a) 50 deg/atm
(b) 0.02 deg/atm
(c) 5.0 deg/atm
(d) 0.05 deg/atm

32. 72 g of glucose is dissolved in 1 kg of water in a sauce pan. At what temperature will the solution boil at 1.013 bar pressure? The value of K_b for water is 0.52 K-kg mol^{-1}.

(a) 337.208 K
(b) 373.208°C
(c) 373.208 K
(d) 375.08 K

33. The boiling point of pure benzene is 353.23 K. When 1.80 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point is raised to 354.11 K. Calculate the molar mass of the solute. The value of K_b for benzene is 2.53 K kg mol^{-1}.

(a) 85 g mol^{-1} (b) 57.5 g mol^{-1}
(c) 23 g mol^{-1} (d) 38.4 g mol^{-1}

34. At 100°C, the vapour pressure of a solution of 4.0 g of solute in 100 g of water is 750 mm. The boiling point of the solution is (k_b of water = 0.52 K-kg/mol)

(a) 100°C (b) 100.04°C
(c) 100.4°C (d) 104.0°C

35. A quantity of 6.4 g sulphur dissolved in 200 g of CS_2 raises the boiling point of the solvent by 0.32°C. Boiling point of CS_2 = 47°C and latent heat of vaporization of CS_2 = 80.0 cal/g. The molecular formula of sulphur in this liquid is

(a) S_8 (b) S_4
(c) S_2 (d) S

36. What is the boiling point of a solution of 1.00 g of naphthalene dissolved in 94.0 g of toluene? The normal boiling point of toluene is 110.75°C and $K_{x,b}$ = 32.0 K for toluene.

(a) 110.95°C (b) 111.0°C
(c) 113.41°C (d) 110.75°C

37. The vapour pressure of an aqueous solution is found to be 750 torr at a temperature T, and the same solution shows an elevation in boiling point equal to 1.04 K. If T is the boiling point of pure water, then the atmospheric pressure should be (K_b of water = 0.52 K-kg/mol)

(a) 760 torr (b) 777 torr
(c) 746 torr (d) 750 torr

38. When glycerin is added to a litre of water, then which of the following is observed?

(a) Water evaporates more easily.
(b) The temperature of water increases.
(c) The freezing point of water is lowered.
(d) The viscosity of water is lowered.

39. The molar mass of substance forming 7.0% (by mass) solution in water which freezes at −0.93°C, is (The cryoscopic constant of water is 1.86°C kg mol^{-1}).

(a) 140 g mol^{-1} (b) 150.5 g mol^{-1}
(c) 160 g mol^{-1} (d) 155 g mol^{-1}

40. When 36.0 g of a solute having the empirical formula CH_2O is dissolved in 1.20 kg of water, the solution freezes at −0.93°C. What is the molecular formula of the solute? (K_f = 1.86°C kg mol^{-1})

(a) $C_6H_{12}O_6$ (b) $C_3H_6O_3$
(c) CH_2O (d) $C_2H_4O_2$

41. The approximate molality of ethylene glycol ($C_2H_6O_2$) in an aqueous solution which freezes at a temperature not higher than −15°C is (k_f of water = 1.86°C kg mol^{-1})

(a) 8.06 m (b) 0.806 m
(c) 0.145 m (d) 1.5 m

42. An aqueous solution of non-volatile and non-electrolyte solute boils at 100.78°C. It should freeze at (for water, K_f and K_b are 1.86 and 0.52 K-kg/mol, respectively)

(a) 2.79°C (b) 270.21°C
(c) −2.79°C (d) −270.21°C

43. How many grams of sucrose (molecular weight = 342) should be dissolved in 100 g water in order to produce a solution with a 104.76°C difference between the freezing point and the boiling point temperature? (K_f = 1.86, K_b = 0.52)

(a) 34.2 g (b) 68.4 g
(c) 684 g (d) 313.06 g

44. Molal depression constant for Pb is 8.5°C kg/mol. How many grams of Sn must be dissolved in 425 g of Pb to produce an alloy with melting point of 322°C? The melting point of pure Pb is 327°C. (Sn = 120)

(a) 30.0 g (b) 15.0 g
(c) 86.7 g (d) 41.3 g

45. The boiling point and freezing point of a solvent ‘A’ are 90.0°C and 3.5°C, respectively. The K_f and K_b values of the solvent are 17.5 and 5.0 K-kg/mol, respectively. What is the boiling point of a solution of ‘B’ (non-volatile, non-electrolyte solute) in ‘A’, if the solution freezes at 2.8°C?

(a) 90.0°C (b) 89.8°C
(c) 90.2°C (d) 90.7°C

46. A very small amount of non-volatile solute (that does not dissociate) is dissolved in 56.8 cm^3 of benzene (density 0.889 g cm^{-3}). At room temperature, vapour pressure of this solution is 100 mm Hg while that of benzene is 102 mm Hg. If the freezing temperature of this solution is 1.3 degree lower than that of benzene, then what is the value of molal freezing point depression constant of benzene?

(a) 5.07 deg/molal (b) 1.3 deg/molal
(c) 3.9 deg/molal (d) 4.97 deg/molal

47. A liquid freezes at 7°C and boils at 77°C. If the K_f and K_b values for the liquid are 5.6 and 2.5 deg/molal, respectively, then the ratio of molar latent heat of fusion to molar latent heat of vaporization is

(a) 1 : 1 (b) 1 : 3
(c) 2 : 7 (d) 7 : 3

48. The normal freezing point of nitrobenzene is 278.82 K. A non-volatile solute is dissolved in it and a solution of molality 0.25 m is prepared. If the observed freezing point of the solution is 276.82 K, the value for K_f of nitrobenzene is

(a) 6 K-kg mol^{-1} (b) 8 K-kg mol^{-1}
(c) 7 K-kg mol^{-1} (d) 5 K-kg mol^{-1}

49. A 5% (by mass) solution of cane sugar in water has freezing point of 272.85 K. Calculate the freezing point of 5% (by mass) solution of glucose in water, if the freezing point of pure water is 273.15 K.

(a) 0.57 K (b) 272.58 K
(c) 272.85 K (d) 273.72 K

50. Two elements A and B form compounds having molecular formula AB_2 and AB_4. When dissolved in 20 g of C_6H_6, 1 g of AB_2 lowers the freezing point by 2.55 K, whereas 1.0 g of AB_4 lowers it by 1.7 K. The molar depression constant for benzene is 5.1 K-kg mol^{-1}. The atomic masses of A and B are

(a) 50, 25 (b) 50, 50
(c) 25, 50 (d) 75, 25

51. Ice begins to separate at –0.744°C from an aqueous solution containing 2.4 g of a non-volatile, non-electrolyte in 100 g water. The osmotic pressure of the solution at 27°C is (K_f for water = 1.86, assume molality = molarity)

(a) 0.4 atm (b) 9.852 atm
(c) 997.68 atm (d) 240 atm

52. The osmotic coefficient of a non-electrolyte is related to the freezing point depression by the expression, $\phi = \Delta T_f /(m \cdot K_f)$. The depression in freezing point of 0.4 molal aqueous solution of sucrose is 0.93°C. The osmotic coefficient is (K_f of water = 1.86 K-kg/mol)

(a) 0.8 (b) 1.0
(c) 1.25 (d) 0.125

53. A solution of a non-volatile solute in water freezes at −1.0°C. The vapour pressure of pure water at 298 K is 24.24 mm Hg and K_f for water is 1.80 K-kg mol^{-1}. The vapour pressure of this solution at 298 K is

(a) 24.00 mm Hg (b) 22.04 mm Hg
(c) 24.12 mm Hg (d) 23.76 mm Hg

54. A solution of '*x*' mole of sucrose in 100 g of water freezes at – 0.2°C. As ice separates out, the freezing point goes down to – 0.25°C. How many grams of ice would have separated?

(a) 18 g (b) 20 g
(c) 80 g (d) 25 g

55. In KI solution, mercuric iodide is added. The osmotic pressure of resultant solution will

(a) increase
(b) decrease
(c) remains unchanged.
(d) increase or decrease, depending on amount.

56. If 0.1 M solution of NaCl has same osmotic pressure as 0.1 M solution of $CaCl_2$, then the degree of dissociation of $CaCl_2$ will be

(a) 0.5 (b) 0.2
(c) 0.4 (d) 0.33

57. The osmolarity of 0.2 M-Na_2SO_4 is

(a) 0.6 M (b) 0.4 M
(c) 0.2 M (d) 0.8 M

58. $PtCl_4 \cdot 6H_2O$ can exist as a hydrated complex. 1.0 molal aqueous solution has depression in freezing point of 3.72°C. Assume 100% ionization and K_f of water = 1.86°C mol^{-1} kg. The complex is

(a) $[Pt(H_2O)_6]Cl_4$
(b) $[Pt(H_2O)_4Cl_2]Cl_2 \cdot 2H_2O$
(c) $[Pt(H_2O)_3Cl_3]Cl \cdot 3H_2O$
(d) $[Pt(H_2O)_2Cl_4] \cdot 4H_2O$

59. One molal solution of benzoic acid in benzene boils at 81.53°C. The normal boiling point of benzene is 80.10°C. Assuming that the solute is 90% dimerized, the value of K_b for benzene is

(a) 3.5 deg/molal (b) 5.2 deg/molal
(c) 2.6 deg/molal (d) 0.75 deg/molal

60. A quantity of 2 g of C_6H_5COOH dissolved in 25 g of benzene shows a depression in freezing point equal to 1.96 K. Molar depression constant for benzene is 4.9 K-kg mol^{-1}. What is the percentage association of acid if it forms double molecules (dimer) in solution?

(a) 39% (b) 78%
(c) 61% (d) 19.5%

61. The pH of a 0.1 M solution of a monobasic acid is 2.0. Its osmotic pressure at a given temperature T K is

(a) $0.1RT$ (b) $0.11RT$
(c) $0.09RT$ (d) $0.01RT$

62. To one litre of 0.1 M-HCl solution, 0.025 mole of solid NH_4Cl is added. Assuming complete dissociation of solutes, the freezing point of solution is (K_f of water = 1.86 K-kg mol^{-1})

(a) −0.465°C (b) −0.93°C
(c) −0.372°C (d) −0.279°C

63. 'x' moles of KCl and 'y' mole of $BaCl_2$ are dissolved in 1 kg of water. If $(x + y) = 0.1$, then the observed range of ΔT_f is (K_f of water = 1.86 K-kg mol^{-1})

(a) 0.372°C to 0.558°C
(b) 0.186°C to 0.93°C
(c) 0.558°C to 0.93°C
(d) 0.372°C to 0.93°C

64. A quantity of 3.125 g of a mixture of KCl and NaCl dissolved in 1 kg of water produces a depression of 0.186°C in freezing point. The molar ratio of KCl to NaCl in the solution (assuming complete dissociation of the salts) is (K_f = 1.86 deg/molal)

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

65. A dilute solution contains n mole of solute 'A' in 1 kg of a solvent with molal elevation constant K_b. The solute A undergoes dimerization as $2A \rightleftharpoons A_2$. If ΔT_b is the elevation in boiling point of a given solution and molality = molarity, the equilibrium constant K_C for dimer formation is

(a) $\dfrac{K_b\,(n.K_b - \Delta T_b)}{(2.\Delta T_b - n.K_b)}$ (b) $\dfrac{K_b\,(n.K_b - \Delta T_b)}{(2.\Delta T_b - n.K_b)^2}$

(c) $\dfrac{K_b.n.\Delta T_b}{(2.\Delta T_b - n.K_b)^2}$ (d) $\dfrac{(n.K_b - \Delta T_b)}{(n.\Delta T_b - 2.K_b)^2}$

66. Two solvents 'A' and 'B' have K_f values 1.86 and 2.79 K mol^{-1} kg, respectively. A given amount of a substance when dissolved in 500 g of 'A' completely dimerizes and when the same amount of the substance is dissolved in 500 g of 'B', the solute undergoes trimerization. The ratio of observed lowering of freezing point in two cases is

(a) 2 : 3 (b) 4 : 9
(c) 1 : 1 (d) 1 : 2

67. Which of the following solution will show minimum osmotic effect?

(a) KCl solution
(b) Colloidal gold sol
(c) $CaCl_2$ solution
(d) Na_3PO_4 solution

68. A 0.001 molal solution of a complex MA_8 in water has the freezing point of –0.0054°C. Assuming 100% ionization of the complex in water, which of the following is the correct representation of the complex? (K_f of water = 1.86 Km^{-1})

(a) $[MA_8]$ (b) $[MA_7]A$
(c) $[MA_6]A_2$ (d) $[MA_5]A_3$

69. The vapour pressure of a saturated solution of sparingly soluble salt (XCl_3) was 17.20 mm Hg at 27°C. If the vapour pressure of pure water is 17.25 mm Hg at 27°C, then what is the solubility of the sparingly soluble salt XCl_3 in mole per litre?

(a) 4.04×10^{-2} (b) 8.08×10^{-2}
(c) 2.02×10^{-2} (d) 4.04×10^{-3}

70. A non-volatile solute 'X' completely dimerizes in water, if the temperature is below –3.72°C and the solute completely dissociates as X → Y + Z, if the temperature is above 100.26°C. In between these two temperatures (including both temperatures), the solute is neither dissociated nor associated. One mole of 'X' is dissolved in 1.0 kg water ($K_b = 0.52$ K-kg/mol, $K_f = 1.86$ K-kg/ mol). Identify the incorrect information related with the solution.

(a) The freezing point of solution is –1.86°C.

(b) The boiling point of solution is 101.04°C.

(c) When the solution is cooled to –7.44°C, 75% of water present initially will separate as ice.

(d) When the solution is heated to 102.08°C, 50% of water present initially will escape out as vapour.

Section B (One or More than one Correct)

1. A cylinder fitted with a movable piston contains liquid water in equilibrium with water vapour at 25°C. Which of the following operation(s) results in a decrease in the equilibrium vapour pressure at 25°C?

(a) Moving the piston downward for a short distance.

(b) Removing small amount of vapour.

(c) Removing a small amount of liquid water.

(d) Dissolving some salt in the water.

2. Which is a colligative property?

(a) Osmotic pressure (b) Vapour pressure

(c) Freezing point (d) Boiling point

3. The colligative properties of a solution may depend on

(a) Temperature

(b) Nature of solute

(c) Nature of solvent

(d) Amount of solution

4. The vapour pressures of pure liquids A, B and C are 75, 22 and 10 torr, respectively. Which of the following is/are possible value(s) of vapour pressure of binary or ternary solutions having equimolar amounts of these liquids? Assume ideal behaviour for all possible solutions.

(a) 53.5 torr (b) 35.67 torr

(c) 48.5 torr (d) 16 torr

5. Which of the following statement(s) is/are correct?

(a) Minimum boiling azeotropic mixture boils at temperature lower than either of the two pure components.

(b) Maximum boiling azeotropic mixture boils at temperature higher than either of the two pure components.

(c) Minimum boiling azeotropic mixture shows (+) ve deviation.

(d) Maximum boiling azeotropic mixture shows (–) ve deviation.

6. Which of the following liquid pairs do not show positive deviation from Raoult's law?

(a) Acetone–Chloroform

(b) Benzene–Methanol

(c) Water–Nitric acid

(d) Water–Hydrochloric acid

7. A mixture of liquids 'A' and 'B' in the molar ratio 1 : 2 forms a maximum boiling azeotrope. Identify the incorrect statement, if 'A' is more volatile. (Molar masses: A = 100, B = 50).

(a) A liquid solution of 'A' and 'B' having mass % of A = 50 will have vapours having mass % of A = 50.

(b) A liquid solution of 'A' and 'B' having mass % of A > 50 will have vapours having mass % of A > 50.

(c) A mixture of 'A' and 'B' in the molar ratio 1 : 3 can be separated into azeotropic mixture and pure 'A'.

(d) A mixture of 'A' and 'B' in the molar ratio 2 : 3 can be separated into azeotropic mixture and pure 'A'.

8. Which of the following statement(s) is/are correct?

(a) Two sucrose solution of same molality prepared in different solvent will have the same freezing point depression.

(b) Osmotic pressure (π) of a solution is given by $\pi = MRT$, where M is the molarity of the solution.

(c) At same temperature, the correct order of osmotic pressure for 0.01 M aqueous solution of each compound is $BaCl_2 > KCl > CH_3COOH >$ Sucrose.

(d) Raoult's law states that the vapour pressure of a component over a solution is proportional to its mole fraction.

9. Consider 0.1 m aqueous solutions of two solutes X and Y. The solute X behaves as a univalent electrolyte, while the solute Y dimerizes in solution. Which of the following statement(s) is/are correct regarding these solutions?

(a) The boiling point of the solution of X will be higher than that of Y.

(b) The osmotic pressure of the solution of X will be higher than that of Y.

(c) The freezing point of the solution of X will be higher than that of Y.

(d) The relative lowering of vapour pressure of both the solution will be the same.

10. In which of the following liquid pair, there is contraction in volume on mixing?

(a) $C_6H_{14} + C_6H_6$ (b) $H_2O + HCl$

(c) $H_2O + HNO_3$ (d) $H_2O + C_2H_5OH$

11. In a binary electrolyte (AB type), the observed lowering of vapour pressure as compared to the theoretically calculated one for non-electrolyte can never be

(a) more than double.

(b) exactly equal to double.

(c) less than double.

(d) more than one.

12. Benzene and naphthalene forms an ideal solution at room temperature. For this process, the true statement(s) is(are)

(a) $\Delta G = +\text{ve}$ (b) $\Delta S_{\text{system}} = +\text{ve}$

(c) $\Delta S_{\text{surrounding}} = 0$ (d) $\Delta H = 0$

13. An amount of 1 mole of a non-volatile solid is dissolved in 200 moles of water. The solution is cooled to a temperature 'T' K (lower than the freezing point of the solution) to cause ice formation. After the removal of ice, the remaining solution is heated to 373 K, where the vapour pressure of solution is observed to be 740 mm Hg. Identify the correct information(s) from the following (K_f of water = 2.0 K-kg/mol).

(a) 163 moles of ice is formed at T K.

(b) $T\text{ K} = \left(273 - \dfrac{2000}{37 \times 18}\right)\text{K}$

(c) Freezing point of the original solution is $-\dfrac{10}{18}$ °C.

(d) Relative lowering of vapour pressure of the final solution is $\dfrac{1}{38}$.

14. Blood cells in the human body have semipermeable membrane and depending upon the concentration of solution inside blood cells and outside (in the blood), **'Lysis'** (expansion of blood cells) and **'Crenation'** (contraction of blood cells) may occur. Kidneys are responsible for keeping the solution inside blood cell and blood at the same concentration. Identify the correct information(s).

(a) Lysis will occur when blood cells are kept in a solution which is isotonic with blood.

(b) Crenation will occur when blood cells are kept in a solution which is hypertonic with blood.

(c) Blood cells will have normal shape when placed in an isotonic solution with blood.

(d) Lysis will occur when blood cells are kept in a solution which is hypotonic with blood.

15. Two liquids 'A' and 'B' form a solution which shows significant positive deviation from Raoult's law. The normal boiling point of pure liquid 'A' is higher than that of 'B'. Which of the following information(s) related with the solution must be incorrect?

(a) Normal boiling point of the solution of any composition will always be less than that of 'A'.

(b) Azeotropic mixture of 'A' and 'B' will have normal boiling point lower than that of 'B'.

(c) If a small amount of liquid 'B' is added in the liquid solution, the normal boiling point of solution will always decrease.

(d) On distillation of the solution at constant pressure of 1 atm, the distillate will have pure liquid 'Y' and the residual liquid will be pure liquid 'X'.

Section C (Comprehensions)

Comprehension I

The composition of vapour over a binary ideal solution is determined by the composition of the liquid. X_A and Y_A are the mole fractions of 'A' in the liquid and vapour at equilibrium, respectively.

1. The value of X_A for which $(Y_A - X_A)$ is maximum is

(a) $\dfrac{\sqrt{P_A^o \cdot P_B^o} - P_A^o}{P_A^o - P_B^o}$ (b) $\dfrac{\sqrt{P_A^o \cdot P_B^o} - P_B^o}{P_A^o - P_B^o}$

(c) $\dfrac{\sqrt{P_A^o \cdot P_B^o} - P_B^o}{P_A^o}$ (d) $\dfrac{\sqrt{P_A^o \cdot P_B^o} - P_A^o}{P_B^o}$

2. The vapour pressure of solution at this composition is

(a) $\sqrt{P_A^o \cdot P_B^o}$ (b) $(P_A^o - P_B^o)$

(c) $(P_A^o + P_B^o)$ (d) $0.5\ (P_A^o + P_B^o)$

Comprehension II

Liquids 'A' and 'B' forms an ideal solution. At T K, $P_A^o = 0.4$ bar and $P_B^o = 0.6$ bar. In a cylinder piston arrangement, 2.0 moles of vapours of liquid 'A' and 3.0 moles of vapours of liquid 'B' are taken at T K and 0.3 bar.

3. Predict whether the vapours will condense or not, at the given pressure.

(a) Yes, but only a single drop of liquid will form.
(b) Yes, but only partial condensation will occur.
(c) Yes, complete condensation will occur.
(d) No

4. If the vapours are compressed slowly and isothermally, then at what pressure, the first drop of liquid will appear?

(a) 0.4 bar (b) 0.5 bar
(c) 0.52 bar (d) 0.6 bar

5. If the initial volume of vapours was 10.0 dm^3, then at what volume, the first drop of liquid will form?

(a) 6.0 dm^3 (b) 4.0 dm^3
(c) 10.0 dm^3 (d) 1.0 dm^3

6. What is the composition of first drop of liquid formed?

(a) $X_A = 0.4$ (b) $X_A = 0.5$
(c) $X_A = 0.6$ (d) $X_A = 1.0$

7. If the vapours are compressed further, then at what pressure, almost complete condensation of vapours will occur?

(a) 0.4 bar (b) 0.5 bar
(c) 0.52 bar (d) 0.6 bar

8. What is the composition of last traces of vapours remained?

(a) $Y_A = \dfrac{2}{5}$ (b) $Y_A = \dfrac{1}{2}$

(c) $Y_A = \dfrac{9}{13}$ (d) $Y_A = \dfrac{4}{13}$

9. Which of the following is the only incorrect information regarding the composition of the system at 0.51 bar pressure?

(a) $X_A = 0.45$

(b) $Y_A = \dfrac{6}{17}$

(c) $n_{A(\text{liquid})} = \dfrac{12}{11}$

(d) $n_{A(\text{vapour})} = \dfrac{12}{11}$

10. At what pressure, 20% of the total moles of vapours will liquefy? ($\sqrt{145} = 12.04$)

(a) 0.5 bar (b) 0.504 bar
(c) 0.48 bar (d) 0.508 bar

Comprehension III

One mole of liquid 'A' and two moles of liquid 'B' are mixed at 27°C to form an ideal binary solution. (ln 2 = 0.7, ln 3 = 1.1)

11. The value of ΔH_{mix} is

(a) 0 (b) + ve
(c) − ve (d) any of these

12. The value of ΔG_{mix} is

(a) 0 (b) + 1140 cal/mol
(c) −1140 cal/mol (d) −380 cal/mol

13. The value of ΔS_{mix} is

(a) 0
(b) + 3.8 cal/K
(c) −3.8 cal/K
(d) + 3.8 cal/K-mol

Comprehension IV

Benzene and toluene form an ideal solution. A liquid solution is formed by mixing 10 moles each of benzene and toluene at 300 K and 200 mm Hg pressure. At 300 K, the vapour pressures of pure benzene and toluene are 100 and 40 mm Hg, respectively.

14. If the pressure over the mixture at 300 K is reduced, then at what pressure does the first vapour form?

(a) 40 mm Hg (b) 70 mm Hg
(c) 100 mm Hg (d) 199 mm Hg

15. What is the composition (mole fraction of benzene) of the first traces of vapour formed?

(a) 0.5 (b) 0.857
(c) 0.714 (d) 0.286

16. If the pressure is reduced further, then at what pressure does the last trace of liquid disappear?

(a) 57.14 mm Hg (b) 40 mm Hg
(c) 100 mm Hg (d) 66.67 mm Hg

17. What is the composition (mole fraction of benzene) of the last trace of liquid?

(a) 0.5 (b) 0.857
(c) 0.714 (d) 0.286

18. At what pressure, half of the total moles of liquid solution will vaporize?

(a) 57.14 mm Hg (b) 63.25 mm Hg
(c) 70 mm Hg (d) 66.67 mm Hg

Comprehension V

The two liquids 'A' and 'B' have the same molecular mass and form ideal solution. The solution has the vapour pressure 700 mm at 80°C. The above solution is distilled without reflux. Three-fourth of the solution is collected as condensate. The mole fraction of 'A' in the condensate is 0.75 and that in the residue is 0.3. The vapour pressure of the residue at 80°C is 600 mm.

19. The mass ratio of 'B' and 'A' in the initial solution at equilibrium at 80°C was

(a) 1 : 1 (b) 29 : 51
(c) 51 : 80 (d) 29 : 80

20. The vapour pressure of pure liquid 'A' at 80°C is

(a) 807.4 mm (b) 511.1 mm
(c) 755.6 mm (d) 533.3 mm

21. The vapour pressure of pure liquid 'B' at 80°C is

(a) 807.4 mm (b) 511.1 mm
(c) 755.6 mm (d) 533.3 mm

Comprehension VI

Liquids A (molar mass = 100 g/mol and density = 1.25 g/ml) and B (molar mass = 50 g/mol and density = 1.0 g/ml) form an ideal solution. The molal volume of liquid 'A' increases by a factor of 3800 as it vaporizes at 27°C and that of liquid 'B' increases by a factor of 7600 at 27°C. A solution of liquids 'A' and 'B' at 27°C has a vapour pressure of 54.0 torr. (R = 0.08 L-atm/K-mol).

22. The vapour pressure of pure liquid 'A' at 27°C is

(a) 60 torr
(b) 48 torr
(c) 49.26 torr
(d) 61.58 torr

23. The vapour pressure of pure liquid 'B' at 27°C is

(a) 60 torr
(b) 48 torr
(c) 49.26 torr
(d) 61.58 torr

24. The mole fraction of 'A' in the vapour above the solution in equilibrium at 27°C is

(a) 0.5
(b) 0.44
(c) 0.56
(d) 0.75

Comprehension VII

Two solutions of non-volatile solutes 'A' and 'B' are prepared. The molar mass ratio is $M_A : M_B = 1 : 3$. Both are prepared a 5% solution by mass in water.

25. The ratio of the freezing point depressions ΔT_f (A):ΔT_f (B) of the solution is

(a) 1:3
(b) 3:1
(c) 1:1
(d) 5:3

26. If the above solutions are mixed to prepare two solutions S_1 and S_2, in the ratio 2 : 3 and 3 : 2, by volume, respectively, then what would be the ratio $\Delta T_f (S_1) : \Delta T_f (S_2)$?

(a) 1 : 1
(b) 4 : 9
(c) 9 : 11
(d) 2 : 3

Comprehension VIII

Properties such as boiling point, freezing point and vapour pressure of a pure solvent change when solute molecules are added to get homogeneous solution. These are called colligative properties. Applications of colligative properties are very useful in day-to-day life. One of its examples is the use of ethylene glycol and water mixture as anti-freezing liquid in the radiator of automobiles.

A solution M is prepared by mixing ethanol and water. The mole fraction of ethanol in the mixture is 0.9.

Freezing point depression constant of water (K_f^{water}) = 1.86 K kg mol^{-1}
Freezing point depression constant of ethanol ($K_f^{ethanol}$) = 2.0 K kg mol^{-1}
Boiling point elevation constant of water (K_b^{water}) = 0.52 K kg mol^{-1}
Boiling point elevation constant of ethanol ($K_b^{ethanol}$) = 1.2 K kg mol^{-1}
Standard freezing point of water = 273 K
Standard freezing point of ethanol = 155.7 K
Standard boiling point of water = 373 K
Standard boiling point of ethanol = 351.5 K
Vapour pressure of pure water = 32.8 mm Hg
Vapour pressure of pure ethanol = 40 mm Hg
Molecular weight of water = 18 g mol^{-1}
Molecular weight of ethanol = 46 g mol^{-1}

In answering the following questions, consider the solutions to be ideal dilute solutions and solutes to be non-volatile and non-dissociative.

27. The freezing point of the solution **M** is

(a) 268.7 K (b) 268.5 K

(c) 234.2 K (d) 150.9 K

28. The vapour pressure of the solution **M** is

(a) 39.3 mm Hg (b) 36.0 mm Hg

(c) 29.5 mm Hg (d) 28.8 mm Hg

29. Water is added to the solution **M** such that the mole fraction of water in the solution becomes 0.9. The boiling point of this solution is

(a) 380.4 K (b) 376.2 K

(c) 375.5 K (d) 354.7 K

Comprehension IX

The lowering of vapour pressure on adding a non-volatile solute in a pure liquid solvent may be measured by Ostwald–Walker method. In this method, dry air is first passed through a series of vessels having the solution, then through a series of vessels having pure solvent and finally through a vessel (normally U-tube) having the absorbent of the solvent. The masses of solution and pure solvent decreases due to removal of vapours of solvent in the flow of air and the mass of absorbent increases due to absorption of the vapour of solvent in order to make the air dry. By measuring the changes in mass, we may determine the lowering of vapour pressure and hence, the composition of solution using Raoult's law.

30. If the mass of absorbent is increased by 0.24 g and the mass of pure solvent (water) is decreased by 0.02 g, then the mass percent of solute (glucose) in its aqueous solution is

(a) $\frac{1000}{21}\%$ (b) $\frac{100}{12}\%$

(c) $\frac{1000}{22}\%$ (d) $\frac{100}{11}\%$

31. If the experiment is performed with aqueous $AlCl_3$ solution ($a = 0.8$) prepared by dissolving 1 mole of $AlCl_3$ in 17 mole of water and the decrease in the mass of solution in the experiment is found to be 0.18 g, then the increase in the mass of absorbent should be

(a) 0.216 g (b) 0.225 g

(c) 0.191 g (d) 1.08 g

32. If the arrangement of vessels is changed in the experiment as

$$\text{Dry air} \xrightarrow{\text{Pure Solvent}} \xrightarrow{\text{Solution}} \xrightarrow{\text{Absorbent}} \text{Dry air}$$

then, which of the following must be incorrect?

(a) The mass of pure solvent will decrease.

(b) The mass of solution will decrease.

(c) The mass of absorbent will increase.

(d) The experiment will obey the law of conservation of mass.

Section D (Assertion – Reason)

The following questions consist of two statements. Mark the answer as follows.

(a) If both statements are CORRECT, and **Statement II** is the CORRECT explanation of **Statement I**.

(b) If both statements are CORRECT, and **Statement II** is NOT the CORRECT explanation of **Statement I**.

(c) If **Statement I** is CORRECT, but **Statement II** is INCORRECT.

(d) If **Statement I** is INCORRECT, but **Statement II** is CORRECT.

1. **Statement I:** The solubility of the gas in a liquid increases with increase in pressure.

Statement II: The solubility of a gas in a liquid, expressed by mole fraction of gas in the liquid solution at equilibrium is directly proportional to the pressure of the gas.

2. **Statement I:** At the same temperature, water has higher vapour pressure than acetic acid.

Statement II: Hydrogen bonding in water is weaker than in acetic acid.

3. **Statement I:** 0.1 m aqueous solution of glucose has higher depression in freezing point than 0.1 m aqueous solution of urea.

Statement II: k_f has same value in both.

4. **Statement I:** The boiling point of 0.1 m of urea solution is less than that of 0.1 m of KCl solution.

   Statement II: Elevation of boiling point is directly proportional to the number of species present in the solution.

5. **Statement I:** Addition of ethylene glycol (non-volatile) to water lowers the freezing point of water.

   Statement II: Addition of any substance to water lowers the freezing point of water.

6. **Statement I:** Addition of a non-volatile solute to a volatile solvent increases the boiling point.

   Statement II: Addition of non-volatile solute to a volatile solvent results decrease in the vapour pressure.

7. **Statement I:** Addition of a non-volatile solute to a volatile solvent decreases the freezing point.

   Statement II: Addition of non-volatile solute to a volatile liquid solvent in equilibrium with the solid solvent results in the fusion of some solid solvent. In order to re-achieve the equilibrium, the temperature of the system must be decreased.

8. **Statement I:** When an ideal binary solution of liquids A and B is distilled, the boiling point of the distillate becomes lower than that of the parental liquid solution.

   Statement II: When an ideal binary solution of liquids A and B is distilled, the distillate contains relatively larger amount of the more volatile liquid.

9. **Statement I:** Except osmotic pressure, all other colligative properties depend on the nature of solvent.

   Statement II: Colligative properties are intensive properties.

10. **Statement I:** The vapours above a liquid solution of two volatile liquids is always more rich in more volatile component.

    Statement II: More volatile component has lower boiling point.

Section E (Column Match)

1. Match the solution in Column I with its nature in Column II.

Column I	Column II
(A) Benzene + Toluene	(P) Non-ideal solution
(B) Ethanol + Water	(Q) Ideal solution
(C) Benzene + Ethanol	(R) $\Delta H_{mix} > 0$
(D) Acetone + Chloroform	(S) $\Delta H_{mix} < 0$

2. Match the solution in Column I with its nature in Column II.

Column I	Column II
(A) *n*-hexane + *n*-heptane	(P) Can be perfectly separated by distillation.
(B) Acetone + Chloroform	(Q) Maximum boiling azeotrope.
(C) Acetone + Aniline	(R) Cannot be perfectly separated by distillation.
(D) Ethanol + Water	(S) Minimum boiling azeotrope.

3. Match the solutions in Column I with their osmotic properties in Column II.

Column I	Column II
(A) S_1 : 0.1 M-glucose; S_2 : 0.1 M-urea	(P) S_1 and S_2 are isotonic.
(B) S_1 : 0.1 M-NaCl; S_2 : 0.1 M-Na_2SO_4	(Q) S_1 is hypertonic to S_2.
(C) S_1 : 0.1 M-NaCl; S_2 : 0.1 M-KCl	(R) S_1 is hypotonic to S_2.
(D) S_1 : 0.1 M-$CuSO_4$ S_2 : 0.1 M-sucrose	

4. Match the following if the molecular masses of X, Y and Z are same.

Column I (Solvent and its boiling point)	Column II (Molal elevation constant, K_b)
(A) X (100°C)	(P) 0.68
(B) Y (27°C)	(Q) 0.53
(C) Z (253°C)	(R) 0.98
(D) W (182°C)	(S) 0.79

5. Match the columns.

Column I (Solute in water)	Column II (Degree of dissociation to make van't Hoff factor equal to 2)
(A) KCl	(P) 0.33
(B) Na_2SO_4	(Q) 1.00
(C) $K_4[Fe(CN)_6]$	(R) 0.50
(D) $K_3[Fe(CN)_6]$	(S) 0.25

6. Match the columns.

Column I (Solute in water)	Column II (van't Hoff factor considering complete dissociation)
(A) Glucose	(P) 2.0
(B) NaCl	(Q) 1.0
(C) $MgCl_2$	(R) 3.0
(D) $AlCl_3$	(S) 4.0

7. Match the columns.

Column I (Colligative properties)	Column II (Aqueous solution; molality = molarity)
(A) $\Delta T_f = 0.3K_f$	(P) 0.1 M-$Ca(NO_3)_2$
(B) $\Delta T_b = 0.28K_b$	(Q) 0.14 M-NaBr
(C) $\pi = 0.19RT$	(R) 0.1 M-$MgCl_2$ ($\alpha = 0.9$)
(D) $\dfrac{P^\circ - P}{P^\circ} = \dfrac{\left(\dfrac{\Delta T_f}{K_f}\right)}{\dfrac{1000}{18} + \left(\dfrac{\Delta T_f}{K_f}\right)}$	(S) 0.28 M-urea
	(T) 0.1 M-HA (monobasic acid, $K_a = 0.81$)

Section F (Subjective)

Single Digit Integer Type

1. A quantity of 4 ml of a gas at 1 atm and 300 K is dissolved in 1 L of water. The volume (in ml) of gas that will dissolve in 0.5 L of water at 4 atm and 300 K is

2. A '100 proof' solution of ethanol in water consists of 50.00 ml of $C_2H_5OH(l)$ and 50.00 ml of $H_2O(l)$ mixed at 15.56°C. The density of the solution is 0.9344 g/ml, that of pure H_2O is 1.0000 g/ml and that of pure C_2H_5OH is 0.7939 g/ml. Is the solution ideal? Answer '1', if the solution is ideal and answer '2', if the solution is non-ideal.

3. A mixture of ideal gases is cooled up to liquid helium temperature (4.22 K) to form an ideal solution. Is this statement true or false? Answer '1' for true and '2' for false.

4. The vapour pressure of water over an aqueous solution of NH_3 at 70°C is 186.8 torr. Given that the mole fraction of NH_3 in the solution at equilibrium is 0.20 and the vapour pressure of pure $H_2O(l)$ at 70°C is 233.5 torr, determine whether the solution is ideal or not. Answer '1', if the solution is ideal and answer '2', if the solution is non-ideal.

5. Solutions A and B have osmotic pressures of 2.4 atm and 4.2 atm, respectively, at a certain temperature. The osmotic pressure (in atm) of a solution prepared by mixing the solutions in 2 : 1 volume ratio, respectively, at the same temperature is

6. At 27°C, a solution containing 0.2 g of polyisobutylene in 100 ml of benzene developed a rise of 2.463 mm in osmotic equilibrium. The molar mass of polyisobutylene (in 10^5 g/mol) is (Given: The density of final solution is 1.013 g/ml, $g = 10\ m/s^2$, $R = 0.0821$ L-atm/K-mol)

7. Consider the following arrangement, in which a solution containing 20 g of haemoglobin in 1 dm^3 of the solution is placed in right compartment and pure water is placed in left compartment, separated by SPM. At equilibrium, the height of liquid in the right compartment is 74.5 mm in excess of that in the left compartment. The temperature of the system is maintained at 298 K. The number of millimoles in 320 g of haemoglobin is (Given: The density of final solution is 1.013 g/ml, g = 10 m/s^2, $R = 0.08$ L-atm/K-mol)

8. At 10°C, the osmotic pressure of urea solution is 500 mm. The solution is diluted and the temperature is raised to 25°C, when the osmotic pressure is found to be 105.3 mm. The extent of dilution (ratio of final to initial volume of solution) is

9. A quantity of 1.04 g of ($CoCl_3 \cdot 6NH_3$) (molecular weight = 267) was dissolved in 100 g of H_2O. The freezing point of the solution was −0.29°C. How many moles of solute particle exist in solution for each mole of solute introduced? The value of K_f for water = 1.86° C m^{-1}.

10. The freezing point of an aqueous solution of KCN containing 0.2 mole/kg water was –0.80°C. On adding 0.1 mole of $Hg(CN)_2$ in the solution containing 1 kg of water, the freezing point of the solution was –0.6°C. Assuming that the complex is formed according to the following equation

$$Hg(CN)_2 + m\,CN^- \rightarrow Hg\,(CN)_{m+2}^{m-}$$

and Hg $(CN)_2$ is the limiting reactant, the value of m is

Four Digit Integer Type

1. Vapour pressure of solution containing 6 g of a non-volatile solute in 180 g water is 20 torr. If 1 mole of water is further added, then vapour pressure increases by 0.02 torr. The molar mass (in g/mol) of the non-volatile solute is

2. A solution containing compound 'X' in water and a solution containing glucose in water were put in a closed system. By doing this, some water vapour was removed from one solution and got condensed in the other. It is found that when both the solutions were at equilibrium vapour pressure, one solution contains 10% (w/w) of 'X' and the other 5% (w/w) glucose. The molar mass (in g/mol) of 'X' is

3. At 293 K, the vapour pressure of water is 2400 Pa and the vapour pressure of an aqueous urea solution is 2300 Pa. The osmotic pressure (in atm) of solution at 300 K, if the density of solution at this temperature is 1185 kg/m^3, is ($R = 0.08$ L-atm/K-mol)

4. How many grams of ethylene glycol should be mixed in 795 g water to form an antifreeze solution that will not start to freeze until the temperature reaches –30°C? (K_f for water = 1.86)

5. The mass of ice that will separate out on cooling a solution containing 50 g of ethylene glycol in 375 g water to −6.0°C is (K_f for water = 1.86 K mol^{-1} kg)

6. A solution of 38.4 g of naphthalene in 185 g camphor depresses the freezing point of the latter by 13.5 K while 11.6 g of another substance when dissolved in 185 g of camphor gives depression of 9.0 K in freezing point. The molecular mass of the second substance is

7. Equal masses of two aqueous solutions, one of 3.6 g glucose per 100 g of water and the other of 3.6 g urea per 100 g of water are mixed. If the freezing point of resulting solution is $-x$°C, then the value of '1000x' is (K_f of water = 1.86)

8. Safrole is contained in oil of sassafras and was once used to flavour root beer. A 2.4 mg sample of safrole was dissolved in 100.0 mg of diphenyl ether. The solution had a freezing of 25.64°C. The freezing point of pure diphenyl ether is 26.84°C and the freezing-point-depression constant K_f, is 8.00°C/m. The molecular mass of safrole is

9. A quantity of 2.0 g of benzoic acid dissolved in 26.0 g of benzene shows a depression in freezing point equal to 1.60 K. Molal depression constant of benzene is 4.88 K-kg mol^{-1}. The percentage association of the acid is

10. The value of 'x' g of a non-electrolytic compound ($M = 200$) is dissolved in 1 L of 0.05 M NaCl aqueous solution. The osmotic pressure of this solution is found to be 4.92 atm at 27°C. Assume complete dissociation of NaCl and ideal behaviour for solution. The value of 'x' is ($R = 0.082$ L-atm $mol^{-1}K^{-1}$)

11. At 20°C, the vapour pressure of 0.1 molal aqueous solution of urea is 0.03 mm less than that of water and the vapour pressure of 0.1 molal solution of KCl is 0.0594 mm less than that of water. The apparent percentage dissociation of KCl in water at the given temperature is (Neglect the moles of solute particles in comparison to the moles of water in both solutions.)

12. A current of dry air was passed through a series of bulbs containing 1.25 g of a solute A_2B (molar mass = 90 g/mol) in 49 g of water and then through pure water. The loss in weight of the former series of bulbs was 0.98 g and in the later series 0.01 g. The percentage dissociation of solute is

13. A quantity of 75.2 g of phenol is dissolved in 1 kg of solvent of $k_f = 14$. If the depression in freezing point is 7 K, then the percentage of phenol that dimerizes is

14. An aqueous solution contains 12% (w/w) $MgSO_4$ and 9.5% (w/w) $MgCl_2$. If the sulphate dissociates up to 80% and chloride dissociates up to 60%, the boiling point of solution (in Kelvin) is (K_b of water = 0.785 K-kg/mol)

15. When cells of the skeletal vacuole of a frog were placed in a series of NaCl solutions of different concentrations at 6°C, it was observed microscopically that they remained unchanged in *x*% NaCl solution, it shrank in more concentrated solutions and swells in more dilute solutions. Water freezes from the *x*% salt solution at –0.40°C. If the osmotic pressure of the cell cytoplasm at 6°C is ‘*y*’ × 0.0821 atm, then the value of ‘*y*’ is ($K_f = 1.86\ \text{K mol}^{-1}\ \text{kg}$)

Answer Keys Exercise I

Solution of Gas in Liquid

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

Vapour Pressure

6. (c) 7. (b) 8. (c) 9. (a) 10. (c)

Solution of Liquid in Liquid

11. (b) 12. (c) 13. (b) 14. (a) 15. (d) 16. (b) 17. (c) 18. (a) 19. (a) 20. (b)
21. (c) 22. (d) 23. (b) 24. (a) 25. (d)

Lowering of Vapour Pressure

26. (b) 27. (b) 28. (a) 29. (a) 30. (a) 31. (a) 32. (b) 33. (d) 34. (d) 35. (a)
36. (a) 37. (a) 38. (b) 39. (a) 40. (b)

Osmotic Pressure

41. (a) 42. (b) 43. (a) 44. (d) 45. (a) 46. (a) 47. (b) 48. (d) 49. (d) 50. (a)
51. (a) 52. (b) 53. (c) 54. (c) 55. (d)

Elevation in Boiling Point

56. (a) 57. (a) 58. (d) 59. (a) 60. (c) 61. (a) 62. (a) 63. (c) 64. (a) 65. (c)

Depression in Freezing Point

66. (b) 67. (d) 68. (b) 69. (b) 70. (a) 71. (d) 72. (a) 73. (d) 74. (b) 75. (c)

Abnormal Colligative Properties

76. (b) 77. (a) 78. (b) 79. (b) 80. (c) 81. (d) 82. (c) 83. (b) 84. (c) 85. (c)
86. (d) 87. (d) 88. (c) 89. (d) 90. (a) 91. (b) 92. (c) 93. (b) 94. (b) 95. (c)
96. (a) 97. (a) 98. (a)

Answer Keys Exercise II

Section A (Only one Correct)

1. (a) 2. (c) 3. (b) 4. (c) 5. (b) 6. (c) 7. (b) 8. (d) 9. (a) 10. (a)
11. (c) 12. (c) 13. (c) 14. (d) 15. (b) 16. (b) 17. (c) 18. (a) 19. (b) 20. (a)
21. (a) 22. (d) 23. (b) 24. (c) 25. (a) 26. (a) 27. (b) 28. (c) 29. (d) 30. (d)
31. (a) 32. (c) 33. (b) 34. (c) 35. (a) 36. (b) 37. (b) 38. (c) 39. (b) 40. (d)
41. (a) 42. (c) 43. (b) 44. (a) 45. (c) 46. (a) 47. (c) 48. (b) 49. (b) 50. (a)
51. (b) 52. (c) 53. (a) 54. (b) 55. (b) 56. (a) 57. (a) 58. (c) 59. (c) 60. (b)
61. (b) 62. (a) 63. (a) 64. (a) 65. (b) 66. (c) 67. (b) 68. (c) 69. (a) 70. (c)

Section B (One or More than one Correct)

1. (d) 2. (a) 3. (a), (c) 4. (b), (c), (d)
5. (a), (b), (c), (d) 6. (a), (c), (d) 7. (c) 8. (b), (c), (d)
9. (a), (b) 10. (b), (c) 11. (a) 12. (b), (c), (d)
13. (a), (b), (c), (d) 14. (b), (c), (d) 15. (c), (d)

Section C

Comprehension I

1. (b) 2. (a)

Comprehension II

3. (d) 4. (b) 5. (a) 6. (b)
7. (c) 8. (d) 9. (d) 10. (b)

Comprehension III

11. (a) 12. (d) 13. (b)

Comprehension IV

14. (b) 15. (c) 16. (a) 17. (d) 18. (b)

Comprehension V

19. (b) 20. (a) 21. (b)

Comprehension VI

22. (a) 23. (b) 24. (c)

Comprehension VII

25. (b) 26. (c)

Comprehension VIII

27. (d) 28. (b) 29. (b)

Comprehension IX

30. (a) 31. (a) 32. (b)

Section D (Assertion – Reason)

1. (a) 2. (a) 3. (d) 4. (a) 5. (c) 6. (a) 7. (a) 8. (a) 9. (d) 10. (d)

Section E (Column Match)

1. A → Q, B → P, R, C → P, R; D → P, S
2. A → P, B → Q, R, C → R, S; D → R, S
3. A → P, B → R, C → P; D → Q
4. A → P; B → Q; C → R; D → S
5. A → Q; B → R; C → S; D → P
6. A → Q; B → P; C → R; D → S
7. A → P; B → Q, R, S; C → T; D → P, Q, R, S, T

Section F (Subjective)

Single-digit Integer Type

1. (2) 2. (2) 3. (2) 4. (1) 5. (3) 6. (2) 7. (5) 8. (5) 9. (4) 10. (2)

Four-digit Integer Type

1. (0054) 2. (0380) 3. (0060) 4. (0795) 5. (0125)
6. (0058) 7. (0744) 8. (0160) 9. (0096) 10. (0020)
11. (0098) 12. (0050) 13. (0075) 14. (0377) 15. (0060)

HINTS AND EXPLANATIONS

EXERCISE I (JEE MAIN)

Solution of Gas in Liquid

1. Low pressure unfavours the solubility of gas in liquid.

2. Solubility increases on increasing pressure.

3. O_2 is less soluble in water than H_2.

4. $$\mathrm{P} = \mathrm{K}_H \cdot \mathrm{X} \Rightarrow 3.2\times10^5 = 1.6\times10^8 \times \frac{n_{CO_2}}{n_{CO_2} + \frac{500}{18}}$$

$$\therefore\ n_{CO_2} \approx 5.5\times10^{-2} \Rightarrow n_{CO_2} \approx 2.44 \text{ gm}$$

5. $$\mathrm{P} = \mathrm{K}_H \cdot \mathrm{X} \Rightarrow 1 \text{ bar} = \mathrm{K}_H \times \frac{0.2}{0.2 + \frac{1000}{18}}$$

$$\therefore\ \mathrm{K}_H = 277.78 \text{ bar} \simeq 2.78\times10^7 \text{ Pa}$$

Vapour Pressure

6. Vapour pressure is a function of temperature only.

7. Low boiling point means weak intermolecular forces and hence, higher vapour pressure.

8. Viscosity should be high.

9. Theory based

10. Vapour pressure is a function of temperature only.

Solution of Liquid in Liquid

11. $$P_{\text{total}} = X_A \cdot P^{\circ}_A + X_B \cdot P^{\circ}_B = (1 - X_B)\cdot P^{\circ}_A + X_B \cdot P^{\circ}_B$$

$$= P^{\circ}_A + X_B(P^{\circ}_B - P^{\circ}_A)$$

Graph is a straight line with slope $(P^{\circ}_B - P^{\circ}_A) = +\text{ve}$

12. $$\frac{1}{P_{\text{total}}} = \frac{Y_A}{P^{\circ}_A} + \frac{Y_B}{P^{\circ}_B} = \frac{Y_A}{P^{\circ}_A} + \frac{1-Y_A}{P^{\circ}_A}$$

$$= \frac{1}{P^{\circ}_A} + Y_A\left(\frac{1}{P^{\circ}_A} - \frac{1}{P^{\circ}_B}\right)$$

Hence, the graph of $\frac{1}{P_{\text{total}}}$ vs Y_A is straight line.

13. When $X = 0 \Rightarrow P = P^{\circ}_{\text{EtOH}} = 140$ mm Hg

14. $$P_{\text{total}} = X_{\text{Benzene}} \cdot P^{\circ}_{\text{Benzene}} + X_{\text{toluene}} \cdot P^{\circ}_{\text{toluene}}$$

or, $760 = x \times 960 + (1 - x) \times 380 \Rightarrow x = 0.655$

15. $$n_{\text{neptane}}, C_7H_{16} = \frac{30}{100} = 0.3 = n_1$$

$$n_{\text{octane}}, C_8H_{18} = \frac{34.2}{114} = 0.3 = n_2$$

Now, $P = X_1 \cdot P_1{}^{\circ} + X_2 \cdot P_2{}^{\circ} = \frac{0.3}{0.6}\times106 + \frac{0.3}{0.6}\times46$

$= 76$ KPa $= 0.76$ bar

16. $$\frac{1}{p} = \frac{Y_{\text{Benzene}}}{P^{\circ}_{\text{Benzene}}} + \frac{Y_{\text{Toluene}}}{P^{\circ}_{\text{Toluene}}} = \frac{0.75}{75} + \frac{0.25}{25}$$

$\therefore\ P = 50$ mm

17. Solution of methanol and ethanol is almost ideal.

18. Solution of ether and HCl shows negative deviation.

19. $P_{\text{ideal}} = 0.4\times80 + 0.6\times120 = 104 \text{ mm} > 100 \text{ mm}$

$\Rightarrow$ Negative deviation

20. > 50 ml, as the solution will show positive deviation.

21. $$\frac{n_{\text{aniline}}}{n_{water}} = \frac{P^{\circ}_{\text{aniline}}}{p^{\circ}_{\text{water}}} \Rightarrow \frac{m_a/93}{m_w/18} = \frac{760-700}{700}$$

$$\Rightarrow \frac{m_a}{m_w} = 0.44$$

$\therefore$ Mass percent of aniline in distillate

$$= \frac{m_a}{m_a + m_w}\times100 = 30.7\%$$

22. Azeotropic mixture cannot be separated by any kind of distillation.

23. Theory based.

24. A solution of benzene and aniline is almost ideal.

25. The composition of distillate and solution remains same in azeotrope.

Lowering of Vapour Pressure

26. $\dfrac{P^\circ - P}{X_1} = P^\circ$

27. Nature of solute does not affect any colligative property.

28. $\dfrac{P^\circ - P}{P} = \dfrac{n_1}{n_2} \Rightarrow \dfrac{1}{99} = \dfrac{4/\mathrm{M}}{54/18} \Rightarrow \mathrm{M} = 132$

29. $P = X_2 \cdot P^\circ = \dfrac{\dfrac{1000}{18}}{0.5 + \dfrac{1000}{18}} \times 25 = 24.78 \text{ mm Kg}$

30. $n_{\text{Solution}} = n_{\text{Solvent}}$

31. Theory based

32. Rate of evaporation decreases as the available surface area for solvent molecules decreases.

33. $\dfrac{P^\circ - P}{P} = \dfrac{n_1}{n_2} \Rightarrow \dfrac{20}{80} = \dfrac{w/40}{114/114} \Rightarrow w = 10 \text{ gm}$

34. $\dfrac{P^\circ - P}{P} = \dfrac{n_1}{n_2} \Rightarrow \dfrac{5}{95} = \dfrac{n_1}{n_2}$

$\therefore$ Molality of solution $= \dfrac{n_1}{n_2 \times 18} \times 1000 = 2.92$

35. $\dfrac{P^\circ - P}{P} = \dfrac{n_1}{n_2} \Rightarrow \dfrac{1}{99} = \dfrac{w/180}{500/18} \Rightarrow w = 50.5 \text{ gm}$

36. $\dfrac{P^\circ - P}{P} = \dfrac{n_{\text{Solute}}}{n_{\text{Solvent}}} = \dfrac{n}{N}$

37. Loss in mass of solution $\alpha\, P$

and loss in mass of water $\alpha\, (P^\circ - P)$.

$\therefore \dfrac{\text{Loss in mass of water}}{\text{Loss in mass of solution}} = \dfrac{P^\circ - P}{P} = \dfrac{n_1}{n_2}$

or $\dfrac{0.04}{2.5} = \dfrac{5/\mathrm{M}}{80/18} \Rightarrow \mathrm{M} = 70.3$

38. $Y_{\text{methanol}} = \dfrac{P_{\text{methanol}}}{P_{\text{total}}} = \dfrac{2.8}{2.8 + 4.2} = 0.4$

39. Theory based

Osmotic Pressure

40. $\dfrac{Y_A}{Y_B} = \dfrac{X_A}{X_B} \cdot \dfrac{P_A{}^\circ}{P_B{}^\circ} \Rightarrow \dfrac{0.5}{0.5} = \dfrac{0.25}{0.75} \times \dfrac{\overset{\circ}{P_A}}{\overset{\circ}{P_B}} \Rightarrow \dfrac{\overset{\circ}{P_A}}{\overset{\circ}{P_B}} = \dfrac{3}{1}$

41. Information

42. Solvent will move from higher vapour pressure to lower vapour pressure.

43. Water will come out as the concentration of salt solution will be very high.

44. Informative

45. Informative

46. $\pi = \mathrm{CRT} \Rightarrow 0.006 = \dfrac{4}{\mathrm{M}} \times 0.0821 \times 300$

$\Rightarrow \mathrm{M} = 16420$

47. Solution of higher concentration as osmosis occurs from lower to higher concentration.

48. Theory based

49. $\mathrm{C}_1 = \mathrm{C}_2 \Rightarrow \dfrac{5}{\mathrm{M}} = \dfrac{0.855}{342} \Rightarrow \mathrm{M} = 2000$

50. $\pi = \mathrm{CRT} = 0.1 \times 0.0821 \times 303 = 2.487 \text{ atm}$

51. Informative

52. Osmosis is not a very fast process.

53. $\pi\ \alpha\ C = \dfrac{n_{\text{Solute}}}{V_{\text{Solution}}}$

54. $\pi_1 = \dfrac{10}{180} \cdot RT; \pi_2 = \dfrac{10}{60} \cdot RT; \pi_1 = \dfrac{10}{342} \cdot RT$

55. $4.56 = \dfrac{54}{180} \cdot RT$ and $1.52 = C.RT \Rightarrow C = 0.1\,\mathrm{M}$

56. Saline water, as it increases boiling points.

Elevation in Boiling Point

57. Theory based

58. $m = 1 \Rightarrow \Delta T_b = K_b$

59. $\Delta T_b = K_b \cdot m \Rightarrow 0.13 = 0.52 \times \dfrac{2.6/\mathrm{M}}{200/1000} \Rightarrow \mathrm{M} = 52$

60. Boiling point decreases on decreasing the external pressure.

61. $K_\mathrm{b} = \dfrac{RT^2 \cdot \mathrm{M}}{1000 \cdot \Delta\mathrm{H}_\mathrm{vap}} = \dfrac{2 \times (400)^2 \times 80}{1000 \times 8 \times 10^3}$

$= 3.2\ \mathrm{K.Kg/mol}$

62. $m_\mathrm{Sugar} = \dfrac{34.2/342}{65.8/1000} m;\ m_\mathrm{glucose} = \dfrac{18/180}{82/1000} m$

and $m_\mathrm{urea} = \dfrac{6/60}{94/1000} m$

63. $\Delta T_b = K_b \cdot m = 0.513 \times \dfrac{0.1}{200/1000} = 0.2565°\mathrm{C}$

$\therefore$ B.P. of solution = 100.2565°C

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

$\Rightarrow 0.1 = \mathrm{K_b} \times \dfrac{1.8/180}{100/1000} \Rightarrow \mathrm{K_b} = 1.0\ \mathrm{K/m}$

65. $\Delta T_b = K_b \cdot m \Rightarrow 0.26 = 0.52 \times \dfrac{w_1/150}{w_2/1000} \Rightarrow \dfrac{w_1}{w_2} = \dfrac{3}{40}$

$\therefore$ Mass percent of solute $= \dfrac{w_1}{w_1 + w_2} \times 100\% = 6.98\%$

Depression in Freezing Point

66. Only solvent freezes.

67. $\Delta T_f = K_f \cdot m$

$$1.86 = K_f \cdot \frac{1}{1} \qquad (1)$$

$$\Delta T_f = K_f \cdot \frac{1}{0.5} \qquad (2)$$

$\therefore$ Required $\Delta T_f = 3.72°\ \mathrm{C} \Rightarrow$ Freezing point = – 3.72°C

68. $\Delta T_f = K_f \cdot m \Rightarrow 1.29 = 1.86 \times \dfrac{10/\mathrm{M}}{100/1000}$

$\Rightarrow \mathrm{M} = 150$

69. For any solvent, $K_f > K_b$ and hence, $\Delta T_f > \Delta T_b$.

70. Theory based

71. Greater K_f, greater ΔT_f.

72. Osmotic pressure is easily measurable even at very concentration of solute.

73. $\Delta T_f = K_f \cdot m = 1.86 \times \dfrac{5/60}{1} = 0.155°\mathrm{C}$

$\therefore$ F.P. = – 0.155° C

74. $\Delta T_f = K_f \cdot m \Rightarrow 0.2 = 1.86 \times \dfrac{5/60}{m_\mathrm{Solvent}}$

$\Rightarrow \mathrm{M}_\mathrm{Solvent} = 0.775\ \mathrm{Kg}$

$\therefore$ Mass of water separate as ice = 1 – 0.775 = 0.225 Kg

75. Osmotic pressure is easily measurable.

Abnormal Colligative Properties

76. $\alpha = \dfrac{M_O - M}{(n-1) \cdot \mathrm{M}} = \dfrac{94 - 120}{\left(\dfrac{1}{2} - 1\right) \times 120} = 0.433$

$[\text{For } 2\mathrm{A} \rightleftharpoons \mathrm{A}_2, n = \tfrac{1}{2}]$

77. $\mathrm{K_3[Fe(CN)_6]} \rightleftharpoons 3\mathrm{K}^+ + \mathrm{Fe(CN)}_6^{3-} \Rightarrow i = 4$

78. Dissociation results in the decrease of molar mass.

79. $\mathrm{Na_2SO_4} \rightleftharpoons 2\mathrm{Na}^+ + \mathrm{SO}_4^{2-} \Rightarrow i = 3$

80. Effective molality of NaCl = 2 × molality of glucose

81. $\Delta T_f = K_f \cdot m \Rightarrow 2 = 1.86 \times \dfrac{(w/74.5) \times 2}{500/1000}$

$\Rightarrow w = 20.03\ \mathrm{gm}$

82. For $\mathrm{K_3PO_4}$, $i = 4$

83. For greater number of solute particles, ΔT_f is maximum and hence freezing point will be lowest.

84. Effective molarity of $Ca(NO_3)_2 = 0.07 \times 3 = 0.21$ M

85. Effective molality of urea = 0.1 m
Effective molality of NaCl = $0.1 \times 2 = 0.2$ m
Effective molality of $Na_2SO_4 = 0.1 \times 3 = 0.3$ m

86. As there is no movement of solute particles through SPM, the colour will not change in any side.

87. The effective molarity of solutions should be same.

88. $$\underset{0.004(1-\alpha)\text{M}}{Na_2SO_4} \rightleftharpoons \underset{0.004\times 2\alpha}{2Na^+} + \underset{0.004\times\alpha}{SO_4^{2-}}$$

Effective molarity $= 0.004(1-\alpha) + 0.008\alpha + 0.004\alpha$
$= 0.004 + 0.008\alpha$

For solution to be isotonic,
$0.004 + 0.008\alpha = 0.01 \Rightarrow \alpha = 0.75$

89. Greater the number of particles, lower will be vapour pressure.

90. Greater the number of particles, higher will be osmotic pressure.

91. $\Delta T_f = K_f \cdot m \Rightarrow 0.3348 = 1.86 \times 0.1(1+\alpha)$
$\Rightarrow \alpha = 0.8$

92. $\Delta T_{f(\text{theo})} = K_f \cdot m = 1.86 \times \dfrac{0.25}{500/1000} = 0.93\text{K}$

Now, $i = \dfrac{\Delta T_{f(\text{exp})}}{\Delta T_{f(\text{theo})}} = \dfrac{2.79}{0.93} = 3$

As, $i = 1 + \alpha(n-1) \Rightarrow 3 = 1 + 1(n-1) \Rightarrow n = 3$

93. Molarity of solution $= \dfrac{0.85/85}{100/1000} = 0.1\,\text{M}$

$\pi_{\text{theo}} = \text{CRT} = 0.1 \times 0.0821 \times 300 = 2.463$ atm
$i = 1 + \alpha(n-1) = 1 + 0.9(2-1) = 1.9$
$\therefore \pi_{\text{exp}} = i \cdot \pi_{\text{theo}} = 1.9 \times 2.463 = 4.68$ atm

94. $i = 1 + \alpha(n-1) \Rightarrow 2.74 = 1 + \alpha(3-1) \Rightarrow \alpha = 0.87$

95. $\Delta T_{b(\text{theo})} = K_b \cdot m = 0.52 \times \dfrac{13.44}{134.4} = 0.052$ K

$i = 1 + \alpha(n-1) = 1 + 1(3-1) = 3$
$\therefore \Delta T_{b(\text{exp})} = i \cdot \Delta T_{b(\text{theo})} = 3 \times 0.52 = 0.156$ K

96. $\Delta^{T}_{f(\text{theo})} = K_f \cdot m = 1.72 \times \dfrac{20/172}{50/1000} = 4\text{K}$

Now, $i = \dfrac{\Delta^T_f\,(\text{exp})}{\Delta^T_f\,(\text{theo})} = \dfrac{2}{4} = 0.5$

97. $i = 1 + \alpha(n-1) = 1 + \alpha(x + y - 1)$

$\therefore \alpha = \dfrac{i-1}{x+y-1}$

98. Lower freezing point means greater number of particles and hence, the extent of dissociation of α-alanine is greater.

EXERCISE II (JEE ADVANCED)

Section A (Only one Correct)

1. $P_{N_2} = K_H \cdot X_{N_2(\text{Solution})}$

or $5 \times 0.8 = (1.0 \times 10^5) \times \dfrac{n_{N_2}}{n_{N_2} + 10} \simeq 10^5 \times \dfrac{n_{N_2}}{10}$

$\therefore\ n_{N_2} = 4 \times 10^{-4}$

2. $p = K_H \cdot X \approx K_H \cdot \dfrac{n_{\text{gas}}}{n_{\text{liq}}} \Rightarrow m_{\text{gas}}\ \alpha\ P \cdot V_{\text{liq}}$

$\therefore \dfrac{m_2}{m_1} = \dfrac{P_2 \cdot V_2}{P_1 \cdot V_1} \Rightarrow \dfrac{m_2}{m} = \dfrac{5 \times 2}{1 \times 1} \Rightarrow m_2 = 10$ m

Now, $P = K_H \cdot \dfrac{n_{\text{gas}}}{n_{\text{liq}}} = \dfrac{K_H}{n_{\text{liq}}} \cdot \dfrac{P \cdot V}{RT}$

$\therefore$ Volume of gas dissolved, $V = \dfrac{RT}{K_H} \cdot n_{\text{liq}}$

(Volume of gas dissolved is independent of pressure of gas)

$\therefore \dfrac{V_2}{V_1} = \dfrac{V_2,\text{liquid}}{V_1,\text{liquid}} \Rightarrow \dfrac{V_2}{V\text{ ml}} = \dfrac{2}{1} \Rightarrow V_2 = 2\text{V ml}$

3. $$P_{Hg} = X_{Hg}\cdot P_{\text{total}} = \frac{\dfrac{0.8\times10^{-3}}{200}}{\dfrac{0.8\times10^{-3}}{200}+\dfrac{50.4}{28}}\times720$$

$$=1.6\times10^{-3}\text{ torr}$$

4. Final vapour pressure and hence, the composition of both solutions must be same. As solution in beaker (A) has higher concentration, its vapour pressure is low. Hence, water from (B) will transfer in (A) as vapour.

$$\therefore\ \frac{20}{200+x} = \frac{10}{100-x} \Rightarrow x = 33.33$$

5. $$Y_A = \frac{P_A}{P_{\text{total}}} = \frac{X_A\cdot P_A{}^\circ}{P_{\text{total}}}$$

$$\frac{1}{X_A} = \frac{1}{Y_A}\cdot P_A{}^\circ\cdot\left(\frac{Y_A}{P_A{}^\circ}+\frac{(1-Y_A)}{P_B{}^\circ}\right)$$

$$=\frac{1}{Y_A}\cdot\frac{P_A{}^\circ}{P_B{}^\circ}+\frac{P_B{}^\circ-P_A{}^\circ}{P_B{}^\circ}$$

6. $$\left(\frac{n_P}{n_Q}\right)_{2^{\text{nd}}\text{ condense}} = \left(\frac{n_P}{n_Q}\right)_{\text{initial}}\cdot\left(\frac{P_P{}^\circ}{P_Q{}^\circ}\right)^n$$

Where n = number of condensation steps.

Now, $$\left(\frac{n_P}{n_Q}\right)_{\text{final}} = \frac{1}{1}\times\left(\frac{300}{100}\right)^2 = \frac{9}{1}$$

$$\therefore X_P = \frac{9}{9+1} = 0.90$$

7. The mole fraction of A in distillate,

$$X'_A = Y_A = \frac{X_A\cdot P_A{}^\circ}{P_{\text{total}}} = \frac{\frac{1}{4}\times100}{\frac{1}{4}\times100+\frac{3}{4}\times80} = \frac{5}{17}$$

Now, V.P. of distillate, $P = X'_A\cdot P_A{}^\circ + X'_B\cdot P_B{}^\circ$

$$=\frac{5}{17}\times100+\frac{12}{17}\times80 = 85.88\text{ mm Kg}$$

8. Let the final composition:
liquid (10 mole): A = x mole, B = $(10-x)$ mole
Vapour (10 mole): A = $(10-x)$ mole, B = x mole

Now, $$\frac{Y_A}{Y_B} = \frac{X_A}{X_B}\cdot\frac{P_A{}^\circ}{P_B{}^\circ} \Rightarrow \frac{10-x}{x} = \frac{x}{10-x}\cdot\frac{200}{100}$$

$\therefore x = 4.14$

Now, $p = X_A\cdot P_A{}^\circ + X_B\cdot P_B{}^\circ$

$$=\frac{x}{10}\times200+\frac{10-x}{10}\times100$$

$= 141.4$ torr

9. $$\frac{1}{P_{\text{total}}} = \frac{Y_A}{P_A{}^\circ}+\frac{Y_B}{P_B{}^\circ} = \frac{0.4}{0.4}+\frac{0.6}{1.2} = \frac{3}{2}$$

$$\Rightarrow P_{\text{total}} = \frac{2}{3}\text{ atm}$$

10. If the solution were ideal,

$$P_{\text{total}} = \frac{10}{30}\times90+\frac{20}{30}\times87 = 88\ \text{ mm kg}$$

As the solution of phenol and aniline shows negative deviation, the V.P. must be less than 88 mm kg.

11. For ideal behavior,

$P_{\text{total}} = 0.25\times512 + 0.725\times344$
$= 386$ mm Hg $<$ 600 mm Hg

Hence, the solution shows positive deviation
$\Rightarrow \Delta H_{\text{mix}}$ = positive

12. For increase in temperature, the solution shows negative deviation (ΔH = negative).

13. $$\frac{n_{\text{Chlorobenzene}}}{n_{\text{water}}} = \frac{P^\circ_{\text{Chlorobenzene}}}{P^\circ_{\text{water}}}$$

or, $$\frac{x/112.5}{(100-x)/18} = \frac{9.031\times10^4-7.031\times10^4}{7.031\times10^4}$$

$\Rightarrow x = 64$

14. As the available surface area for solvent molecules decreases, the rate of vaporization decreases.

15. $$\frac{P^\circ-P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{5}{95} = \frac{m_1/\text{M}}{m_2/0.3\text{ M}} \Rightarrow \frac{m_2}{m_1} = \frac{57}{10}$$

16. $P^\circ - P = X_1\cdot P^\circ$
$10 = 0.2\times P^\circ$ (1)
$20 = X_1\times P^\circ$ (2)
From (1) and (2): $X_1 = 0.4 \Rightarrow X_2 = X_{\text{solvent}} = 0.6$

17. $$\frac{P^\circ-P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{3000-2985}{2985} = \frac{5/\text{M}}{100/18}$$

$\Rightarrow \text{M} = 179.1$

18. $$\frac{P^\circ-P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{0.85-0.845}{0.845} = \frac{0.5/\text{M}}{39/78} \Rightarrow \text{M} = 169$$

19. $$P = X_2 \cdot P^\circ = \frac{\frac{1000}{18}}{1+\frac{1000}{18}} \times 12.3 = 12.08 \text{ K Pa}$$

20. $P = X_2 \cdot P^\circ$

$$2.8 = \frac{\frac{90}{18}}{\frac{30}{\text{M}}+\frac{90}{18}} \times P^\circ \text{ and } 2.9 = \frac{\frac{108}{18}}{\frac{30}{\text{M}}+\frac{108}{18}} \cdot P^\circ$$

$\therefore M = 23$

21. $$P^\circ - P = X_1 \cdot P^\circ = \frac{1}{1+\frac{1000}{18}} \times 760 = 13.44 \text{ mm kg}$$

22. $$\frac{P^\circ - P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{89.78-89}{89} = \frac{2/\text{M}}{100/78} \Rightarrow \text{M} = 178$$

Now, the number of C-atoms in each molecule

$$= \frac{178 \times \frac{94.4}{100}}{12} = 14$$

and the number of H-atoms in each molecule

$$= \frac{178 \times \frac{5.6}{100}}{1} = 10$$

$\therefore$ Hydrocarbon is $C_{14}H_{10}$.

23. Loss is mass of solvent, $w_1 \,\alpha\, (P^\circ - P)$

and gain is mass of absorbent, $w_2 \,\alpha\, P^\circ$

$$\therefore \frac{w_1}{w_2} = \frac{P^\circ - P}{P^\circ} = X_1 \Rightarrow \frac{0.05}{2.05} = \frac{\frac{40}{\text{M}}}{\frac{40}{\text{M}}+\frac{100}{18}} \Rightarrow \text{M} = 288$$

24. $$\text{C}_1 = \text{C}_2 \Rightarrow \frac{10}{\text{M}_A} + \frac{20}{\text{M}_B} = \frac{6.67}{M_A} + \frac{30}{\text{M}_B} \Rightarrow \frac{\text{M}_A}{\text{M}_B} = \frac{1}{3}$$

25. As solution have same concentration, mixing will not change the total molar concentration.

26. Isopiestic refers to the same pressure. Blood is isotonic with 0.9% (*w*/*v*) NaCl solution.

$$\therefore \text{Osmolarity} = \frac{0.9/58.5}{100/1000} \times 2 \approx 0.31\,\text{M}$$

27. $$\pi = \text{CRT} = \left(\frac{2.5/58.5}{100/1000} \times 2\right) \times 0.0821 \times 300$$

$= 21.05$ atm

28. Theory based

29. $$\Delta T_b = K_b \cdot m \Rightarrow 0.104 = 0.52 \times \frac{2/\text{M}}{98/1000}$$

$\Rightarrow \text{M} = 104$

30. Theory based

31. Clausius–Clapeyron equation:

$$\frac{dT}{dP} = \frac{RT^2}{\Delta H.P} = \frac{2 \times (350)^2}{4.9 \times 10^3} = 50 \text{ K/atm}$$

32. $$\Delta T_b = K_b \cdot m = 0.52 \times \frac{72}{180} = 0.208 \text{ K}$$

$\therefore$ B.P. of solution = 373.208 K

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

$$\Rightarrow (354.11 - 353.23) = 2.53 \times \frac{1.8/\text{M}}{90} \times 1000$$

$\therefore \text{M} = 57.5$

34. If molality of solution is '*m*', then

$$\frac{P^\circ - P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{760-750}{750} = \frac{m}{1000/18} \Rightarrow m = \frac{20}{27}$$

Now, $\Delta T_b = K_b \cdot m = 0.52 \times \frac{20}{27} = 0.385 \text{ K}$

$\therefore$ B.P. of solution = 100.385° C

35. $$K_b = \frac{0.002\ \text{T}_\text{o}^2}{\Delta H_\text{vap}(\text{Cal/gm})} = \frac{0.002 \times (320)^2}{80}$$

$= 2.56$ K/m

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

$$\Rightarrow 0.32 = 2.56 \times \frac{6.4/32\,x}{200/1000} \Rightarrow x = 8$$

$\therefore$ Molecular formula of sulphur = $S_x = S_8$

36. $$\Delta T_b = K_{x,b} \cdot X_\text{solute} = 32 \times \frac{1/128}{\frac{1}{128}+\frac{94}{94}} \approx 0.25^\circ\text{C}$$

$\therefore$ B.P. of solution = 110.75 + 0.25 = 111° C

37. $\Delta T_b = K_b \cdot m \Rightarrow 1.04 = 0.52 \times m \Rightarrow m = 2$

Now, $$\frac{P^\circ - P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{P^\circ - 750}{750} = \frac{2}{1000/18}$$

$\Rightarrow P^\circ = 777$ torr

38. Theory based

39. $$\Delta T_f = K_f \cdot m \Rightarrow 0.93 = 1.86 \times \frac{7/\text{M}}{93/1000}$$

$\Rightarrow \text{M} = 150.5$

40. $\Delta T_f = K_f \cdot m \Rightarrow 0.93 = 1.86 \times \frac{36/\mathrm{M}}{1.2} \Rightarrow \mathrm{M} = 60$

If the molecular formula is $C_xH_{2x}O_x$, then

$12x + 2x + 16x = 60 \Rightarrow x = 2$

$\therefore$ Molecular formula = $C_2H_4O_2$

41. $\Delta T_f = K_f \cdot m \Rightarrow 15 = 1.86 \times m \Rightarrow m = 8.06$

42. $\frac{\Delta T_f}{\Delta T_b} = \frac{K_f}{K_b} \Rightarrow \frac{\Delta T_f}{0.78} = \frac{1.86}{0.52} \Rightarrow \Delta T_f = 2.79°\mathrm{C}$

$\therefore$ F.P. of solution = –2.79° C

43. $\Delta T_f + \Delta T_b = (K_f + K_b) \cdot m$

or $4.76 = (1.86 + 0.52) \times \frac{w/342}{100/1000} \Rightarrow w = 68.4$ gm

44. $\Delta T_f = K_f \cdot m \Rightarrow 5 = 8.5 \times \frac{w/120}{425/1000} \Rightarrow w = 30$ gm

45. $\frac{\Delta T_f}{\Delta T_b} = \frac{K_f}{K_b} \Rightarrow \frac{\Delta T_b}{0.7} = \frac{5}{17.5} \Rightarrow \Delta T_b = 0.2°\mathrm{C}$

$\therefore$ B.P. of solution = 90.2°C

46. If the molarity of solution is m, then

$$\frac{P° - P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{2}{100} = \frac{m}{1000/78} \Rightarrow m = \frac{10}{39}$$

Now, $\Delta T_f = K_f \cdot m \Rightarrow 1.3 = K_f \times \frac{10}{39}$

$\Rightarrow K_f = 5.07$ K/m

47. $\frac{K_f}{K_b} = \frac{T_f^{\circ 2}/\Delta H_{\text{fus}}}{T_b^{\circ 2}/\Delta H_{\text{vap}}} \Rightarrow \frac{\Delta H_{\text{fus}}}{\Delta H_{\text{vap}}} = \left(\frac{T_f°}{T_b°}\right)^2 \times \frac{K_b}{K_f}$

$= \left(\frac{280}{350}\right)^2 \times \frac{2.5}{5.6} = \frac{2}{7}$

48. $\Delta T_f = K_f \cdot m \Rightarrow 2.0 = K_f \times 0.25 \Rightarrow K_f = 8$ K/m

49. $\Delta T_f = K_f \cdot m$

For cane sugar solution:

$$(273.15 - 272.85) = K_f \cdot \frac{5/342}{95/1000} \qquad (1)$$

For glucose solution:

$$\left(273.15 - T_f\right) = K_f \cdot \frac{5/180}{95/1000} \qquad (2)$$

From (1) and (2), $T_f = 272.58$ K

50. $\Delta T_f = K_f \cdot m$

For AB_2 solution: $2.55 = 5.1 \times \frac{1/(x+2y)}{20/1000}$ (1)

For AB_4 solution: $1.7 = 5.1 \times \frac{1/(x+4y)}{20/1000}$ (2)

$\therefore$ Atomic mass of A = $x = 50$

Atomic mass of B = $y = 25$

51. $\Delta T_f = K_f \cdot m \Rightarrow 0.744 = 1.86 \times m \Rightarrow m = 0.4$

Now, $\pi = CRT = 0.4 \times 0.0821 \times 300 = 9.852$ atm

52. $\phi = \frac{\Delta T_f}{K_f \cdot m} = \frac{0.93}{1.86 \times 0.4} = 1.25$

53. $\Delta T_f = K_f \cdot m \Rightarrow 1.0 = 1.80 \times m \Rightarrow m = \frac{1}{1.8}$

$$P = X_2 \cdot P° = \frac{\frac{1000}{18}}{\frac{1}{1.8} + \frac{1000}{18}} \times 24.24 = 24 \text{ mm Hg}$$

54. $\Delta T_f = K_f \cdot m$

$\therefore 0.2 = K_f \times \frac{x}{100/1000}$ and $0.25 = K_f \times \frac{x}{y/1000}$

$\therefore$ Mass of ice separated out = 100 – y = 20 gm

55. $$\underset{(4\text{ particles})}{2\,\mathrm{KI(aq)}} + \underset{(\text{added})}{\mathrm{HgI_2}} \longrightarrow \underset{(3\text{ particles})}{\mathrm{K_2HgI_4(aq)}}$$

As the number of ions in solution decreases, osmotic pressure decreases.

56. Osmolarity of both solution should be equal

$\therefore 0.1 \times 2 = 0.1 \times (1 + 2\alpha) \Rightarrow \alpha = 0.5$

57. Osmolarity = 0.2 × 3 = 0.6 M

58. $\Delta T_f = K_f \cdot m \Rightarrow 3.72 = 1.86 \times 1.0 \times n \Rightarrow n = 2$

$\therefore$ From each particle, two ions should form.

59. $\Delta T_b = K_b \cdot m \Rightarrow 1.43 = K_b \times 1\left[1 + 0.9\left(\frac{1}{2} - 1\right)\right]$

$\therefore K_b = 2.6$ K/m

60. $\Delta T_f = K_f \cdot m\left[1 + \alpha\left(\frac{1}{n} - 1\right)\right]$

$$\therefore 1\ 96 = 4\ 9 \times \frac{2\ \ 122}{25/1000}\left[1 + \alpha\left(\frac{1}{2} - \ \ \right)\right] \Rightarrow \alpha = \ \ .$$

61. $$\underset{(0.1-x)\text{M}}{\text{HA}} \rightleftharpoons \underset{\substack{x\text{M}\\=0.01\text{M}}}{\text{H}^+} + \underset{x\text{M}}{\text{A}^-}$$

$\therefore$ Osmolarity = $(0.1 - x) + x + x = 0.11$ M

Now, $\pi = \text{CRT} = 0.11\ \text{RT}$

62. $\Delta T_f = K_f \cdot m = 1.86 \times [0.1 \times 2 + 0.025 \times 2]$

$= 0.465°\text{C}$

$\therefore$ F.P. of solution = – 0.465° C

63. The effective molality will be in the range of 0.2 to 0.3 and $\Delta T_f = K_b \cdot m$ will be in the range of $1.86 \times 0.2 = 0.372°$ C to $1.86 \times 0.3 = 0.558°$ C.

64. Let the mixture contain x mole KCl and y mole NaCl. Then

$x \times 74.5 + y \times 58.5 = 3.125$ (1)

and $(x+y) \times 2 = \dfrac{\Delta T_f}{K_f} = \dfrac{0.186}{1.86} = 0.1$ (2)

$\therefore\ \dfrac{x}{y} = \dfrac{1}{3}$

65.

	2A $\rightleftharpoons$	A_2
Initial conc.	nM	0
Equilibrium conc.	$(n-x)$M	$\frac{x}{2}$M

Now, $\Delta T_b = K_b \cdot m = K_b \cdot \left[n - x + \dfrac{x}{2}\right]$

$\therefore\ x = 2n - \dfrac{2\Delta T_b}{K_b}$

$$\text{Now, } K_c = \frac{[A_2]}{[A]^2} = \frac{\left(\frac{x}{2}\right)}{(n-x)^2} = \frac{n - \frac{\Delta T_b}{K_b}}{\left(\frac{2\Delta T_b}{K_b} - n\right)^2}$$

$$= \frac{K_b(n \cdot K_b - \Delta T_b)}{(2\Delta T_b - n \cdot K_b)^2}$$

66. $$\frac{\Delta T_f(A)}{\Delta T_f(B)} = \frac{K_f, A \cdot m_1}{K_f, B \cdot m_2} = \frac{1.86 \times m/2}{2.79 \times m/3} = \frac{1}{1}$$

67. Colloidal solutions have low value of any colligative property than the true solution of same composition.

68. If the complex dissociates into n ions, then

$\Delta T_f = K_f \cdot m \Rightarrow 0.0054 = 1.86 \times [0.001 \times n] \Rightarrow n \approx 3$

69. $$\text{XCl}_3(\text{s}) \rightleftharpoons \underset{\text{SM}}{\text{X}^{3+}} + \underset{3\text{SM}}{3\text{Cl}^-}$$

$$\frac{P° - P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{17.25 - 17.20}{17.20} = \frac{4\text{S}}{1000/18}$$

$\Rightarrow \text{S} = 4.04 \times 10^{-2}$ M

70. (a) $\Delta T_f = K_f \cdot m = 1.86 \times 1 = 1.86°\text{C}$

$\therefore$ F.P. of solution = – 1.86° C

(b) $\Delta T_b = K_b \cdot m = 0.52 \times 1 = 0.52°\text{C}$

$\therefore$ B.P. of solution should be 100.52° C. As the solute dissociates completely above 100.26° C, its actual $\Delta T_b = 0.52 \times 2 = 1.04°\text{C}$ and hence, B.P. = 101.04° C.

(c) $\Delta T_f = K_f \cdot m \Rightarrow 7.44 = 1.86 \times \dfrac{1/2}{m_{\text{solvent}}}$

(as solute dimerizes)

$\therefore\ m_{\text{Solvent}}$ left = 0.125 kg

$\therefore$ Percentage of water separated as ice = (1 – 0.125) × 100 = 87.5%

(d) $\Delta T_b = K_b \cdot m \Rightarrow 2.08 = 0.52 \times \dfrac{2}{m_{\text{solvent}}}$

(Complete dissociation)

$\therefore\ m_{\text{Solvent}}$ left = 0.5 kg

Percentage of water evaporated = (1 – 0.5) × 100 = 50%

Section B (One or More than one Correct)

1. At constant temperature, the vapour pressure may be changed by changing the composition.

2. Theory based

3. Theory based

4. $P_{AB} = \dfrac{75 + 22}{2} = 48.5$ torr

$P_{BC} = \dfrac{22 + 10}{2} = 16$ torr

$P_{AC} = \dfrac{75 + 10}{2} = 42.5$ torr

$P_{ABC} = \dfrac{75 + 22 + 10}{2} = 35.67$ torr

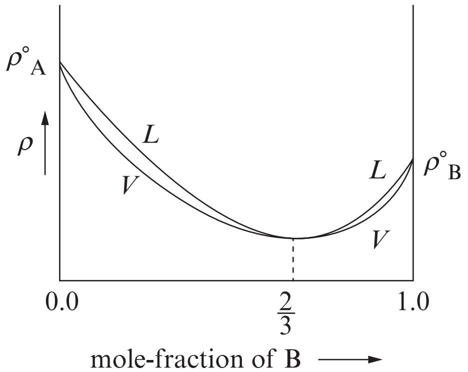
5. Theory based

6. A, C, D shows negative deviation.

7. (a) Mass percent of A = 50 $\Rightarrow n_A : n_B = 1 : 2$ $\Rightarrow$ Azeotrope

Hence, vapour will have the same composition of liquid.

(b) Mass percent of A > 50 $\Rightarrow n_A : n_B = 1 : 2$



In this case, the vapour must be more rich in A than liquid.

(c) $X_B = \frac{3}{4} = 0.75 > \frac{2}{3}$ $\Rightarrow$ Pure A cannot be obtained.

(d) $X_B = \frac{3}{5} = 0.60 < \frac{2}{3} \Rightarrow$ Pure A cannot be obtained in traces.

8. (a) On changing the solvent, K_f will change.

9. F. P. and V. P. will become lower for X.

10. Informative

11. Theory based

12. Theory based

13. (a) $\frac{P° - P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{760 - 740}{740} = \frac{1}{n_2} \Rightarrow n_2 = 37$

$\therefore$ Moles of water separated as ice $= 200 - 37 = 163$

(b) $\Delta T_f = K_f \cdot m = 2.0 \times \frac{1}{(37 \times 18)/1000}$

$= \frac{2000}{37 \times 18} \text{K}$

$\therefore T = \left(273 - \frac{2000}{37 \times 18}\right) K$

(c) For original solution:

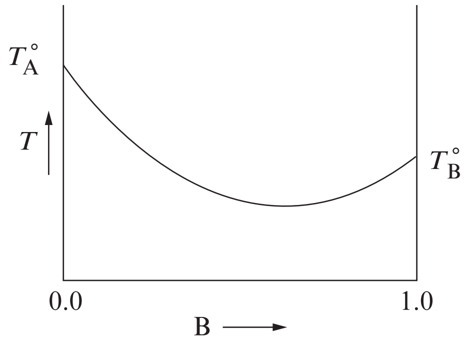
$\Delta T_f = K_f \cdot m = 2 \times \frac{1}{(200 \times 18)/1000}$

$\therefore$ F. P. $= 0 - \Delta T_f = -\frac{10°}{18} C$

(d) For final solution: $\frac{P° - P}{P°} = X_1 = \frac{1}{1 + 37} = \frac{1}{38}$

14. Theory based

15.



Section C (Comprehensions)

Comprehension I

1. $Y_A - X_A = \frac{X_A \cdot P_A°}{P_B° + X_A \cdot (P_A° - P_B°)} - X_A$

$= \frac{X_A(P_A° - P_B°) - X_A^2(P_B° - P_A°)}{P_B° + X_A \cdot (P_A° - P_B°)} = f(X_A)$

For maximum $(Y_A - X_A)$, $\frac{d(Y_A - X_A)}{dX_A} = 0$

$\therefore\ X_A = \frac{\sqrt{P_A° \cdot P_B°} - P_B°}{P_A° - P_B°}$

2. $P_{\text{total}} = P_B° + X_A \cdot (P_A° - P_B°) = \sqrt{P_A° \cdot P_B°}$

Comprehension II

3. $\dfrac{1}{P_{\text{total}}} = \dfrac{Y_A}{P_A{}^\circ} + \dfrac{Y_B}{P_B{}^\circ} = \dfrac{2/5}{0.4} + \dfrac{3/5}{0.6}$

$\Rightarrow P_{\text{total}} = 0.5 > 0.3$ bar

As the applied pressure is less than equilibrium pressure, the system must be 100% vapour.

4. First drop of liquid will form at 0.5 bar.

5. $P_1V_1 = P_2V_2 \Rightarrow 0.3 \times 10 = 0.5 \times V_2 \Rightarrow V_2 = 6.0\ \text{dm}^3$

6. $P_{\text{total}} = X_A \cdot P_A{}^\circ + X_B \cdot P_B{}^\circ$

$\Rightarrow 0.5 = X_A \times 0.4 + (1 - X_A) \times 0.6$

$\therefore\ X_A = 0.5$

7. Liquid composition: $A \approx 2$ mole, $B \approx 3$ mole

$\therefore\ P_{\text{total}} = \dfrac{2}{5} \times 0.4 + \dfrac{3}{5} \times 0.6 = 0.52$ bar

8. $Y_A = \dfrac{X_A \cdot P_A{}^\circ}{P_{\text{total}}} = \dfrac{\frac{2}{5} \times 0.4}{0.52} = \dfrac{4}{13}$

9. $P_{\text{total}} = X_A \cdot P_A{}^\circ + X_B \cdot P_B{}^\circ$

$\Rightarrow 0.51 = X_B \times 0.4 + (1 - X_A) \times 0.6$

$\therefore\ X_A = 0.45$

Now, $Y_A = \dfrac{X_A \cdot P_A{}^\circ}{P_{\text{total}}} = \dfrac{0.45 \times 0.4}{0.51} = \dfrac{6}{17}$

Let moles of A and B in liquid form is x and y, respectively.

$X_A = \dfrac{x}{x+y} = 0.45$ and $Y_A = \dfrac{2-x}{(2-x)+(3-y)} = \dfrac{6}{17}$

$\therefore\ n_A\,(\text{liquid}) = x = \dfrac{12}{11}$

and $n_{A(\text{vapour})} = 2 - x = \dfrac{10}{11}$

10. Final total moles of liquid $= 5 \times \dfrac{20}{100} = 1$ and total moles of vapour $= 5 - 1 = 4$. Let the liquid contain x mole A.

$$P_{\text{total}} = \frac{x}{1} \times 0.4 + \frac{1-x}{1} \times 0.6 = 0.6 - 0.2x \qquad (1)$$

$$\text{and } Y_A = \frac{X_A \cdot P_A{}^\circ}{P_{\text{total}}} \Rightarrow \frac{2-x}{4} = \frac{\frac{x}{1} \times 0.4}{0.6 - 0.2x} \qquad (2)$$

From (2): $x = 0.48$

$\therefore$ From (1): $P_{\text{total}} = 0.504$ bar

Comprehension III

11. $\Delta H_{\text{mix}} = 0$

12. $\Delta G_{\text{mix},\,m} = \text{RT}\,[X_1 \cdot \ln X_1 + X_2 \cdot \ln X_2]$

$= 2 \times 300 \left[\dfrac{1}{3} \cdot \ln \dfrac{1}{3} + \dfrac{2}{3} \cdot \ln \dfrac{2}{3}\right] = -380$ cal/mol

13. $\Delta S_{\text{mix},m} = -\dfrac{\Delta G_{\text{mix},m}}{T} = -\dfrac{-380}{300} = \dfrac{3.8}{3}$ cal / K-mol

and $\Delta S_{\text{mix}} = 3 \times \dfrac{3.8}{3} = 3.8$ cal / K

Comprehension IV

14. $P_{\text{total}} = X_B \cdot P_B{}^\circ + X_T \cdot P_T{}^\circ$

$= \dfrac{10}{20} \times 100 + \dfrac{10}{20} \times 40 = 70$ mm Hg

15. $Y_A = \dfrac{X_B \cdot P_B{}^\circ}{P_{\text{total}}} = \dfrac{0.5 \times 100}{70} = \dfrac{5}{7} = 0.714$

16. The vapour will contain almost 10 moles of both

$\dfrac{1}{P_{\text{total}}} = \dfrac{Y_B}{P_B{}^\circ} + \dfrac{Y_T}{P_T{}^\circ} = \dfrac{0.5}{100} + \dfrac{0.5}{40}$

$\Rightarrow P_{\text{total}} = 57.14$ mm kg

17. $X_B = \dfrac{Y_B \cdot P_{\text{total}}}{P_B{}^\circ} = \dfrac{0.5 \times 57.14}{100} = 0.286$

18. Final system contains 10 moles of liquid and 10 moles of vapour. Let the moles of benzene in liquid be x.

$P_{\text{total}} = X_B \cdot P_B{}^\circ + X_T \cdot P_T{}^\circ = \dfrac{x}{10} \times 100 + \dfrac{10-x}{10} \times 40$

$$\text{or, } P_{\text{total}} = 40 + 6x \qquad (1)$$

$Y_B = \dfrac{X_B \cdot P_B{}^\circ}{P_{\text{total}}} \Rightarrow \dfrac{10-x}{10} = \dfrac{\frac{x}{10} \times 100}{40 + 6x} \Rightarrow x = 3.87$

From Equation (1): $P_{\text{total}} = 63.25$ mm kg

Comprehension V

A + B

($n_A + n_B$) moles

Residual solution $= \frac{1}{4}(n_A + n_B)$ moles

A = x mole

B = y mole

Condensate $= \frac{3}{4}(n_A + n_B)$

A = ($n_A - x$) mole

B = ($n_B - y$) mole

From question:

$$700 = \frac{n_A}{n_A + n_B} \times P_A{}^\circ + \frac{n_B}{n_A + n_B} \times P_B{}^\circ \qquad (1)$$

$$600 = \frac{x}{x+y} \times P_A{}^\circ + \frac{y}{x+y} \times P_B{}^\circ \qquad (2)$$

$$x + y = \frac{1}{4}(n_A + n_B) \qquad (3)$$

$$\frac{x}{x+y} = 0.3 \qquad (4)$$

$$\frac{n_A - x}{\frac{3}{4}(n_A + n_B)} = 0.75 \qquad (5)$$

19. $n_B : n_A = 29.51$

20. $P_A{}^\circ = 807.4$ mm

21. $P_B{}^\circ = 511.1$ mm

Comprehension VI

22. $P_A{}^\circ = \frac{RT}{V_m} = \frac{0.08 \times 300}{\frac{100}{1.25} \times \frac{3800}{1000}} \times 760 = 60$ torr

23. $P_B{}^\circ = \frac{RT}{V_m} = \frac{0.08 \times 300}{\frac{50}{1.00} \times \frac{7600}{1000}} \times 760 = 48$ torr

24. $\frac{1}{P_{\text{total}}} = \frac{Y_A}{P_A{}^\circ} + \frac{Y_B}{P_B{}^\circ} \Rightarrow \frac{1}{54} = \frac{Y_A}{60} + \frac{1 - Y_A}{48} \Rightarrow Y_A = \frac{5}{9}$

Comprehension VII

25. $\Delta T_f = K_f \cdot m = K_f \cdot \frac{50}{\text{M}}$

$\therefore\ \Delta T_f(A) : \Delta T_f(B) = \text{M}_B : \text{M}_B = 3:1$

26. Average molar mass of solute in S_1

$$\text{M}(S_1) = \frac{2 \times \text{M}_A + 3 \times \text{M}_B}{2+3} = \frac{11}{5}\text{M}_A$$

and average molar mass of solute in S_2.

$$\text{M}(S_2) = \frac{3\text{M}_A + 2 \times M_B}{2+3} = \frac{9}{5}\text{M}_A$$

$\therefore\ \Delta T_f(S_1) : \Delta T_f(S_2) = M(S_2) : M(S_1) = 9:11$

Comprehension VIII

27. $\Delta T_f = K_f \cdot m = 2.0 \times \frac{0.1}{0.9 \times 46} \times 1000 = 4.8$ K

$\therefore$ Freezing point of solution = 155.7 – 4.8
= 150.9 K

28. $P = X_2 \cdot P^\circ = 0.9 \times 40 = 36$ mm kg

29. $\Delta T_b = K_b \cdot m = 0.52 \times \frac{0.1}{0.9 \times 18} \times 1000 = 3.2$ K

$\therefore$ B.P. of solution = 373 + 3.2 = 376.2 K

Comprehension IX

30. Increase in mass of absorber $\alpha\, P^\circ$ and decrease in mass of pure solvent $\alpha\,(P^\circ - P)$.

$$\therefore\ \frac{P^\circ - P}{P^\circ} = \frac{0.02}{0.24} = X_1 = \frac{\frac{x}{180}}{\frac{x}{180} + \frac{100 - x}{18}}$$

$\therefore$ Mass percent of glucose, $x = \frac{1000}{21}\%$

31. $$\underset{\substack{1-0.8\\=0.2}}{AlCl_3} \rightleftharpoons \underset{0.8}{Al^{3+}} + \underset{\substack{3\times0.8\\=2.4}}{3Cl^-}$$

Total effective mole of solute = 0.2 + 0.8 + 2.4
= 3.4

Now, decrease in mass of solution $\alpha\, P$
and increase in mass of absorber $\alpha\, P^\circ$.

$$\therefore\ \frac{P}{P^\circ} = X_2 = \frac{17}{17+3.4} = \frac{5}{6} = \frac{0.18}{|\Delta m|_{\text{absorber}}}$$

$\therefore$ Increase in mass of absorber = 0.216 gm

32. As $P^\circ > P$, some vapour above the solution from saturated moist air coming will condense and hence, the mass of solution will increase.

Section D (Assertion – Reason)

1. Henry's law
2. Theory based
3. Both have same ΔT_f
4. KCl will dissociate.
5. Theory based
6. Theory based
7. Theory based
8. Theory based
9. Relative lowering of V.P. is also independent of solvent.
10. Deviation may occur in non-ideal solution.

Section E (Column Match)

1. Informative

2. Informative

3. (A) Some concentrations

(B) Osmolarity : NaCl = 0.2 M, Na_2SO_4 = 0.3 M

(C) Osmolarity : NaCl = KCl = 0.2 M

(D) Osmolarity : $CuSO_4$ = 0.2 M,
Sucrose = 0.1 M

4. Higher the B.P. of solvent, normally higher is its K_b value.

5. (A) $2 = 1 + \alpha(2-1) \Rightarrow \alpha = 1.00$

(B) $2 = 1 + \alpha(3-1) \Rightarrow \alpha = 0.50$

(C) $2 = 1 + \alpha(5-1) \Rightarrow \alpha = 0.25$

(D) $2 = 1 + \alpha(4-1) \Rightarrow \alpha = 0.33$

6. (A) $i = 1$

(B) $i = 1 + 1(2-1) = 2$

(C) $i = 1 + 1\,(3-1) = 3$

(D) $i = 1 + 1(4-1) = 4$

7. (P) Effective conc. = 0.1 × 3 = 0.3 M = 0.3 m

(Q) Effective conc. = 0.14 × 2 = 0.28 M = 0.28 m

(R) Effective conc. = 0.1 [1+0.9(3 – 1) = 0.28
M = 0.28 m

(S) Effective conc. = 0.28 M = 0.28 m

(T) $$\underset{(0.1-x)M}{HA} \rightleftharpoons \underset{xM}{H^+} + \underset{xM}{A^-}$$

$$K_a = 0.81 = \frac{x\cdot x}{0.1-x} \Rightarrow x = 0.09$$

$\therefore$ Effective conc. = $(0.1 + x)$ = 0.19 M = 0.19 m

Section F (Subjective)

Single Digit Integer Type

1. $V_{gas}\ \alpha\ n_{Solvent}$ but independent of pressure.

$$\therefore \left(\frac{V_2}{V_1}\right)_{gas} = \left(\frac{V_2}{V_1}\right)_{Solvent} \Rightarrow \frac{V_2}{4\,\text{ml}} = \frac{0.5}{1} \Rightarrow V_2 = 2\ \text{ml}$$

2. $m_{solution} = m_{water} + m_{ethanol}$

or, $V \times 0.9344 = 50 \times 1.000 + 50 \times 0.7939$

$\therefore\ V \approx 96$ ml < 100 ml

Solution is non-ideal with negative deviation.

3. Ideal gas can never be liquefied.

4. $P = X_2 \cdot P^\circ = 0.8 \times 233.5 = 186.8 \text{ torr} = P_{\text{exp}}$

$\therefore$ Solution is ideal.

5. $$\pi = \frac{\pi_1 V_1 + \pi_2 V_2}{(V_1 + V_2)} = \frac{2.4 \times 2V + 4.2 \times V}{2V + V} = 3 \text{ atm}$$

6. $\pi = CRT = \rho g h$

$$\text{or } \frac{0.2/\text{M}}{100/1000} \times 0.0821 \times 300 = \frac{1.013 \times 1000 \times 0.2463}{1.013 \times 10^6}$$

$\therefore$ $\text{M} = 2 \times 10^5$

7. $\pi = CRT = \rho g h$

$$\text{or } \frac{n}{1} \times 0.08 \times 298 = \frac{1.013 \times 1000 \times 7.45}{1.013 \times 10^6}$$

$$\therefore\ n = \frac{25 \times 10^{-3}}{80}$$

$$\therefore \text{ Millimoles in 320 gm} = \frac{25}{80} \times \frac{320}{20} = 5$$

8. $$\frac{V_2}{V_1} = \frac{C_1}{C_2} = \frac{\pi_1 / T_1}{\pi_2 / T_2} = \frac{500/283}{105.3/298} \approx 5$$

9. $$\Delta T_f = K_f \cdot m \Rightarrow 0.29 = 1.86 \times \frac{1.04/267}{100/1000} \times n$$

$\Rightarrow n \approx 4$

10. $\Delta T_f = K_f \cdot m$

For KCN solution: $0.80 = K_f \times 0.2 \times 2$ (1)

$$\begin{array}{lccc} & \text{Hg(CN)}_2 + & \text{mCN}^- & \rightleftharpoons \text{Hg(CN)}_{m+2}^{m-} \\ & 0.1 \text{ mole} & 0.2 \text{ mole} & 0 \\ \text{Final} & 0 & (0.2 - 0.1\text{m}) \text{mole} & 0.1 \text{ mole} \end{array}$$

Final effective molality = (0.2 – 0.1 m) + 0.1 + 0.2
= 0.5 – 0.1 m

Now, $0.60 = K_f \times (0.5 - 0.1 \text{ m})$ (2)

From (1) and (2): $m = 2$

Four Digit Integer Type

1. $P = X_2 \cdot P^\circ$

$$20 = \frac{180/18}{\frac{6}{\text{M}} + \frac{180}{18}} \times P^\circ \quad (1)$$

$$\text{and } 20.02 = \frac{11}{\frac{6}{\text{M}} + 11} \times P^\circ \quad (2)$$

$\therefore$ $\text{M} = 54$

2. Mole fraction of solvent is same in both.

$$\therefore\ \frac{\frac{90}{18}}{\frac{10}{\text{M}} + \frac{90}{18}} = \frac{\frac{95}{18}}{\frac{5}{180} + \frac{95}{18}} \Rightarrow \text{M}_X = 380$$

3. $$\frac{P^\circ - P}{P^\circ} = X_1 = \frac{2400 - 2300}{2400} = \frac{1}{24}$$

$$\text{1 mole solution} \begin{cases} \text{Urea} = \frac{1}{24} \text{ mole} = \frac{1}{24} \times 60 = 2.5 \text{ gm} \\ \text{Water} = \frac{23}{24} \text{ mole} = \frac{23}{24} \times 18 = 17.25 \text{ gm} \end{cases}$$

$$\therefore \text{ Volume of 1 mole solution} = \frac{2.5 + 17.25}{1.185} = \frac{50}{3} \text{ ml}$$

$$\text{Now, } \pi = CRT = \left(\frac{1/24}{50/3} \times 1000 \right) \times 0.08 \times 300$$

$= 60$ atm

4. $\Delta T_f = K_f \cdot m$

$$\text{or, } 30 = 1.86 \times \frac{w/62}{795/1000} \Rightarrow w = 795 \text{ gm}$$

5. $\Delta T_f = K_f \cdot m$

$$\text{or, } 6 = 1.86 \times \frac{50/62}{w/1000} \Rightarrow w_{\text{water (final)}} = 250 \text{ gm}$$

$\therefore$ Mass of water separated as ice = 375 – 250
= 125 gm

6. $\Delta T_f = K_f \cdot m$

$$\text{Naphthalene solution: } 13.5 = K_f \times \frac{38.4/128}{185/1000} \quad (1)$$

Unknown substance solution:

$$9.0 = K_f \times \frac{11.6/\text{M}}{185/1000} \quad (2)$$

$\therefore$ $\text{M} = 58$

7. $$\Delta T_f = K_f \cdot m = 1.86 \times \frac{\left(\frac{3.6}{180} + \frac{3.6}{60} \right)}{200} \times 1000$$

$= 0.744°\text{C}$

$\therefore$ F. P. of solution = – 0.744°C

8. $\Delta T_f = K_f \cdot m$

$$(26.84 - 25.64) = 8 \times \frac{2.4 \times 10^{-3}/\text{M}}{100 \times 10^{-3}/1000} \Rightarrow \text{M} = 160$$

9. $\Delta T_f = K_f \cdot m$

$$\Rightarrow 1.60 = 4.88 \times \frac{2/122}{26/1000} \times \left[1 + \alpha\left(\frac{1}{2} - 1\right)\right]$$

$\therefore\ \alpha = 0.96$ or 96%

10. $\pi = CRT \Rightarrow 4.92 = \left(\frac{x}{200} + 0.05 \times 2\right) \times 0.08 \times 300$

$\therefore\ x = 20$

11. $P^\circ - P = X_1 \cdot P^\circ = \frac{n_1}{n_1 + n_2}, P^\circ \approx \frac{n_1}{n_2} \cdot P^\circ$

Urea solution: $0.03 = \frac{0.1}{\left(\frac{1000}{18}\right)} \times P^\circ$

KCl solution: $0.0594 = \frac{0.1[1 + \alpha(2-1)]}{\left(\frac{1000}{18}\right)} \times P^\circ$

$\therefore\ \alpha = 0.98$ or 98%

12. Loss in weight of solution αP

Loss in weight of water $\alpha(P^\circ - P)$

Now, $\frac{P^\circ - P}{P} = \frac{n_1}{n_2} \Rightarrow \frac{0.01}{0.98} = \frac{\frac{1.25}{90}[1 + \alpha(3-1)]}{\frac{49}{18}}$

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

13. $\Delta T_f = K_f \cdot m \Rightarrow 7 = 14 \times \frac{75.2}{94} \times \left[1 + \alpha\left(\frac{1}{2} - 1\right)\right]$

$\therefore\ \alpha = 0.75$ or 75%

14.

100 gm solution (Say)

→ $MgSO_4$ = 12 gm = $\frac{12}{120}$ = 0.1 mole

→ $MgCl_2$ = 9.5 gm = $\frac{9.5}{9.5}$ = 0.1 mole

→ Water = 100 – (12 + 9.5) = 78.5 gm

Effective moles of solute

= 0 · 1 [1 + 0.8(2 – 1)] + 0.1 [1 + 0.6 (3– 1)] = 0.4

Now, $\Delta T_b = K_b \cdot m = 0.785 \times \frac{0.4}{78.5/1000} = 4$ K

$\therefore$ B. P. of solution = 373 + 4 = 377 K

15. $\Delta T_f = K_f \cdot m \Rightarrow 0.40 = 1.86 \times m$

$\therefore$ Effective molality of NaCl solution = $\frac{20}{93}$ m

Now, $\pi = CRT = \frac{20}{93} \times 0.0821 \times 279$

$= 60 \times 0.0821$ atm