A solution is a homo... liquid and gas... ...ation of a solution ... are classified as solid, liquid and gaseous... expressed in terms of mole fraction, molarity, molality and in percentages. The dissolution of a gas in a liquid is governed by **Henry's law**, according to which, at a given temperature, the **solubility of a gas in a liquid is directly proportional to the partial pressure of the gas**. The vapour pressure of the solvent is lowered by the presence of a non-volatile solute in the solution and this lowering of vapour pressure of the solvent is governed by Raoult's law, according to which the **relative lowering of vapour pressure of the solvent over a solution is equal to the mole fraction of a non-volatile solute present in the solution**. However, in a binary liquid solution, if both the components of the solution are volatile then another form of Raoult's law is used. Mathematically, this form of the Raoult's law is stated as: $p_{total} = p_1^0 x_1 + p_2^0 x_2$. **Solutions which obey Raoult's law over the entire range of concentration are called ideal solutions**. Two types of deviations from Raoult's law, called positive and negative deviations are observed. Azeotropes arise due to very large deviations from Raoult's law.

The properties of solutions which depend on the number of solute particles and are independent of their chemical identity are called colligative properties. These are lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure. The process of osmosis can be reversed if a pressure higher than the osmotic pressure is applied to the solution. Colligative properties have been used to determine the molar mass of solutes. Solutes which dissociate in solution exhibit molar mass lower than the actual molar mass and those which associate show higher molar mass than their actual values.

Quantitatively, the extent to which a solute is dissociated or associated can be expressed by van't Hoff factor *i*. This factor has been defined as ratio of normal molar mass to experimentally determined molar mass or as the ratio of observed colligative property to the calculated colligative property.

Only tick mark questions.

Exercis

2.1 Define the term solution. How many types of solutions are formed? Write briefly about each type with an example.

2.2 Give an example of a solid solution in which the solute is a gas.

2.3 Define the following terms:
(i) Mole fraction (ii) Molality (iii) Molarity (iv) Mass percentage.

2.4 Concentrated nitric acid used in laboratory work is 68% nitric acid by mass in aqueous solution. What should be the molarity of such a sample of the acid if the density of the solution is 1.504 g mL^{-1}?

Only tick mark questions

2.5 A solution of glucose in water is labelled as 10% w/w, what would be the molality and mole fraction of each component in the solution? If the density of solution is 1.2 g mL^{-1}, then what shall be the molarity of the solution?

2.6 How many mL of 0.1 M HCl are required to react completely with 1 g mixture of Na_2CO_3 and $NaHCO_3$ containing equimolar amounts of both?

2.7 A solution is obtained by mixing 300 g of 25% solution and 400 g of 40% solution by mass. Calculate the mass percentage of the resulting solution.

2.8 An antifreeze solution is prepared from 222.6 g of ethylene glycol ($C_2H_6O_2$) and 200 g of water. Calculate the molality of the solution. If the density of the solution is 1.072 g mL^{-1}, then what shall be the molarity of the solution?

2.9 A sample of drinking water was found to be severely contaminated with chloroform ($CHCl_3$) supposed to be a carcinogen. The level of contamination was 15 ppm (by mass):

(i) express this in percent by mass

(ii) determine the molality of chloroform in the water sample.

2.10 What role does the molecular interaction play in a solution of alcohol and water?

2.11 Why do gases always tend to be less soluble in liquids as the temperature is raised?

2.12 State Henry's law and mention some important applications.

2.13 The partial pressure of ethane over a solution containing 6.56×10^{-3} g of ethane is 1 bar. If the solution contains 5.00×10^{-2} g of ethane, then what shall be the partial pressure of the gas?

2.14 What is meant by positive and negative deviations from Raoult's law and how is the sign of $\Delta_{mix}H$ related to positive and negative deviations from Raoult's law?

2.15 An aqueous solution of 2% non-volatile solute exerts a pressure of 1.004 bar at the normal boiling point of the solvent. What is the molar mass of the solute?

2.16 Heptane and octane form an ideal solution. At 373 *K*, the vapour pressures of the two liquid components are 105.2 kPa and 46.8 kPa respectively. What will be the vapour pressure of a mixture of 26.0 g of heptane and 35 g of octane?

2.17 The vapour pressure of water is 12.3 kPa at 300 *K*. Calculate vapour pressure of 1 molal solution of a non-volatile solute in it.

2.18 Calculate the mass of a non-volatile solute (molar mass 40 g mol^{-1}) which should be dissolved in 114 g octane to reduce its vapour pressure to 80%.

2.19 A solution containing 30 g of non-volatile solute exactly in 90 g of water has a vapour pressure of 2.8 kPa at 298 *K*. Further, 18 g of water is then added to the solution and the new vapour pressure becomes 2.9 kPa at 298 *K*. Calculate:

(i) molar mass of the solute (ii) vapour pressure of water at 298 *K*.

2.20 A 5% solution (by mass) of cane sugar in water has freezing point of 271*K*. Calculate the freezing point of 5% glucose in water if freezing point of pure water is 273.15 *K*.

2.21 Two elements A and B form compounds having formula AB_2 and AB_4. When dissolved in 20 g of benzene (C_6H_6), 1 g of AB_2 lowers the freezing point by 2.3 *K* whereas 1.0 g of AB_4 lowers it by 1.3 *K*. The molar depression constant for benzene is 5.1 *K* kg mol^{-1}. Calculate atomic masses of A and B.

3. Calculate the mole fraction of ethanol and water in a sample of rectified spirit which contains 95% ethanol by mass. [**Ans.** Ethanol = 0.88, water = 0.
4. Commercially available concentrated HCl contains 38% HCl by mass and has density 1.19 g cm^{-3}. Calculate the molarity of this solution. [**Ans.** 12.4
5. The mole fraction of benzene in a solution with toluene is 0.50. Calculate the mass per cent of benzene in the solution. [**Ans.** 45.9
6. Concentrated sulphuric acid has a density of 1.9 g/mL and 99% H_2SO_4 by weight. Calculate the molarity of sulphuric acid. [**Ans.** 19.19
7. The mole fraction of helium in a saturated solution at 20°C is 1.2×10^{-6}. Find the pressure of helium above the solution. Given Henry's constant at 20°C = 144.97 K bar. [**Ans.** 0.174 ba
8. The Henry's law constant for oxygen dissolved in water is 4.34×10^4 atm at 25°C. If the partial pressure of oxygen in air is 0.2 atm under atmospheric conditions, calculate the concentration (in moles/litre) of dissolved oxygen in water in equilibrium with air at 25°C. [**Ans.** 2.55×10^{-4} mol L^{-1}
9. How many grams of ethylene glycol (molar mass = 62) should be added to 10 kg of water so that the resulting solution freezes at – 10°C. ($K_f = 1.86$). [**Ans.** 3.3 kg
10. Calculate the osmotic pressure of a solution containing 10 g each of glucose ($C_6H_{12}O_6$) and sucrose ($C_{12}H_{22}O_{11}$) in 1000 cm^3 of solution at 25°C. ($R = 0.083$ L bar K^{-1} mol^{-1}). [**Ans.** 2.1 ba
11. The boiling point of water (100°C) becomes 100.52°C if 3 g of a non-volatile solute is dissolved in 20 mL of it. Calculate the molar mass of solute (K_b for water = 0.52 Km^{-1}). [**Ans.** 150
12. The vapour pressure of pure water at 30°C is 31.80 mm Hg. How many grams of urea (molar mass = 60) should be dissolved in 100 g of water to lower the vapour pressure. by 0.25 mm of Hg? [**Ans.** 2.62 g
13. The freezing point of a solution containing 0.2 g of acetic acid in 20 g of benzene is lowered by 0.45°C. Calculate the degree of association of acetic acid in benzene (K_f for benzene ≈ 5.12 K kg mol^{-1}) [**Ans.** α = 94.5% or 0.945
14. Calculate the boiling point of a solution containing 0.61 g of benzoic acid in 50 g of CS_2 (l) assuming 84% dimerisation of the acid. The boiling point and K_b of CS_2 are 46.2°C and 2.3 K kg mol^{-1} respectively. [**Ans.** 46.3334°C
15. If the osmotic pressure of a solution of 6 g of a substance in 1 litre of water at standard temperature is 2.24 atm. What is the molar mass of the substance ? [**Ans.** 60 g/mol
16. A solution of 2.95 g of sulphur in 100 g of cyclohexane had a freezing point of 4.18°C. The freezing point of pure cyclohexane is 6.5°C. What is the molecular formula of sulphur? (K_f for cyclohexane = 20.2 Km^{-1}) [**Ans.** S_8
17. The boiling point of ethanol is 78°C and its molar boiling point elevation constant per 1000 g is 1.15 K. A solution of 1.12 g of a camphor in 32 g of ethanol has a boiling point of 78.28°C. Calculate the molecular mass of camphor. [**Ans.** 143.75 g mol^{-1}
18. An aqueous solution of NaCl is marked 10% (w/w) on the bottle. If the density of the solution is 1.071 g/cc. What is the molality and molarity ? Also what is mole fraction component in the solution? [**Ans.** 1.9 m, 1.83 M, 0.03
19. A solution of sucrose has been prepared by dissolving 68.4 g of sucrose in 1 kg of water. Calculate the following :
    (i) The vapour pressure of the solution at 298 K.
    (ii) Osmotic pressure of the solution at 298 K.
    (iii) Freezing point of the solution.
    (Given : Vapour pressure of water at 298 K = 0.024 atm, K_f for water 1.86 K kg mol^{-1})
    [**Ans.** (i) 0.0239 atm, (ii) 4.89 atm, (iii) 272.628 K
20. A 1.7% solution of $AgNO_3$ is isotonic with 3.4% solution of glucose ($C_6H_{12}O_6$). Calculate the degree of dissociation of $AgNO_3$. (Molecular mass of $AgNO_3$ = 107.87) [**Ans.** 90%
21. The molal freezing point depression constant of benzene (C_6H_6) is 4.9 K $molal^{-1}$. Selenium exists as a polymer of Se_x type. When 3.26 g of selenium is dissolved in 226 g of benzene the observed freezing point is 0.112°C lower than for pure benzene. Deduce the molecular formula of selenium. (At mass of Se = 78.8
22. Calculate the freezing point of an aqueous solution of a non-
    300 K. (K_f for water = 1.86 K kg mol^{-1})

Solutions

23. M
    po
24. A
    m
25. Tw
    A
    w
26. C
    a
27. T
    n
28. C
    v
29. C
    =
30. A
    5
31. 1
    b
    (
    (
32.
33.
34.
35.
36.
37.
38.
39.
40.