Important Questions on Solutions

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1. For $H_2(g)$, the Henry's law constant in water is 5.34×10^7 torr. Determine the solubility of this gas in water at 25°C if its partial pressure over the solution is 760 torr. Assume that the density of the solution is the same as the density of the solvent.
A. 8×10^{-3} mol dm^{-3}
B. 8×10^{-2} mol dm^{-3}
C. 8×10^{-4} mol dm^{-3}
D. 8×10^{-5} mol dm^{-}

2. A solution containing 8.6 g per dm^3 of urea (molar mass = 60 g mol^{-1}) was found to be isotonic with a 5 per cent solution of an organic non-volatile solute. Determine the molar mass of the latter.
A. 432.7 g/mol
B. 246.3 g/mol
C. 532.4 g/mol
D. 348.8 g/mol

3. Acetic acid (CH_3COOH) associates in benzene to form a double molecule. 1.65 g of acetic acid when dissolved in 100 g of benzene raised the boiling point to 0.36°C. Determine the Van't Hoff factor and the degree of association of acetic acid in benzene (K_b = 2.57 K kg mol^{-1}).
A. 0.508, 0.983
B. 0.403, 0.893
C. 0.580, 0.983
D. 0.508, 0.893

4. Origin of the colligative properties of a dilute solution is
A. volatility of solute molecule
B. interaction of solute-solvent molecules
C. zero enthalpy of mixing
D. entropy of mixing

5. For a pure solvent, the vapour pressure is 0.8 atm. A non-volatile substance B is added to the solvent due to which its vapour pressure drops to 0.6 atm. Calculate the mole fraction of the component B in the solution.
A. 0.15
B. 0.25
C. 0.45
D. 0.35

6. For calcium nitrate, the values of observed and calculated molecular weight are 65.6 and 164 respectively. Calculate its degree of dissociation.
A. 75%
B. 32%
C. 25%
D. 85%

7. When the addition of sugar takes place, the sugar solution feels cool. Select the suitable condition for rapid dissolution.
A. In cold water added powdered sugar
B. In cold water added crystal sugar
C. In hot water added crystal sugar
D. In hot water added powdered sugar

8. Two miscible liquids A and B form a solution. Assume that the solution is non-ideal but the vapor above it behaves ideally. For pure A and B, the vapor pressures are 550 torr and 700 torr respectively at 35°C. If the total pressure above a solution that is 48 mole percent A, is 500 torr and the mole fraction of A in the vapor is 0.45, determine the activity coefficients of A and B in the solution.
A. 0.854, 0.756
B. 0.765, 0.324
C. 0.854, 0.765
D. 0.845, 0.765

9. For water, the heat of vaporization 100°C is 40.585 kJ mol^{-1}. Determine the temperature at which a solution will contain 5.60 g of glucose per 1000 g of water boil.

A. 101.26°C

B. 100.16°C

C. 105.20°C

D. 104.16°C

10. The complex compound $K_4[Fe(CN)_6]$ undergoes 45% dissociation in 0.1 M aqueous solutions of the complex at 27°C . Calculate the osmotic pressure of the solution.

A. 5.342 atm

B. 6.894 atm

C. 4.324 atm

D. None of the above

Answer Key

| 1. C | 2. D | 3. A | 4. D | 5. B | 6. A | 7. D |
| 8. A | 9. B | 10. B | | | | |

Solutions

Solution 1.

$x_2 = n_2/ (n_1 + n_2) \approx n_2/n_1$ (assume that the number of moles of H_2, n_2, is negligible in comparison with the number of moles, n_1, of the solvent).

The number of moles in one dm^3 of water will be as:

$n_1 = 100$ g/18 g $mol^{-1} = 55.5$ mol so that $x_2 = n_2/55.5$ mol

$p_2 = k\ x_2$ [Henry's law]

$$k = 5.34 \times 10^7\, torr = \frac{p_2}{x_2} = \frac{760\, torr}{n_2/(55.5\, mol)} = \frac{760\, torr \times 55.5\, mol}{n_2}$$

$\therefore n_2 = (760$ torr $\times 55.5$ mol$)/(5.34 \times 10^7$ torr$) = 8 \times 10^{-4}$

Thus, the solubility of H_2 gas in water is 8×10^{-4} mol dm^{-3}.

Solution 2.

According to the Van't Hoff theory, isotonic solutions have the same osmotic pressure at the same temperature and the same molar concentration.

Molar concentration of urea solution = 8.6 g dm^{-3}/60 g mol^{-1}

Let M_2 be the molar mass of the unknown solute.

∴ Molar concentration of unknown solution = 50 g dm^{-3}/M_2

Since both the solutions are isotonic, hence, their molar concentrations are equal. Thus,

50 g dm^{-3}/M_2 = 8.6 g dm^{-3}/60 g mol^{-1}

M_2 = 348.8 g mol^{-1}

Solution 3.
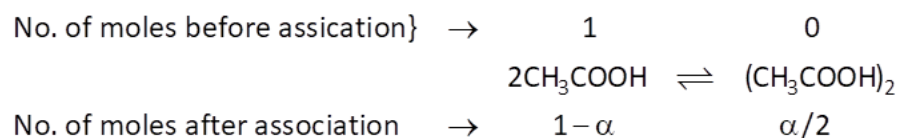
Normal molar mass of acetic acid = 60 g mol^{-1}

Observed molar mass of acetic acid, $M_2 = \dfrac{K_b w_2}{w_1 \Delta T_b}$

$$= \frac{(2.57\, K\, kg\, mol^{-1})(1.65 \times 10^{-3}\, kg)}{(100 \times 10^{-3}\, kg) \cdot (0.36\, K)} = 0.1178\, kg\, mol^{-1} = 117.8\, g\, mol^{-1}$$

$$i = \frac{Normal\ molar\ mass}{Observed\ molar\ mass} = \frac{60\, g\, mol^{-1}}{117.8\, g\, mol^{-1}} = 0.508$$

Since acetic acid associates to form double molecules, hence,

No. of moles before assiation} →   1   0

                            $2CH_3COOH \rightleftharpoons (CH_3COOH)_2$

No. of moles after association   → $1 - \alpha$ $\alpha/2$

Here, α is the degree of association.

The number of unassociated moles = $1 - \alpha$; the number of associated moles = $\alpha/2$

The number of effective moles = $1 - \alpha + \alpha/2$

Hence,

$$\frac{\text{Normal molar mass}}{\text{Observed molar mass}} = \frac{1 - \alpha + \alpha/2}{1}$$

$$\frac{60\,g\,mol^{-1}}{117.8\,mol^{-1}} = 1 - \alpha + \alpha/2$$

∴ α = 0.983

Solution 4.

Colligative properties depend on the number of particles but are independent of the nature of particles. For dilute solution, it has been observed that colligative property depends upon change in entropy of solution which can be determined by concentration of molecules or ions of solute.

Solution 5.

$$P^0_{solvent} = 0.8 \text{ atm}$$

$$P_{solution} = 0.6 \text{ atm}$$

Raoult's law, $P_{solution} = X_{solvent} \times P^0_{solvent}$

$$x_{solvent} = \frac{0.6}{0.8} = 0.75; \quad x_{solute} = 1 - 0.75 = 0.25$$

Solution 6.

For $Ca(NO_3)_2$;

$$i = \frac{normal\ mol.wt.}{exp.mol.wt.} = 1 + 2\alpha$$

$$\frac{164}{65.6} = 1 + 2\alpha$$

α = 0.75 or 75%

Solution 7.

As compared to crystals, powdered sugar has greater surface area. The solution becomes cool as dissolution is an endothermic process.

Solution 8.

$x_{A,\ vap} = 0.45$

Since, the vapor behaves ideally, hence,

$p_A = x_{A,\ vap} \times P = 0.45 \times 500$ torr = 225 torr

$p_B = P - p_A = 500$ torr − 225 torr = 275 torr

Since, the solution behaves non-ideally, Raoult's law becomes:

$$p_i = a_i p_i^{\circ}$$

$a_A = p_A / p_A^{\circ} = 225$ torr/550 torr = 0.41

Hence,

$\gamma_A = a_A / x_A = 0.41/0.48 = 0.854$

$a_B = p_B / p_B^\circ = 275$ torr/700 torr = 0.393

γB = a_B/x_B = 0.393/0.52 = 0.756

Solution 9.

$$K_b = \frac{RT_b^2 M_1}{\Delta H_{vap}}$$

$$= \frac{(8.314\,JK^{-1}mol^{-1})(373K)^2 \times 0.0180\,kg\,mol^{-1}}{40585\,J\,mol^{-1}} = 0.513 \text{ K kg mol}^{-1}$$

M_2 (glucose) = 180 g mol^{-1} = 0.180 kg mol^{-1}

$$\therefore \Delta T_b = \frac{K_b w_2}{w_1 M_2} = \frac{(0.513\,kg\,mol^{-1})(5.6 \times 10^{-3}kg)}{(1kg)(18 \times 10^{-3}kg\,mol^{-1})} = 0.16 \text{ K}$$

∴ Boiling point of solution = 373 K + 0.16 K = 373.16 K = 100.16°C

Solution 10.

If the complex $K_4[Fe(CN)_6]$ had not been dissociated, its normal osmotic pressure would have been given by the Van't Hoff equation, viz,

Π = cRT = (0.1 mol dm^{-3}) (0.08206 dm^3 atm K^{-1} mol^{-1}) (300 K) = 2.462 atm

The complex, however, undergoes dissociation in aqueous solution. If α is the degree of dissociation, then, the dissociation reaction may be represented as:

$$\underset{1-\alpha}{K_4[Fe(CN)]_6} \rightleftharpoons \underset{4\alpha}{4K^+} + \underset{\alpha}{[Fe(CN)_6]^{4-}}$$
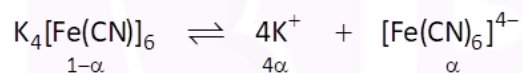
Number of moles after dissociation = 1 − α + 4α + α = 1 + 4α

Number of moles without dissociation = 1

Since, osmotic pressure is directly proportional to the number of moles, hence

Π$_{observed}$/Π$_{normal}$ = (1 + 4α)/1

Since,

α = 0.45, hence,

Π$_{observed}$ = 2.462 × (1 + 4 × 0.45)/1 = 6.894 atm

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