Solutions

1. What is the molar solubility of $Al(OH)_3$ in 0.2 M NaOH solution? Given that, solubility product of $Al(OH)_3 = 2.4\times10^{-2}$
2. At room temperature, a dilute solution of urea is prepared by dissolving 0.60 g of urea in 360 g of water. If the vapour pressure of pure water at this temperature is 35 mmHg, what will be the lowering of vapour pressure? (molar mass of urea = 60 g mol^{-1})
3. Molal depression constant for a solvent is 4.0 K kg mol^{-1}. Calculate the depression in the freezing point (in K) of the solvent for 0.03 mol kg^{-1} solution K_2SO_4. (Assume complete dissociation of the electrolyte)
4. The osmotic pressure of a dilute solution of an ionic compound XY in water is four times that of a solution of 0.01 M $BaCl_2$ in water. Assuming complete dissociation of the given ionic compounds in water, find the concentration of XY (in mol L^{-1}) in solution.
5. Calculate the amount of sodium chloride (in g) which must be added to 1000 mL of water so that its freezing point is depressed by 0.744K. For water, $K_f = 1.86$ K/m. Assume density of water to be 1 g mL^{-1}.
6. What weight of the non-volatile solute (in g), urea ($NH_2 - CO - NH_2$) needs to be dissolved in 100g of water, in order to decrease the vapour pressure of water by 25%?
7. A bottle of commercial sulphuric acid (density 1.787 g/mL) is labelled as 86 percent by weight. What volume of the acid has to be used to make 1 litre of 0.2 M H_2SO_4?
8. 0.5 gm of fuming H_2SO_4 (Oleum) is diluted with water. This solution is completely neutralized by 26.7 ml of 0.4 N NaOH. Find the percentage of free SO_3 in the sample of oleum.
9. The vapour pressure of pure benzene at a certain temperature is 640mm Hg. A non-volatile solid weighing 2.175g is added to 39.0g of benzene. The vapour pressure of the solution is 600mm Hg. What is the molecular weight (in g) of the solid substance ?
10. 0.400 g of an acid HA (mol. mass = 80) was dissolved in 100 g of water. The solution showed a depression of freezing point of 0.12 K. What will be the dissociation constant (in multiple of 10^{-3}) of the acid at about 0°C? Given K_f (water) = 1.86 K Kg mol^{-1} (Assume molarity of solution $\approx$ molality)
11. An element X (Atomic mass = 25) exists as X_4 is benzene. 51g of saturated solution of X in benzene was added to 50.0 g of pure benzene. The resulting solution showed a depression of freezing point of 0.55 K. Find the solubility of X per 100 g of benzene. (K_f for benzene = 5.5 K kg mol^{-1})
12. 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, determine extent of dilution.
13. A mixture of two immiscible liquids nitrobenzene and water boiling at 99°C has a partial vapour pressure of water 733 mm and that of nitrobenzene 27 mm. Find the ratio of the weights of nitrobenzene to the water in distillate.
14. A solution containing 28 g phosphorus in 315 g CS_2 (b. pt. 46.3°C) boils at 47.98°C. K'_b for CS_2 is 2.34 K mol^{-1} kg. What are the no. of phosphorus atom present in its molecular formula?
15. Calculate the molality of 1 litre solution of 93% H_2SO_4 (weight/volume). The density of the solution is 1.84 g/mL.

SOLUTIONS

1. **(3)** Let the solubility of $Al(OH)_3$ in 0.2M NaOH solution be s.
Then,

$$Al(OH)_3 \rightleftharpoons \underset{s}{Al^{3+}} + \underset{3s}{3OH^-}$$

and $$\underset{0.2M}{NaOH} \rightleftharpoons \underset{0.2M}{Na^+} + \underset{0.2M}{OH^-}$$

$[Al^{3+}] = s$ and $[OH^-] = 3s + 0.2 \approx 0.2$

$K_{sp} = 2.4 \times 10^{-2} = [Al^{3+}][OH]^3$

$2.4 \times 10^{-2} = s(0.2)^3$

$$s = \frac{2.4 \times 10^{-2}}{8 \times 10^{-3}} = 3\,\text{mol/L}$$

2. **(0.017)** Relative lowering of vapour pressure, is given by, $\frac{p^\circ - p}{p^\circ} = x_A = \frac{n_A}{n_A + n_B} \simeq \frac{n_A}{n_B}$

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

$$n_{water} = \frac{360}{18}$$

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

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

3. **(0.36)** Dissociation of Potassium Sulphate (K_2SO_4),

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

i (Van't Hoff factor) = 3

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

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

$\therefore \Delta T_f = 3 \times 4 \times 0.03 = 0.36$ K

4. **(0.06)** We know, $\pi = iCRT$; $\pi_{xy} = 4\pi_{BaCl_2}$

$\therefore 2[XY] = 4 \times (0.01) \times 3$

$[XY] = 0.06$

$= 6 \times 10^{-2}$ mol/L = 0.06 mol/L

5. **(11.7)** Mass of NaCl, w_2 = ?, Volume of water = 1000 mL, ΔT_f = 0.744 K, Density of water = 1 g mL^{-1}

So, mass of water w_1 = 1000 mL × 1 g mL^{-1} = 1000g = 1 kg

$$\Delta T_f = iK_f m = iK_f \times \frac{(w_2/58.5)}{w_1} = \frac{iK_f w_2}{58.5 \times w_1}$$

$$w_2 = \frac{\Delta T_f \times 58.5 \times 1}{i \times K_f} = \frac{0.744 \times 58.5}{2 \times 1.86} = 11.7\text{g}$$

($\because$ i for NaCl = 2)

So, Mass of NaCl required = 11.7g.

6. **(111)** $$\frac{P^o - P}{P^o} = \frac{\frac{w}{m}}{\frac{w}{m} + \frac{W}{M}}$$

Let the initial (normal) pressure $(P^o) = P$

$\therefore$ Pressure of solution $= \frac{75}{100} \times P = \frac{3}{4}P$

$m = 60, M = 18, W = 100$ g

$$\therefore \frac{P - \frac{3}{4}P}{P} = \frac{w/60}{\frac{w}{60} + \frac{100}{18}}$$

$$\frac{1}{4} = \frac{w/60}{(w/60) + 5.55} \text{ or } \frac{4w}{60} = \frac{w}{60} + 5.55$$

or $w = 111$ g

7. **(12.65)** Molarity

$$= \frac{\text{Mass of solute /M. wt. of solute}}{\text{Mass of solution/density of solution}} \times 1000$$

$$M = \frac{86/98}{100/1.787} \times 1000$$

$$= \frac{0.8775}{55.5} \times 1000 = 15.81\text{ M}$$

Now,

$M_1V_1 = M_2V_2$

$\therefore 15.81 \times V_1 = 0.2 \times 1000$

or $V_1 = \frac{0.2 \times 1000}{15.81} = 12.65$ mL

$\therefore$ Amount of acid to be used to make 1 L of 0.2 M H_2SO_4 = 12.65.

8. **(3.84)** $N_1 = 1, V_1 = ?, N_2 = 26.7, V_2 = 0.4$

$N_1V_1 = N_2V_2$

$1 \times V_1 = 26.7 \times 0.4$

$$V_1 = \frac{26.7 \times 0.4}{1} = 10.68$$

49g ($\because$ eq wt of H_2SO_4 = 49) of H_2SO_4 will be neutralised by 1N 1000 mL of NaOH.

$\therefore$ 0.5g of H_2SO_4 will be neutralised by

$$= \frac{1000}{49} \times 0.5 = 10.20\text{ mL 1N NaOH}$$

Volume of 1 N NaOH used by dissolved SO_3

= 10.68 – 10.20 = 0.48 mL

$$SO_3 + 2NaOH \longrightarrow Na_2SO_4 + H_2O$$

$$\therefore \text{Eq wt of } SO_3 = \frac{\text{Mol wt}}{2} = \frac{80}{2} = 40$$

Wt of SO_3 in 0.48 ml of 1 M solution

$$= \frac{40}{1000} \times 0.48 = 0.0192\text{ g}$$

$$\% \text{ of } SO_3 = \frac{0.0192}{0.5} \times 100 = 3.84\%$$

9. **(65.25)** According to Raoult's law

$$\frac{P^\circ - P}{P^\circ} = \frac{w/m}{w/m + W/M}$$

Here, $P^\circ = 640$ mm Hg, $P = 600$ mm Hg, $w = 2.175$g, $W = 39.0$ g,

$M = 78$, m = Molecular weight of solute

Substituting the various values in the above equation, $\frac{640-600}{640} = \frac{2.175/m}{2.175/m + 39/78}$

$m = 65.25$ g

10. **(5.92)** Molality (m) of solution $= \frac{0.4 \times 1000}{80 \times 100} = 0.05$

$\Delta T_f\text{(normal)} = K_f \times m = 1.86 \times 0.05 = 0.093$ K

Van't Hoff factor,

$$i = \frac{\Delta T_f\text{(observed)}}{\Delta T_f\text{(normal)}} = \frac{0.12}{0.093} = 1.290$$

$$HA + H_2O \rightleftharpoons H_3O^+ + A^-$$

$$\alpha = \frac{i-1}{n-1} = \frac{1.290-1}{2-1} = 0.29$$

$$K_a = \frac{C\alpha^2}{1-\alpha} = \frac{0.05 \times (0.29)^2}{1-0.29} = 5.92 \times 10^{-3}$$

11. **(2)** Let x g be the mass of element in 51.0 g of saturated solution.

Mass of benzene in 51.0 g of saturated solution
$= 51.0 - x$ g

Total mass of benzene containing x g of solute
$= 50 + 51 - x = (101 - x)$ g

$$\Delta T_f = \frac{1000 K_f W_B}{M_B W_A} = \frac{1000 \times 5.5 \times x}{4 \times 25 \times (101 - x)}$$

$= 0.55$ (given)

$\Rightarrow \quad x = 1.0$ g

Hence, solubility

$$= \frac{W_B \times 100}{W_A} = \frac{1}{(51-1)} \times 100 = 2.0 \text{ g}$$

12. **(5)** For initial solution,

$\because \quad \pi = \frac{500}{760}$ atm, $\quad T = 283$ K

$$\frac{500}{760} \times V_1 = n \times R \times 283 \quad ...(i)$$

After dilution, let volume becomes V_2 and temperature is raised to 25°C, i.e., 298 K.

$$\pi = \frac{105.3}{760} \text{atm}$$

$$\frac{105.3}{760} \times V_2 = n \times R \times 298 \quad ...(ii)$$

$\therefore$ By Eqs. (i) and (ii), we get $\frac{V_1}{V_2} = \frac{283}{298} \times \frac{105.3}{500}$

$$\frac{V_1}{V_2} = \frac{1}{5}$$

$\therefore V_2 = 5V_1$

i.e., Solution was diluted to 5 times.

13. **(4)** $P' = P_M \cdot X_A$

where X'_A is mole fraction is gaseous phase

$$\therefore \ 27 = 760 \times \frac{\frac{w_2}{123}}{\frac{w_1}{18} + \frac{w_2}{123}} \text{ (for nitrobenzene)}$$

$$\text{and } 733 = 760 \times \frac{w_1/18}{\frac{w_1}{18} + \frac{w_2}{123}} \quad \text{(for water)}$$

$$\therefore \ \frac{w_1}{w_2} = 4$$

14. **(4)** $\Delta T = \frac{1000 \times K_b' \times w}{m \times W}$

$$1.68 = \frac{1000 \times 2.34 \times 28}{m \times 315}$$

$\therefore m_{exp} = 123.80$

$$\frac{m_N}{m_{exp}} = 1 - \alpha + \frac{\alpha}{n}$$

$\because \alpha = 1 \ \therefore \ \frac{m_N}{m_{exp}} = \frac{1}{n}$ (m_N of P = 31)

$$\therefore \ \frac{31}{123.80} = \frac{1}{n}$$

$\therefore n \approx 4$

15. **(10.43)** Mass of H_2SO_4 in 100ml of 93% H_2SO_4 solution
$= 93g$

$\therefore$ Mass of H_2SO_4 in 1000 ml of the H_2SO_4 solution
$= 930g$

Mass of 1000 ml H_2SO_4 solution
$= 1000 \times 1.84 = 1840g$

Mass of water in 1000 ml of solution
$= 1840 - 930 = 910$ g

$$\text{Moles of } H_2SO_4 = \frac{\text{Wt. of } H_2SO_4}{\text{Mol Wt. of } H_2SO_4} = \frac{930}{98}$$

$\therefore$ Moles of H_2SO_4 in 1 kg of water

$$= \frac{930}{98} \times \frac{1000}{910} = 10.43 \text{ mol kg}^{-1}$$

$\therefore$ Molality of 1 litre solution = 10.43