Electrochemical Technology in Pollution Control

Live session: Week 1
Le’ Chatelier’s Principle:
if dissolution is endothermic ($\Delta H_{\text{sol}} > 0$): solubility increases with temperature
Exothermic ($\Delta H_{\text{sol}} < 0$)… s↓ as T↑

Henry’s law: at constant temperature, the solubility of a gas is directly proportional to the partial pressure of the gas present above the surface of the solution.

$$P_1 = K_H x_1$$

Rault’s law: for a solution of volatile liquids, the partial pressure of each components in the solution is directly proportional to its mole fraction in the solution.

$$P_1 = P_1^0 x_1 \& P_2 = P_2^0 x_2$$

Dalton’s law: total pressure over the solution is the sum of partial pressure of components of the solution.

$$P_{\text{total}} = P_1 + P_2 + \ldots$$
Q.1 Wavelength of the Lyman series lies in the

(a) Visible region
(b) Ultraviolet region
(c) Infrared region
(d) None of these

Sol:

\[ \frac{1}{\lambda} = R_H \left( \frac{1}{m^2} - \frac{1}{n^2} \right) \]

\[ \frac{1}{\lambda} = R_H \left( 1 - \frac{1}{n^2} \right) \]

\[ \frac{1}{\lambda} = 1.09677 \times 10^7 \times \left( \frac{1}{1^2} - \frac{1}{2^2} \right) \text{ m}^{-1} \]

\[ \lambda = 121.57 \text{ nm} \]

\[ m = 1 \text{ (Lyman series)} \]
\[ n = 2 \text{ (for maximum wavelength)} \]

[for minimum \( \lambda, n = \infty \) & \( \lambda = 91.17 \text{ nm} \)]
\[ \lambda = 91.17 \text{ to } 121.57 \text{ nm} \]

Ultra violet region
Q.2 Calculate the mole fraction of ethylene glycol \((C_2H_6O_2)\) in a solution containing 20% of \(C_2H_6O_2\) by mass

(a) 0.068  
(b) 0.932  
(c) 0.034  
(d) 0.687

Sol:

Molar mass of ethylene glycol \((EG)\) = 62.07 g mol\(^{-1}\)

Molar mass of water (solvent) = 18 g mol\(^{-1}\)

Moles of water \((n_w)\) = \(\frac{80}{18} = 4.44\)

Moles of EG \((n_{EG})\) = \(\frac{20}{62.07} = 0.32\)

Mole fraction of 20% of EG = \(\frac{n_{EG}}{n_{EG} + n_w} = \frac{0.32}{0.32 + 4.44} = 0.068\)
Q. 3 \( \text{H}_2\text{S} \), a toxic gas with rotten egg like smell, is used for the qualitative analysis. If the solubility of \( \text{H}_2\text{S} \) in water at STP is 0.2 m, calculate Henry’s law constant.

**Solution:**

It is given that the solubility of \( \text{H}_2\text{S} \) in water at STP is 0.2 m, i.e., 0.2 mol of \( \text{H}_2\text{S} \) is dissolved in 1000 g of water.

Moles of **water** = \( \frac{1000\text{ g}}{18\text{ g mol}^{-1}} = 55.56 \text{ mol} \)

\[ \therefore \text{Mole fraction of } \text{H}_2\text{S}, x = \frac{\text{Moles of } \text{H}_2\text{S}}{\text{Moles of } \text{H}_2\text{S} + \text{Moles of water}} = \frac{0.2}{0.2 + 55.56} = 0.0036 \]

At STP, pressure (\( p \)) \( \sim \) 1 bar

According to Henry’s law: \( p = K_H \times x \Rightarrow K_H = \frac{p}{x} = \frac{1}{0.0036} = 277.79 \text{ bar} \)
Q. 4. The vapour pressure of dilute aqueous solution of glucose is 740 mm of Hg at 100°C. Calculate mole fraction of solute?
(Vapour pressure of pure water at 100°C = 760mm of Hg.)

Vapor pressure of pure water: \(P_w^0\)
Mole fraction of water = \(x_w\)
Mole fraction of the solute = \(x_s\)

Vapor pressure of the solution after adding solid solute: \(P_w = P_w^0 x_w\)

Lowering in vapor pressure: \(\Delta P = P_w - P_w^0 = P_w^0 x_w - P_w^0 = P_w^0 (1 - x_w)\)

\[
\frac{\Delta P}{P_w^B} = x_s
\]

\[
x_s = \frac{760 - 740}{760} = 0.026
\]
Q. 5. The vapour pressure of pure benzene at a certain temperature is 0.850 bar. A non-volatile, non-electrolyte solid weighing 0.5 g when added to 39.0 g of benzene (molar mass 78 g mol\(^{-1}\)). Vapour pressure of the solution, then, is 0.845 bar. What is the molar mass of the solid substance?

Sol:

Vapor pressure of pure Benzene: \(P_B^0\)
Mole fraction of benzene = \(x_B\)
Mole fraction of the substance = \(x_s\)

Vapor pressure of the solution after adding solid substance: \(P_B = P_B^0 x_B\)

Lowering in vapor pressure:
\[\Delta P = P_B - P_B^0 = P_B^0 x_B - P_B^0 (1 - x_B)\]

\[
\frac{\Delta P}{P_B^0} = \frac{x_s}{x_B} \\
\frac{\Delta P}{P_B^0} = \frac{n_s}{n_s + n_B} \\
\frac{\Delta P}{P_B^0} = \frac{n_s}{n_B} \quad \text{(if } n_s < n_B) \\
\frac{\Delta P}{P_B^0} = \frac{w_s M_B}{w_B M_s} = \frac{0.5 \times 78}{39 \times M_s} \\
M_s = \frac{(0.85-0.845)\times0.5\times78}{0.85\times39} = 170 \text{ g mol}^{-1}\]
Q.6. A mixture of hydrogen gas and oxygen gas exerts a total pressure of 2.5 atm on the walls of its container. If the partial pressure of hydrogen is 0.5 atm, find the mole fraction of oxygen in the mixture.

Sol:

A/c Dalton’s law of partial pressure: $P_{total} = P_1 + P_2 + ...$

$P_{total} = P_{H2} + P_{O2}$

$P_{O2} = 2.5 - 0.5$

$P_{O2} = 2$ atm

Mole fraction of oxygen $= \frac{P_{O2}}{P_{total}} = \frac{2}{2.5} = 0.8$