Ionic Equilibrium

Ionic equilibrium is the equilibrium established between the unionized molecules and the ions in a solution of weak electrolytes.

Weak electrolytes:- Electrolytes that ionizes to a small extent or ionizer incompletely in its solution form is said to be weak electrolytes, for example HCN, CH_3COOH, NH_4OH, $H_2C_2O_4$, H_2CO_3, CH_3NH_2, HF, C_6H_5OH, C_6H_7N.

① Ionization of weak acid

$$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

$$H_2S \rightleftharpoons H^+ + HS^- \qquad K_a = \frac{[H^+][HS^-]}{[H_2S]}$$

$$HS^- \rightleftharpoons H^+ + S^- \qquad K_a = \frac{[H^+][S^-]}{[HS^-]}$$

$$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$$

$$K_a = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$$

$$HCN + H_2O \rightleftharpoons H_3O^+ + CN^-$$

$$K_a = \frac{[H_3O^+][CN^-]}{[HCN]}$$

2-Ionization of Weak Base

$$A + H_2O_{(L)} \rightleftharpoons OH^-_{(aq)} + HA^+ \qquad K_b = \frac{[OH^-][HA^+]}{[A]}$$

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^- \qquad K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

3-Solubility and Solubility product.

A saturated solution is one containing the maximum amount of solute soluble in the solvent under equilibrium conditions.

Solubility :- The amount of a substance that can be dissolved in a given amount of solvent.

Expression of Solubility product (K_{sp})

$$M_mA_a \rightleftharpoons mM + aA$$

The solubility-product expression then takes the form

$$K_{sp} = [M]^m[A]^a$$

K_{sp} = Solubility product Constant
M and A are molar solubility of ions

$$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)} \qquad K_{sp} = [Ag^+][Cl^-]$$

$$Ba(IO_3)_{2(s)} \rightleftharpoons Ba^{+2} + 2IO_3^- \qquad K_{sp} = [Ba^{+2}][IO_3^-]^2$$

Solubility Product:- It is defined as the product of the concentrations of the ions of the salt in its saturated solution at a given temperature raised to the power of the ions produced by the dissociation of one mole of the salt.

Application of Solubility

The concept product of K_{sp} helps in predicting the formation of precipitate. In general if

Ionic product (I.P) $>$ K_{sp} precipitate is formed

Ionic product (I.P) $<$ K_{sp} precipitate is not formed

Ionic product (I.P) $=$ K_{sp} saturated solution

Factors that affect Solubility of precipitates.

There are several factors can effect the Solubility like

1- Temperature effect
2- Common-Ion effect
3- Nature of solvent effect
4- Nature of precipitates
5- Complex formation effect
6- Ph effect.

Question (1)

The solubility product of silver chloride in water is about 1×10^{-10}. Calculate the formal solubility of salt.

Since the solution contains one silver ion for every chloride ion, the molar concentration of these two ions are identical and equal the formal solubility of the salt.

$$[Ag^+] = [Cl^-] = S$$

$$AgCl_{(s)} \rightleftharpoons Ag^{+1}_{(aq)} + Cl^-_{(aq)}$$

$$K_{sp} = [Ag^+][Cl^-] \rightarrow 1 \times 10^{-10} = S^2 \rightarrow S = 10^{-5}$$

Question (2)

Calculate the formal solubility of silver chromate Ag_2CrO_4 when its solubility product has the value 2×10^{-2}

$$Ag_2CrO_4 \rightleftharpoons \underset{2S}{2Ag^+} + \underset{S}{CrO_4^=}$$

$$[CrO_4^=] = S$$

$$[Ag^+] = 2[CrO_4^=] = 2S$$

$$K_{sp} = [Ag^+]^2[CrO_4^=]$$

$$K_{sp} = (2S)^2(S) \rightarrow 2 \times 10^{-12} = 4S^3$$

$$S^3 = \frac{2 \times 10^{-12}}{4} \rightarrow S = 8 \times 10^{-5} \text{ mol/L}$$

The Solubility in gram per liter is molar solubility multiplied by molecular weigh as shown

$$\text{Solubility (g/L)} = \text{Solubility (mol/L)} \times \text{m.wt (g/mol)}$$

$$\text{Solubility (mol/L)} = \frac{\text{Solubility (g/L)}}{\text{m.wt (g/mol)}}$$

Question (3)

The solubility of AB_2 salt (105) is 0.4 g per 1.000ml
Calculate the solubility constant.

$$\text{Solubility}\left(\frac{\text{mol}}{L}\right) = \frac{0.4\ g/L}{105\ g/mol} = 3.8 \times 10^{-3}\ mol/L$$

$$AB_2 \rightleftharpoons A + 2B$$

$$S \quad 2S$$

$$K_{sp} = [A][B]^2 \rightarrow K_{sp} = (S)(2S)^2 \rightarrow$$

$$K_{sp} = 4S^3 \rightarrow K_{sp} = 4(3.8 \times 10^{-3})^3 \Rightarrow K_{sp} = 2.2 \times 10^{-7}$$

Question (4)

The solubility of AB_2 salt (100) is 0.6 g per 100ml
Calculate the solubility constant. (Homework)