Problems-2

(Acid-Base, Solubility & pH

<u>Problem 1</u>. The solubility product of $CuCl_2$ is 3.2×10^{-7} at 25^0C. Calculate the solubility of $CuCl_2$ in mole $litre^{-1}$.

- $CuCl_2$ is a sparingly soluble salt.
- Let x is the solubility of $CuCl_2$ in mole $litre^{-1}$
- The following equilibrium exists in its saturated solution:
- $CuCl_2 \leftrightarrow Cu^{+2} + 2Cl^-$
- *Equilibrium concentration*, x x 2x
- Therefore, solubility product, $K_{sp} = [Cu^{+2}]\,[Cl^-]^2$ *
- or, $3.2 \times 10^{-7} = [x]\,[2x]^2$
- or, $4x^3 = 3.2 \times 10^{-7}$
- $\therefore$ $x = 4.3 \times 10^{-3}$ mole $litre^{-1}$
- * ***As per laws of rate equation***

<u>Ans</u>

Problem 3. K_{sp} of CaF_2 is 1.7×10^{-10} and its mol. wt. is 78 g $mole^{-1}$. What volume of the saturated solution will contain 0.078 g of CaF_2?

- CaF_2 is a sparingly soluble salt.
- Let x is the solubility of CaF_2 in mole $litre^{-1}$
- The following equilibrium exists in its saturated solution:
- $$CaF_2 \leftrightarrow Ca^{+2} + 2F^-$$
- *Equilibrium concentration*, x x 2x
- Therefore, solubility product, $K_{sp} = [Ca^{+2}]\,[F^-]^2$
- or, $1.7 \times 10^{-10} = [x]\,[2x]^2$
- or, $4x^3 = 1.7 \times 10^{-10}$
- $\therefore$ $x = 3.5 \times 10^{-4}$ mole $litre^{-1}$
- $\therefore$ 1 litre saturated solution contains 3.5×10^{-4} mole of CaF_2

……Problem-3 (contd.)

- No. moles of CaF_2 = 0.078g / (78g/mole)
- = 1.0×10^{-3} moles
- $\therefore$ Volume of the solution = $\dfrac{1\,litre \times 1.0 \times 10^{-3}\ mole}{3.5 \times 10^{-4}\ mole}$
- = 2.857 litre
- Thus, 0.078 g of CaF2 is contained in 2.9 litres of the saturated solution. Ans

Problem 5. Calculate the solubility of AgCl ($K_{sp} = 1.7 \times 10^{-10}$) in 0.01 M NaCl solution.

- $AgCl \leftrightarrow Ag^+ + Cl^-$ $\quad\quad$ $NaCl \leftrightarrow Na^+ + Cl^-$

  equilib. conc. $\quad$ x $\quad$ x $\quad$ x $\quad\quad$ 0.01 $\quad$ 0.01 $\quad$ 0.01M
- Complete ionization of the salt in aqueous solution is assumed. Therefore, total concentration of Cl^- in the solution =
- 0.01 M (from NaCl) + x M (from AgCl)
- As AgCl is sparingly soluble, x is negligibly small.
- $\therefore [Cl^-] \cong 0.01$ M
- $\therefore K_{sp} = [Ag^+] [Cl^-]$
- *or,* $1.7 \times 10^{-10} = (x)(0.01)$ M
- or, $x = 1.7 \times 10^{-8}$ M
- $\therefore$ The solubility of AgCl in 0.01M NaCl solution is 1.7×10^{-8} M Ans

Problem 7. K_{sp} of $Mg(OH)_2$ is 1.8×10^{-11} at 25^0C. Calculate the solubility of $Mg(OH)_2$ in 0.1 M aqueous NaOH solution.

- $Mg(OH)_2 \leftrightarrow Mg^{+2} + 2OH^-$ $NaOH \leftrightarrow Na^+ + OH^-$
  equilib. conc.   x   x   2x   0.1   0.1   0.1M
- Complete ionization of the salt in aqueous solution is assumed. Therefore, total concentration of OH^- in the solution =
- 0.1 M (from NaOH) + 2x M (from $Mg(OH)_2$)
- As $Mg(OH)_2$ is sparingly soluble, x is negligibly small.
- $\therefore [OH^-] = (0.1 + 2x)M \cong 0.1$ M
- $\therefore K_{sp} = [Mg^{+2}] [OH^-]^2$
- *or,* $1.8 \times 10^{-11} = (x)(0.1)^2$ M
- or, $x = 1.8 \times 10^{-9}$ M
- $\therefore$ The solubility of $Mg(OH)_2$ in 0.1M NaOH solution is 1.8×10^{-9}M

Ans

Problem 9. Calculate pH and pOH of 0.02 M H_2SO_4 solution. $K_w = 1 \times 10^{-14}$ at 25^0C.

- $H_2SO_4 \leftrightarrow 2H^+ + SO_4^-$
- ***equilib. conc.*** 1M 2M 1M

$(2H_3O^+)$

If H_2SO_4 in 1M solution ionizes completely, $[H_3O^+]$ will be 2M.

- Therefore, in a 0.02 M H_2SO_4 solution
- $[H_3O^+] = 0.04$ M
- $\therefore [OH^-] = K_w / [H_3O^+] = (1 \times 10^{-14})/ 0.04 = 2.5 \times 10^{-13}$ M
- $\therefore pH = -\log [H_3O^+] = -\log (0.04) = 1.40$
- $\therefore pOH = -\log [OH^-] = -\log (2.5 \times 10^{-13}) = 12.60$ Ans.

Problem 11. pH of an aqueous solution of HCl is 2.699 at 25^{0}C. Calculate the molarity of the solution.

- We know from the definition of pH,

$$\text{pH} = \boxed{-\log_{10}[H^+] = \log_{10}\frac{1}{[H^+]}}$$

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- $\therefore$ 2.699 = -log [H_3O^+]
- or, [H_3O^+] = antilog (- 2.699) = 0.002 M
- As HCl is a strong acid, it will ionize completely in the aqueous solution. So the molarity of HCl in the solution will be equal to the concentration of H_3O^+.
- $\therefore$ Molarity of HCl in the solution is 0.002. Ans.

<u>Problem 13</u>. Calculation of normality of strong acids, (a) 36% (w/w) HCl, specific gravity 1.18; (b) 96% (w/w) H_2SO_4, specific gravity 1.84.

- (a) Given, 36% (w/w) HCl, specific gravity 1.18
- Mol. Wt. of HCl = 36.5, gram-equiv-wt = 36.5
- ∴ 1 ml conc. HCl contains = 0.36 × 1.18 gm of HCl
- ∴ 1000 ml conc. HCl contains = 0.36 × 1.18 × 1000
- = 424.8 gm of HCl

- ∴ 36.5 gm of HCl in 1000ml solution = 1.0 N HCl
- ∴ 424.8 gm HCl in 1000ml = (1 x 424.8 gm) / 36.5 gm
  - = 11.64 N HCl <u>Ans.</u>

…..Problem-13 (contd.)

- (b) Given, 96% (w/w) $\mathbf{H_2SO_4}$, specific gravity 1.84
- Mol. Wt. of $\mathbf{H_2SO_4}$ = 98, gram-equiv-wt = 49
- ∴ 1 ml conc. $\mathbf{H_2SO_4}$, contains = 0.96 × 1.84 gm of $\mathbf{H_2SO_4}$,
- ∴ 1000 ml conc. $\mathbf{H_2SO_4}$, contains = 0.96 × 1.84 × 1000
- = 1766.4 gm of $\mathbf{H_2SO_4}$,
- ∴ 49 gm of $\mathbf{H_2SO_4}$, in 1000ml solution = 1.0 N $\mathbf{H_2SO_4}$,
- ∴ 1766.4 gm $\mathbf{H_2SO_4}$, in 1000ml = (1 x 1766.4 gm) / 49 gm
  - = 36.05 N $\mathbf{H_2SO_4}$, <u>Ans.</u>