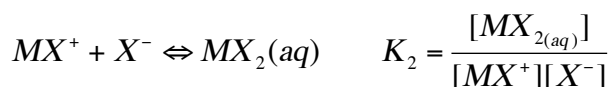


### CHEM 201 Self Quiz - 3 (Equilibrium calculations)

1. Write a charge balance for a solution containing  $H^+$ ,  $OH^-$ ,  $Ca^{2+}$ ,  $HCO_3^-$ ,  $CO_3^{2-}$ ,  $Ca(HCO_3)^+$ ,  $Ca(OH)^+$ ,  $K^+$ ,  $ClO_4^-$ .

$$\begin{aligned} [H^+] + 2[Ca^{2+}] + [Ca(HCO_3)^+] + [Ca(OH)^+] + [K^+] &= \\ &= [OH^-] + [HCO_3^-] + 2[CO_3^{2-}] + [ClO_4^-] \end{aligned}$$

2. Considering the equilibria below, derive an equation relating  $[M^{2+}]$ ,  $K_1$  and  $K_2$  when 0.10 mol of  $MX_2$  is dissolved in 1 L of water.



$$[MX^+] = K_1[M^{2+}][X^-]$$

$$[MX_{2(aq)}] = K_2[MX^+][X^-] = K_2K_1[M^{2+}][X^-]^2$$

**Mass balance equation:**

$$\begin{aligned} MX_2 = \frac{0.10 \text{ mol}}{1 \text{ L}} = 0.10 \text{ M} &= [MX_{2(aq)}] + [MX^+] + [M^{2+}] = \\ &= K_2K_1[M^{2+}][X^-]^2 + K_1[M^{2+}][X^-] + [M^{2+}] \end{aligned}$$

**Charge balance equation:**

$$2[M^{2+}] + [MX^+] = [X^-]$$

By substituting of  $[M^{2+}]$  and  $[MX^+]$  we have an expression for the  $[X^-]$

$$2[M^{2+}] + K_1[M^{2+}][X^-] = [X^-]$$

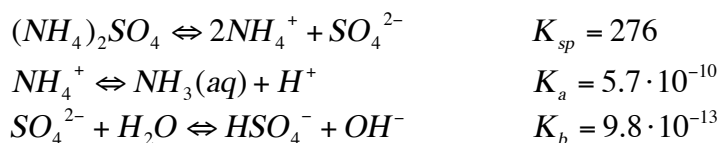
By solving this equation for  $[X^-]$ , we have:

$$[X^-] = \frac{2[M^{2+}]}{1 - K_1[M^{2+}]}$$

Now we put expression for  $[X^-]$  into the mass balance equation:

$$0.10 \text{ M} = K_2K_1[M^{2+}] \left( \frac{2[M^{2+}]}{1 - K_1[M^{2+}]} \right)^2 + K_1[M^{2+}] \frac{2[M^{2+}]}{1 - K_1[M^{2+}]} + [M^{2+}]$$

3. When ammonium sulfate dissolves, both the anion and cation have acid-base reactions:



- a. write a charge balance for this system

$$[NH_4^+] + [H^+] = 2 [SO_4^{2-}] + [HSO_4^-] + [OH^-]$$

- b. write a mass balance for this system

$$[NH_3] + [NH_4^+] = 2 \{ [SO_4^{2-}] + [HSO_4^-] \}$$

- c. find the concentration of the  $NH_3(aq)$  if the pH is 9.25

$$[H^+] = 10^{-9.25} \text{ and } [OH^-] = 10^{-4.75}$$

$$\frac{[NH_3][H^+]}{[NH_4^+]} = 5.7 \cdot 10^{-10} = \frac{[NH_3] \cdot 10^{-9.25}}{[NH_4^+]} \Rightarrow \frac{[NH_3]}{[NH_4^+]} = 10^{-0.75} = 1.014$$

Therefore,

$$[NH_3] = 1.014 [NH_4^+]$$

From another hand,

$$\frac{[HSO_4^-][OH^-]}{[SO_4^{2-}]} = 9.8 \cdot 10^{-13} = \frac{[HSO_4^-] 10^{-4.75}}{[SO_4^{2-}]} \Rightarrow \frac{[HSO_4^-]}{[SO_4^{2-}]} = 9.8 \cdot 10^{-8.25} = 5.51 \cdot 10^{-8}$$

Therefore,

$$[HSO_4^-] = 5.51 \cdot 10^{-8} [SO_4^{2-}]$$

Putting these values of  $[NH_3]$  and  $[HSO_4^-]$  into the mass balance gives:

$$1.014 \cdot [NH_4^+] + [NH_4^+] = 2 \left( [SO_4^{2-}] + 5.51 \cdot 10^{-8} [SO_4^{2-}] \right)$$

$$1.007 \cdot [NH_4^+] = [SO_4^{2-}]$$

Now an expression for the  $K_{sp}$  is used:

$$K_{sp} = [NH_4^+]^2 [SO_4^{2-}] = 1.007 [NH_4^+]^3 \Rightarrow [NH_4^+] = \sqrt[3]{\frac{276}{1.007}} = 6.5M$$

$$[NH_3] = 1.014 [NH_4^+] = 1.014 \cdot 6.5 = 6.59M$$