Week 6 Problem Set - Acid Base Equlibrium Problem

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$M := \frac{mole}{liter}$

1.For a 0.1 M solution of HCl calculate the equlibrium concentration of

a.H_3O^{1+}

b.Cl^{1-}

c.OH^{1-}

Given the initial concentration of HCl:

$$C_{HCl} := 0.1 \cdot M$$

Since HCl is a strong acid, it undergoes complete dissociation by the reaction:

$$HCl + H_2O \text{ --> } H_3O^{1+} + Cl^{1-}$$

$C_{H3O} := C_{HCl}$ $\qquad$ $C_{H3O} = 0.1 \cdot M$

$C_{Cl} := C_{HCl}$ $\qquad$ $C_{Cl} = 0.1 \cdot M$

The concentration of OH^{1-} is determined by the equlibrium reaction:

$$2\ H_2O \text{ <--> } H_3O^{1+} + OH^{1-}$$

$$K_w := 1.0 \cdot 10^{-14} \cdot M^2$$

$$K_w = C_{H3O} \cdot C_{OH}$$

$$C_{OH} := \frac{K_w}{C_{H3O}}$$

$$C_{OH} = 1 \cdot 10^{-13} \cdot M$$

2.For a 0.1 M solution of KOH calculate the equlibrium concentration of

a.K^{1+}

c.OH^{1-}

Given the initial concentration of KOH:

$$C_{KOH} := 0.1 \cdot M$$

Since KOH is a strong base, it undergoes complete dissociation by the reaction:

KOH --> K^{1+} + OH^{1-}

$C_K := C_{KOH}$ $\qquad$ $C_K = 0.1 \cdot M$

$C_{OH} := C_{KOH}$ $\qquad$ $C_{OH} = 0.1 \cdot M$

3.For a 0.1 M solution of acetic acid (K_a = 1.8*10^{-5}) calculate the equlibrium concentration of

a.CH_3COOH

b.CH_3COO^{1-}

c.H_3O^{1+}

Given the initial concentration of acetic acid:

$$C_{CH3COOH} := 0.1 \cdot M$$

The acetic acid is in equlibrium with acetate ion in the following reaction

$$CH_3COOH + H_2O \;\; \texttt{<-->} \;\; CH_3COO^{1-} + H_3O^{1+}$$

The equlibrium expression for this is:

$$K_A = \frac{C_{CH3COO} \cdot C_{H3O}}{C_{CH3COOH}}$$

At equlibrium the concentration of each of these is:

$$C_{CH3COOH\_eq} = C_{CH3COOH} - X$$

$$C_{CH3COO\_eq} = X$$

$$C_{H3O\_eq} = X$$

$$K_a = \frac{X \cdot X}{C_{CH3COOH} - X}$$

$$1.8 \cdot 10^{-5} \cdot M = \frac{X^2}{0.1 \cdot M - X}$$

$$X := \begin{pmatrix} -.0013506709730779748818 \cdot M \\ .0013326709730779748818 \cdot M \end{pmatrix}$$

The two possible roots for X, Solved using the quadratic. Only one of these roots gives a possible solution below.

$$C_{CH3COOH\_eq} := \left(C_{CH3COOH} - X\right) \qquad C_{CH3COOH\_eq} = \begin{pmatrix} 0.101 \\ 0.099 \end{pmatrix} \cdot M$$

$$C_{CH3COO\_eq} := X \qquad C_{CH3COO\_eq} = \begin{pmatrix} -1.351 \times 10^{-3} \\ 1.333 \times 10^{-3} \end{pmatrix} \cdot M$$

$$C_{H3O\_eq} := X \qquad C_{H3O\_eq} = \begin{pmatrix} -1.351 \times 10^{-3} \\ 1.333 \times 10^{-3} \end{pmatrix} \cdot M$$

4.For a 0.1 M solution of Ammonia (K_b = 1.78*10^{-5}) calculate the equlibrium concentration of

a.NH_3

b.NH_4^{1+}

c.OH^{1-}

Given the initial concentration of ammonia:

$$C_{NH3} := 0.1 \cdot M$$

The ammonia is in equlibrium with ammonium ion in the following reaction

$$NH_3 + H_2O \; \text{<-->} \; NH_4^{1+} + HO^{1-}$$

The equlibrium expression for this is:

$$K_B = \frac{C_{NH4} \cdot C_{OH}}{C_{NH3}}$$

At equlibrium the concentration of each of these is:

$$C_{NH3\_eq} = C_{NH3} - X$$

$$C_{NH4\_eq} = X$$

$$C_{OH\_eq} = X$$

$$K_b = \frac{X \cdot X}{C_{NH3} - X}$$

$$1.78 \cdot 10^{-5} \cdot M = \frac{X^2}{0.1 \cdot M - X}$$

$$X := \begin{pmatrix} -.0013430960912849355219 \cdot M \\ .0013252960912849355219 \cdot M \end{pmatrix}$$

The two possible roots for X, Solved using the quadratic. Only one of these roots gives a possible solution below.

$$C_{NH3\_eq} := (C_{NH3} - X) \qquad C_{NH3\_eq} = \begin{pmatrix} 0.101 \\ 0.099 \end{pmatrix} \cdot M$$

$$C_{NH4\_eq} := X \qquad C_{NH4\_eq} = \begin{pmatrix} -1.343 \times 10^{-3} \\ 1.325 \times 10^{-3} \end{pmatrix} \cdot M$$

$$C_{OH\_eq} := X \qquad C_{OH\_eq} = \begin{pmatrix} -1.343 \times 10^{-3} \\ 1.325 \times 10^{-3} \end{pmatrix} \cdot M$$