

Chemistry 146 Lecture Problems

Ammonium Chloride Equilibrium

Calculate the H₃O⁺, OH⁻, acid, base pH and pOH when 1.00 g ammonium chloride is added to 250 mL water.

$$M := \text{mole} \cdot \text{liter}^{-1} \quad K_w := 1.0 \cdot 10^{-14} \cdot \text{M}^2 \quad K_b := 1.8 \cdot 10^{-5} \cdot \text{M}$$

$$K_a := \frac{K_w}{K_b} \quad K_a = 5.556 \cdot 10^{-10} \cdot \text{M} \quad i := 0, 1, \dots, 1$$

The concentration of the salt is):

$$\text{mass}_{\text{salt}} := 1.00 \cdot \text{gm}$$

$$\text{MW}_{\text{salt}} := ((14.007) + (4 \cdot 1.0079) + (35.45)) \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{salt}} := \frac{\text{mass}_{\text{salt}}}{\text{MW}_{\text{salt}}} \quad \text{mole}_{\text{salt}} = 0.019 \text{ mol}$$

$$\text{volume}_{\text{salt}} := 250 \cdot \text{mL}$$

$$C_{\text{salt}} := \frac{\text{mole}_{\text{salt}}}{\text{volume}_{\text{salt}}}$$

$$C_{\text{salt}} = 0.075 \cdot \text{M}$$

The equilibrium solution for	AH	+	H ₂ O	<->	H ₃ O	+	A ⁻
Initial Concentraion	C _{salt}						
Equilibrium Concentration	C _{salt} - X				X		X

Equilibrium expression:

$$K_a = \frac{X^2}{C_{\text{salt}} - X}$$

Assuming X is smaller than [acid], this reduces to:

$$K_a = \frac{X^2}{C_{\text{salt}}}$$

Solving for X:

$$X := \sqrt{K_a \cdot C_{\text{salt}}}$$

$$X = 6.4456 \cdot 10^{-6} \cdot \text{M}$$

Equilibrium Concentrations:

$$\begin{array}{ll}
 C_{\text{HA}} := X & C_{\text{HA}} = 6.446 \cdot 10^{-6} \text{ M} \\
 C_{\text{OH}} := X & C_{\text{OH}} = 6.446 \cdot 10^{-6} \text{ M} \\
 C_{\text{A}} := C_{\text{salt}} - X & C_{\text{A}} = 0.075 \text{ M} \\
 \text{pOH} := -\log(C_{\text{OH}} \cdot \text{M}^{-1}) & \text{pOH} = 5.191 \\
 \text{pH} := 14 - \text{pOH} & \text{pH} = 8.809
 \end{array}$$

Solving for X without assumptions:

$$K_a = \frac{X^2}{C_{\text{salt}} - X}$$

$$X := \left[\begin{array}{l} \frac{-1}{2} \cdot K_a + \frac{1}{2} \cdot \sqrt{K_a^2 + 4 \cdot K_a \cdot C_{\text{salt}}} \\ \frac{-1}{2} \cdot K_a - \frac{1}{2} \cdot \sqrt{K_a^2 + 4 \cdot K_a \cdot C_{\text{salt}}} \end{array} \right]$$

$$X = \left[\begin{array}{l} 6.4453 \cdot 10^{-6} \\ -6.4459 \cdot 10^{-6} \end{array} \right] \text{ M}$$

Equilibrium Concentrations (Calculated for both roots, select the reasonable answer [top or bottom in ()]):

$$\begin{array}{ll}
 C_{\text{A}} := X & C_{\text{HA}} = 6.446 \cdot 10^{-6} \text{ M} \\
 C_{\text{H}_3\text{O}} := X & C_{\text{H}_3\text{O}} = \left[\begin{array}{l} 6.445 \cdot 10^{-6} \\ -6.446 \cdot 10^{-6} \end{array} \right] \text{ M} \\
 C_{\text{HA}} := C_{\text{salt}} - X & C_{\text{A}} = \left[\begin{array}{l} 6.445 \cdot 10^{-6} \\ -6.446 \cdot 10^{-6} \end{array} \right] \text{ M} \\
 \text{pH}_i := -\log(C_{\text{H}_3\text{O}_i} \cdot \text{M}^{-1}) & \text{pH} = \left[\begin{array}{l} 5.191 \\ 5.191 - 1.364i \end{array} \right] \\
 \text{pOH} := 14 - \text{pH} & \text{pOH} = \left[\begin{array}{l} 8.809 \\ 8.809 + 1.364i \end{array} \right]
 \end{array}$$