

# Chemistry 146 Lecture Problems

## Nitrous Acid Equilibrium

Calculate the H<sub>3</sub>O<sup>+</sup>, OH<sup>-</sup>, acid, base pH and pOH when 1.00 g nitrous acid added to 250 mL water

$$M := \text{mole} \cdot \text{liter}^{-1} \quad K_w := 1.0 \cdot 10^{-14} \cdot M^2 \quad K_a := 4.5 \cdot 10^{-4} \cdot M \quad i := 0, 1.. 1$$

The concentration of the acid is

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

$$\text{MW}_{\text{acid}} := ((1 \cdot 1.0079) + (14.007) + (2 \cdot 15.999)) \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{acid}} := \frac{\text{mass}_{\text{acid}}}{\text{MW}_{\text{acid}}} \quad \text{MW}_{\text{acid}} = 47.013 \frac{\text{gm}}{\text{mol}}$$

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

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

$$C_{\text{acid}} = 0.085 \cdot M$$

|                              |                       |   |                  |     |                               |   |                |
|------------------------------|-----------------------|---|------------------|-----|-------------------------------|---|----------------|
| The equilibrium solution for | HA                    | + | H <sub>2</sub> O | <-> | H <sub>3</sub> O <sup>+</sup> | + | A <sup>-</sup> |
| Initial Concentraion         | $C_{\text{acid}}$     |   |                  |     |                               |   |                |
| Equilibrium Concentration    | $C_{\text{acid}} - X$ |   |                  |     | X                             |   | X              |

Equilibrium expression:

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

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

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

Solving for X:

$$X := \sqrt{K_a \cdot C_{\text{acid}}} \quad X = 6.1877 \cdot 10^{-3} \cdot M$$

Equilibrium Concentrations:

$$\begin{array}{ll}
 C_{\text{HA}} := C_{\text{acid}} - X & C_{\text{HA}} = 0.079 \text{eM} \\
 C_{\text{H3O}} := X & C_{\text{H3O}} = 6.188 \cdot 10^{-3} \text{eM} \\
 C_{\text{A}} := X & C_{\text{A}} = 6.188 \cdot 10^{-3} \text{eM} \\
 \text{pH} := -\log(C_{\text{H3O}} \cdot \text{M}^{-1}) & \text{pH} = 2.208 \\
 \text{pOH} := 14 - \text{pH} & \text{pOH} = 11.792
 \end{array}$$

Solving for X without assumptions:

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

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

$$X = \left[ \begin{array}{l} 5.9668 \cdot 10^{-3} \\ -6.4168 \cdot 10^{-3} \end{array} \right] \text{eM}$$

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

$$\begin{array}{ll}
 C_{\text{HA}} := C_{\text{acid}} - X & C_{\text{HA}} = \left[ \begin{array}{l} 0.079 \\ 0.091 \end{array} \right] \text{eM} \\
 C_{\text{H3O}} := X & C_{\text{H3O}} = \left[ \begin{array}{l} 5.967 \cdot 10^{-3} \\ -6.417 \cdot 10^{-3} \end{array} \right] \text{eM} \\
 C_{\text{A}} := X & C_{\text{A}} = \left[ \begin{array}{l} 5.967 \cdot 10^{-3} \\ -6.417 \cdot 10^{-3} \end{array} \right] \text{eM} \\
 i := 0, 1.. 1 & \\
 \text{pH}_i := -\log(C_{\text{H3O}}_i \cdot \text{M}^{-1}) & \text{pH} = \left[ \begin{array}{l} 2.224 \\ 2.193 - 1.364i \end{array} \right] \\
 \text{pOH} := 14 - \text{pH} & \text{pOH} = \left[ \begin{array}{l} 11.776 \\ 11.807 + 1.364i \end{array} \right]
 \end{array}$$