Calculating the pH of an acid from its concentration

1. Determine whether the acid is strong or weak. If it is a strong acid, \([\text{Acid}] = [\text{H}_3\text{O}^+]\). Skip to step 6. If it is weak, write the equation for the dissociation and continue to step 2.

2. Create a table for initial and equilibrium concentrations using initial weak acid concentration and the variable \(x\).

3. Write the expression for the \(K_a\) of the acid, and look up the \(K_a\) value for the acid from the table.

4. Substitute equilibrium concentrations into the \(K_a\) expression and set equal to the value of \(K_a\).

5. Solve for \(x\) and, assuming that \(x\) is negligible compared to the initial concentration, perform a successive approximation. To do this, start with \(x = 0\) and use the result obtained from that approximation for a second approximation. Continue in this manner until the same value is obtained twice. \(x = [\text{H}_3\text{O}^+]\)

6. Use \([\text{H}_3\text{O}^+]\) to determine pH \((\text{pH} = -\log[\text{H}_3\text{O}^+])\).

Example: Using the Strategy

What is the pH of a solution of 0.150 M \(\text{NH}_4\text{Cl}\)?

1. Ammonium chloride is an ionic compound that undergoes dissociation to produce \(\text{NH}_4^+\) and \(\text{Cl}^-\). \(\text{Cl}^-\) has no acid/base properties, but \(\text{NH}_4^+\) is a weak acid that undergoes dissociation in the following manner:

\[
\text{NH}_4^+ (\text{aq}) + \text{H}_2\text{O} (l) \rightleftharpoons \text{NH}_3 (\text{aq}) + \text{H}_3\text{O}^+ (\text{aq})
\]

2. \(\begin{array}{c|c}
\text{Initial} & \text{Equilibrium} \\
\hline
[\text{NH}_4^+] & 0.150 \\
[\text{NH}_3] & 0 \\
[\text{H}_3\text{O}^+] & 0 \\
\end{array}\)

3. \(K_a = [\text{NH}_3][\text{H}_3\text{O}^+]/[\text{NH}_4^+]\), \(K_a (\text{NH}_4^+) = 5.6 \times 10^{-10}\)

4. \((x)(x)/(0.150 - x) = 5.6 \times 10^{-10}\)

5. \(x = \sqrt{5.6 \times 10^{-10}(0.150 - x)}\)
   \((1) x = 0, x = \sqrt{5.6 \times 10^{-10}(0.150 - 0)} = 9.2 \times 10^{-6}\)
   \((2) x = 9.2 \times 10^{-6}, x = \sqrt{5.6 \times 10^{-10}(0.150 - 9.2 \times 10^{-6})} = 9.2 \times 10^{-6} \text{ (same answer)}\)

6. \(x = [\text{H}_3\text{O}^+] = 9.2 \times 10^{-6} \text{ M}\)

6. \(\text{pH} = -\log(9.2 \times 10^{-6}) = 5.04\)