The worksheets are available in the tutorials and form an integral part of the learning outcomes and experience for this unit.

**Model 1: pH**

1. \[ \begin{array}{ccccccccc}
\text{pH} & 0.50 & 1.50 & 2.50 & 3.50 & 4.50 & 5.50 & 5.75 \\
[H_3O^+(aq)] & 3.2 \times 10^{-1} & 3.2 \times 10^{-2} & 3.2 \times 10^{-3} & 3.2 \times 10^{-4} & 3.2 \times 10^{-5} & 3.2 \times 10^{-6} & 1.8 \times 10^{-6} \\
\end{array} \]

2. The part of the pH value after the decimal point affects the coefficient (i.e. the numerical value).

3. The part of the pH value before the decimal point affects the exponent (i.e. the position of the decimal point).

**Model 2: Strong and Weak Acids**

1. The major species present are H_3O^+(aq), Cl^-(aq) and H_2O(l). There is essentially no “HCl(aq)”.

2. The major species present are CH_3COOH(aq) and H_2O(l). The percentage ionization is very small and there is very little H_3O^+(aq), CH_3COO^-(aq).

3. CH_3COO^-(aq) is the dominant species only at high pH.

4. \[
\text{CH}_3\text{COOH(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{CH}_3\text{COO}^-(aq) \]
   \[
   K_a = \frac{[\text{H}_3\text{O}^+(aq)][\text{CH}_3\text{COO}^-(aq)]}{[\text{CH}_3\text{COOH(aq)}]} \]

5. The major species present are CH_3NH_2(aq) and H_2O(l).

6. CH_3NH_3^+(aq) is the dominant species only at low pH.

7. (a) Aspirin is absorbed in the stomach. In the intestine, it is deprotonated.

   (b) Amphetamine is absorbed in the intestine. In the stomach, it is protonated.

8. See below.

   \[
   \begin{array}{cccccccccccc}
   \text{pH} & 0 & 2 & 4 & 6 & 8 & 10 & 12 & 14 \\
   [\text{CH}_3\text{COO}^-(aq)] \times 10^n & 1.74 & 1.74 & 1.74 & 1.74 & 1.74 & 1.74 & 1.74 & 1.74 \\
   [\text{CH}_3\text{COOH(aq)}] \times 10^n & 10^5 & 10^3 & 10^1 & 10^{-1} & 10^{-3} & 10^{-5} & 10^{-7} & 10^{-9} \\
   \end{array} \]

9. See below.

10. \[
[\text{CH}_3\text{COOH(aq)}] = [\text{CH}_3\text{COO}^-(aq)] \text{ where the two lines cross: } \text{pH} = 4.76 = pK_a. \]
Model 3: A Solution Containing a Weak Acid

1. \([\text{CH}_3\text{COOH(aq)}]_{\text{initial}} = 2.0 \text{ M and } [\text{CH}_3\text{COOH(aq)}]_{\text{equilibrium}} = 2.0 - x\).
The small \(x\) approximation corresponds to the approximation:

\[
\text{CH}_3\text{COOH(aq)}]_{\text{equilibrium}} = [\text{CH}_3\text{COOH(aq)}]_{\text{initial}}
\]

2. \(x = \sqrt{K_a \times [\text{HA}]_{\text{initial}}} \quad \text{or} \quad \text{pH} = -\log_{10}(\sqrt{K_a \times [\text{HA}]_{\text{initial}}})\)

3. (a) pH = 2.229, % dissociation = 0.30  
   (b) pH = 2.380, % dissociation = 0.42  
   (c) pH = 2.531, % dissociation = 0.59  
   (d) pH = 2.681, % dissociation = 0.83

4. See below.

The major species present \(\text{H}_2\text{O(l)}\) and \(\text{CH}_3\text{COOH(aq)}\). The amount of dissociation is very small (< 1%) and so the amount of \(\text{CH}_3\text{COO}^-\text{(aq)}\) and \(\text{H}_3\text{O}^+\text{(aq)}\) is tiny.

5. The degree of dissociation increases as the weak acid is diluted, even though the amount of dissociated acid decreases.

6. (a) \(\text{CH}_3\text{COOH(aq)}\) and \(\text{H}_2\text{O(l)}\)  
   (b) \(\text{CH}_3\text{NH}_2\text{(aq)}\) and \(\text{H}_2\text{O(l)}\)

7. \(\text{CH}_3\text{COO}^-\text{(aq)}, \text{CH}_3\text{NH}_2^+\text{(aq)}\) and \(\text{H}_2\text{O(l)}\)

8. \(K = K_a(\text{CH}_3\text{COOH}) / K_a(\text{CH}_3\text{NH}_2) = 10^{-4.76} / 10^{-10.64} = 10^{5.88}\). It is very large.

9. The reaction between a weak acid and a weak base proceeds essentially to completion.

10. \(\text{\textsuperscript{+}NH}_3\text{CH}_2\text{COO}^-\text{(aq)}\) and \(\text{H}_2\text{O(l)}\).

11. See below.

\[
\text{\textsuperscript{+}NH}_3\text{CH}_2\text{COOH(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{\textsuperscript{+}NH}_3\text{CH}_2\text{COO}^-\text{(aq)} + \text{H}_3\text{O}^+(aq) \quad \text{pK}_a = 2.34
\]

\[
\text{\textsuperscript{+}NH}_3\text{CH}_2\text{COO}^-\text{(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{NH}_2\text{CH}_2\text{COO}^-\text{(aq)} + \text{H}_3\text{O}^+(aq) \quad \text{pK}_a = 9.60
\]

In the first step, \(\text{\textsuperscript{+}NH}_3\text{CH}_2\text{COOH(aq)}\) is the acid and \(\text{\textsuperscript{+}NH}_3\text{CH}_2\text{COO}^-\text{(aq)}\) is its conjugate base.

In the second step, \(\text{\textsuperscript{+}NH}_3\text{CH}_2\text{COO}^-\text{(aq)}\) is the acid and \(\text{NH}_2\text{CH}_2\text{COO}^-\text{(aq)}\) is its conjugate base.