**B rønsted-Løwry Definition of Acids**

**Acid:** A substance that donates a proton (H⁺) to another substance.

\[
\text{HNO}_3(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{NO}_3^-(\text{aq})
\]

\[
\text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{NH}_3(\text{aq}) \rightleftharpoons \text{NH}_4^+ + \text{CH}_3\text{CO}_2^- \text{(aq)}
\]

**B rønsted-Løwry Definition of Bases**

**Base:** A substance that accepts a proton from another substance.

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

\[
(\text{CH}_3)_2\text{NH}(\text{aq}) + \text{HClO}_3(\text{aq}) \rightleftharpoons (\text{CH}_3)_2\text{NH}^+(\text{aq}) + \text{ClO}_3^-(\text{aq})
\]

\[
\text{KOH}(\text{aq}) \rightarrow \text{K}^+(\text{aq}) + \text{OH}^-(\text{aq})
\]

*KOH is still a base by this definition – it produces OH⁻, which is an excellent proton acceptor.*

**B rønsted-Løwry Acids and Bases**

- **A**) Hydrochloric acid
- **B**) Ammonia

**Weak Acid-Base Dissociations: Equilibrium Processes**

- Weak acids and bases only partially dissociate in water.
- The equilibrium constant for the dissociation of an acid in water is known as the acid dissociation constant, Kₐ.
- Consider a generic acid, HA:
  \[
  \text{HA}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{A}^-(\text{aq})
  \]
  \[
  K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]}
  \]
- Why doesn’t water appear in the reaction quotient?
- Would the reaction quotient change if the reaction were expressed as: HA(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{A}^-(\text{aq})

**Weak Acid-Base Dissociations: Equilibrium Processes**

- The equilibrium constant for the reaction of a weak base with water is known as the base ionization constant, Kₐ.
- Consider the generic base, B:
  \[
  \text{B}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{BH}^+(\text{aq}) + \text{OH}^-(\text{aq})
  \]
  \[
  K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}
  \]

**Acid Dissociation**

- Acetic acid, \text{CH}_3\text{CO}_2\text{H}, only partially dissociates in water.
- It dissociates in a reactant-favored equilibrium (small K).
- [\text{H}_3\text{O}^+] < [\text{CH}_3\text{CO}_2\text{H}]

\[
\text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_2\text{O}^+(\text{aq}) + \text{CH}_3\text{CO}_2^-(\text{aq})
\]

\[
K_a = \frac{[\text{CH}_3\text{CO}_2^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CO}_2\text{H}]} = 1.8 \times 10^{-5}
\]
**Base Ionization**
- Methylamine, CH₃NH₂, only partially ionizes water.
- It ionizes water in a reactant favored equilibrium.
- $[\text{OH}^-]_{\text{eq}} < [\text{CH}_3\text{NH}_3^+]_{\text{eq}}$

$$\text{CH}_3\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(l) \rightleftharpoons \text{CH}_3\text{NH}_3^+ + \text{OH}_-$$

$$K_b = \frac{[\text{CH}_3\text{NH}_3^+][\text{OH}^-]}{[\text{CH}_3\text{NH}_2]} = 4.4 \times 10^{-4}$$

---

**Dissociation of HCN**
- Because the pH of a solution is not directly calculated from the concentration of the acid, we must analyze the equilibrium to determine the pH.
- Consider the dissociation of HCN:
  $$\text{HCN} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CN}^-$$
- Write the reaction quotient expression for $K_a$ and look up the value.
- What is the [H⁺] concentration and pH of a 0.50 M solution of HCN?

---

**HCN (continued)**
- We will need to consider the equilibrium condition.
- $K_a = 6.2 \times 10^{-10}$ (very small relative to 0.5 M)

<table>
<thead>
<tr>
<th></th>
<th>HCN</th>
<th>H₂O</th>
<th>H₃O⁺</th>
<th>CN⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial</td>
<td>0.50</td>
<td>N/A</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>change</td>
<td>- x</td>
<td>N/A</td>
<td>+ x</td>
<td>+ x</td>
</tr>
<tr>
<td>equilib.</td>
<td>0.50 - x</td>
<td>N/A</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

---

**Dissociation of Acetic Acid**
- What is the pH of a 0.50 M solution of acetic acid, CH₃CO₂H?
- What is the percent of the original CH₃CO₂H (0.50 M) dissociated?
- What would be the % dissociation of a 2.0 M acetic acid solution?
- What would be the % dissociation of a 0.010 M acetic acid solution?
- What is the percent dissociation of a strong acid like HCl at 2.0 M? At 0.50 M? At 0.010 M?

---

**Dissociation of NH₃**
- What is the [OH⁻] and the pH for a solution that is 0.75 M in NH₃?

<table>
<thead>
<tr>
<th></th>
<th>NH₃</th>
<th>H₂O</th>
<th>OH⁻</th>
<th>NH₄⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial</td>
<td>0.75</td>
<td>N/A</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>change</td>
<td>- x</td>
<td>N/A</td>
<td>+ x</td>
<td>+ x</td>
</tr>
<tr>
<td>equilib.</td>
<td>0.75 - x</td>
<td>N/A</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

---

**Hydroxylamine**
- Hydroxylamine (HONH₂) is a weak base with a base ionization constant of $1.0 \times 10^{-5}$. What is the pH of a 0.10 M solution of hydroxylamine?
Brensted-Lowry Acid-Base Definition: Review

An acid is a proton donor, any species which donates an $\text{H}^+$. An acid reactant will produce a base product and the two will constitute an acid-base conjugate pair.

A base is a proton acceptor, any species which accepts an $\text{H}^+$. An acid-base reaction can be viewed from the standpoint of the reactants AND the products.

Identifying Conjugate Acid-Base Pairs

- Identify the species acting as the acids and those acting as the bases in the forward and reverse reactions represented by the following equations:

  \[
  \begin{align*}
  \text{HClO}_2 & \quad + \quad \text{NH}_3 & \Leftrightarrow & \quad \text{NH}_4^+ & \quad + \quad \text{ClO}_2^- \\
  \text{HONH}_2 & \quad + \quad \text{CH}_3\text{CO}_2\text{H} & \Leftrightarrow & \quad \text{HONH}_3^+ & \quad + \quad \text{CH}_3\text{CO}_2^- \\
  \text{CO}_3^{2-} & \quad + \quad \text{H}_2\text{O} & \Leftrightarrow & \quad \text{HCO}_3^- & \quad + \quad \text{H}_3\text{O}^+
  \end{align*}
  \]

- What is the conjugate acid of $\text{OH}^-$?

Conjugate Pairs in Some Acid-Base Reactions

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Acid</th>
<th>Base</th>
<th>Acid</th>
<th>Base</th>
<th>Conjugate Pair</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HF</td>
<td>$\text{H}_2\text{O}$</td>
<td>$\text{F}^-$</td>
<td>$\text{H}_3\text{O}^+$</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>$\text{HCOOH}$</td>
<td>$\text{CN}^-$</td>
<td>$\text{HCOO}^-$</td>
<td>$\text{HCN}$</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>$\text{NH}_4^+$</td>
<td>$\text{CO}_3^{2-}$</td>
<td>$\text{NH}_3$</td>
<td>$\text{HCO}_3^-$</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>$\text{H}_3\text{PO}_4^-$</td>
<td>$\text{OH}^-$</td>
<td>$\text{HPO}_4^{2-}$</td>
<td>$\text{H}_2\text{O}$</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>$\text{H}_2\text{SO}_4$</td>
<td>$\text{N}_2\text{H}_5^+$</td>
<td>$\text{HSO}_4^-$</td>
<td>$\text{N}_2\text{H}_6^{2+}$</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>$\text{HPO}_4^{2-}$</td>
<td>$\text{SO}_3^{2-}$</td>
<td>$\text{PO}_4^{3-}$</td>
<td>$\text{HSO}_3^-$</td>
<td></td>
</tr>
</tbody>
</table>

Identifying Conjugate Acid-Base Pairs

- Based on the relative strengths of the acids for the forward & reverse reactions, you can predict whether an acid-base reaction will be product-favored or reactant-favored.

- Consider: $\text{CH}_3\text{CO}_2\text{H} + \text{NH}_3 \Leftrightarrow \text{NH}_4^+ + \text{CH}_3\text{CO}_2^-$.

  - Because acetic acid is a stronger acid than the ammonium ion, we would predict this reaction to be product-favored.

Predicting the Net Direction of an Acid-Base Reaction

- Predict whether the following reactions are reactant-favored or product-favored:

  \[
  \begin{align*}
  \text{HCN} & \quad + \quad \text{F}^- & \Leftrightarrow & \quad \text{HF} & \quad + \quad \text{CN}^- \\
  \text{CO}_3^{2-} & \quad + \quad \text{H}_2\text{PO}_4^- & \Leftrightarrow & \quad \text{HCO}_3^- & \quad + \quad \text{HPO}_4^{2-}
  \end{align*}
  \]
Conjugate Acid / Base Pairs and $K_a / K_b$ Relationships

To be presented in class as overhead notes.

Conjugate acid/base pairs
- A **weak acid** will have a **weak** conjugate base.

Consider the HCN / CN$^-$ conjugate pair:

\[
\begin{align*}
HCN + H_2O & \rightleftharpoons H_3O^+ + CN^- \\
K_a &= 6.2 \times 10^{-10}
\end{align*}
\]

\[
\begin{align*}
CN^- + H_2O & \rightleftharpoons OH^- + HCN \\
K_a &= \frac{K_w}{K_b} = \frac{1 \times 10^{-14}}{6.2 \times 10^{-10}} = 1.6 \times 10^{-5}
\end{align*}
\]

Conjugate acid/base pairs
- A **strong acid** will have a **very weak** conjugate base.

Consider the HNO$_3$ / NO$_3^-$ conjugate pair:

\[
\begin{align*}
HNO_3 + H_2O & \rightarrow H_3O^+ + NO_3^- \\
K_a &>> 1 \text{ (cannot be measured in water)}.
\end{align*}
\]

\[
\begin{align*}
NO_3^- + H_2O & \rightleftharpoons OH^- + HNO_3 \\
K_b &<< 1 \text{ (cannot be measured in water)}
\end{align*}
\]

Conjugate acid/base pairs
- A **strong base** will have a **very weak** conjugate acid.

Consider the NaOH / Na$^+$ conjugate pair:

\[
\begin{align*}
NaOH & \rightarrow Na^+ + OH^- \\
K &>> 1 \text{ (100% ionization)}
\end{align*}
\]

\[
\begin{align*}
Na^+ + H_2O & \rightleftharpoons NaOH + H^+ \\
K_b &<< 1 \text{ (does not occur)}
\end{align*}
\]

Acid/Base Properties of Salts
- Soluble ionic salts produce may produce neutral, acidic, or basic solutions depending on the acid-base properties of the individual ions.

Consider the salt sodium nitrate, NaNO$_3$. It dissociates into sodium and nitrate ions.

- Sodium nitrate produces a neutral solution because neither sodium nor nitrate reacts with water.

\[
\begin{align*}
Na^+ + H_2O & \not\leftrightarrow NaOH + H^+ \\
NO_3^- + H_2O & \not\leftrightarrow OH^- + HNO_3
\end{align*}
\]