Arrhenius Acid
Definition

• An *acid* is a substance that generates hydronium ions, $\text{H}_3\text{O}^+$ (often described as $\text{H}^+$), when added to water.

• An *acidic solution* is a solution with a significant concentration of $\text{H}_3\text{O}^+$ ions.
When HCl dissolves in water, hydronium ions, $\text{H}_3\text{O}^+$, and chloride ions, $\text{Cl}^-$, ions form.

This proton, $\text{H}^+$, is transferred to a water molecule.

$\text{HCl}(g) + \text{H}_2\text{O}(l) \rightarrow \text{Cl}^-(aq) + \text{H}_3\text{O}^+(aq)$
Solution of a Strong Acid

Hydronium ions, $\text{H}_3\text{O}^+$, surrounded by the negatively charged oxygen ends of water molecules.

Chloride ions, $\text{Cl}^-$, surrounded by the positively charged hydrogen ends of water molecules.
Acetic acid reacts with water in a reversible reaction, which forms hydronium and acetate ions.

\[
\text{HC}_2\text{H}_3\text{O}_2(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{C}_2\text{H}_3\text{O}_2^- (aq) + \text{H}_3\text{O}^+(aq)
\]

This proton, \( \text{H}^+ \), is transferred to a water molecule. Indicates a reversible reaction. This proton, \( \text{H}^+ \), may be transferred back to the acetate ion.
Solution of Weak Acid

In a typical acetic acid solution, there are about 250 times as many uncharged acetic acid molecules, $\text{HC}_2\text{H}_3\text{O}_2$, as acetate ions, $\text{C}_2\text{H}_3\text{O}_2^-$. 

Hydronium ions, $\text{H}_3\text{O}^+$, surrounded by the negatively charged oxygen ends of water molecules.

Acetate ion, $\text{C}_2\text{H}_3\text{O}_2^-$, surrounded by the positively charged hydrogen ends of water molecules.
Strong and Weak Acids

- **Weak Acid** = due to a reversible reaction with water, generates significantly less than one $\text{H}_3\text{O}^+$ for each molecule of acid added to water.

- **Strong Acid** = due to a completion reaction with water, generates close to one $\text{H}_3\text{O}^+$ for each acid molecule added to water.
Strong and Weak Acids

For every 250 molecules of the weak acid acetic acid, $\text{HC}_2\text{H}_3\text{O}_2$, added to water, there are about

$$\text{HC}_2\text{H}_3\text{O}_2(\text{aq}) + \text{H}_2\text{O}(l) \rightleftharpoons \text{C}_2\text{H}_3\text{O}_2^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$$

249 uncharged acetic acid molecules

For every 250 molecules of the strong acid hydrochloric acid, $\text{HCl}$, added to water, there are about

$$\text{HCl(g)} + \text{H}_2\text{O}(l) \rightarrow \text{Cl}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$$

Zero uncharged HCl molecules

250 chloride ions
250 hydronium ions
• There is an animation on the textbook’s website that will give you a better understanding of weak and strong acids.

https://preparatorychemistry.com/acids_Canvas.html
H$_2$SO$_4$(aq) + H$_2$O(l) → H$_3$O$^+$ (aq) + HSO$_4^-$ (aq)

HSO$_4^-$ (aq) + H$_2$O(l) ⇌ H$_3$O$^+$ (aq) + SO$_4^{2-}$ (aq)
## Acid Summary

<table>
<thead>
<tr>
<th></th>
<th>Strong</th>
<th>Weak</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Binary acid</strong></td>
<td>hydrochloric acid, HCl(aq)</td>
<td>Hydrofluoric acid, HF(aq)</td>
</tr>
<tr>
<td><strong>Oxyacid</strong></td>
<td>nitric acid, HNO₃</td>
<td>other acids with HₐXₐOₐ</td>
</tr>
<tr>
<td></td>
<td>sulfuric acid, H₂SO₄</td>
<td></td>
</tr>
<tr>
<td><strong>Organic acid</strong></td>
<td>none</td>
<td>acetic acid, HC₂H₃O₂</td>
</tr>
</tbody>
</table>
• A **base** is a substance that generates OH$^-$ when added to water.

• A **basic** solution is a solution with a significant concentration of OH$^-$ ions.
• Bases have a bitter taste.
• Bases feel slippery on your fingers.
• Bases turn litmus from red to blue.
• Bases react with acids.
Strong Bases

- **Strong Base** = due to a completion reaction with water, generates close to one (or more) OH\(^-\) for each formula unit of base added to water.

  - Metal hydroxides are strong bases.
    
    \[
    \begin{align*}
    \text{NaOH}(s) & \rightarrow \text{Na}^+(aq) + \text{OH}^-(aq) \\
    \text{LiOH}(s) & \rightarrow \text{Li}^+(aq) + \text{OH}^-(aq) \\
    \text{KOH}(s) & \rightarrow \text{K}^+(aq) + \text{OH}^-(aq)
    \end{align*}
    \]
Ammonia and Water

Ammonia reacts with water in a reversible reaction, which forms ammonium and hydroxide ions.

This proton, $H^+$, is transferred to an ammonia molecule.

Indicates a reversible reaction

This proton, $H^+$, may be transferred back to the hydroxide ion.

$$\text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)$$
Ammonia Solution

In a typical ammonia solution, there are about 200 times as many uncharged ammonia molecules, $\text{NH}_3$, as ammonium ions $\text{NH}_4^+$.  

Ammonium ion, $\text{NH}_4^+$, surrounded by the negatively charged oxygen ends of water molecules.

Hydroxide ion, $\text{OH}^-$, surrounded by the positively charged hydrogen ends of water molecules.
• **Weak Base** = due to a reversible reaction with water, generates significantly less than one OH\(^{-}\) for each formula unit of base added to water.

  – Ammonia and ionic compounds that contain CO\(_3^{2-}\) or HCO\(_3^{-}\) are weak bases.

\[
\text{Na}_2\text{CO}_3(s) \rightarrow 2\text{Na}^+(aq) + \text{CO}_3^{2-}(aq)
\]
\[
\text{CO}_3^{2-}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HCO}_3^{-}(aq) + \text{OH}^{-}(aq)
\]

\[
\text{NaHCO}_3(s) \rightarrow \text{Na}^+(aq) + \text{HCO}_3^{-}(aq)
\]
\[
\text{HCO}_3^{-}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_2\text{CO}_3(aq) + \text{OH}^{-}(aq)
\]
<table>
<thead>
<tr>
<th></th>
<th>Strong</th>
<th>Weak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionic Compounds</td>
<td>Metal hydroxides</td>
<td>Ionic compounds with $\text{CO}_3^{2-}$ and $\text{HCO}_3^-$</td>
</tr>
<tr>
<td>Certain Uncharged</td>
<td>None</td>
<td>NH$_3$</td>
</tr>
<tr>
<td>molecules</td>
<td></td>
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</tr>
</tbody>
</table>
• There is a tool on the textbook’s website that will allow you to practice identifying whether substances are acids or bases, and if they are, whether they are strong or weak. A link to this tool is below.

https://preparatorychemistry.com/Bishop_acid_base_Canvas.html