Read Section 7.1, 7.2, and 7.3 before viewing the slide show.
Unit 25
Acids and Bases (Chapter 7)

• Properties of Acids and Bases (7.1)
• Theories of Acids and Bases (7.2)
  • Arrhenius Theory
  • Brønsted-Lowry Theory
• Salts (7.2)
• Acidic and Basic Anhydrides (7.3)
• Neutralization Reactions (7.5)
There are some key distinctions between acids and bases in terms of their properties.

<table>
<thead>
<tr>
<th>Acids</th>
<th>Bases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause litmus paper to turn red</td>
<td>Cause litmus paper to turn blue</td>
</tr>
<tr>
<td>Taste sour</td>
<td>Taste bitter</td>
</tr>
<tr>
<td>Dissolves active metals producing hydrogen gas</td>
<td>Feels slippery on the skin</td>
</tr>
<tr>
<td>React with bases to form water and salts</td>
<td>React with acids to form water and salts</td>
</tr>
</tbody>
</table>

To see the reaction of the metals with acids, go to the link: [http://www.chemeddl.org/resources/ptl/](http://www.chemeddl.org/resources/ptl/) and click on a metal like sodium (Na). Click on the Media tab to the left and choose Reactions with Acids. You will see the reaction type referred to in the table above. (If you click on the Reactions with Bases you will see the same sort of reaction, but it is a little deceptive. It is reacting with the water in the basic solution.)
Theories of Acids and Bases (7.2)

• Arrhenius Theory of Acids and Bases:
  • Svante Arrhenius proposed the first successful theory of acids and bases in 1887. The theory states that acids are materials that ionize to produce hydrogen ions (H\(^+\), sometimes called protons) in water. Along a similar vein, bases produce hydroxide ions (OH\(^-\)) in water.

  • According to Arrhenius, the properties associated with acids are due to the hydrogen ion in water and properties associated with bases are due to the hydroxide ion.

  • Acids are typically recognizable because the formulas will be written with the acidic hydrogen first. Examples: HCl, HBr, HNO\(_3\), H\(_2\)SO\(_4\), HC\(_2\)H\(_3\)O\(_2\)

  • Bases are typically recognizable because of the hydroxide ion in the formula, though some are a little harder to recognize.
    • Examples of simple bases: NaOH, LiOH, Ba(OH)\(_2\)
    • Example of a "trickier" base: NH\(_3\) (It reacts with water to produce hydroxide ions.)

  • Arrhenius also recognized that acids and bases react together to form water and compounds called salts. From an acid standpoint, a salt is a compound (not a base) where the hydrogen ion has been replaced by some other cation. Examples:

    • NaCl, Ba(NO\(_3\))\(_2\), AlBr\(_3\), etc.
Theories of Acids and Bases cont. (7.2)

- Drawbacks to the Arrhenius theory:

  - It applies only to aqueous reactions.

  - The H⁺ does not exist as such in water. It is such a high region of positive charge that it is surrounded by water molecules. Sometimes this “surrounding” is represented as H₃O⁺, fundamentally a water molecule with an H⁺. This species is called a hydronium ion.

  - The Arrhenius theory does not explain well compounds that do not contain OH⁻ but still cause basic behavior, such as NH₃.
Two investigators – J.N. Brønsted (Denmark) and T. M. Lowry (Great Britain) – simultaneously proposed an alternative acid-base theory in 1923. The key ideas behind the theory are:

- An acid is a proton donor
- A base is a proton acceptor

The Brønsted-Lowry theory, as it is known, does not depend on the solvent or even the presence of a solvent – it can be applied in the gas phase as well.

In general terms, the reactions of acids (HA) and bases (B) in the Brønsted-Lowry theory may be written in aqueous solution as:

Acid: Donates $\text{H}^+$

$$\text{HA} (\text{aq}) + \text{H}_2\text{O} (\ell) \rightarrow \text{A}^- (\text{aq}) + \text{H}_3\text{O}^+ (\text{aq})$$

Base: Accepts $\text{H}^+$

$$\text{B} (\text{aq}) + \text{H}_2\text{O} (\ell) \rightarrow \text{HB}^+ (\text{aq}) + \text{OH}^- (\text{aq})$$
Examples of Brønsted-Lowry Theory (7.2)

• Consider the following examples of acids according to the Brønsted-Lowry theory:

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

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

\[ \text{H}_2\text{SO}_4\text{ (aq)} + 2\text{H}_2\text{O (ℓ)} \rightarrow \text{SO}_4^{2-}\text{ (aq)} + 2\text{H}_3\text{O}^+\text{ (aq)} \]

• Consider the following example of the base NH\textsubscript{3} according to the Brønsted-Lowry theory:

\[ \text{NH}_3\text{ (aq)} + \text{H}_2\text{O (ℓ)} \rightarrow \text{NH}_4^+\text{ (aq)} + \text{OH}^-\text{ (aq)} \]
The reaction between an acid and a base is called a neutralization reaction. The products of a neutralization reaction are water and a compound called a salt. Examples:

\[
\begin{align*}
\text{HCl (aq)} & \quad + \quad \text{NaOH (aq)} \quad \rightarrow \quad \text{NaCl (aq)} & \quad + \quad \text{H}_2\text{O (ℓ)} \\
\text{H}_2\text{SO}_4 (aq) & \quad + \quad \text{KOH (aq)} \quad \rightarrow \quad \text{K}_2\text{SO}_4 (aq) & \quad + \quad \text{H}_2\text{O (ℓ)} \\
2 \text{HC}_2\text{H}_3\text{O}_2 (aq) & \quad + \quad \text{Ba(OH)_2 (aq)} \quad \rightarrow \quad \text{Ba(C}_2\text{H}_3\text{O}_2)_2 (aq) & \quad + \quad 2 \text{H}_2\text{O (ℓ)}
\end{align*}
\]
• **Nonmetal oxides** tend to react with water to form acidic solutions. Nonmetal oxides that react in this fashion are called acidic anhydrides.

• Recall that a nonmetal is to the right of the stair-step line on the periodic chart.

Examples of reactions of acidic anhydrides with water:

\[
\text{SO}_3 \ (g) \ + \ H_2O \ (l) \ \rightarrow \ H_2SO_4 \ (aq)
\]

\[
\text{CO}_2 \ (g) \ + \ H_2O \ (l) \ \rightarrow \ H_2CO_3 \ (aq)
\]

• **Metal oxides** tend to react with water to form basic solutions. Metal oxides that react in this fashion are called basic anhydrides.

• Examples of reactions of basic anhydrides with water:

\[
2 \text{NaO} \ (s) \ + \ H_2O \ (l) \ \rightarrow \ 2 \text{NaOH} \ (aq)
\]

\[
\text{BaO} \ (s) \ + \ H_2O \ (l) \ \rightarrow \ \text{Ba(OH)}_2 \ (aq)
\]