CHAPTER 9

7.1 Acids and Bases: Experimental Definitions

Acids are compounds that:

1. Taste sour.
2. Cause a prickling or stinging sensation.
3. Cause litmus (a dye) to turn red.
4. Dissolve active metals, forming hydrogen gas.
5. Neutralize bases, forming salts.

Bases are compounds that:

1. Taste bitter.
2. Feel slippery.
3. Cause litmus to turn blue.
4. Neutralize acids, forming salts.

Acids release H^+ ions in aqueous solutions, while **bases** release OH^- ions in aqueous solution. The H^+ and OH^- ions react to form water (H_2O) during neutralization, with the remaining positive ion from the base and the negative ion from the acid combining to form a salt.

The H^+ ion is a proton without electrons. The H^+ ion actually attaches itself to a water molecule to form a **hydronium** ion:

$$H^+ \quad + \quad H_2O \quad \rightarrow \quad H_3O^+$$

For convenience, lazy chemists use the H^+ notation quite often rather than the more cumbersome H_3O^+.

The Brønsted-Lowry acid-base theory is more general. In the Brønsted-Lowry theory, an acid is a proton donor and a base is a proton acceptor. For example, hydrochloric acid is a proton donor while water is a proton acceptor:

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

The Brønsted-Lowry theory also explains why ammonia, which contains no OH^- ions, is a base:

$$NH_3 + H_2O \Leftrightarrow NH_4^+ + OH^-$$

Ammonia, NH_3, accepts a proton from water, thus generating a hydroxide ion. Therefore, by the Brønsted-Lowry theory, water is acting as an acid (donating a proton) in the above equation, while NH_3 is acting as a base by accepting that proton. In the reverse equation, NH_4^+ is acting as an acid, that is, donating a proton to OH^-, which by accepting that proton is acting as a base.

In Brønsted-Lowry terminology, NH_4^+ is the **conjugate acid** of NH_3, and NH_3 is the **conjugate base** of NH_4^+. Water, H_2O, is the conjugate acid of OH^-, and OH^- is the conjugate base of water. Conjugate acids differ from their conjugate bases by just one proton.

9.2 Strong and Weak Acids

Strong acids ionize in water nearly completely:

$$HCl \xrightarrow{H_2O} H^+ + Cl^-$$

Weak acids ionize in water very little:

$$HCN \underset{0.0025\%}{\rightleftharpoons} H^+ + CN^-$$

Notice the use of the double arrow in the case of the weak acid, indicating that the reaction is reversible.

Acids which release one H^+ per molecule are called **monoprotic**. If an acid releases two H^+ ions it is called **diprotic**, etc. **Polyprotic** acids release more than one H^+ ion per molecule.

Notice that the mineral acids (those which do not contain carbon) listed in Table 9.1 on page 228 begin with hydrogen atoms. Organic acids (those containing carbon) often end with those hydrogen atoms which will ionize.

9.3 Names of Some Common Acids

Acids containing no oxygen atoms are named as follows:

*hydro*_____*ic acid*

For example: HCl is hydrochloric acid.

Acids containing oxygen use names based on their corresponding polyatomic ions.

"ate" polyatomic ions become "ic" acids
"ite" polyatomic ions become "ous" acids

For example: SO_4^{2-} is sulfate, so H_2SO_4 is sulfuric acid. Likewise, SO_3^{2-} is sulfite, so H_2SO_3 is sulfurous acid.

9.4 Some Common Bases

Strong bases ionize in water nearly completely:

$$NaOH \xrightarrow{H_2O} Na^+ + OH^-$$

Strong bases include all Group 1A and 2A hydroxides, except for $Mg(OH)_2$. (See Table 9.3, page 232.)

Weak bases, such as $Mg(OH)_2$ are only slightly ionized:

$$Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2\ OH^-$$

Other weak bases include ammonia (NH_3) and organic (carbon containing) amines. These compounds are bases because they are proton acceptors.

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

$$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$$

9.5 Acidic and Basic Anhydrides

The word anhydride means "without water." So an **acidic anhydride** is an acid with water removed and a **basic anhydride** is a base with water removed. If we were to add water to an acidic anhydride the resulting solution would be an acid. If we were to add water to a basic anhydride the resulting solution would be an base.

Nonmetal oxides are acidic anhydrides.

$$CO_2 + H_2O \rightarrow H_2CO_3 \text{ (Carbonic acid)}$$

Metal oxides are basic anhydrides.

$$MgO + H_2O \rightarrow Mg(OH)_2$$

9.5 Neutralization

Neutralization occurs when an acid reacts with a base. The properties of the acid and base are lost. The products of neutralization are a salt and water:

$$\text{acid} + \text{base} \rightarrow \text{salt} + \text{water}$$

The positive ion from the base combines with the negative ion from the acid to form the salt. The hydrogen ion from the acid combines with the hydroxide ion from the base to form water.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

$$H_2SO_4 + 2\ NH_4OH \rightarrow (NH_4)_2SO_4 + 2\ H_2O$$

$$Mg(OH)_2 + 2\ HNO_3 \rightarrow Mg(NO_3)_2 + 2\ H_2O$$

The above are complete formula equations or molecular equations. If we were to cancel out the spectator ions in each of the above equations, the following net ionic equation would result:

$$H^+ + OH^- \rightarrow H_2O$$

9.7 Reactions of Acids with Carbonates and Bicarbonates

Carbonic acid (H_2CO_3) is unstable and tends to decompose:

$$H_2CO_3 \rightarrow H_2O + CO_2$$

Carbonic acid exists only in aqueous solution and not as a pure compound. Carbonic acid is formed by reaction of bicarbonates or carbonates with acid:

$$NaHCO_3 + HCl \rightarrow NaCl + \underset{\downarrow}{H_2CO_3}$$
$$H_2O + CO_2$$

$$Na_2CO_3 + 2\ HCl \rightarrow 2\ NaCl + \underset{\downarrow}{H_2CO_3}$$
$$H_2O + CO_2$$

9.8 Acids, Bases and Human Health

Rainwater does not have a pH of 7 as you might expect, but is around 5.6, due to dissolved carbon dioxide. The dissolved carbon dioxide forms carbonic acid, a weak acid.

Some by-products of combustion and industry include the gaseous oxides of sulfur and nitrogen. When these gaseous pollutants combine with rainwater, they form acidic solutions with pH's below 5.6.

Many people have "heartburn," a burning sensation due to the acidic contents of their stomachs "refluxing" into their esophaguses. Antacids are weak bases which may be taken internally that neutralize the acids in the esophagus and stomach and relieve the pain of heartburn.

People with heart conditions should avoid any antacid containing sodium ions. Baking soda ($NaHCO_3$) causes alkalosis, a condition where the blood becomes too basic. Antacids containing magnesium ions may also act as laxatives. Antacids containing aluminum ions and calcium ions can cause constipation.