4.10: Acids, Bases and Salts

Other than binary molecular compounds, most inorganic compounds can be classified as acids, bases, or salts. These three categories of compounds and their names are addressed briefly here.

Acids

Acids are characterized by the H^+ ion, the presence of which in water, makes the water **acidic**. An acid either contains this ion or produces it when it dissolves in water. Sulfuric acid, H_2SO_4, is an example of a compound that contains H^+ ion. Dissolved in water, a molecule of sulfuric acid exists as 2 H^+ ions and 1 SO_4^{2-} ion. An example of a compound that is classified as acidic because it *produces* H^+ ion when it dissolves in water is carbon dioxide, which undergoes the following reaction in water solution:

$$CO_2 + H_2O \rightarrow H^+ + HCO_3^- \tag{4.10.1}$$

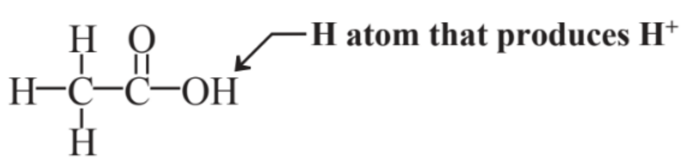
In this case, only a small fraction of the CO_2 molecules dissolved in water undergo the above reaction to produce H^+ so water solutions of CO_2 are **weakly acidic** and carbon dioxide is classified as a **weak acid**. It is the presence of dissolved CO_2 from the carbon dioxide naturally present in air that makes rainfall coming from even nonpolluted atmospheres slightly acidic and, as discussed in Chapter 9, the weakly acidic properties of CO_2 are very important in natural waters in the environment. Other acids, such as hydrochloric acid, HCl, are completely dissociated to H^+ and an anion (in the case of HCl the Cl^- anion) when they are dissolved in water; such acids are **strong acids.**

The naming of acids follows certain rules. In the case of an acid that contains only H and one other element, the acid is a hydro-ic acid. So HCl is called *hydro*chlor*ic* acid. Somewhat different rules apply when an acid contains oxygen. Some elements form acids in which the anion has different amounts of oxygen; examples are H_2SO_4 and H_2SO_3. The acid with more oxygen is an “-ic” acid, so H_2SO_4 is sulfuric acid. The acid with the lesser amount of oxygen is an “-ous” acid, so H_2SO_3 is sulfurous acid. A greater amount of oxygen than even the “-ic” acid is denoted by the prefix “per-”, and a lesser amount of oxygen than even the “-ous” acid is denoted by the prefix “hypo-”. These names are shown very well by the names of the oxyacids of chlorine. So the names of $HClO_4$, $HClO_3$, $HClO_2$, and HClO are, respectively, perchloric acid, chloric acid, chlorous acid and hypochlorous acid.

Acids are extremely important as industrial chemicals, in the environment, and in respect to green chemistry. About 40 million metric tons (40 billion kilograms) of sulfuric acid are produced in the United States each year. It is the number 1 synthetic chemical, largely because of its application to treat phosphate minerals to make phosphate crop fertilizers. Sulfuric acid is also used in large quantities to remove corrosion from steel, a process called steel pickling. Other major uses include detergent synthesis, petroleum refining, lead storage battery manufacture, and alcohol synthesis. About 7-8 million tons of nitric acid, HNO_3, are produced in the U.S. each year giving it a rank of 10th, and hydrochloric acid ranks about 25th with annual production around 3 million metric tons.

Acids are important in the environment. Improperly disposed acid has caused major problems around hazardous waste sites. Sulfuric acid along with smaller quantities of hydrochloric and nitric acid are the major constituents of acid rain (see Chapter 10). Acids figure prominently in the practice of green chemistry. Reclamation and recycling of acids are commonly performed in the practice of industrial ecology. As noted earlier, much of the sulfuric acid now manufactured uses a potential waste and pollutant, hydrogen sulfide, H_2S, removed from sour natural gas sources as a source of sulfur.

In cases where a relatively weak acid can be used, acetic acid made by the fermentation of carbohydrates is an excellent green alternative to stronger acids, such as sulfuric acid. Yeasts can convert the carbohydrates to ethanol (ethyl alcohol, which is present in alcoholic beverages) and other microorganisms in the presence of air convert the ethanol to acetic acid by the same process that vinegar, a dilute solution of acetic acid, is made from cider or wine. The structural formula of acetic acid is



in which only one of the 4 H atoms is ionizable to produce H+ion. The production of acetic acid is a green process that uses biological reactions acting upon renewable biomass raw materials. As a weak acid, acetic acid is relatively safe to use, and contact with humans is not usually very dangerous (we ingest dilute acetic acid as vinegar, but pure acetic acid attacks flesh and is used to remove warts from skin). Another advantage of acetic acid is that it is biodegradable, so any of it released to the environment does not persist.

Bases

A **base** either contains hydroxide ion, OH^-, or reacts with water to produce hydroxide. Most bases that contain hydroxide consist of metal cations and hydroxide; examples are sodium hydroxide, NaOH, and calcium hydroxide, $Ca(OH)_2$. The most common basic substance that produces hydroxide in water is ammonia, NH_3, which reacts with water as follows:

$$NH_3 + H_2O \rightarrow NH_4^+ + OH^- \tag{4.10.2}$$

Only a small fraction of the ammonia molecules undergo this reaction in water, so ammonia does not produce much OH-in water and is known as a **weak base**. The metal hydroxides, such as KOH, that completely dissociate in water are **strong bases**. Metal hydroxides are named by the metal followed by "hydroxide." Therefore, $Mg(OH)_2$ is magnesium hydroxide.

Salts

Acids and bases react to form a **salt**, an ionic compound that has a cation other than H+and an anion other than OH^-. This kind of reaction always produces water and is known as a **neutralization reaction**. The most well known salt is sodium chloride, NaCl. Although it is commonly what one means in referring to "salt," there are many other salts as well. These include calcium chloride, $CaCl_2$, used to melt road ice, sodium carbonate, Na_2CO_3, used in cleaning formulations and potassium chloride, KCl, a source of potassium fertilizer for crops. A typical neutralization reaction is the one between NaOH and hydrochloric acid, HCl, to produce sodium chloride:

$$\underbrace{NaOH}_{\text{Base}} + \underbrace{HCl}_{\text{acid}} \rightarrow \underbrace{NaCl}_{\text{a salt, sodium chloride}} + \underbrace{H_2O}_{\text{water}} \tag{4.10.3}$$

Salts are named very simply with just the name of the cation followed by that of the anion. The charges of the ions determine the formulas of the salts, so it is not necessary to add prefixes to denote the relative numbers of each ion. Therefore, $CaCl_2$ is simply calcium chloride, not calcium dichloride. As noted earlier in this chapter, prefixes are added in names of salts that contain more than 1 kind of cation or more than 1 kind of anion to show the relative numbers of ions. As an example, KH_2PO_4 is called potassium dihydrogen phosphate.

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