Strength of Conjugate Acids and Bases

The extent of the reaction between a Brønsted-Lowry acid and base depends on the relative strengths of the acids and bases involved. Consider the following example. Hydrochloric acid is a strong acid. It gives up protons readily. Therefore, the Cl^- ion has little tendency to attract and retain a proton. Consequently, the Cl^- ion is an extremely weak base.

$$\underset{\text{strong acid}}{HCl(g)} + \underset{\text{base}}{H_2O(l)} \longrightarrow \underset{\text{acid}}{H_3O^+(aq)} + \underset{\text{weak base}}{Cl^-(aq)}$$

This observation leads to an important conclusion: *the stronger an acid is, the weaker its conjugate base; the stronger a base is, the weaker its conjugate acid.*

This concept allows strengths of different acids and bases to be compared to predict the outcome of a reaction. As an example, consider the reaction of perchloric acid, $HClO_4$, and water.

$$\underset{\text{stronger acid}}{HClO_4(aq)} + \underset{\text{stronger base}}{H_2O(l)} \longrightarrow \underset{\text{weaker acid}}{H_3O^+(aq)} + \underset{\text{weaker base}}{ClO_4^-(aq)}$$

The hydronium ion is too weak an acid to compete successfully with perchloric acid in donating a proton; $HClO_4$ is the stronger acid. In this reaction, the perchlorate ion, ClO_4^-, and H_2O are both bases. Because $HClO_4$ is a very strong acid, ClO_4^- is an extremely weak base. Therefore, H_2O competes more strongly than ClO_4^- to acquire a proton. The reaction proceeds such that the stronger acid reacts with the stronger base to produce the weaker acid and base.

Now consider a comparable reaction between water and acetic acid.

$$\underset{\text{weaker acid}}{CH_3COOH(aq)} + \underset{\text{weaker base}}{H_2O(l)} \longleftarrow \underset{\text{stronger acid}}{H_3O^+(aq)} + \underset{\text{stronger base}}{CH_3COO^-(aq)}$$

The H_3O^+ ion concentration in this solution is much lower than it was in the $HClO_4$ solution because acetic acid is a weak acid. The CH_3COOH molecule does not compete successfully with the H_3O^+ ion in donating protons to a base. The acetate ion, CH_3COO^-, is a stronger base than H_2O. Therefore, the H_2O molecule does not compete successfully with the CH_3COO^- ion in accepting a proton. The H_3O^+ ion is the stronger acid, and the CH_3COO^- ion is the stronger base. Thus, the reaction to the left is more favorable.

Note that in the reactions for both perchloric acid and acetic acid, the favored direction is toward the weaker acid and the weaker base. This observation leads to a second important general conclusion: *proton-transfer reactions favor the production of the weaker acid and the weaker base.* For a reaction to approach completion, the reactants must be much stronger as an acid and as a base than the products.

By comparing many different acids and bases, a table of relative strengths, such as **Table 6,** can be assembled. Note that a very strong acid, such as $HClO_4$, has a very weak conjugate base, ClO_4^-. The strongest base listed in the table, the hydride ion, H^-, has the weakest

CROSS-DISCIPLINARY

"It's a Bitter Pill"

Have you ever wondered about the origin of the saying, "It's a bitter pill to swallow"? This saying is used to describe a situation that is difficult to accept. Many medications contain bases, and a bitter taste is a property of bases. So, many medications actually have a bitter taste. If you look at the chemical formulas of the components of medications, you will see that they often contain nitrogen. One such component is caffeine, which acts as a stimulant on the central nervous and respiratory systems. Its molecular formula is $C_8H_{10}O_2N_4$. Like ammonia, caffeine has basic properties because it has a nitrogen that can accept a proton.