11.14: Lewis Acids and Bases

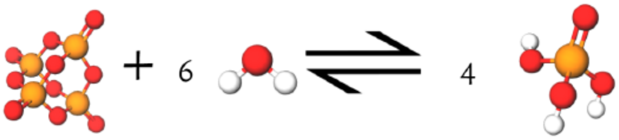
Many oxyacids are rather unstable and cannot be isolated in pure form. An example is carbonic acid, H_2CO_3, which decomposes to water and carbon dioxide:

$$H_2CO_3(aq) \rightleftharpoons H_2O(l) + CO_2(g)$$

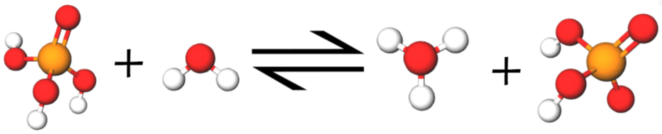
This decomposition process is familiar to us, as it is responsible for the fizzy nature of soda. When the CO_2 is dissolved in the soda, it becomes H_2CO_3, but when the soda is released from high pressure, the decomposition process occurs rapidly, forming bubbles of CO_2 and water.

Since it can be made by removing H_2O from H_2CO_3, CO_2 is called the **acid anhydride** of H_2CO_3. (The term anhydride is derived from anhydrous, meaning "not containing water.") Acid anhydrides are usually oxides of nonmetallic elements. Some common examples and their corresponding oxyacids are SO_2—H_2SO_3; SO_3—H_2SO_4; P_4O_{10}—H_3PO_4; N_2O_5—HNO_3. Any of these anhydrides increases the hydronium-ion concentration when dissolved in water; for example,

$$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$$



$$H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + H_2PO_4^-(aq)$$



In the Arrhenius sense, then, acid anhydrides are acids, but according to the Brönsted-Lowry definition, they are not acids because they contain no hydrogen.

In 1923, at the same time that the Brönsted-Lowry definition was proposed, G. N. Lewis suggested another definition which includes the acid anhydrides and a number of other substances as acids. According to the **Lewis definition**, an acid is any species which can accept a lone pair of electrons, and a base is any species which can donate a lone pair of electrons. An acid-base reaction in the Lewis sense involves formation of a coordinate covalent bond (where one atom provides both shared electrons).

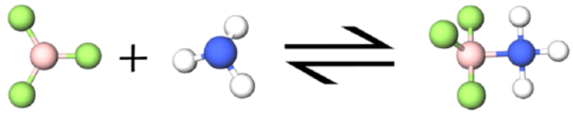
The Lewis definition has little effect on the types of molecules we expect to be basic. All the Brönsted-Lowry bases, for example, NH_3, O^{2-}, H^-, contain at least one lone pair. Lewis' idea does expand the number of acids, though. The proton is not the only species which can form a coordinate covalent bond with a lone pair. Cations of the transition metals, which are strongly hydrated, do the same thing:

$$\underset{\text{Lewis acid}}{Cr^{3+}} + \underset{\text{Lewis base}}{6H_2O} \rightarrow Cr(H_2O)_6^{3+} \tag{11.14.1}$$

$$\underset{\text{Lewis acid}}{Cu^{2+}} + \underset{\text{Lewis base}}{4NH_3} \rightarrow Cu(NH_3)_4^{2+} \tag{11.14.2}$$

So can electron deficient compounds such as boron trifluoride:

$$\underset{\text{Lewis acid}}{BF_3} + \underset{\text{Lewis base}}{:NH_3} \rightarrow F_3B:NH_3$$



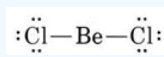
Many Lewis acid-base reactions occur in media other than aqueous solution. The Brönsted-Lowry theory accounts for almost all aqueous acid-base chemistry. Therefore the Brönsted-Lowry concept is most often intended when the words acid or base are used. The Lewis definition is useful when discussing transition-metal ions, however, and is discussed again in the sections on Metals.

Example 11.14.1 : Lewis Acids and Bases

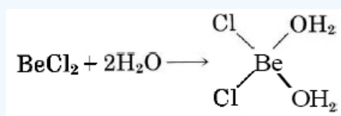
Identify the Lewis acids and bases in the following list. Write an equation for the combination of each acid with the Lewis base H_2O.(a) $BeCl_2$(*g*); (b) CH_3OH; (c) SO_2; (d) CF_4.

Solution

a) The Lewis diagram

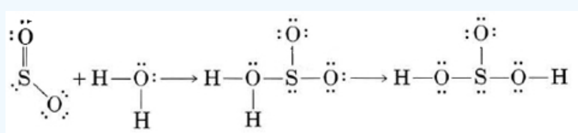


shows that Be is electron deficient. Therefore $BeCl_2$(*g*) is a Lewis acid. Because of the lone pairs on the Cl atoms, $BeCl_2$ can also act as a Lewis base, but Cl is rather electronegative and reluctant to donate electrons, so the Lewis base strength of $BeCl_2$ is less than the Lewis acid strength.



b) There are lone pairs on O in CH_3OH, and so it can serve as a Lewis base.

c) The S atom in SO_2 can accept an extra pair of electrons, and so SO_2 is a Lewis acid. The O atoms have lone pairs but are only weakly basic for the same reason as the Cl atoms in part (a).



d) Although there are lone pairs on the F atoms, the high electronegativity of F prevents them from being donated to form coordinate covalent bonds. Consequently CF_4 has essentially no Lewis-base character.