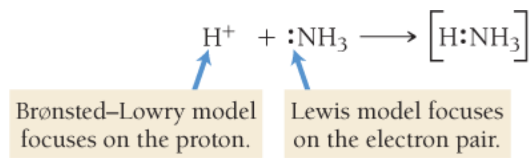
16.11: Lewis Acids and Bases

We began our definitions of acids and bases with the Arrhenius model. We then saw how the Brønsted–Lowry model, by introducing the concept of a proton donor and proton acceptor, expanded the range of substances that we consider acids and bases. We now introduce a third model, which further broadens the range of substances that we can consider acids. This third model is the *Lewis model*, named after G. N. Lewis, the American chemist who devised the electron-dot representation of chemical bonding (Section 4.4). While the Brønsted–Lowry model focuses on the transfer of a proton, the Lewis model focuses on the donation of an electron pair.

Consider the simple acid–base reaction between the H^+ ion and NH_3, shown here with Lewis structures:



According to the Brønsted–Lowry model, the ammonia accepts a proton, thus acting as a base. According to the Lewis model, the ammonia acts as a base by *donating an electron pair*. The general definitions of acids and bases according to the Lewis model focus on the electron pair:

Lewis acid: Electron pair acceptor

Lewis base: Electron pair donor

According to the Lewis definition, H^+ in the above reaction is acting as an acid because it is accepting an electron pair from NH_3. NH_3 is acting as a Lewis base because it is donating an electron pair to H^+

Although the Lewis model does not significantly expand the substances that can be considered bases—because all proton acceptors must have an electron pair to bind the proton—it does significantly expand the substances that can be considered acids. According to the Lewis model, a substance doesn't even need to contain hydrogen to be an acid. For example, consider the gas-phase reaction between boron trifluoride and ammonia shown here:

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

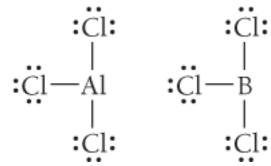
Boron trifluoride has an empty orbital that can accept the electron pair from ammonia and form the product (the product of a Lewis acid–base reaction is sometimes called an *adduct*). The above reaction demonstrates an important property of Lewis acids:

> *A Lewis acid has an empty orbital (or can rearrange electrons to create an empty orbital) that can accept an electron pair.*

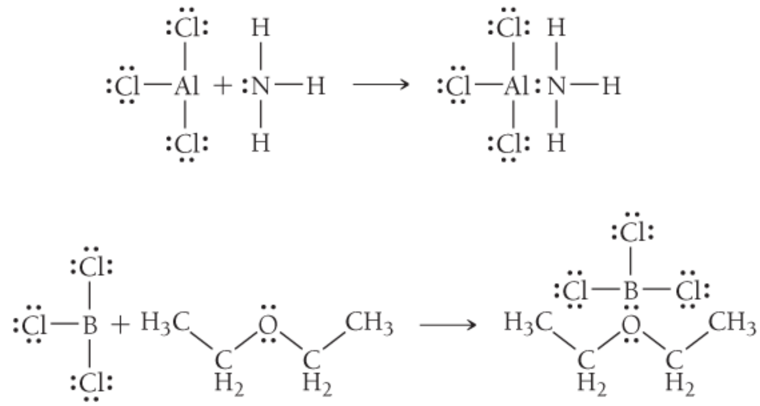
Consequently, the Lewis definition subsumes a whole new class of acids. Next we examine a few examples.

Molecules That Act as Lewis Acids

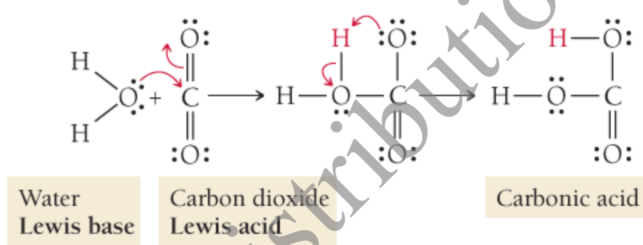
Since molecules with incomplete octets have empty orbitals, they can serve as Lewis acids. For example, both $AlCl_3$ and BCl_3 have incomplete octets:



These both act as Lewis acids, as shown in the following reactions:



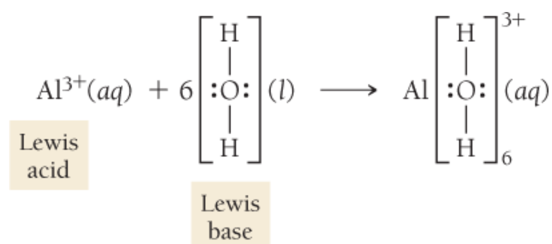
Some molecules that may not initially contain empty orbitals can rearrange their electrons to act as Lewis acids. Consider the reaction between carbon dioxide and water:



The electrons in the double bond on carbon move to the terminal oxygen atom, allowing carbon dioxide to act as a Lewis acid by accepting an electron pair from water. The molecule then undergoes a rearrangement in which the hydrogen atom shown in red bonds with the terminal oxygen atom instead of the internal one.

Cations That Act as Lewis Acids

Some cations, since they are positively charged and have lost some electrons, have empty orbitals that allow them to also act as Lewis acids. Consider the hydration process of the Al^{3+} ion discussed in Section 16.9 shown here:



The aluminum ion acts as a Lewis acid, accepting lone pairs from six water molecules to form the hydrated ion. Many other small, highly charged metal ions also act as Lewis acids in this way.