LEWIS ACIDS AND BASES

Previously, you learned what acids and bases are and how they react to make a salt and water. This original theory of acids and bases was proposed in 1884 by Svante Arrhenius, and is called the **Arrhenius Theory of Acids and Bases**. Arrhenius proposed that acids are substances which produce H^+ ions in solution and bases are substances which produce OH^- ions in solution. A later theory of acids and bases, called **Brønsted–Lowry Theory**, broadened the usefulness of acid-base theories by proposing that acids donate H^+ ions in solution while bases accept H^+ ions in solution. (You will study Brønsted–Lowry Theory in great depth in Chemistry 12.)

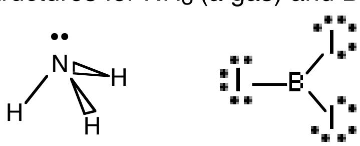
In 1923, G.N. Lewis proposed an alternate definition for acids and bases. This alternate definition was needed because previous theories only applied to solutions and many reactions occurred in gases and solids where these theories didn't seem to fit very well. These reactions had some similarities to acid-base reactions but sometimes involved compounds that couldn't be classified as acids or bases according to previous theories. Lewis' acid-base definitions, which follow below, are broader and more inclusive.

Definitions: A **LEWIS ACID** is a species that ACCEPTS a pair of electrons. (Memory Aid: **A**cids **A**ccept)

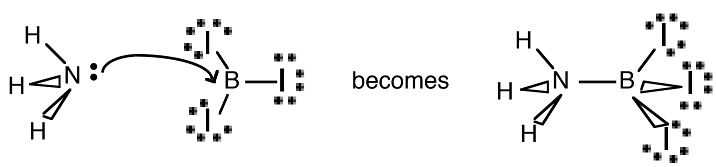
A **LEWIS BASE** is a species that DONATES a pair of electrons.

NEUTRALIZATION is the process of forming a bond between an electron pair donor and an electron pair acceptor.

Look at the Lewis structures for NH_3 (a gas) and BI_3 (a solid):



The boron atom has less than a full "octet" of electrons surrounding it and is **ELECTRON–DEFICIENT.** On the other hand, the nitrogen atom has a **LONE PAIR** of electrons that is not used for bonding. When BI_3 and NH_3 react, there is a transfer of an electron pair from N to a **VACANT p–ORBITAL** on B.



A covalent bond involving the transfer of a pair of electrons from one atom to another atom is called a **COORDINATE COVALENT BOND.** Strictly speaking, a coordinate covalent bond is indistinguishable from any other covalent bond once it is formed; it is only the source of the electrons in the bond that distinguishes a normal covalent bond from a coordinate covalent bond.

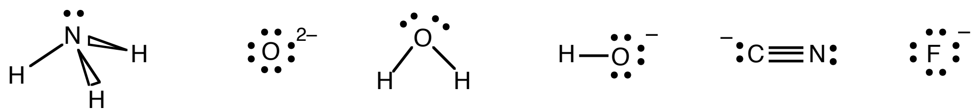
Note: The concept of a "SALT" is NOT defined in the Lewis theory because there are no "leftover ions" from which to make a salt.

The Lewis concept does not significantly add to the number of substances considered to be **bases,** but does greatly add to the number of species considered to be **acids**. For example, all metal ions have vacant orbitals and are therefore Lewis acids.

RECOGNIZING A LEWIS BASE

A species is a LEWIS BASE if it has a LONE PAIR of electrons (which can be shared with a Lewis acid). Lewis bases frequently have negative charges.

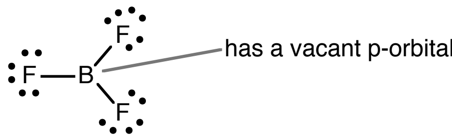
Example: The following substances are all Lewis bases.



RECOGNIZING A LEWIS ACID

A species is a LEWIS ACID if it is ELECTRON–DEFICIENT in some way. Lewis acids frequently have positive charges.

Example: The following substances are all Lewis acids.



Ag^+, Co^{2+} — positively charged ions can attract a lone pair of electrons

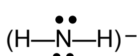
H – C ≡ C – H — a deficiency of electrons requires multiple bonds to form in order to allow the carbon atoms to attain an octet of electrons

GENERAL RULE: A species can act as a Lewis acid if one or more of three conditions are met:
- (a) The central atom is found in columns I, II or III and therefore has a vacant orbital (eg. LiH, BeH_2, BeF_2, BF_3, $AlCl_3$)
- (b) It has a positive charge
- (c) It is a neutral molecule and has a double or triple bond

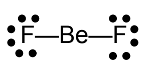
SPECIAL NOTE: If a molecule has some feature that makes it a Lewis acid, this will generally override any tendency to act as a Lewis base as a result of having lone pairs of electrons present elsewhere in the molecule. For example, in BF_3 (above; an example of a Lewis acid) the boron is electron–deficient, but each fluorine has lone pairs of electrons. In this case, the electron–deficiency of the central boron demands that the molecule act as a Lewis acid.

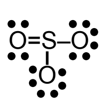
EXERCISES:

1. Classify each of the following as a Lewis acid or a Lewis base.

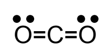
(a) NH_2^-: 

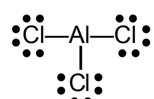
(b) Cl^-: 

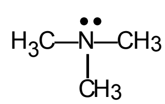
(c) BeF_2: 

(d) SO_3: 

(e) Zn^{2+}

(f) CO_2: 

(g) $AlCl_3$: 

(h) $N(CH_3)_3$: 

2. In the following reactions identify which species is the Lewis acid and which is the Lewis base.

(a) $O^{2-} + CO_2 \longrightarrow CO_3^{2-}$

(b) $Cu^{2+} + 4\ H_2O \longrightarrow Cu(H_2O)_4^{2+}$

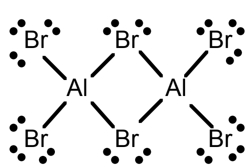
(c) $Ag^+ + 2\ CN^- \longrightarrow Ag(CN)_2^-$

(d) $H^+ + F^- \longrightarrow HF$

(e) $NH_3 + AlH_3 \longrightarrow H_3N{\cdot}AlH_3$

(f) $CN^- + CO_2 \longrightarrow [CN\text{–}CO_2]^-$

3. Aluminum bromide forms a "dimeric" molecule in the liquid phase.



How can the reaction $2\ AlBr_3 \longrightarrow Al_2Br_6$ be a Lewis acid–base reaction?