Chemistry Lecture #90: Arrhenius, Bronsted-Lowry, and Lewis Theories of Acids & Bases

The Arrhenius model of acids says that an acid is a substance that contains hydrogen and ionizes to produce hydrogen ions in aqueous solutions. For example, HCl gas would be an acid since it ionizes in water to produce H⁺.

\[
\text{water} \quad \text{HCl(g)} \rightarrow \text{H}^+(aq) + \text{Cl}^-(aq)
\]

The Arrhenius model of bases says that a base is a substance that contains a hydroxide group and dissociates to produce OH⁻ in aqueous solution. For example, NaOH would be a base since it dissociates in water to produce OH⁻.

\[
\text{water} \quad \text{NaOH (s)} \rightarrow \text{Na}^+(aq) + \text{OH}^-(aq)
\]

The Arrhenius model is not the only definition for an acid and base. You need to be aware of two other models: the Bronsted-Lowry model and the Lewis model.
The Bronsted-Lowry model states that an acid is a hydrogen ion donor. A base is a hydrogen ion acceptor. For example, when NH₃ and water are mixed, water will act as an acid and donate a hydrogen ion to the NH₃.

\[
\text{H}_2\text{O} \quad + \quad \text{NH}_3 \quad \xleftrightarrow{} \quad \text{OH}^- \quad + \quad \text{NH}_4^+ \\
\text{acid} \quad \qquad \text{base} \quad \qquad \text{conjugate} \quad \qquad \text{conjugate}
\]

donates H⁺ \qquad accepts H⁺ \qquad \text{base} \quad \text{acid}

Notice that if the reaction goes in reverse, NH₄⁺ could donate H⁺ and \text{OH}⁻ could accept it. Since \text{NH}_4^+ and \text{OH}⁻ are on the right side of the arrows, we'll call them the conjugate acid and base.

After an acid donates its H⁺, it becomes a conjugate base. After a base accepts an H⁺, it becomes a conjugate acid.

Here's another reaction:

\[
\text{HCl} \quad + \quad \text{H}_2\text{O} \quad \xleftrightarrow{} \quad \text{Cl}^- \quad + \quad \text{H}_3\text{O}^+ \\
\text{acid} \quad \quad \quad \text{base} \quad \quad \quad \text{conjugate} \quad \text{conjugate}
\]

donates H⁺ \qquad accepts H⁺ \qquad \text{base} \quad \text{acid}

In this reaction, \text{H}_2\text{O} accepts the H⁺, so it acts as a base. \text{H}_2\text{O} can either donate or accept a hydrogen ion, it can be an acid or a base. A substance that can act as an acid or a base is said to be amphoteric.
The Lewis model of acids and bases states that a base is a substance that can donate a pair of electrons to the formation of a covalent bond. An acid is a substance that can accept a pair of electrons to form the covalent bond.

For example, OH$^-$ has a pair of electrons that are accessible. A hydrogen ion, H$^+$, can accept these electrons and form a covalent bond.

\[
\text{H}^+ + [\text{O} \text{--H}]^- \rightarrow \text{H} \text{O}^-.
\]

OH$^-$ donates the electrons and is the base. H$^+$ accepts the electrons and is the acid.

In another example, OH$^-$ can donate electrons to CO$_2$ and form a covalent bond between the two.

\[
\text{H} \text{O}^+ + \text{C} \rightarrow \text{H} \text{O}^- + \text{CO}^- \rightarrow \text{H} \text{O}^- \text{C} \text{O}^-.
\]

In this reaction, the OH$^-$ is the base and the CO$_2$ is the acid. This is how carbon dioxide gas is removed from the atmosphere in space ships. Carbon dioxide passes through a filter that contains LiOH. The carbon dioxide bonds with the OH$^-$ and the resulting bicarbonate ion remains in the filter, thus removing CO$_2$ from the air.