Other than covalently bound binary compounds, most inorganic compounds can be classified as acids, bases, or salts.

**Acids**

Acids are characterized by H\(^+\) ion in water.

H\(^+\) ion dissolved in water makes the water acidic.

An acid either contains H\(^+\) ion or produces it when it dissolves in water.

Sulfuric acid, H\(_2\)SO\(_4\), contains 2 H\(^+\) ions per molecule.

**Carbon Dioxide As Acid**

Carbon dioxide produces H\(^+\) ion by reacting with water:

- \(\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{HCO}_3^-\)
- Only a small fraction of the CO\(_2\) molecules dissolved in water undergo the above reaction to produce H\(^+\) ion, so water solutions of CO\(_2\) are weakly acidic.
- Carbon dioxide is classified as a weak acid.
- Rainfall is weakly acidic because of dissolved CO\(_2\) from air.

**Strong Acids**

Acids such as hydrochloric acid, HCl, are completely dissociated in water to H\(^+\) and an anion.

- Such acids are strong acids.
- HCl \(\rightarrow\) H\(^+\) + Cl\(^-\) (Reaction to 100% complete dissociation)
- HNO\(_3\) \(\rightarrow\) H\(^+\) + NO\(_3^-\) (Complete dissociation)

**Acids With Different Numbers of Oxygen Atoms**

- An acid that contains only H and one other element is a “hydro-ic” acid, such as HCl, which is called hydrochloric acid.
- Different rules apply when an acid contains oxygen.
- With acids containing oxygen, the one with more oxygen, such as H\(_2\)SO\(_4\), is sulfuric acid, the one with less oxygen, H\(_2\)SO\(_3\), is sulfurous acid.
- For greater or lesser amounts of oxygen consider the following example:

  HClO\(_4\), perchloric acid HClO\(_3\), chloric acid
Uses and Occurrence of Acids

**Sulfuric acid** is the top chemical produced at about 40 million metric tons (40 billion kilograms) annually in the United States

- Greatest use is to treat phosphate minerals to produce phosphate crop fertilizers
- Other uses include removal of corrosion from steel (steel pickling), detergent synthesis, petroleum refining, lead storage battery manufacture, and alcohol synthesis

About 7-9 metric million tons of **nitric acid**, HNO₃, are produced in the U.S. each year ranking it 10th in chemical manufacture

**Hydrochloric acid** ranks about 25th, with annual production around 3 million metric tons

Acids and Green Chemistry

Because of their widespread use and corrosive nature, acids are very important in the practice of green chemistry

- Reclamation and recycling of acids
- Much of sulfuric acid now manufactured uses hydrogen sulfide, H₂S, removed from sour natural gas as a source of sulfur

Acetic acid made by the fermentation of carbohydrates can be an excellent green alternative to harsher acids

The production of acetic acid is a **green process** that uses biological reactions acting upon renewable biomass raw materials

As a weak acid, acetic acid is relatively safe to use, **biodegradable**, contact of relatively dilute solutions with humans is not usually dangerous

Bases

A **base** either contains hydroxide ion, OH⁻, or reacts with water to produce hydroxide

Most bases that contain hydroxide are metal hydroxides: Sodium hydroxide, NaOH, and calcium hydroxide, Ca(OH)₂, are examples.
The most common basic substance that does not contain, but produces, hydroxide ion in water is ammonia, \( \text{NH}_3 \):

\[
\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^- 
\]

**Weak and Strong Bases**

The reaction of ammonia with \( \text{H}_2\text{O} \) to produce \( \text{OH}^- \) ion is a **reversible** reaction that lies far to the left:

\[
\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^- 
\]

Only a small fraction of the ammonia reacts

- Therefore, ammonia is a **weak base**

The metal hydroxides, such as KOH, that completely dissociate in water are **strong bases**

Metal hydroxides are named by the metal followed by “hydroxide”

\( \text{Mg(OH)}_2 \) is a weak base because of low solubility (ingredient of milk of magnesia)

**Salts**

An acid and a base react to form a **salt**, an ionic compound that has a cation other than \( \text{H}^+ \) and an anion other than \( \text{OH}^- \)

- Always produces water and is known as a **neutralization reaction**

\[
\begin{alignat}{3}
\text{NaOH} & \quad \text{&&} \quad \text{HCl} & \quad \rightarrow & \quad \text{NaCl} + \text{H}_2\text{O} \\
\text{base} & \quad \text{&&} \quad \text{acid} & \quad \text{&&} \quad \text{salt} & \quad (\text{sodium}: \text{ chloride})
\end{alignat}
\]

Some example salts:

- \( \text{NaCl} \), sodium chloride
- \( \text{CaCl}_2 \), calcium chloride, used to melt ice
- \( \text{NaCO}_3 \), sodium carbonate, used to make glass, treat water, other

Salts with only one cation and one anion are named with just the name of the cation followed by the name of the anion

Salts with more than one cation or anion are named to denote the number of each:

\( \text{KH}_2\text{PO}_4 \) is potassium dihydrogen phosphate