Acid-Base Theories

Properties of Acids and Bases

Acids have several distinct properties. Acidic compounds give foods a tart or sour taste. Vinegar, for example, contains ethanoic acid (acetic acid). Lemons contain citric acid.

Aqueous solutions of acids are called electrolytes. Electrolytes can conduct electricity.

Acids cause certain chemical dyes, called indicators, to change color.

Some common acids

Name	Formula
Hydrochloric Acid	HCl
Nitric acid	HNO_3
Sulfuric acid	H_2SO_4
Phosphoric acid	H_3PO_4
Ethanoic acid	CH_3COOH
Carbonic acid	H_2CO_3

Bases on the other hand taste bitter. Most bases are hazardous to taste.

Bases also feel slippery, and will change the color an acid-base indicator. Like acids, aqueous solutions of bases are electrolytes.

Very little of the foods we eat are bases. (ex. lime water - $Ca(OH)_2$)

Arrhenius Acids and Bases

Swedish chemist Svante Arrhenius came up with the idea that acids are hydrogen-containing compounds that ionize to yield hydrogen ions (H^+) in aqueous solutions.

$$HCl_{(g)} \xrightarrow{H_2O} H^+_{(aq)} + Cl^-_{(aq)}$$

He also added that bases are compounds that ionize to yield hydroxide ions (OH^-)

$$NaOH_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$$

Acids are called monoprotic, diprotic, or triprotic acids if they contain 1, 2, or 3 ionizable hydrogens.

Ex - H_3PO_4

is a triprotic acid.

Some common bases

Name	Formula	Solubility in Water
potassium hydroxide	KOH	high
sodium hydroxide	$NaOH$	high
calcium hydroxide	$Ca(OH)_2$	very low
magnesium hydroxide	$Mg(OH)_2$	very low

Because of its corrosive nature, sodium hydroxide is a major component of consumer products used to clean clogged drains.

The elements in group 1A, the alkali metals, react with water to produce solutions that are basic.

Example:

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

From looking at the tables given for acids and bases:

a) What elements do all of the acids in the table have in common?

b) Looking at the solubility of bases, is LiOH likely to be soluble in water?

c) Hydroxides involving Group 2A elements increase in solubility as we move down the table. Do you think $Be(OH)_2$ is soluble in water? What about $Sr(OH)_2$?

Bronsted-Lowry Acids and Bases

The Arrhenius definitions of acids and bases is incomplete. In 1923, Johannes Bronsted and Thomas Lowry independently proposed a new definition.

The Bronsted-Lowry theory defines an acid as a hydrogen-ion donor, and a base as a hydrogen-ion acceptor.

If we look at ammonia being dissolved in water.

$$NH_{3(aq)} + H_2O \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

NH_3: hydrogen ion acceptor

H_2O: hydrogen ion donor

OH^-: hydroxide ion, makes the solution basic

Because the reaction is in equilibrium it goes in reverse as well.

A **conjugate acid** is the particle formed when a base gains a hydrogen ion.

A **conjugate base** is the particle that remains when an acid has donated a hydrogen ion.

Conjugate acids and bases are always paired with a base or acid, respectively.

$$NH_{3(aq)} + H_2O \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

base, acid, conjugate acid, conjugate base

The Bronsted-Lowry theory also applies to acids....

$$HCl_{(g)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + Cl^-{}_{(aq)}$$

acid (hydrogen ion donor), base (hydrogen ion acceptor), conjugate acid, conjugate base

Sometimes water accepts a hydrogen ion. Other times, it donates a hydrogen ion. Water is **amphoteric**, it can act as both an acid and a base.

Lewis Acids and Bases

A third theory of acids and bases, Gilbert Lewis proposed that *an acid accepts a pair of electrons during a reaction, while a base donates a pair of electrons.*

A **Lewis acid** is a substance that can accept a pair of electrons to form a covalent bond.

A **Lewis base** is a substance that can donate a pair of electrons to form a covalent bond.

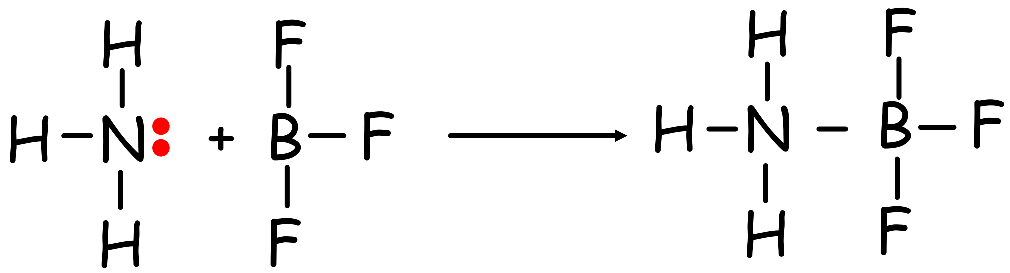
A hydrogen ion can accept a pair of electrons when forming a bond. Therefore, a hydrogen ion is a Lewis acid.

$$H^+ + OH^- \longrightarrow$$

In this reaction, the hydroxide ion is a Lewis base.

Example

Ammonia is widely used in fertilizers, plastics, and explosives. Identify the Lewis acid and the Lewis base in the following reaction involving ammonia.



Try questions 1-8 on page 593