ACIDS, BASES & pH & Solubility

A third class of compounds involves acids. There are 3 main theories for defining acids & bases- ***Arrhenius, Brønsted-Lowry, & Lewis***. While these definitions do not contradict each other, they do vary in how inclusive they are. In this course, the emphasis will be on the Arrhenius definition.

Acid & Base Definitions:
Arrhenius Theory:

Acids-chemical compound that increases the concentration of ***hydrogen*** ions [H^+] in an aqueous solution

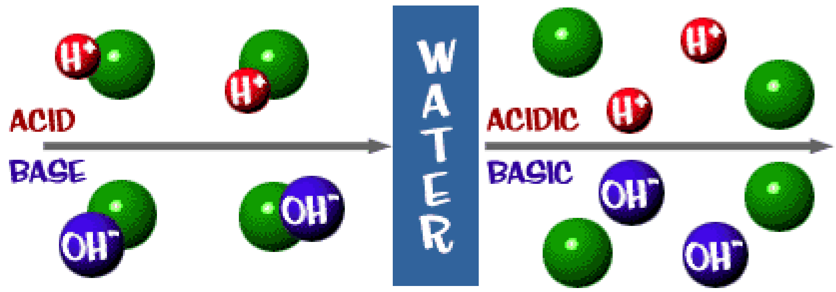
- [ ] = concentration in moles per liter (mol / L) or M
- H+ = hydrogen ion
- H_3O^+ = hydronium ion (represents a hydrogen ion in water)
  - ***NOTE***: hydrogen ions and hydronium ions are equivalent, so they are often used interchangeably
- Strong acids are those that ionize (split into ions) completely in water, so they are strong electrolytes
- Weak acids are those that release few hydrogen ions in solution

Bases-chemical compound that increases the concentration of ***hydroxide ions*** [OH^-] in an aqueous solution

- [ ] = concentration in moles per liter (mol / L) or M
- OH^- = hydroxide ion
- Strong bases are those that ionize (split into ions) completely in water, so they are strong electrolytes
- Weak bases are those that release few hydroxide ions in solution

Arrhenius Theory Summary

- Acids produce [H^+] or {H_3O^+] ions in aqueous solutions.
- Bases produce [OH^-] ions in aqueous solutions.
  - Water required, so only allows for aqueous solutions.
  - Only protic acids are allowed; required to produce hydrogen ions.
  - Only hydroxide bases are allowed.



Ionization of a Strong Acid & Strong Base in H_2O

Some Properties of Acids & Bases

	Acidic Solutions	Basic or Alkaline Solutions
Taste	sour, like: household vinegar (acetic acid) lemon juice, orange juice or citrus fruit juices (citric acid) Vitamin C (ascorbic acid) Coca-Cola (contains phosphoric acid) Green apples (contain malic acid) sour milk (lactic acid)	bitter, like: Milk of Magnesia (magnesium hydroxide) Maalox antacid (magnesium hydroxide and aluminum hydroxide) baking soda (sodium bicarbonate)
Feel	sting, burn -concentrated acids can cause skin burn	slippery or soapy - concentrated bases can cause skin burn
Reaction to indicator	change blue litmus paper (a blue vegetable dye) from blue to red r	don't change the color of litmus; they can turn red (acidified) litmus back to blue
Reactions	React with bases to form salt and water (i.e.neutralization reaction-form of double displacement) React with active metals such as magnesium, zinc, aluminum, iron to produce hydrogen gas, H_2 (g).	React with acids to form salt and water (i.e. neutralization reaction-form of double displacement)
Conductivity	are electrolytes -their aqueous (water) solutions conduct electric current.	are electrolytes -their aqueous (water) solutions conduct electric current.
Examples	car battery (sulfuric acid) stomach acid (hydrochloric acid) carbonated water (carbonic acid)	drain cleaner, oven cleaner (sodium hydroxide)cleaning products (ammonia solution)

Nomenclature for Acids- How to name acid compounds

Remember that an acid is a compound that produces positively-charged hydrogen ions, H^+, when dissolved in water. Generally, an acid is a compound that begins with an H. Because acids are involved in many chemical reactions it is helpful to learn how acids are named.

Naming of an acid depends on the anion in the formula. Follow these rules for naming acids.

Binary Acids:

A **<u>bi</u>nary** compound consists of **<u>2</u>** two elements. A binary acid has an H as the first element and a nonmetal (N, P, S, Cl, F, I).

The rules for forming the formula for acids are the same as ionic compounds, but the naming is different.

Binary acids have the prefix hydro in front of the full name of the nonmetallic element. They have the ending –ic. The word acid is always written in the name.

Examples: HCl = hydro**chlor**ic acid H_2S = hydro**sulfur**ic acid

Format for naming a binary acid is: hydro***(root of nonmetal)*** ic**.**

Ternary Acids

Ternary acids commonly contain hydrogen, a nonmetal, and oxygen. Here the nonmetal and oxygen are referring to a polyatomic anion such as SO4 2- or PO43-. The name of the most common form of the acid consists of the nonmetal root name with the –ic ending, The acid containing one less oxygen atom than the most common form is designated by the –ous ending. For this course, we will only study the most common ternary acids- those ending in ic.

NOTE: The prefix hydro is not used when naming acids that contain a polyatomic anion.

Examples: H_2SO_3 = sulfur**ous** acid H_2SO_4 = sulfur**ic** acid

Format for naming a ternary/polyatomic acid is:
(root of nonmetal) ending is **ous** or **ic** depending on the polyatomic ending.

Polyatomic ending	**Acid ending**	**Summary Polyatomic→Acid**
Sulf**ite** $\mathbf{SO_3^{2-}}$	sulfur**ous** acid	ite→ous
Sulf**ate** $\mathbf{SO_4^{2-}}$	sulfur**ic** acid	ate→ic

The following acids and ammonia are used extensively in other science courses; therefore it would be wise to memorize them:

HCl = hydrochloric acid
HNO_3 = nitric acid
H_2SO_4 = sulfuric acid
NH_3 = ammonia (is more basic but can act as a very weak acid)

Acids and bases

Acids and bases are often used in the classification of matter. A simple definition of acid and base: **acids** are chemicals that produce positively-charged hydrogen ions, H^+, when dissolved in water, while **bases** are chemicals that produce negatively-charged hydroxide ions, OH^-, in water.
Acids and bases have some general properties. Many acids have a sour taste, such as citric acid, found in oranges and lemons. Acids can conduct electricity. Many acids will react with metals (corrosive), producing metal containing compounds as well as a gas, often hydrogen gas. Bases usually have a bitter taste, like caffeine. Bases make solutions that are slippery. Bases are corrosive and can conduct electricity.
A useful classification of acids and bases is the **pH scale** which uses a range of colors to assign the acidity or basicity to a substance. The pH scale is based on the ability of acids and bases to change colors of certain chemicals known as **indicators**. Litmus has been used since it turns blue in the presence of bases and red in the presence of acids. Extracts made from red onions, red cabbage, and many other fruits and vegetables change colors in the presence of acids and bases. There are three ranges on the pH scale: **$1 < pH < 7$** is an acid, **$7 < pH < 14$** is a base, and a pH of **7** is neutral (pure water).

Chemically, acids and bases may be considered opposites of each other. Acids and bases react with each other in a reaction called neutralization. In a neutralization reaction, the hydrogen ion and the hydroxide ion react to form a molecule of water.

There are two main forms of matter: **pure substances** (element, compound) and **mixtures** (suspension, colloid, solution, mixture). An **element** is a substance composed of only one type of atom (details later). A **compound** is a chemical combination of 2+ elements and always has a definite ratio of those elements (2 H + 1 O = water). The elements in a compound can only be separated by a chemical change such as combustion, electrical separation, or other chemical reaction.

A **mixture** is a physical combination of 2+ pure substances. Some specific types of mixtures have definite identifying properties. A **suspension** is a **heterogeneous** mixture where some of the particles are large enough to see with the naked eye and will often settle out of the other substance(s) over time, they can also be filtered. In a **solution**, which is **homogeneous**, one of the substances (**solute**) is disassociated (pulled apart a little) in the other, **solvent**. This process is called dissolving. This makes the individual pieces so small they are invisible to the naked eye and cannot be filtered. A **colloid** is heterogeneous, and falls between a suspension and a solution, the particles can be seen by the naked eye, but they will not settle out over time nor can they be filtered in most cases. To determine whether or not particles are visible, simply use light. If you can see a beam of light as it passes through the substance, such as headlights in fog, the particles are visible. This is called the **Tyndall Effect**. A solution does not exhibit the Tyndall Effect.

A mixture can be separated by physical processes such as distillation, filtering, a centrifuge, magnetism, and paper chromatography.

As mentioned above, a **solution** is a homogeneous mixture. A solution results when a solute dissolves in a solvent. You are probably most familiar with solid solutes in liquid solvents, however, a solution can also result from two liquids, such as an **alloy**, or a gas in a liquid. Other combinations are much less likely due to the dissolving process itself. We will use solid in liquid as well as gas in liquid solutions since these are more familiar to us and are fairly easy to observe.
One simple example would be to put sugar in tea. A spoonful of sugar will dissolve in the tea. We commonly recognize this since the sugar slowly disappears. Basically the solute is "pulled apart" by the solvent. The sugar is in a crystal form and is composed of many molecules. The water is also composed of many molecules and the water being liquid can surround the surface of the sugar. The water molecule(s) will attract the sugar molecule(s) and pull the sugar as it moves along. This leaves more sugar molecules exposed to more water molecules, and on and on…eventually you cannot see the sugar molecules. But, when you taste the tea you know the sugar is still there. Carbonated beverages, CO_2 in flavored water, as well as everyday water, oxygen for the marine animals and CO_2 for the marine plants, are good examples of gas solutes in a liquid solvent. Three basic factors effect the rate at which a solute will dissolve in a solvent.
(1) The rate increases with an increase in the solute's **surface area**, granules of sugar v. a sugar cube.
(2) Increased **agitation** (stirring) of the mixture will speed the dissolving.
(3) **Temperature** - for a solid solute an increase in temperature will speed the dissolving, while it slows the dissolving of a gas. Think of this last one in terms of average KE of the materials.
Solubility is a measure of the amount of solute that can dissolve in a certain amount of solvent. The solubility of most solutes changes as the temperature changes (much like
(3) above) and is often represented on a **solubility curve**. A solubility curve is quite useful in determining whether a solution is **saturated** (the solvent has dissolved the maximum amount of solute), **unsaturated** (the solvent has dissolved less than the maximum amount of solute), or **supersaturated** (the solvent has dissolved more than the maximum amount of solute).
Dissolving a solute in a solvent also effects the boiling point and melting/freezing point of the solvent. It lowers the melting/freezing point and raises the boiling point. Two examples of the usefulness of this are antifreeze and water in a car and salt on ice in the winter.