Acids and Bases

What is an acid? What is a base? You have probably heard of acids, but do you know what makes something an acid? This question is complicated because of the several different (but related) definitions of acids. One of the first definitions of acids and bases was made by Svante Arrhenius (shown below).

Arrhenius Acid: any compound that forms H_3O^+ ions in water

Arrhenius Base: any compound that forms OH^- ions in water

Note: ions are charged species

Before the discussion can go any further, the structure of water needs to be discussed. Water is made up of molecules of H_2O. A molecule is a collection of atoms, held together by covalent bonds, that has no charge (as opposed to an ion). A single molecule of water is shown below in figure 1.

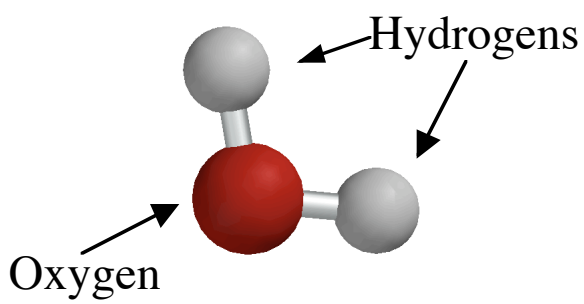


Figure 1. A molecule of water

Note that the molecule has 2 hydrogen atoms and one oxygen atom, hence the formula H_2O. A sample of water (or solution of water) contains many water molecule. A glass of water contains about 1.2×10^{25} water molecules.

$$1.2 \times 10^{25} = 12{,}000{,}000{,}000{,}000{,}000{,}000{,}000{,}000$$

When an acid is placed into the water, the some H_3O^+ (hydronium) ions are produced (Figure 2). These look very similar to water, except to the extra H and a +1 charge. They aren't molecules, because of the charge, they are ions (charged species). It is essentially like a H^+ ion is added to the water as shown in equation 1 below.

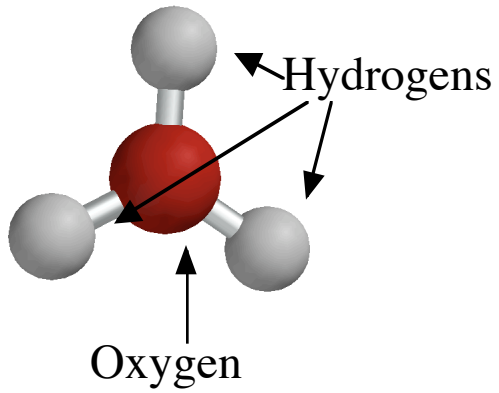
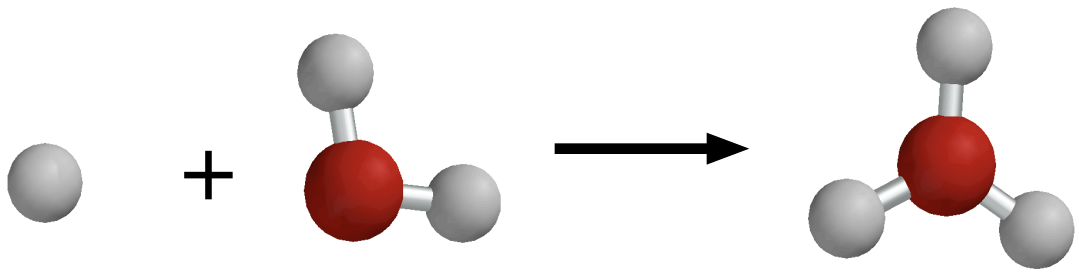


Figure 2. An H_3O^+ ion



(1)

When a base is placed in water, the ion OH^- (or hydroxide) is produced (figure 3). One way hydroxide can be produced is by removing an H^+ from water as shown in equation 2 below.

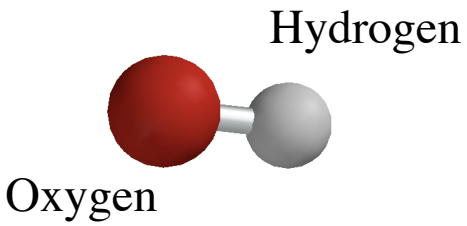
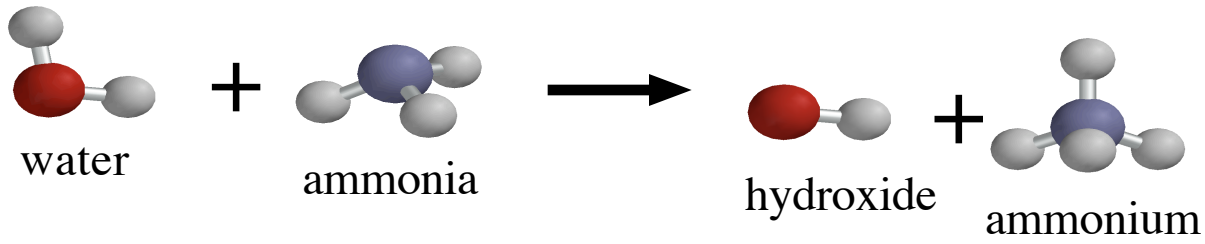


Figure 3. The hydroxide ion, OH^-



(2)

In equation 2 (above), a molecule of ammonia (NH_3) removes an H^+ from the water to form OH^- and ammonium (NH_4^+). Notice that the charge at the beginning of the reaction and the end of the reaction is the same (zero).

pH Scale

The acidity of a liquid or solution is often reported by the pH scale. The pH is a measure of the amount of H_3O^+ in the solution. The more H_3O^+, the more acidic it is. The term pH is an abbreviation for *puissance de hydrogen* or "strength of hydrogen (ion)". The pH scale is a logarithmic scale. The meaning of the scale is shown in equation 3 below.

$$pH = -\log[x] \qquad x = 10^{-pH} \qquad (3)$$

In equation 3, x is the concentration of H_3O^+ in units of molarity. As you can see from the table below, the larger the pH value, the *less acidic* the solution is. Low pH values (less than 7) corresponds to an acidic solution. The concentration of H_3O^+ changes by 10 for every 1 pH unit.

Table 1. pH values and their corresponding H_3O^+ concentrations.

pH	$[H_3O^+]$	$[H_3O^+]$
1	10^{-1}	0.1
2	10^{-2}	0.01
4	10^{-4}	0.0001
7	10^{-7}	0.0000001

High pH values (larger than 7) reflect a basic solution. At pH=7, the solution is considered neutral. Distilled water has a pH of 7. This means that the hydronium ion concentration is not 0 in neutral water.

Which substances are acidic, which are basic?

An old observation is that acidic solutions and foods taste sour (or tart) and basic foods or solutions taste bitter. Using this basic guide, predict whether the following substances are acidic or basic:

- lemon juice
- apple juice
- baking soda
- vinegar

Verify your predictions using the pH meters provided.

What happens when acids and bases are mixed?

What do you expect will happen if a base is added to an acid? Why do you think this will happen? Is your theory supported by experiment?