Acids, Bases and Buffers

Before any discussion of acids, bases and buffers can occur it is important to understand that molecules in solution can gain or lose a hydrogen ion (proton). The loss of a hydrogen ion is called dissociation or ionization. The extent to which a compound loses or gains hydrogen ions is determined by the chemical characteristics of that specific compound. Some molecules lose hydrogen ions very easily and a solution of those molecules contains a large number of free hydrogen ions; other molecules do not lose hydrogen ions easily and in any solution only a few molecules dissociate.

The Ionization of Water

Water dissociates to produce a hydrogen ion (H^+) and a hydroxide ion (OH^-).

$$H_2O \rightarrow H^+ + OH^-$$

In any drop of pure water there are approximately 1.6×10^{21} molecules of water, that is 1.6 sextillion water molecules! In that drop only 1.6×10^7 molecules dissociate to release hydrogen and hydroxide ions. Most of the water molecules remain undissociated as H_2O.

Acids, Bases and the pH Scale

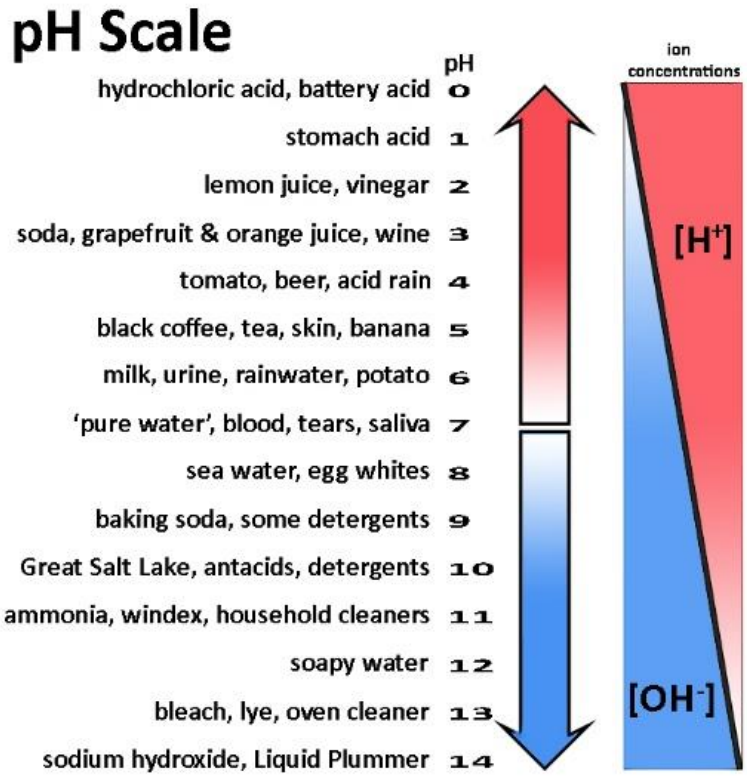
An acid is defined as any substance in solution that donates a hydrogen ion. The hydrogen ion (proton) is called the acid functional group. Acids can be abrasive (corrode metal) and have a sour taste, like vinegar. Remember, we don't eat or drink in lab. Bases by definition accept hydrogen ions or release hydroxide ions. Bases bind hydrogen ions in a solution and thereby decrease the number of free hydrogen ions. The hydroxide ion (OH^-) is known as the base functional group. Bases taste bitter and are slippery to the touch. Bases do not react with metals. Solutions with a basic pH are sometimes described as alkaline.

The pH scale is how we measure the level of hydrogen and/or hydroxide ions in a solution. The scale range is 0 to 14. pH 7, right in the middle of the scale is neutrality. A solution with a pH of 7 has equal numbers of hydrogen (1×10^{-7}) and hydroxide ions (1×10^{-7}). As you proceed down the scale from 7 to 0, the solutions are more and more acidic and have more and more hydrogen ions. Moving in the opposite direction, from 7 to 14, the solutions become more and more basic or alkaline and contain more hydroxide ions than hydrogen ions. The pH scale is a logarithmic scale (base 10). That means for each unit change in pH the number of acid units actually increases 10 fold. So a solution at pH 6 has 10 times more hydrogen ions than a solution at pH 7. A solution at pH 5 has 100 times more hydrogen ions than a solution at pH 7. That is why what appears to be a slight change in pH is actually quite a significant change in the number of acid or base functional groups.

Combining an acid and a base in the correct equal proportions creates a neutral solution. The combination of the acid functional group (H^+) and base functional group (OH^-) produces water! The products of the combination of an acid and a base is salt water. Review the equation depicting the combination of an acid (hydrochloric acid, HCl) and a base (sodium hydroxide, NaOH). The products are NaCl (table salt) and water.

$$HCl + NaOH \rightarrow H^+ + Cl^- + Na^+ + OH^- \rightarrow NaCl + H_2O$$

The pH of the external and internal environments is critically important to living organisms. Most biological molecules and processes function within a given pH range. If the pH falls outside that permitted range, the functions of molecules or processes can be drastically affected. For example, blood pH can range between 7.35 and 7.45. If pH drops below 7.35 the patient has acidosis; if blood pH is higher than 7.45 the patient has alkalosis. Both conditions have many side effects and can lead to organ failure and death.



pH 7 is neutral. Substances with a pH of 7 have equal numbers of hydrogen and hydroxide ions. Remember this is a log scale. Substances with a pH of 0 have 10,000,000 more hydrogen ions than substances at pH7.

Buffers assist in maintaining a stable pH by absorbing or releasing hydrogen ions as needed. The blood plasma contains 3 different buffering systems. Plasma proteins buffer the blood by absorbing and releasing hydrogen ions. A second buffering system is a based on potassium phosphate. The third and most important buffering system in the plasma is the carbonate-bicarbonate buffering system. Water and CO_2 combine to form carbonic acid. Carbonic acid dissociates to form bicarbonate and hydrogen ions. This reaction is reversible and the reaction gets 'pushed' in one direction or another depending on pH and the level of hydrogen ions.

$$H_2O + CO_2 \leftarrow \rightarrow H_2CO_3 \leftarrow \rightarrow HCO_3^- + H^+$$