Acids and Bases

-- water molecules can collide to induce the following reaction:

$$2H_2O \longleftrightarrow H_3O^+ + OH^-$$

-- however, in the Biological realm, we tend to use the 'abbreviated' form of this reaction in order to keep things simpler:

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

-- very few water molecules actually react in this manner (roughly only 2 in every 20 million), so few H^+ and OH^- ions exist; and even if they do, they "cancel each other out" with respect to their actual effects on a solution (ie. the amount of hydrogen ions in solution equals the amount of hydroxide ions in solution), which keeps water at a *neutral* pH of 7.

Acids:

-- ACIDS are molecules that dissociate in water to produce H^+ ions.

eg. HCl, CH_3COOH, H_2S, etc...

-- thus, acids increase the concentration of hydrogen ions in solution (ie. increased $[H^+]$).

-- strong acids tend to dissociate completely (eg. HCl, HNO_3, H_2SO_4, HBr, HI, $HClO_4$).

-- fig 2.11 p. 28 -- if an acid is added to water, the amount of free hydrogen ions in the solution increases.

-- therefore, acids are said to *liberate* hydrogen ions in solution.

Bases:

-- BASES are molecules that dissociate in water to produce OH^- ions (or, to accommodate for the existence of NH_3 and other non-OH^- possessing bases, BASES are also known as molecules that take up (or neutralize) H^+ ions).

eg. NaOH, $Ca(OH)_2$, NH_3, CH_3COO^-, F^- etc...

-- thus, bases increase the concentration of hydroxide ions in solution (ie. increased $[OH^-]$) OR bases decrease $[H^+]$ in solution.

-- strong bases tend to dissociate completely or nearly completely (eg. NaOH, KOH, $Ca(OH)_2$, any alkali metal or alkaline earth metal hydroxide compound.
-- fig 2.12 p. 28 -- if a base is added to water, the amount of hydroxide ions in solution increases.

pH Scale
-- used to indicate the acidity or alkalinity of a solution.

increasing $[H^+]$ / decreasing $[OH^-]$ increasing $[OH^-]$ / decreasing $[H^+]$

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|--|--|

0   7   14

ACIDIC   ALKALINE (BASIC)

-- a pH of 7 is exactly NEUTRAL (well, at least at 25° C – see Chem12).
eg. Pure Water: same number of hydrogen ions as hydroxide ions; therefore it is neutral.
-- notice that as $[H^+]$ increases, $[OH^-]$ decreases (by the same proportion), and vice versa.
-- the pH scale was invented to simplify the 'complex' numbering involved with explaining the concentration of hydrogen ions ($[H^+]$) and, consequently, the concentration of hydroxide ions ($[OH^-]$).
-- For example, in water with a pH of 7, the $[H^+] = 1 \times 10^{-7}$ M and the $[OH^-] = 1 \times 10^{-7}$ M. Seems that 7 is a 'nicer' number to deal with…

-- The formula for converting a known solution concentration into pH is:

$$pH = -\log [H^+]$$

eg. 1×10^{-3} M $[H^+]$ = pH 3

1×10^{-4} M $[H^+]$ = pH 4

1×10^{-5} M $[H^+]$ = pH 5

1×10^{-6} M $[H^+]$ = pH 6

-- notice that the hydrogen ion concentration increases ten-fold per one unit pH decrease (and vice versa).

*at the same time, hydroxide ion concentration decreases ten-fold per one unit pH decrease (and vice versa).

-- thus, a solution with a pH of 3 has $10^3 = 1000$ times more hydrogen ions than one with a pH of 6.

$$\text{pH } 3 \xrightarrow{\times 10} \text{pH } 4 \xrightarrow{\times 10} \text{pH } 5 \xrightarrow{\times 10} \text{pH } 6$$

-- similarly, a pOH scale exists:

$$pOH = -\log [OH^-]$$

-- furthermore, the relationship between pH and pOH is as follows:

$$pH + pOH = 14$$

eg. a solution with a pH of 6 possesses a pOH of 8.

-- acidic solutions have more hydrogen ions than hydroxide ions.
-- basic solutions have more hydroxide ions than hydrogen ions.

pH in Biological Systems

-- within animals, pH regulation is extremely important since certain enzymes only function in certain pH ranges.

eg. enzymes of the human digestive tract:

1. Salivary Amylase in the mouth (optimum pH ~7)
2. Pepsin in the stomach (optimum pH ~2-3)
3. Various enzymes in the small intestine (optimum pH ~8-10)

** notice that the pHs required in the stomach and small intestine are extremely different. Considering that only centimeters separate these two regions, some sort of BUFFER is required in order to change the pH of the substances exiting the stomach.

Salts

-- if an acid is combined with a base, generally a salt and a water molecule are produced:

Eg. $HCl + NaOH \rightarrow NaCl + H_2O$

-- if equal amounts/concentrations of a strong acid and strong base are present, the resulting solution is NEUTRAL in pH.

Buffers

-- buffers regulate pH (ie. keep pH relatively constant)

-- a buffer generally consists of a combination of chemicals (weak acid and a weak base in equilibrium) that consume excess H^+ ions or excess OH^- ions; a buffer may also be represented as a protein, or as a salt that has acidic and/or basic tendencies.

Examples:

1. **Combination of Acid/Base** (in *equilibrium*) -- blood always contains some carbonic acid (H_2CO_3) and some bicarbonate ions (HCO_3^-).

$$H_2CO_3 \Longleftrightarrow HCO_3^- + H^+$$

[bicarbonate ion] > [H_2CO_3]; about 70% : 30%; blood pH is 7.4.

* if H^+ ions are added to blood (more common in diet):

$$H^+ + HCO_3^- \Longleftrightarrow H_2CO_3$$

* if OH^- ions are added to blood:

$$OH^- + H_2CO_3 \Longleftrightarrow HCO_3^- + H_2O$$

2. **Protein** (HEMOGLOBIN) -- found in red blood cells. Primary function is to carry oxygen throughout the bloodstream but can also carry hydrogen ions formed when carbon dioxide (a product of metabolism) reacts with water in the plasma. This buffers the blood, allowing it to remain at its optimal pH of 7.4.

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

(hemoglobin picks up these H^+ ions)

3. A **salt** -- the salt Sodium bicarbonate ($NaHCO_3$) (which functions better as a weak base in the form HCO_3^-) is produced by the pancreas and released into the small intestine (duodenum) in order to neutralize the acidic substances exiting the stomach in the digestive tract. In other words, the bicarbonate ion keeps the pH of the small intestine at 8-10 (slightly basic) by disallowing the acid from the stomach to alter the pH.

$$NaHCO_3 \rightarrow Na^+ + HCO_3^-$$

Then...

$$HCO_3^- + H^+ \rightarrow H_2CO_3 \text{ (weaker acid than in stomach).}$$