BIO 244
Acids, Bases, and Buffers

Homeostasis is defined as the maintenance of a stable internal environment. One of the most critical factors in preserving homeostasis is keeping pH within narrow limits. pH is a measure of the concentration of H+ ions in a solution. The pH scale ranges from 0 to 14. A pH of 7 is neutral, meaning that the number of H+ ions is equal to the number of OH- ions. A pH below 7 is acidic (more H+ ions) and a pH above 7 is basic (more OH- ions). The term "alkaline" is interchangeable with "basic."

The metabolic activities of the human body constantly produce acids. Carbonic acid (H_2CO_3) is an important and common acid found in the body. It is formed when carbon dioxide (CO_2), a waste product of cellular respiration, reacts with water in cells, blood, and other fluids. Carbonic acid is a weak acid; it dissociates only weakly into a hydrogen ion and a bicarbonate ion.

$$\underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{water}}{H_2O} \leftrightarrow \underset{\text{carbonic acid}}{H_2CO_3} \leftrightarrow \underset{\text{hydrogen ion}}{H^+} + \underset{\text{bicarbonate ion}}{HCO_3^-}$$

Blood pH must be kept within a very narrow range of 7.35 to 7.45. If the pH of the blood deviates from this range, acidosis (blood pH below 7.35) or alkalosis (blood pH above 7.45) will result. These are serious conditions that can be fatal. There are several ways that the body maintains a safe pH. We will look at two today ... buffers and the exhalation of carbon dioxide.

Part 1. Ability of a buffer to stabilize pH

Intro: A buffer resists changes in the pH of a solution. Some proteins, like hemoglobin and albumin in our blood, are good buffers. Another important buffer is the sodium bicarbonate - carbonic acid system.

$H^+ + Cl^-$	+	$Na^+ + HCO_3^-$	←→	H_2CO_3	+	$Na^+ + Cl^-$
hydrochloric acid (strong acid)		sodium bicarbonate		carbonic acid (weak acid)		sodium chloride

$Na^+ + OH^-$	+	H_2CO_3	←→	$Na^+ + HCO_3^-$	+	H_2O
sodium hydroxide (strong base)		carbonic acid (weak acid)		sodium bicarbonate		water

Weak acids and bases do not dissociate readily into their ions, while strong acids and bases dissociate almost completely.

In the first reaction when HCI, a strong acid, is added the H^+ ions are taken out of solution. $NaHCO_3$ dissociates into Na^+ and HCO_3^- ions. HCO_3 combines with the H^+ from the HCI to form H_2CO_3, a weak acid.

In the second reaction, when NaOH, a strong base, is added, the OH^- ions are taken out of solution. H_2CO_3 dissociates into H^+ and HCO_3^- ions. H^+ combines with the OH^- from the NaOH to form water. Whether a strong acid or a strong base is added, the sodium bicarbonate - carbonic acid system resists a pH change.

Procedure:

1. Fill two beakers with 10 ml of water (label #1 and #2). Fill two beakers with 10 ml of buffer solution (label #3 and #4).
2. Measure and record the starting pH of the solution in each beaker using the pH electrode.
3. Measure and record the pH of the .5% HCL and .5% NaOH solutions.
4. Repeat the following procedure with each beaker, using the indicated acid or base:

   Add 5 drops of acid or base to the beaker, swirl to mix, then measure and record the pH. Repeat this until you have added 25 drops to the beaker.

   beaker #1 (water): Add HCl
   beaker #2 (water): Add NaOH
   beaker #3 (buffer): Add HCl
   beaker #4 (buffer): Add NaOH

Data:

pH of .5% HCl _____

pH of .5% NaOH _____

Beaker 1 : Water and Acid

Drops added	pH
0	
5	
10	
15	
20	
25	

Beaker 2: Water and Base

Drops added	pH
0	
5	
10	
15	
20	
25	

Beaker 3: Buffer and Acid

Drops added	pH
0	
5	
10	
15	
20	
25	

Beaker 4: Buffer and Base

Drops added	pH
0	
5	
10	
15	
20	
25	

Observations:

Part 2. Maintenance of pH during exercise

Intro: The rate of CO_2 production is greater during exercise than at rest because muscles must increase the oxidation of glucose. However, the level of CO_2 in the blood (and thus, the pH) barely changes. Increased breathing during exercise allows the excess CO_2 to be removed. The following experiment will allow you to compare the amount of CO_2 exhaled while resting and shortly after exercising.

* Universal indicator is red. It turns purple in basic solutions and yellow in acidic solutions.

Procedure:

1. Pour 50 ml of water in a 100 ml beaker. Add 20 drops of .5% NaOH and 20 drops of universal indicator to the water. Swirl to mix. The solution should be purple.

2. Pour half of the solution into another beaker, and put one straw into each beaker.

3. Have a member of your group sit and breathe into one of the beakers using the straw. Record the amount of time that it takes for the solution to become yellow.

4. Have the same student do strenuous exercise (Jumping jacks or sprints) until they are breathing much heavier than normal. Immediately after exercising, have the student sit down and blow into the other solution. Again, record the time that it takes to turn yellow.