The Concept of pH

The relative acidity or alkalinity of a solution can be indicated by its pH. A solution's pH is the negative, base-10 logarithm of the hydrogen ion (H^+) concentration of the solution. As an example, a pH four solution has a H^+ concentration that is ten times greater than that of a pH five solution. That is, a solution with a pH of 4 is ten times more acidic than a solution with a pH of 5. The concept of pH will begin to make more sense when you study the pH scale shown in Figure 2.32. The scale consists of a series of increments ranging from 0 to 14. A solution with a pH of 7 is considered neutral, neither acidic nor basic. Pure water has a pH of 7. The lower the number below 7, the more acidic the solution, or the greater the concentration of H^+. The higher the number above 7, the more basic (alkaline) the solution, or the lower the concentration of H^+. Human urine, for example, is ten times more acidic than pure water, and HCl is 10,000,000 times more acidic than water.

Most cells operate within a very narrow pH range. For example, the pH of human blood typically ranges from 7.2 to 7.6. If the pH fluctuates outside of this range, several organ systems in the body can malfunction. Cells that make up plants also function within specific pH limits. Corn, for example, often grows best when the pH is between 5.5-7. If the pH varies too high or too low, cells no longer function properly, and proteins will break down. Deviation outside of the pH range can even result in death.

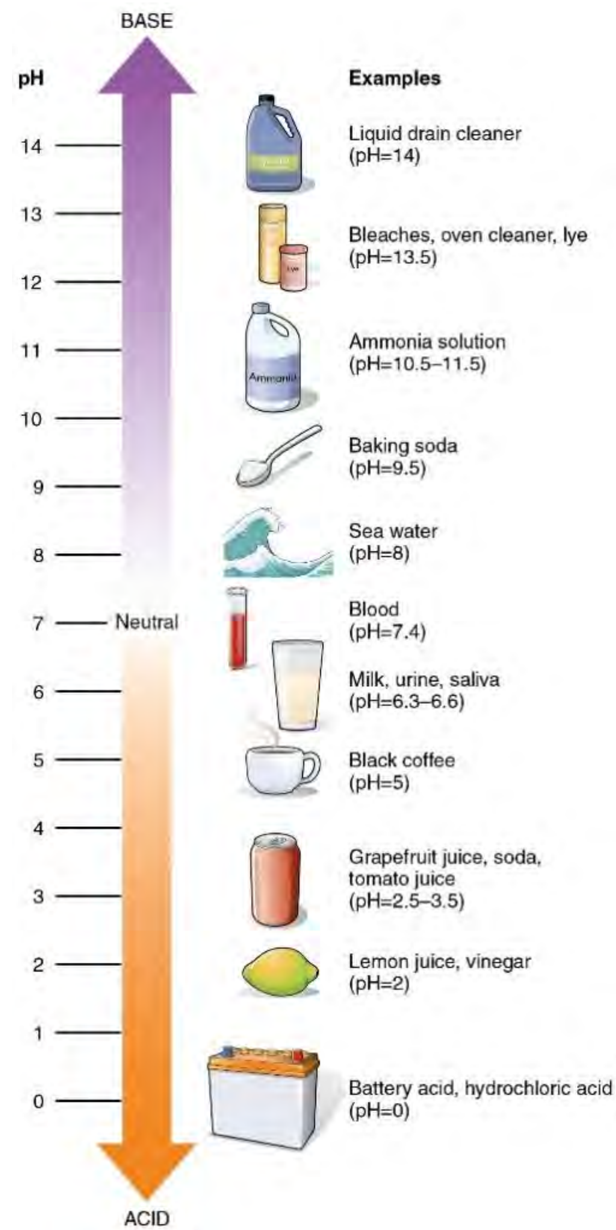

Figure 2.32 The pH Scale (credit: Betts et al./Anatomy and Physiology OpenStax)

So how is it that organisms deal with changes in pH? How is it that we can ingest or inhale acidic or basic substances and not die? For example, how is that we can drink orange juice, an acidic solution, and yet survive? The body has several mechanisms for regulation, involving breathing, the excretion of chemicals in urine, and the internal release of chemicals called buffers into body fluids. **Buffers** readily absorb excess H^+ or OH^-, keeping the pH of the body carefully maintained within a narrow range. Carbon dioxide is part of a prominent buffer system in the human body; it keeps the blood pH within the proper range of approximately 7.4. This buffer system involves carbonic acid (H_2CO_3) and bicarbonate (HCO_3^-) anion (Figure 2.33). If too much H^+ enters the body, bicarbonate will combine with the H^+ to create carbonic acid and limit the decrease in pH. Likewise, if too much OH^- is introduced into the system, carbonic acid will rapidly dissociate into bicarbonate and H^+ ions. The H^+ ions can combine with the OH^- ions, limiting the increase in pH. Without this buffer system, the pH in our bodies would fluctuate too much, and we would fail to survive.

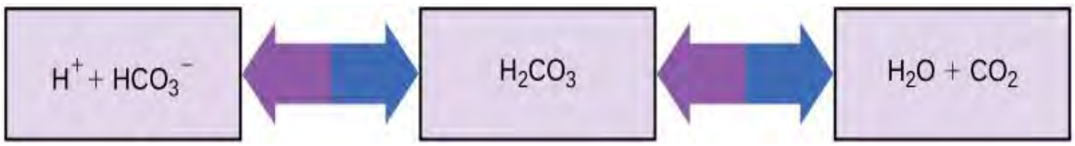

Figure 2.33 This diagram shows the body's buffering of blood pH levels. The blue arrows show the process of raising pH as more CO2 is made. The purple arrows indicate the reverse process: the lowering of pH as more bicarbonate is created. (credit: Clark et. al / Biology 2E OpenStax)

Antacids are another example of buffers that people sometimes use to deal with excess stomach acid. Many of these over-the-counter medications work in the same way as blood buffers, usually with at least one ion capable of absorbing hydrogen ions. This results in an increase of pH, bringing relief to those who suffer "heartburn" after eating.

HOMEOSTATIC IMBALANCES - Acids and Bases

Excessive acidity of the blood and other body fluids is known as acidosis. Common causes of acidosis are situations and disorders that reduce the effectiveness of breathing, especially the person's ability to exhale fully, which causes a buildup of CO_2 and H^+ in the bloodstream. Acidosis can also be caused by metabolic problems that reduce the level or function of buffers that act as bases or promote the production of acids. For instance, with severe diarrhea, too much bicarbonate can be lost from the body, allowing acids to build up in body fluids. In people with poorly managed diabetes ineffective regulation of blood sugar, acids called ketones are produced as a form of energy to fuel the body. These can build up in the blood, causing a serious condition called diabetic ketoacidosis. Kidney failure, liver failure, heart failure, cancer, and other disorders also can prompt metabolic acidosis.

In contrast, alkalosis is a condition in which the blood and other body fluids are too alkaline (basic). As with acidosis, respiratory disorders are a major cause. In respiratory alkalosis, carbon dioxide levels fall too low. Lung disease, aspirin overdose, shock, and ordinary anxiety can cause respiratory alkalosis, which reduces the normal concentration of H^+.

Metabolic alkalosis often results from prolonged, severe vomiting, which causes a loss of hydrogen and chloride ions. Medications can also prompt alkalosis. These include diuretics that cause the body to lose potassium ions, as well as antacids when taken in excessive amounts.

Section Summary

The pH of a solution is a measure of the concentration of hydrogen ions in the solution. A solution with a high number of hydrogen ions is acidic and has a low pH value. A solution with a high number of hydroxide ions is basic and has a high pH value. The pH scale ranges from 0 to 14, with a pH of 7 being neutral. Buffers are solutions that moderate pH changes when an acid or base is added to the buffer system. Buffers are important in biological systems because of their ability to maintain constant pH conditions.

Exercises

1. Acids:
    a. Increase OH^- ions in solution
    b. Decrease OH^- ions in solution
    c. Decrease H^+ ions in solution
    d. Increase H^+ ions in solution

2. Using a pH meter, you find the pH of an unknown solution to be 8.0. How would you describe this solution?
    a. weakly acidic
    b. strongly acidic
    c. weakly basic
    d. strongly basic

3. The pH of lemon juice is about 2.0, whereas tomato juice's pH is about 4.0. Approximately how much of an increase in hydrogen ion concentration is there between tomato juice and lemon juice?
    a. 2 times
    b. 10 times
    c. 100 times
    d. 1000 times

4. Explain why buffers are biologically important.

Answers

1. (d)
2. (c)
3. (c)
4. Buffers readily absorb excess H^+ or OH^-, keeping the pH of the body carefully maintained within a specific range. If the pH deviates outside of this range, body systems can malfunction. Cells no longer function properly, and proteins will break down.