

# 2

## THE CHEMISTRY OF LIFE

**FOCUS:** Chemistry is the study of the composition and structure of substances and the reactions they undergo. Matter is composed of atoms which consist of a nucleus (protons and neutrons) surrounded by electrons. The chemical bonds between atoms of molecules include ionic,

covalent, and hydrogen bonds. A chemical reaction is the process by which atoms or molecules interact to form or break chemical bonds. Important large organic molecules in humans are carbohydrates, lipids, proteins, and nucleic acids.

### CONTENT LEARNING ACTIVITY

#### Basic Chemistry

“Matter is anything that occupies space and has mass.”

A. Match these terms with the correct statement or definition:

Kilogram  
Mass

Matter  
Weight

- \_\_\_\_\_ 1. Anything that occupies space and has mass.
- \_\_\_\_\_ 2. Amount of matter in an object.
- \_\_\_\_\_ 3. Gravitational force acting on an object of given mass.
- \_\_\_\_\_ 4. International unit for mass.



An object with  $1/1000$  the mass of the standard kilogram cylinder is defined to have the mass of 1 gram.

B. Match these terms with the correct statement or definition:

Atom  
Electron  
Electron cloud  
Element

Nucleus  
Neutron  
Proton

- \_\_\_\_\_ 1. Simplest type of matter with unique chemical properties.
- \_\_\_\_\_ 2. Smallest particle of an element that has the chemical characteristics of that element.
- \_\_\_\_\_ 3. Subatomic particle with no electrical charge.
- \_\_\_\_\_ 4. Subatomic particle with a negative charge; moves around nucleus.
- \_\_\_\_\_ 5. Region where electrons are most likely to be found.



The atomic number of an element is equal to the number of protons in each atom.

C. Match these terms with the correct parts labeled in figure 2.1:

Atom  
Electron cloud  
Nucleus

Neutron  
Proton

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_

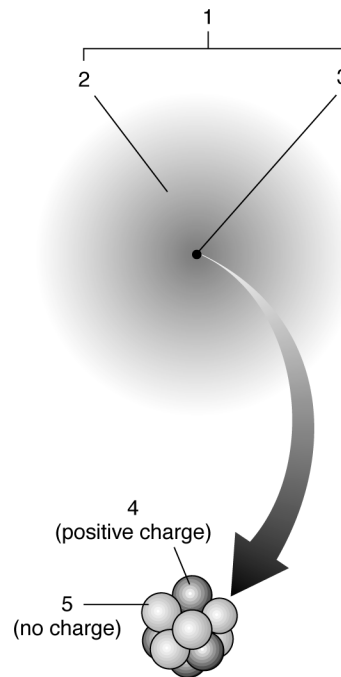


Figure 2.1

## Electrons and Chemical Bonding

“Chemical bonding occurs when the outermost electrons are transferred or shared between atoms.”

Using the terms provided, complete these statements:

Covalent  
Double  
Electrons  
Hydrogen

Ionic  
Ions  
Nonpolar  
Polar

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_

Much of an atom's chemical behavior is determined by its outermost (1). Atoms that have lost or gained electrons are called (2). (3) bonding occurs when oppositely charged ions are attracted to each other. (4) bonds result when two atoms share one or more pairs of electrons. If two pairs of electrons are shared, a (5) covalent bond is formed.

Unequal sharing of electrons produces a (6) covalent bond, such as in water molecules. (7) bonds result when molecules with polar covalent bonds are weakly attracted to ions or other polar covalent molecules.

## Molecules and Compounds

“Atoms can combine to form more complex structures.”

Using the terms provided, complete these statements:

Compound  
Dissociate

Molecule

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_

A (1) is formed when two or more atoms chemically combine to form a structure that behaves as an independent unit. A (2) is a substance composed of two or more *different* types of atoms that are chemically combined.  $H_2$  and  $O_2$  are examples of a (3) that is not a (4). On the other hand, an ionic compound is not a (5) because the ions are held together by the force of attraction between opposite charges. When ionic compounds dissolve in water, their ions separate from each other, or (6).

## Chemical Reactions

“A chemical reaction is the process by which atoms or molecules interact to form or to break chemical bonds.”

Using the terms provided, complete these statements:

ATP	Potential
Decomposition	Products
Equilibrium	Reactants
Exchange	Released
Heat	Reversible
Kinetic	Synthesis

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_
8. \_\_\_\_\_
9. \_\_\_\_\_
10. \_\_\_\_\_
11. \_\_\_\_\_

The atoms or molecules present before the chemical reaction occurs are the (1) and those that result from the chemical reaction are the (2). When two or more atoms, ions, or molecules combine to form a larger, more complex product, the process is called a(n) (3) reaction, whereas in a (4) reaction, reactants are broken down into smaller, less complex products. A(n) (5) reaction is a combination of a decomposition and a synthesis reaction. In a (6) reaction, the reaction can proceed from reactants to products and products to reactants. When the rate of product formation and reactant formation are equal, the reaction is said to be at (7). Energy exists in chemical bonds as (8) energy. If the products of a chemical reaction contain less energy than the reactants, energy is (9). Most of the energy released from a chemical reaction is released as (10). Almost all of the chemical reactions of the cell that require energy use (11) as an energy source.

## Rate of Chemical Reactions

“The rate at which a chemical reaction proceeds is influenced by several factors.”

Using the terms provided, complete these statements:

Catalyst	Enzymes
Decreases	Increases

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_

Chemical reactions are influenced by several factors, including how easily substances react with one another. If the concentration of reactants increases, the rate of a chemical reaction (1). When the temperature decreases, the speed of chemical reactions (2). A (3) is a substance that increases the rate at which a chemical reaction proceeds without itself being permanently changed or depleted. Protein molecules in the body that act as catalysts are called (4). Many of the chemical reactions that occur in the body require enzymes.

## Acids and Bases

“The chemical behavior of many molecules changes as the pH of the solution in which they are dissolved changes.”

A. Match these terms with the correct statement or definition:

Acids  
Bases

Buffers  
Salts

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

1. Substances that are proton ( $H^+$ ) donors.
2. Substances that accept protons.
3. Molecules consisting of a positive ion other than hydrogen and a negative ion other than hydroxide.
4. Chemicals that resists changes in pH when acids or bases are added to a solution.

B. Match these terms with the correct statement or definition:

Acidic solution  
Alkaline (basic) solution

Neutral solution

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

1. pH of 7 (e.g., pure water).
2. pH less than 7.
3. Greater concentration of hydroxide ions than hydrogen ions.



A change in the pH of a solution by one pH unit represents a 10-fold change in the hydrogen ion concentration.

## Inorganic Chemistry

“Inorganic chemistry deals with those substances that do not contain carbon.”

A. Match these terms with the correct statement or definition:

Carbon dioxide ( $CO_2$ )

Oxygen ( $O_2$ )

\_\_\_\_\_

\_\_\_\_\_

1. Comprises about 21% of the gas in the atmosphere; required for the final step of extracting energy from food molecules.
2. Produced when organic molecules such as glucose are metabolized in the cells of the body; toxic if it is allowed to accumulate within cells.

B. Using the terms provided, complete these statements:

Digestion  
Dissociate  
Heat

Lubricant  
React  
Transport

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_

Water has many important properties for living organisms. Water can absorb large amounts of (1) and remain at a stable temperature. Water also acts as an effective (2); for example, tears protect the surface of the eye. Water is necessary in many chemical reactions, such as the (3) of food. Water is necessary for (4) of nutrients, gases, and waste products in the body. When ionic substances dissolve in water, the positive and negative ions separate, or (5), allowing the ions to stay in solution and (6) with other molecules.

## Organic Chemistry

“Organic chemistry is the study of carbon-containing substances.”

Match these terms with the correct statement or definition:

Inorganic molecules  
Organic molecules

\_\_\_\_\_  
\_\_\_\_\_

1. Include carbohydrates, lipids, proteins and nucleic acids.
2. All molecules that do not contain carbon (except carbon dioxide and carbon monoxide).

## Carbohydrates

“Carbohydrates are small to very large molecules that are composed of carbon, hydrogen, and oxygen atoms.”

Match these terms with the correct statement or definition:

Disaccharides  
Monosaccharides

Polysaccharides

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

1. Simple sugars (e.g., glucose) that are the building blocks for other carbohydrates.
2. Sucrose and other double sugars.
3. Many monosaccharides bound in long chains, e.g., glycogen and starch.

## Lipids

“Lipids dissolve in nonpolar solvents such as alcohol or acetone, but not in water.”

Match these terms with the correct statement or definition:

Fatty acids  
Glycerol  
Lipids

Saturated  
Triacylglycerol  
Unsaturated

- \_\_\_\_\_ 1. Fats, phospholipids, and steroids.
- \_\_\_\_\_ 2. Building blocks of fats.
- \_\_\_\_\_ 3. Most common type of fat molecule, with three fatty acids bound to a glycerol molecule.
- \_\_\_\_\_ 4. Fatty acid that contains only single covalent bonds between the carbon atoms.
- \_\_\_\_\_ 5. Believed to be the best type of fat in the diet.

## Proteins

“All proteins contain carbon, hydrogen, oxygen, and nitrogen, and most have some sulfur.”

Using the terms provided, complete these statements:

Activation energy  
Amino acid  
Contraction  
Denaturation  
Enzymes

Essential  
Lock and key  
model  
Shape  
Structural

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_
8. \_\_\_\_\_
9. \_\_\_\_\_

The building blocks of proteins are 20 basic types of (1) molecules. Humans can synthesize 12 of these from simple organic molecules, but the remaining eight are called (2), and must be included in the diet. The ability of proteins to perform their functions depends on their (3). (4) occurs when hydrogen bonds that maintain a protein's shape are broken, and the protein becomes nonfunctional. Proteins perform many important functions. (5) are proteins that regulate the rate of chemical reactions, (6) proteins provide the framework for many of the body's tissues, and muscles contain proteins that are responsible for muscle (7). Enzymes increase the rate of chemical reactions by lowering the (8) necessary to start a chemical reaction. According to the (9) of enzyme action, the shape of enzymes and reactants allows them to bind together easily.



The rate at which enzymes are produced in cells or whether the enzymes are in an active or inactive form determines the rate of each chemical reaction.

## Nucleic Acids

“Nucleic acids are composed of carbon, hydrogen, oxygen, nitrogen, and phosphorus.”

Match these terms with the correct statement or definition:

Chromatin  
Chromosomes  
DNA

Nucleotide  
RNA

- \_\_\_\_\_ 1. Building block for nucleic acids; contains a five-carbon sugar, a nitrogen base, and a phosphate group.
- \_\_\_\_\_ 2. Contains deoxyribose; nucleotides form a double helix.
- \_\_\_\_\_ 3. DNA molecules associated with protein.
- \_\_\_\_\_ 4. Formed when chromatin condenses during cell division.
- \_\_\_\_\_ 5. Single strand of nucleotides that contains the sugar ribose.
- \_\_\_\_\_ 6. Genetic material of the cell; controls cell activities.

### QUICK RECALL

1. List three subatomic particles and give their charge.
2. List three types of bonds between atoms.
3. List three types of chemical reactions according to the size of the reactant and product molecules.
4. List four influences on the rate of a chemical reaction.



5. Name the four types of large organic molecules found in living things. For each type of organic molecule, list its building block(s).
  
6. List three kinds of carbohydrates.
  
7. List three functions of lipids in the human body.
  
8. List six functions of proteins in the human body.
  
9. List three functions of nucleic acids in the human body.

## WORD PARTS

Give an example of a new vocabulary word that contains each word part.

WORD PART	MEANING	EXAMPLE
neutr-	neither	1. _____
iso-	equal; alike	2. _____
syn-	together	3. _____
poly-	many	4. _____
mono-	one	5. _____
sacchar-	sugar	6. _____

## MASTERY LEARNING ACTIVITY

Place the letter corresponding to the correct answer in the space provided.

- \_\_\_\_\_ 1. The smallest particles into which an element can be divided using chemical methods are
- electrons.
  - molecules.
  - neutrons.
  - protons.
  - atoms.
- \_\_\_\_\_ 2. The number of electrons in an atom is equal to
- the number of neutrons.
  - the number of protons.
  - the atomic number.
  - b and c
- \_\_\_\_\_ 3. A polar covalent bond occurs when
- electrons are not shared equally between atoms.
  - two atoms share electrons equally.
  - an electron is lost from one atom and accepted by another.
  - the molecule becomes ionized.
  - a hydrogen atom is shared between two different atoms.
- \_\_\_\_\_ 4. Which of these is a synthesis reaction?
- hydrochloric acid (HCl) and sodium hydroxide (NaOH) combine to form sodium chloride (NaCl) and water (H<sub>2</sub>O).
  - monosaccharides are combined to produce polysaccharides.
  - fats are broken down to fatty acids and glycerol.
  - all of the above
- \_\_\_\_\_ 5. In a decomposition reaction
- atoms are transferred to another molecule.
  - large molecules are broken down to smaller molecules.
  - large molecules are formed from smaller molecules.
  - all of the above
- \_\_\_\_\_ 6. The rate of chemical reactions is influenced by
- the concentration of the reactants.
  - temperature.
  - enzymes.
  - all of the above
- \_\_\_\_\_ 7. A solution with a pH of 5 is a (an) \_\_\_\_\_ and contains \_\_\_\_\_ hydrogen ions than a neutral solution.
- base, more
  - base, fewer
  - acid, more
  - acid, fewer
- \_\_\_\_\_ 8. A buffer
- slows down chemical reactions.
  - speeds up chemical reactions.
  - increases the pH of solutions.
  - maintains a relatively constant pH.
- \_\_\_\_\_ 9. Water
- is composed of two oxygen atoms and one hydrogen atom.
  - carries small amounts of heat from the body when it evaporates.
  - is composed of polar molecules into which ionic substances dissociate.
  - is not involved in most chemical reactions in the body.
- \_\_\_\_\_ 10. Which of these is an example of a carbohydrate?
- glycogen
  - phospholipid
  - steroid
  - DNA
  - none of the above

- \_\_\_\_\_ 11. The basic units or building blocks of fats are
- simple sugars (monosaccharides).
  - double sugars (disaccharides).
  - amino acids.
  - glycerol and fatty acids.
  - nucleotides.
- \_\_\_\_\_ 12. Which of these statements is true?
- There are 12 basic types of amino acids in proteins.
  - Eight essential amino acids can be produced by the human body.
  - Amino acids are arranged in the same order in all proteins.
  - Hydrogen bonds produce folds or coils in an amino acid chain.
  - Shape of proteins does not affect their function.
- \_\_\_\_\_ 13. Enzymes
- function by raising activation energy required for reactions.
  - are protein molecules that act as catalysts.
  - can be used again after a reaction.
  - b and c
- \_\_\_\_\_ 14. Which of these concepts is directly related to the shape of a protein?
- lock and key model of enzymes
  - denaturation
  - hydrogen bonds form between amino acids
  - enzymes are specific for the reactions they control
  - all of the above
- \_\_\_\_\_ 15. DNA
- is the genetic material of the cell.
  - is a single strand of nucleotides.
  - contains the sugar ribose.
  - occurs in three different types.
  - all of the above



## FINAL CHALLENGES



Use a separate sheet of paper to complete this section.

- You fill a glass with water, place a teaspoon of salt (NaCl) in it, and note that the salt "disappears". You then let the glass sit until the water evaporates, and the salt "reappears". Explain the apparent disappearance and reappearance of the salt molecules.
- Two substances, A and B, can combine to form substance C:
 
$$A + B \rightarrow C$$
 Substance A and B each dissolve in water to form a colorless solution, whereas substance C is a red solution. Using this information, explain these two experiments.
  - When solutions A and B are combined, no color change takes place. However, when the combined solution is heated, it turns red.
  - When solution A and B are combined, no color change takes place. However, when substance D is added to the combined solution, it turns red. Later, the exact amount of substance D that was added is recovered from the solution.
- Given that blood is buffered by these reactions:
 
$$\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^-$$
 What happens to blood pH if a person holds his (her) breath?
- Suppose you have two substances and you know one is a carbohydrate and one is a lipid. How could you tell which one was the carbohydrate and which one was the lipid, if you had available the materials found in a bathroom? (Hint: medicine cabinet).