

Basic Chemistry

Everything in the universe is composed of one or more elements, the unique building blocks of all matter. Although over 100 elemental substances exist, only four of these (carbon, hydrogen, oxygen, and nitrogen) make up over 96% of all living material.

The student activities in this chapter consider basic concepts of both inorganic and organic chemistry. Chemistry is the science that studies the composition of matter. Inorganic chemistry studies the chemical composition of nonliving substances that (generally) do not contain carbon. Organic chemistry studies the carbon-based chemistry (or biochemistry) of living organisms, whether they are maple trees, fish, or humans.

Understanding atomic structure, bonding behavior of elements, and the structure and activities of the most abundant biologic molecules (proteins, fats, carbohydrates, and nucleic acids) is tested in various ways. Mastering these concepts is necessary to understand how the body functions.

CONCEPTS OF MATTER AND ENERGY

1. Select *all* phrases that apply to each of the following statements and insert the letters in the answer blanks.

- _____ 1. The energy located in the bonds of food molecules:
- | | |
|----------------------------------|---|
| A. is called thermal energy | C. causes molecular movement |
| B. is a form of potential energy | D. can be transformed to the bonds of ATP |
- _____ 2. Heat is:
- | | |
|-----------------------|-----------------------|
| A. thermal energy | C. kinetic energy |
| B. infrared radiation | D. molecular movement |
- _____ 3. Whenever energy is transformed:
- | | |
|--|-----------------------------|
| A. the amount of useful energy decreases | C. some energy is created |
| B. some energy is lost as heat | D. some energy is destroyed |

2. Use choices from the key to identify the energy *form* in use in each of the following examples.

Key Choices

- A. Chemical B. Electrical C. Mechanical D. Radiant

- _____ 1. Chewing food
 _____ 2. Vision (two types, please—think!)
 _____ 3. Bending your fingers to make a fist
 _____ 4. Breaking the bonds of ATP molecules to energize your muscle cells to make that fist
 _____ 5. Lying under a sunlamp

COMPOSITION OF MATTER

3. Complete the following table by inserting the missing words.

Particle	Location	Electrical charge	Mass
		+ 1	
Neutron			
	Orbitals		

4. Insert the *chemical symbol* (the chemist's shorthand) in the answer blank for each of the following elements.

- _____ 1. Oxygen _____ 4. Iodine _____ 7. Calcium _____ 10. Magnesium
 _____ 2. Carbon _____ 5. Hydrogen _____ 8. Sodium _____ 11. Chloride
 _____ 3. Potassium _____ 6. Nitrogen _____ 9. Phosphorus _____ 12. Iron

5. Using the key choices, select the correct responses to the following descriptive statements. Insert the appropriate answers in the answer blanks.

Key Choices

- A. Atom C. Element E. Ion G. Molecule I. Protons
 B. Electrons D. Energy F. Matter H. Neutrons J. Valence

- _____ 1. An electrically charged atom or group of atoms
 _____ 2. Anything that takes up space and has mass (weight)

- _____ 3. A unique substance composed of atoms having the same atomic number
- _____ 4. Negatively charged particles, forming part of an atom
- _____ 5. Subatomic particles that determine an atom's chemical behavior, or bonding ability
- _____ 6. The ability to do work
- _____ 7. The smallest particle of an element that retains the properties of the element
- _____ 8. The smallest particle of a compound, formed when atoms combine chemically
- _____ 9. Positively charged particles forming part of an atom
- _____ 10. Name given to the electron shell that contains the most reactive electrons
- _____ 11. _____ 12. Subatomic particles responsible for most of an atom's mass

6. For each of the following statements that is true, insert *T* in the answer blank. If any of the statements are false, correct the underlined term by inserting your correction in the answer blank.

- _____ 1. Na^+ and K^+ are needed for nerve cells to conduct electrical impulses.
- _____ 2. The atomic number of oxygen is 8. Therefore, oxygen atoms always contain 8 neutrons.
- _____ 3. The greater the distance of an electron from the nucleus, the less energy it has.
- _____ 4. Electrons are located in more or less designated areas of space around the nucleus called orbitals.
- _____ 5. An unstable atom that decomposes and emits energy is called retroactive.
- _____ 6. Iron is necessary for oxygen transport in red blood cells.
- _____ 7. The most abundant negative ion in extracellular fluid is calcium.
- _____ 8. The element essential for the production of thyroid hormones is magnesium.
- _____ 9. Calcium is found as a salt in bones and teeth.

MOLECULES, CHEMICAL BONDS, AND CHEMICAL REACTIONS

7. Match the terms in Column B to the chemical equations listed in Column A. Enter the correct letter or term in the answer blanks.

Column A	Column B
_____ 1. $A + B \rightarrow AB$	A. Decomposition
_____ 2. $AB + CD \rightarrow AD + CB$	B. Exchange
_____ 3. $XY \rightarrow X + Y$	C. Synthesis

8. Figure 2-1 is a diagram of an atom. Select two different colors and use them to color the coding circles and corresponding structures on the figure. Complete this exercise by responding to the questions that follow, referring to the atom in this figure. Insert your answers in the answer blanks provided.

- Nucleus
- Electrons

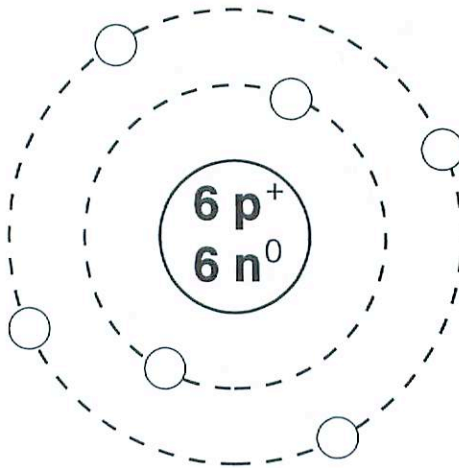
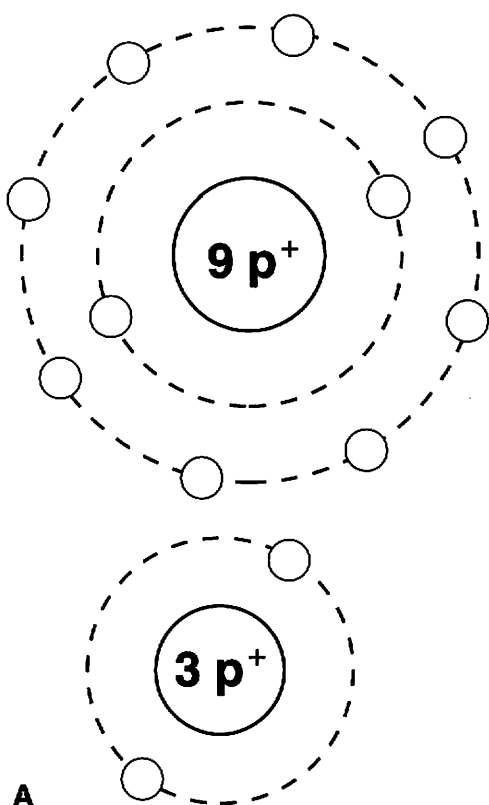


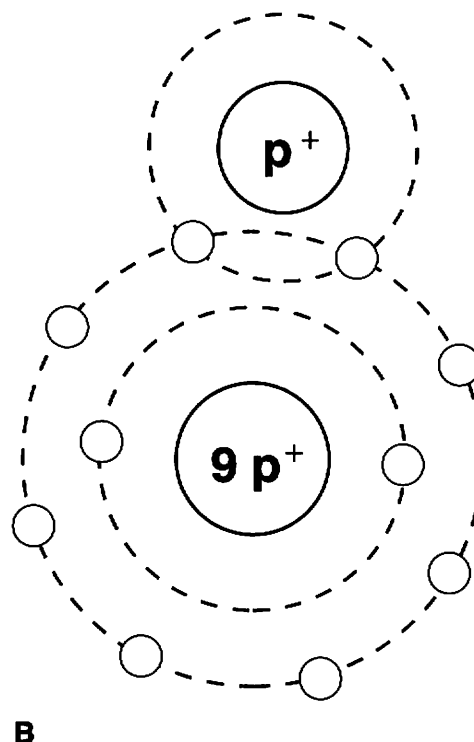
Figure 2-1

1. What is the atomic number of this atom? _____
2. What is its atomic mass? _____
3. What atom is this? _____
4. If this atom had one additional neutron but the other subatomic particles remained the same as shown, this slightly different atom (of the same element) would be called a(n) _____
5. Is this atom chemically active or inert? _____
6. How many electrons would be needed to fill its outer (valence) shell? _____

7. Would this atom most likely take part in forming ionic or covalent bonds? _____ Why? _____
-
9. Both H_2O_2 and 2OH^- are chemical species with two hydrogen atoms and two oxygen atoms. Briefly explain how these species are different:
-
-
10. Two types of chemical bonding are shown in Figure 2-2. In the figure, identify each type as a(n) *ionic* or *covalent* bond. In the case of the ionic bond, indicate which atom has lost an electron by adding a colored arrow to show the direction of electron transfer. For the covalent bond, indicate the shared electrons.



Type of bond: _____



Type of bond: _____

Figure 2-2

11. Figure 2-3 illustrates five water molecules held together by hydrogen bonds. First, correctly identify the oxygen and hydrogen atoms both by color and by inserting their atomic symbols on the appropriate circles (atoms). Then label the following structures in the figure:

- Oxygen
- Hydrogen
- Positive pole (end)
- Negative pole (end)
- Hydrogen bonds

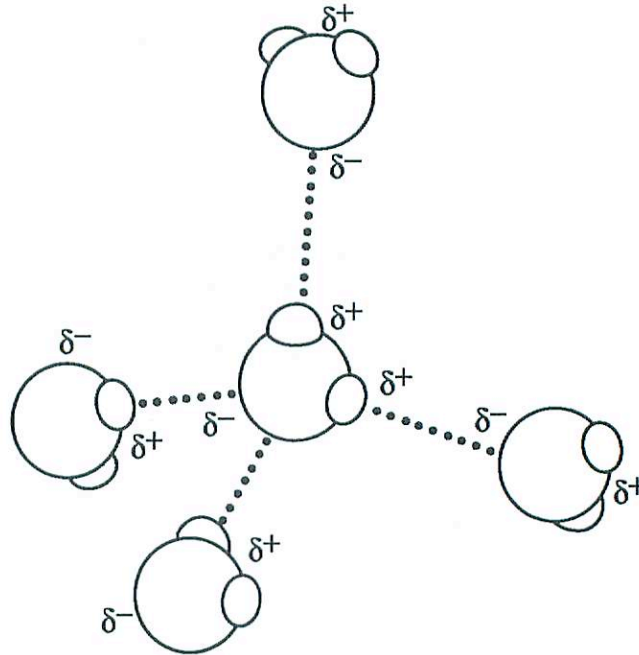
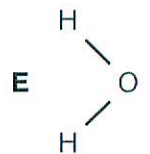
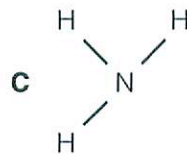
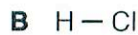
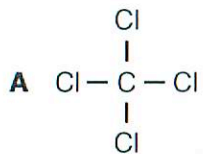


Figure 2-3

12. Circle each structural formula that is likely to be a polar covalent compound.



13. Respond to the instructions following the equation:



1. In the space provided, list the chemical formula(s) of compounds. _____
2. In the space provided, list the chemical formula(s) of ions. _____
3. Circle the product(s) of the reaction.
4. Modify the equation by adding a colored arrow in the proper place to indicate that the reaction is reversible.

BIOCHEMISTRY: THE COMPOSITION OF LIVING MATTER

14. Use key choices to identify the substances described in the following statements. Insert the appropriate letter(s) or corresponding term(s) in the answer blanks.

Key Choices

A. Acid(s) B. Base(s) C. Buffer D. Salt(s)

- _____ 1. _____ 2. _____ 3. Substances that ionize in water; good electrolytes
- _____ 4. Proton (H⁺) acceptor
- _____ 5. Ionize in water to release hydrogen ions and a negative ion other than hydroxide (OH⁻)
- _____ 6. Ionize in water to release ions other than H⁺ and OH⁻
- _____ 7. Formed when an acid and a base are combined
- _____ 8. Substances such as lemon juice and vinegar
- _____ 9. Prevents rapid/large swings in pH

15. Complete the following statements concerning the properties and biological importance of water.

- _____ 1. The ability of water to maintain a relatively constant temperature and thus prevent sudden changes is because of its high _____
- _____ 2. (1). Biochemical reactions in the body must occur in (2). About (3) % of the volume of a living cell is water. Water molecules are bonded to other water molecules because of the presence of (4) bonds. Water, as H⁺ and OH⁻ ions, is essential in biochemical reactions such as (5) and (6) reactions. Because of its (7), water is an excellent solvent and forms the basis of mucus and other body (8).
- _____ 3.
- _____ 4.
- _____ 5.
- _____ 6.
- _____ 7.
- _____ 8.

16. Using the key choices, fully characterize weak and strong acids.

Key Choices

- A. Ionize completely in water
- B. Ionize incompletely in water
- C. Act as part of a buffer system
- D. When placed in water, always act to change the pH
- E. Ionize at high pH
- F. Ionize at low pH
- G. Ionize at pH 7

Weak acid: _____ Strong acid: _____

17. Use an X to designate which of the following are organic compounds.

- _____ Carbon dioxide _____ Fats _____ Proteins _____ H₂O
- _____ Oxygen _____ KCl _____ Glucose _____ DNA

18. Match the terms in Column B to the descriptions provided in Column A. Enter the correct letter(s) or term(s) in the answer blanks.

Column A	Column B
_____ 1. Building blocks of carbohydrates	A. Amino acids
_____ 2. Building blocks of fat	B. Carbohydrates
_____ 3. Building blocks of protein	C. Lipids (fats)
_____ 4. Building blocks of nucleic acids	D. Fatty acids
_____ 5. Cellular cytoplasm is primarily composed of this substance	E. Glycerol
_____ 6. The single most important fuel source for body cells	F. Nucleotides
_____ 7. Not soluble in water	G. Monosaccharides
_____ 8. Contain C, H, and O in the ratio CH ₂ O	H. Proteins
_____ 9. Contain C, H, and O, but have relatively small amounts of oxygen	
_____ 10. _____	11. These building blocks contain N in addition to C, H, and O
_____ 12. Contain P in addition to C, H, O, and N	
_____ 13. Used to insulate the body and found in all cell membranes	
_____ 14. Primary components of meat and cheese	
_____ 15. Primary components of bread and lollipops	
_____ 16. Primary components of egg yolk and peanut oil	

- _____ 17. Include collagen and hemoglobin
 _____ 18. Class that usually includes cholesterol

19. Using key choices, correctly select *all* terms that correspond to the following descriptions. Insert the correct letter(s) or their corresponding term(s) in the answer blanks.

Key Choices

- | | | | |
|----------------|---------------|-------------|------------|
| A. Cholesterol | D. Enzyme | G. Hormones | J. Maltose |
| B. Collagen | E. Glycogen | H. Keratin | K. RNA |
| C. DNA | F. Hemoglobin | I. Lactose | L. Starch |

- _____ 1. Example(s) of fibrous (structural) proteins
 _____ 2. Example(s) of globular (functional) proteins
 _____ 3. Biologic catalyst
 _____ 4. Plant storage carbohydrate
 _____ 5. Animal storage carbohydrate
 _____ 6. The "stuff" of the genes
 _____ 7. A steroid
 _____ 8. Double sugars, or disaccharides

20. Five simplified diagrams of biological molecules are depicted in Figure 2-4. First, identify the molecules and insert the correct names in the answer blanks on the figure. Then select a different color for each molecule listed below and use them to color the coding circles and the corresponding molecules on the illustration.

- | | | |
|--|--------------------------------------|--------------------------------------|
| <input type="radio"/> Fat | <input type="radio"/> Nucleotide | <input type="radio"/> Monosaccharide |
| <input type="radio"/> Functional protein | <input type="radio"/> Polysaccharide | |

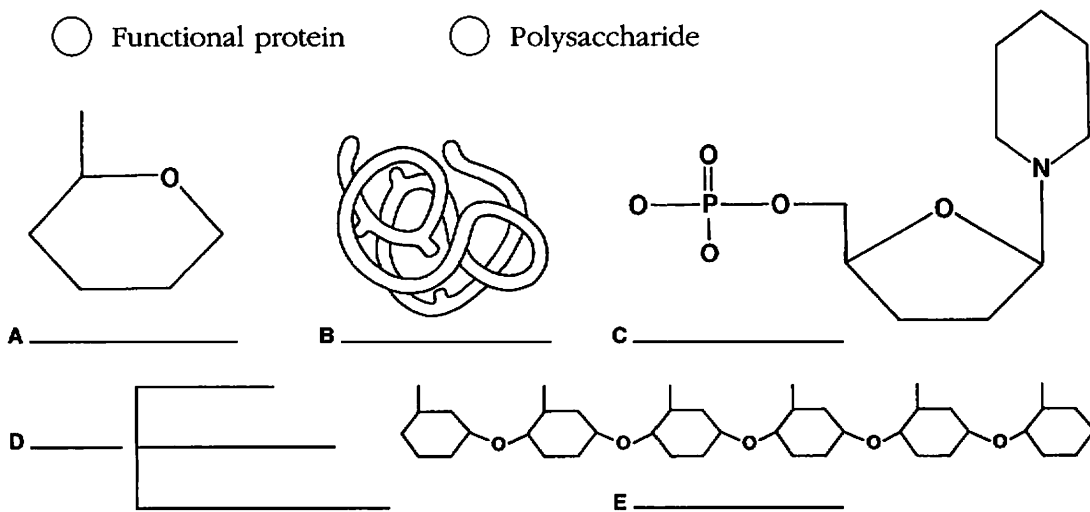


Figure 2-4

21. Circle the term that does not belong in each of the following groupings.

- | | | | |
|---------------|-------------|-----------|-------------|
| 1. Adenine | Guanine | Glucose | Thymine |
| 2. DNA | Ribose | Phosphate | Deoxyribose |
| 3. Galactose | Glycogen | Fructose | Glucose |
| 4. Amino acid | Polypeptide | Glycerol | Protein |
| 5. Glucose | Sucrose | Lactose | Maltose |

22. For each true statement, insert *T* in the answer blank. If any are false, correct the underlined term and insert your correction in the answer blank.

- _____ 1. Phospholipids are polarized molecules.
- _____ 2. Steroids are the major form in which body fat is stored.
- _____ 3. Water is the most abundant compound in the body.
- _____ 4. Nonpolar molecules are generally soluble in water.
- _____ 5. The bases of RNA are A, G, C, and U.
- _____ 6. The universal energy currency of living cells is RNA.
- _____ 7. RNA is single stranded.
- _____ 8. The four elements comprising over 90% of living matter are C, H, N, and Na.

23. Figure 2–5 shows the molecular structure of DNA, a nucleic acid.

- A. First, identify the two unnamed nitrogen bases and insert their correct names and symbols in the two blanks beside the color-coding circles.
- B. Complete the identification of the bases on the diagram by inserting the correct symbols in the appropriate spaces on the right side of the diagram.
- C. Select different colors and color the coding circles and the corresponding parts of the diagram.
- D. Label one d-R sugar unit and one P unit of the “backbones” of the DNA structure by inserting leader lines and labels on the diagram.
- E. Circle the associated nucleotide.

- | | | |
|---|------------------------------------|---------------------------------|
| <input type="radio"/> Deoxyribose sugar (d-R) | <input type="radio"/> Adenine (A) | <input type="radio"/> _____ () |
| <input type="radio"/> Phosphate (P) | <input type="radio"/> Cytosine (C) | <input type="radio"/> _____ () |

Then answer the questions following Figure 2–5 by writing your answers in the answer blanks.

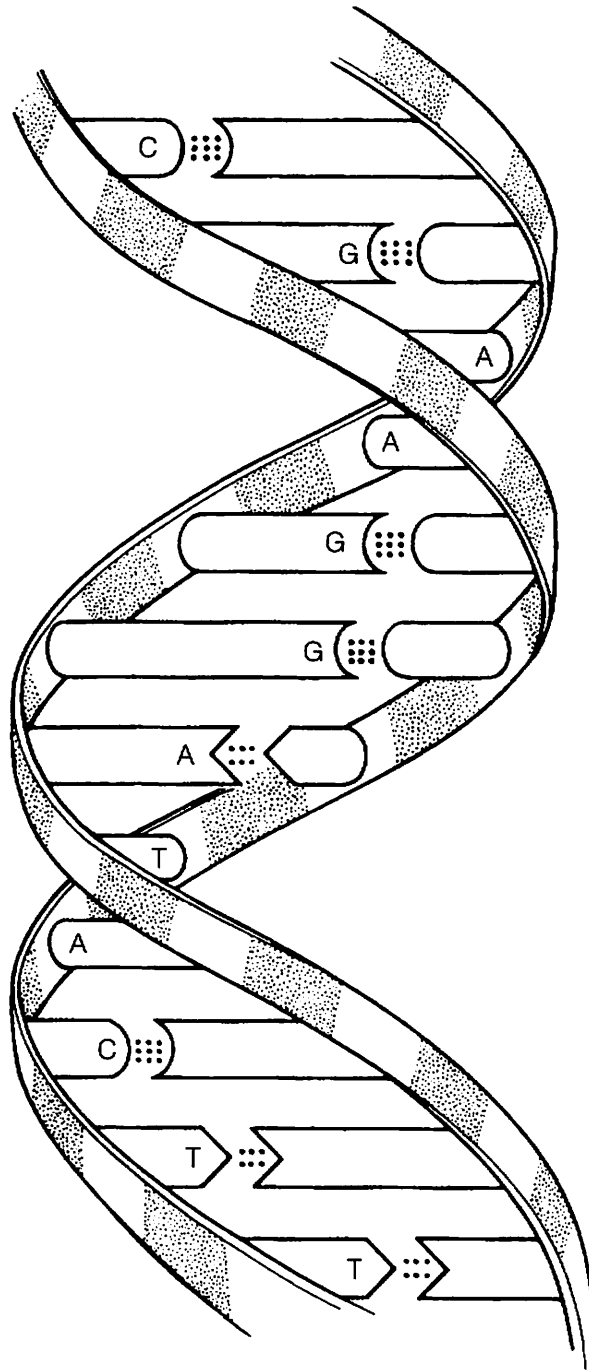


Figure 2-5

1. Name the bonds that help to hold the two DNA strands together. _____
2. Name the three-dimensional shape of the DNA molecule. _____
3. How many base-pairs are present in this segment of a DNA model? _____
4. What is the term that means “base-pairing”? _____

24. The biochemical reaction shown in Figure 2-6 represents the complete digestion of a polymer (a large molecule as consumed in food) down to its constituent monomers, or building blocks. Select two colors and color the coding circles and the structures. Then, select the one correct answer for each statement below and insert your answer in the answer blank.

Monomer Polymer

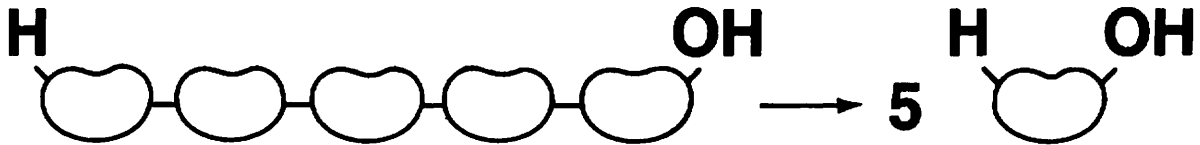
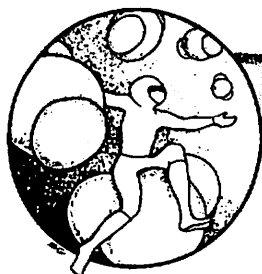


Figure 2-6

- _____ 1. If starch is the polymer, the monomer is:
- A. glycogen B. amino acid C. glucose D. maltose
- _____ 2. During polymer digestion, water as H⁺ and OH⁻ ions would:
- A. be a product of the reaction.
- B. act as a catalyst.
- C. enter between monomers, bond to them, and keep them separated.
- D. not be involved in this reaction.
- _____ 3. Another name for the chemical digestion of polymers is:
- A. dehydration B. hydrolysis C. synthesis D. displacement
- _____ 4. If the monomers are amino acids, they may differ from each other by their:
- A. R group B. amino group C. acid group D. peptide bond



INCREDIBLE JOURNEY

A Visualization Exercise for Biochemistry

... you are suddenly up-ended and are carried along in a sea of water molecules at almost unbelievable speed.

25. Complete the narrative by inserting the missing words in the answer blanks.

- _____ 1. For this journey, you are miniaturized to the size of a very small molecule by colleagues who will remain in contact with you by radio. Your instructions are to play the role of a water molecule and to record any reactions that involve water molecules. Since water molecules are polar molecules, you are outfitted with an insulated rubber wet suit with one (1) charge at your helmet and two (2) charges, one at the end of each leg.
- _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. As soon as you are injected into your host's bloodstream, you feel as though you are being pulled apart. Some large, attractive forces are pulling at your legs from different directions! _____ 7. You look about but can see only water molecules. After a moment's thought, you remember the polar nature of your wet suit. You record that these forces must be the (3) that are easily formed and easily broken in water. _____ 8. _____ 9. _____ 10. After this initial surprise, you are suddenly up-ended and carried along in a sea of water molecules at almost unbelievable speed. You have just begun to observe some huge, red, disk-shaped structures (probably (4)) taking up O₂ molecules, when you are swept into a very turbulent environment. Your colleagues radio that you are in the small intestine. With difficulty, because of numerous collisions with other molecules, _____ 11. you begin to record the various types of molecules you see. _____ 12.

In particular, you notice a very long helical molecule made of units with distinctive R-groups. You identify and record this type of molecule as a (5), made of units called (6) that are joined together by (7) bonds. As you move too close to the helix during your observations, you are nearly pulled apart to form two ions, (8), but you breathe a sigh of relief as two ions of another water molecule take your place. You watch as these two ions move between two units of the long helical molecule. Then, in a fraction of a second, the bond between the two units is broken. As you record the occurrence of this chemical reaction, called (9), you are jolted into another direction by an enormous globular protein, the very same (10) that controls and speeds up this chemical reaction.

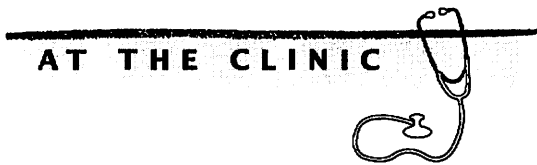
Once again you find yourself in the bloodstream, heading into an organ identified by your colleagues as the liver. Inside a liver cell, you observe many small monomers, made up only of C, H, and O atoms. You identify these units as (11) molecules because the liver cells are bonding them together to form very long, branched polymers called (12). You record that this type of chemical

_____ 13. reaction is called (13), and you happily note that this reaction also produces (14) molecules like you!

_____ 14.

_____ 15. After another speedy journey through the bloodstream, you reach the skin. You move deep into the skin and finally gain access to a sweat gland. In the sweat gland, you collide with millions of water molecules and some ionized salt molecules

that are continually attracted to your positive and negative charges. Suddenly, the internal temperature rises, and molecular collisions (15) at an alarming rate, propelling you through the pore of the sweat gland onto the surface of the skin. So that you will be saved from the fate of evaporating into thin air, you contact your colleagues and are speedily rescued.



26. It is determined that a patient is in acidosis. What does this mean, and would you treat the condition with a chemical that would *raise* or *lower* the pH?

27. A newborn is diagnosed with sickle-cell anemia, a genetic disease in which substitution of one amino acid results in abnormal hemoglobin. Explain to the parents how the substitution can have such a drastic effect on the structure of the protein.

28. Johnny's body temperature is spiking upward. When it reaches 104°F, his mother puts in a call to the pediatrician. She is advised to give Johnny children's aspirin and sponge his body with cool to tepid water to prevent a further rise in temperature. How might a fever (excessively high body temperature) be detrimental to Johnny's welfare?

29. Mrs. Gallo's physician suspects that she is showing the initial signs of multiple sclerosis, a disease characterized by the formation of hardened plaques in the insulating sheaths surrounding nerve fibers. What medical imaging technique will the physician probably order to determine if such plaques are present?