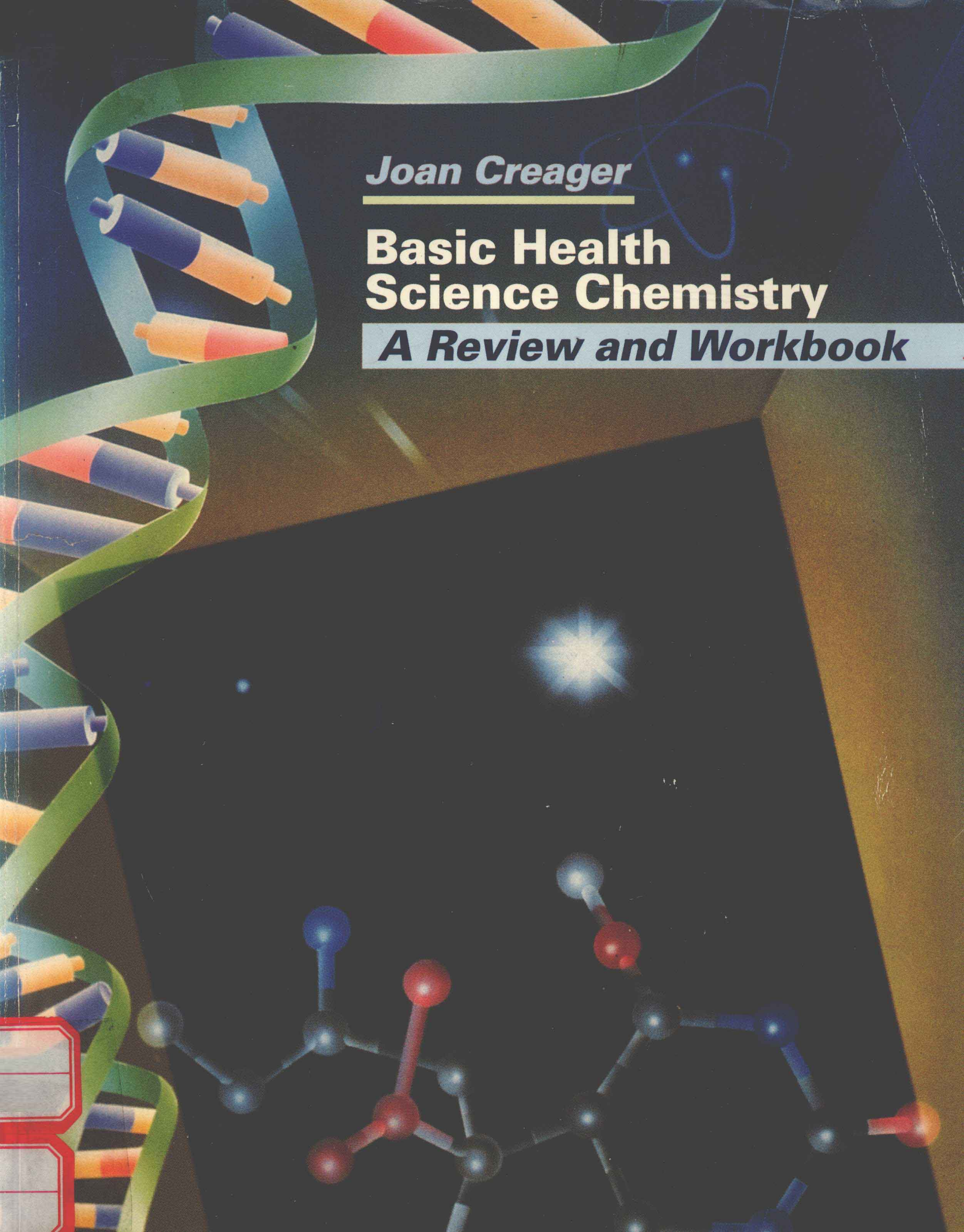
Joan Creager

Basic Health Science Chemistry

A Review and Workbook



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Basic Health Science Chemistry

A Review and Workbook

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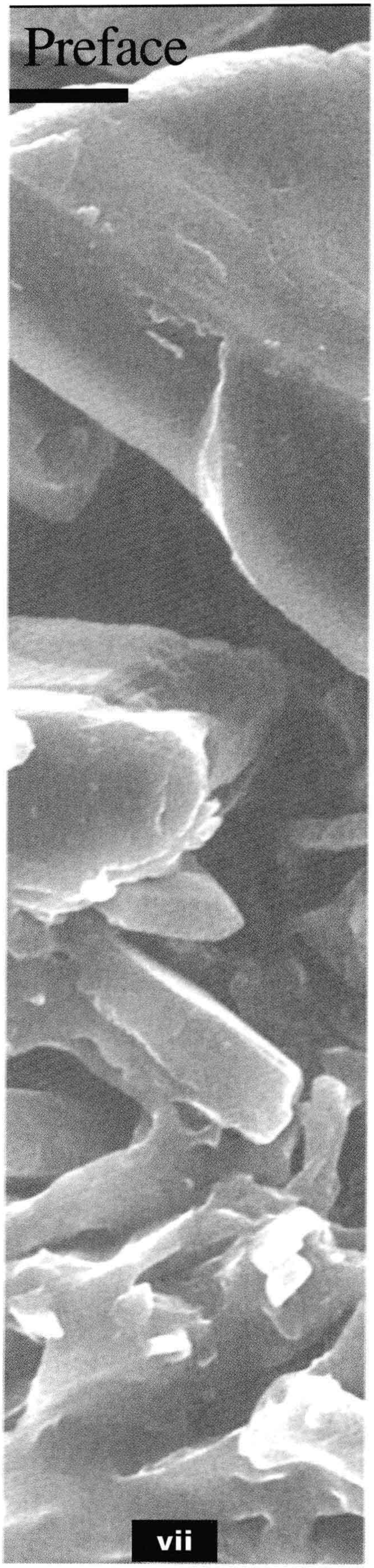
Preface



This book provides a thorough review of basic chemistry relevant to the life sciences, with concepts presented in the context of human physiology. It will serve as a study aid for students in undergraduate curricula in the health sciences and as a review tool for those entering graduate or professional schools.

Each chapter begins with a correlated layout of outline and objectives that give a quick overview of the chapter and allow the reader maximum flexibility in selecting appropriate sections for study or review. Questions in the chapter text ask for information provided in the preceding major section of the chapter. In the Study and Review section, "Did you get the essentials?" requires that boldface terms, which appear throughout each chapter, be used to fill in the blanks. The combined glossary-index gives a definition and page reference for every boldfaced term in the text.

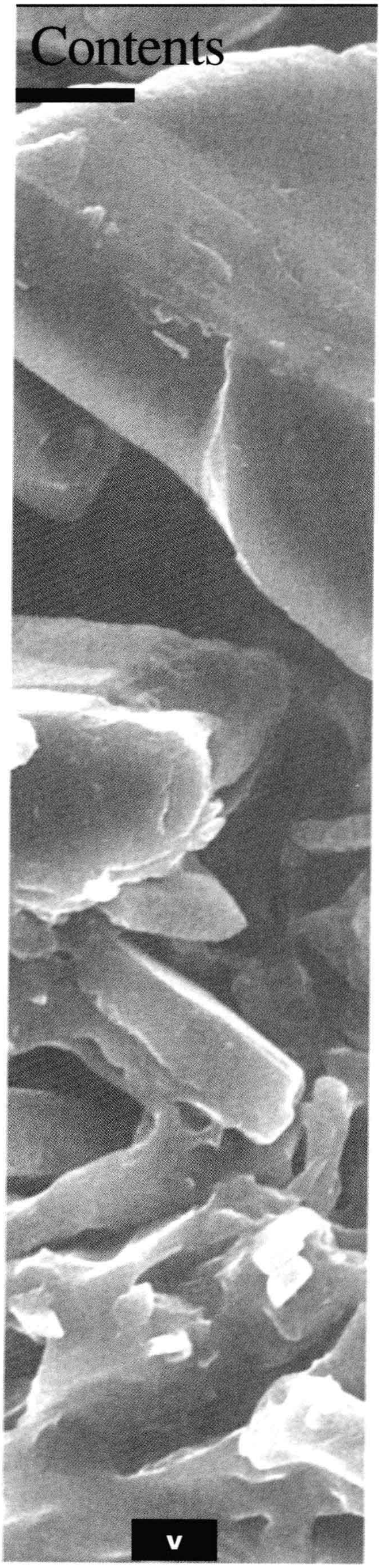
Acknowledgments

In a way, all the people who contributed to the second edition of *Human Anatomy and Physiology* also contributed to this book and I thank them again for their contributions. I am especially indebted to reviewers who considered this manuscript for its usefulness as an aid to mastering basic concepts of chemistry. Those reviewers follow:

Anne E. Lesak
Moraine Valley Community College
Virginia Rivers
Truckee Meadows Community College

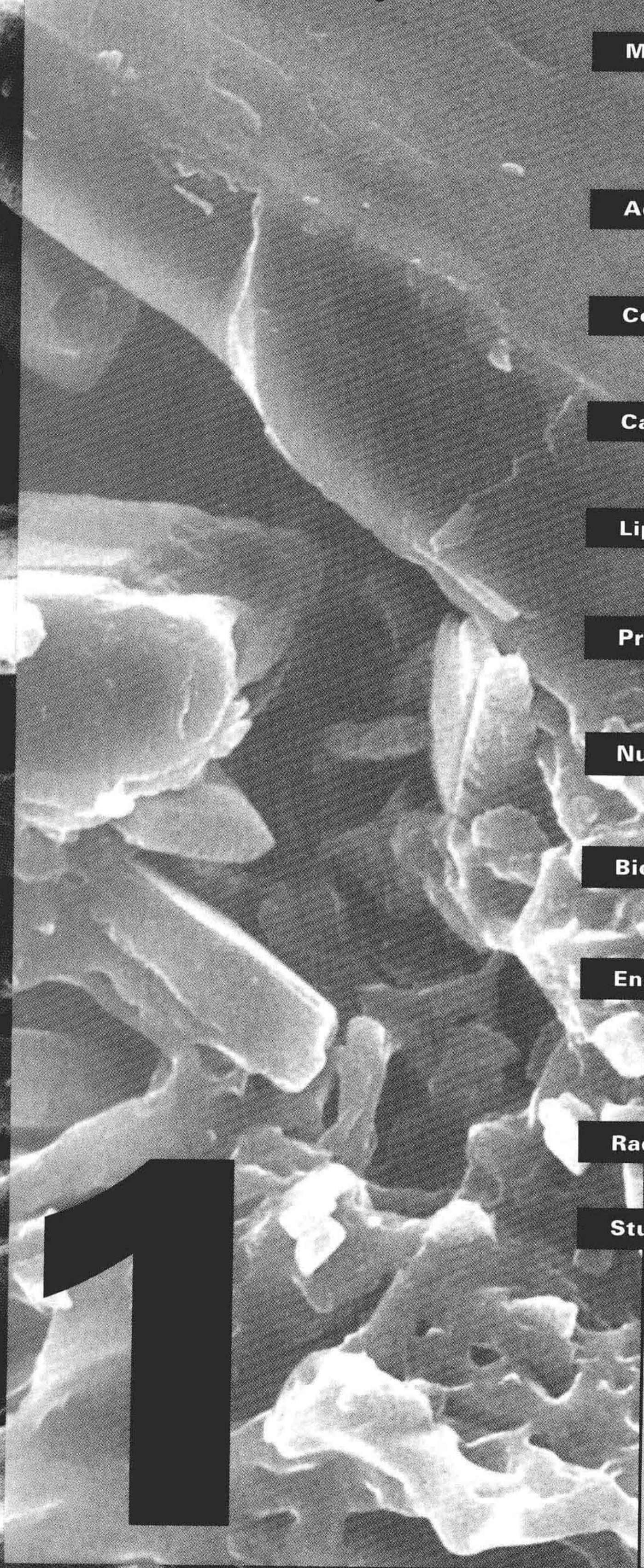
Working with the WCB staff continues to be a rewarding experience. Elizabeth Sievers and Donna Slade have been especially helpful in getting this book into production. No matter how many good helpers I have had, errors may have slipped by and for those I accept responsibility and extend my apologies for any inconvenience to users.

Contents



Fundamentals of Chemistry

1



OUTLINE

OBJECTIVES

Chemical Building Blocks and Chemical Bonds

1. Describe how chemical building blocks and chemical bonds contribute to the structure and function of biological molecules.

Mixtures, Solutions, and Colloidal Dispersions

2. Define the terms solvent, solute, and solution.
3. List the properties of water and explain how water contributes to body functions and homeostasis.
4. Distinguish between a solution and a colloidal suspension.

Acids, Bases, and pH

5. Define acid, base, and pH and relate the characteristics of acids and bases to their physiologic effects.

Complex Molecules

6. Briefly describe the properties of organic molecules and name four kinds of complex biological molecules.

Carbohydrates

7. Describe the properties, categories, and physiologic importance of carbohydrates.

Lipids

8. Describe the properties, categories, and physiologic importance of lipids.

Proteins

9. Describe the properties, categories, and physiologic importance of proteins.

Nucleotides and Nucleic Acids

10. Describe the properties, categories, and physiologic importance of nucleotides and nucleic acids.

Bioenergetics

11. Briefly explain the laws governing chemical changes.
12. Describe and give examples of coupled reactions.

Enzymes

13. Relate the properties of enzymes to the regulation of chemical reactions.
14. Explain how temperature, pH, and the concentrations of substrate and enzyme affect the rate of enzyme reactions.

Radioactivity

15. Define radioactivity and describe its properties.

Study and Review

Chemical Building Blocks and Chemical Bonds

Chemistry is concerned with matter—the properties and interactions of matter. **Matter** is anything that occupies space and has mass (substance), including air, water, rocks, and living things. Many physical and chemical properties of living organisms can be described in terms of physical and chemical properties of matter. Matter is composed of basic chemical building blocks. Just as letters of the alphabet can be combined in different ways to make thousands of words, chemical building blocks can be combined to make thousands of different substances, many of them more complex than words. Although few English words contain more than 20 letters, complex chemical substances can contain more than 20,000 building blocks.

In the body, various chemical substances undergo changes in chemical reactions. The sum total of all the body's chemical reactions is called **metabolism** (met-ab'o-lizm). Metabolism includes the breakdown of nutrients for energy and the making of body substance. Other chemical changes occur as muscles contract and nerves and hormones send signals.

Homeostasis is the maintenance of internal conditions within a narrow, normal range. It is possible only when each of a large variety of chemical processes is occurring at the right time, in the right place, and at the proper rate. Understanding the fundamentals of chemistry is important, not only because of these chemical processes, but because maintaining homeostasis often depends on events at the chemical level.

Particles of matter are too small to be seen even with the strongest microscopes. By using various experiments chemists have deduced certain characteristics of the particles. They have identified the **atom** as smallest chemical unit of matter. Matter consisting of one kind of atom is called an **element.** Each element has specific properties, for example, the graphite in a pencil consists of a vast number of carbon atoms. The earth's atmosphere consists of gaseous elements such as oxygen and nitrogen. Sodium is a soft, metallic element.

Atoms of an element combine with other atoms of the same or different elements. The ability of carbon atoms to form long chains is important in the structure of living things. Chemists use letters to designate elements—C for carbon, N for nitrogen, Na for sodium (*Natrium* is the Latin word for sodium), and subscripts to indicate how many atoms of the element are present. Though oxygen and nitrogen can occur as paired atoms, O_2 or N_2, most atoms combine with atoms of other elements. One atom of carbon combines with two atoms of oxygen to form carbon dioxide (CO_2) and two atoms of hydrogen combine with one atom of oxygen to form water (H_2O). Two or more atoms combined chemically form a **molecule.** A few molecules consist of atoms of the same element, N_2 for example, but most consist of atoms of different elements like CO_2. Molecules that contain atoms of two or more elements are called **compounds.** CO_2 and N_2 are molecules; CO_2 also is a compound.

Table 1.1
Properties of Atomic Particles

Particle	Relative Mass	Charge	Location
Proton	1	+	Nucleus
Electron	1/1836	−	Orbiting the nucleus
Neutron	1	None	Nucleus

More than 85 percent of the human body weight consists of four elements—carbon, hydrogen, oxygen, and nitrogen. A molecule of the sugar glucose contains 24 atoms, $C_6H_{12}O_6$. Carbohydrates, proteins, fats, and nucleic acids can contain thousands of atoms.

Atoms are the smallest particles that retain the properties of an element, but their subatomic components contribute to those properties. Among the many subatomic particles now known, we are concerned with only **protons, neutrons,** and **electrons** (Table 1.1). The mass of a proton and a neutron is arbitrarily designated as equal to one mass unit, and by comparison, electrons have a much smaller mass. Charges are also arbitrarily designated as negative for electrons and positive for protons. Neutrons are neutral—they have no net charge. Protons and neutrons occupy the nucleus of the atom, whereas the electrons move in orbits around the nucleus. All atoms have an equal number of protons and electrons and are electrically neutral; the atoms of a particular element have a specific number of protons that determines the element's **atomic number.** Atomic numbers range from 1 to over 100.

Electrons, being in constant motion, form an **electron cloud** around the nucleus. Some electrons display more energy than others, and their motion can be represented by concentric circles to suggest different energy levels within the cloud (Figure 1.1). Electrons with the least energy stay in orbits near the nucleus and those with more energy move to orbits farther from the nucleus. The negative charge of electrons holds them close to positively charged protons in the nucleus, and orbital motion moves them away from the nucleus. Orbital motion is analogous to the circular path made by swinging an object tied to a string.

Depending on the size of an atom, its electrons occupy one or more concentric circles or shells. An atom of hydrogen has 1 electron located in the innermost shell. An atom of helium has 2 electrons, the maximum number in the innermost shell. Atoms with more than 2 electrons

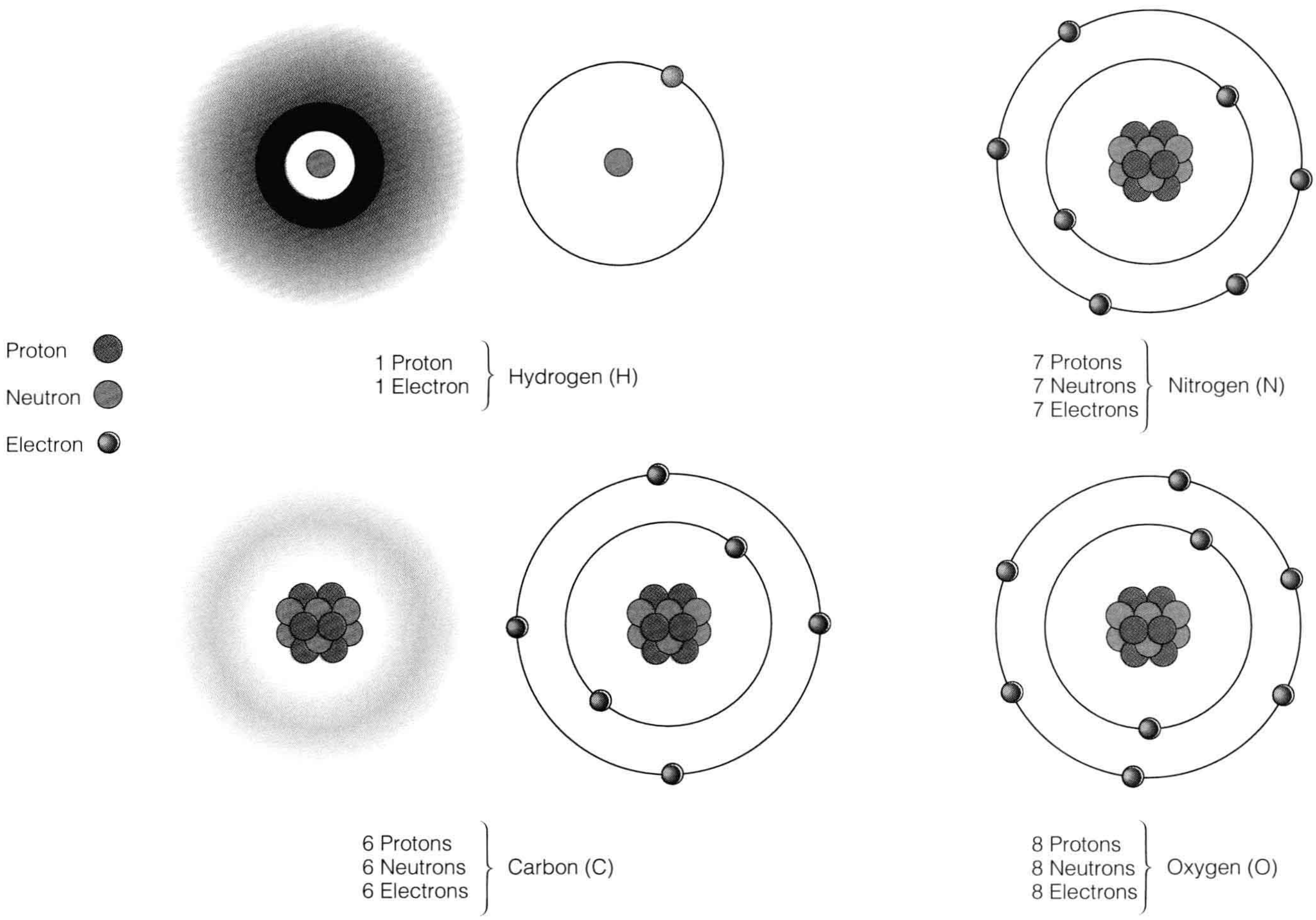


Figure 1.1

The structures of some atoms commonly found in the human body.

always have 2 electrons in the inner shell and up to 8 additional electrons in the second shell. The inner shell is filled before electrons occupy the second shell, the second shell is filled before electrons occupy the third shell, and so on. Very large atoms have several more electron shells, and some shells can contain more than 8 electrons. However, for the elements of physiologic importance, the outer shell is considered filled if it contains 8 electrons.

Atoms with outer electron shells that are nearly full (have 6 or 7 electrons) or nearly empty (have 1 or 2 electrons) have a tendency to form ions. An **ion** is a charged particle produced when an atom gains or loses electrons (Figure 1.2). When a sodium atom with 1 electron in its outer shell loses this electron it has 1 more proton than electrons and becomes a positively charged ion called a **cation** (kat'i-on). (An easy way to remember that cations are positively charged is to notice that the top of the "t" in cation makes a "plus sign.") When a chlorine atom with 7 electrons in its outer shell gains an electron it becomes a negatively charged chloride ion called an **anion** (an'i-on). Sodium or chloride ions are chemically more stable than corresponding atoms because their outer electron shells are full.

Table 1.2

Ions Commonly Found in the Body

Cations	Anions
Sodium (Na^+)	Chloride (Cl^-)
Potassium (K^+)	Hydroxyl (OH^-)
Calcium (Ca^{2+})	Bicarbonate (HCO_3^-)
Hydrogen (H^+)	Phosphate (PO_4^{3-})
Magnesium (Mg^{2+})	

Many elements occur as ions in the body (Table 1.2). Those with 1 or 2 electrons in their outer shell tend to lose electrons and form ions with charges of +1 or +2,

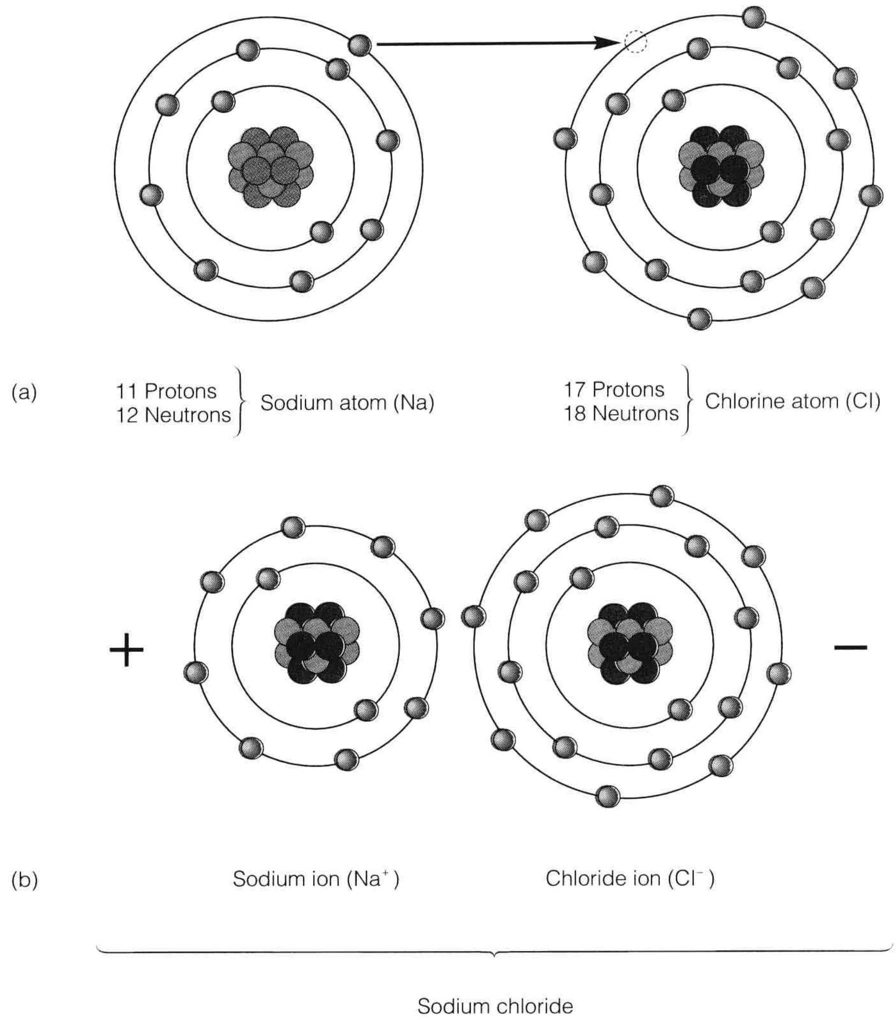


Figure 1.2

The formation of sodium and chloride ions: (*a*) When sodium loses the single electron in its outer shell, it becomes a positively charged sodium ion. When chlorine, which has seven electrons in its outer shell, gains an electron, it becomes a negatively charged chloride ion. (*b*) The oppositely charged sodium and chloride ions attract each other electrically and form a crystalline molecule of sodium chloride.

respectively; those with 6 or 7 electrons in their outer shell tend to gain electrons and form ions with charges of -1 or -2. Some ions, such as the hydroxyl ion (OH^-), contain more than one element.

All atoms of the same element have the same atomic number, but they can have different atomic weights. **Atomic weight** is the total number of protons and neutrons in an atom. For example, carbon atoms with 6 protons and 6 neutrons have an atomic weight of 12. Some naturally occurring carbon atoms have 7 or 8 neutrons and atomic weights of 13 or 14. Such atoms can also be created in the laboratory. Atoms of a particular element that contain different numbers of neutrons are called **isotopes.** For an element that has naturally occurring isotopes, the atomic weight is the average atomic weight of the mixture of isotopes. Atomic weights can be decimal numbers, but a particular atom has a specific number of whole neutrons. Some isotopes are stable, while others are not. Unstable isotopes emit radiation from their nuclei. Such emissions can be used to follow chemical processes in living things, but they also can harm them. Properties of elements found in living things are summarized in Table 1.3.

Chemical bonds are forces between the outer shell electrons that hold the atoms of a molecule together. Three kinds of bonds commonly found in living organisms—ionic, covalent, and hydrogen bonds—vary in strength and help to determine how molecules behave in living organisms.

Table 1.3
Some Properties of Elements Found in Living Organisms

Element	Symbol	Atomic Number	Atomic Weight	Electrons in Outer Orbit	% of Body Weight	Biological Occurrence
Carbon	C	6	12.0	4	18	Forms "backbone" of all organic compounds
Hydrogen	H	1	1.0	1	10	Found in most biological molecules; H^+ important component of solutions
Oxygen	O	8	16.0	6	65	Found in most biological molecules; final electron acceptor in many energy-yielding reactions
Nitrogen	N	7	14.0	5	3	Found in proteins, nucleic acids, and many other biological molecules
Calcium	Ca	20	40.1	2	1.5	Essential component of bones and teeth; important in muscle contraction; controls many cellular processes
Phosphorus	P	15	31.0	5	1	Component of nucleic acids and energy-carrying molecules such as ATP; found in many lipids
Sulfur	S	16	32.0	6	<1	Component of many proteins and other important biological molecules
Iron	Fe	26	55.8	2	<1	Component of electron carriers and oxygen carriers
Potassium	K	19	39.1	1	<1	Important in conduction of nerve signals
Sodium	Na	11	23.0	1	<1	Ion in solutions; important in conduction of nerve signals and transport mechanisms
Chlorine	Cl	17	35.4	7	<1	Ion in solutions; synthesis of HCl
Magnesium	Mg	12	24.3	2	<1	Important in enzyme-catalyzed reactions in most cells; important in photosynthesis in plants
Copper	Cu	29	63.6	1	T*	Important in some energy yielding reactions; important in photosynthesis in plants
Iodine	I	53	126.9	7	T	Essential part of thyroid hormone molecules
Fluorine	Fl	9	19.0	7	T	Prevents microbial growth
Manganese	Mn	25	54.9	2	T	Found in enzymes or important in activating enzymes
Zinc	Zn	30	65.4	2	T	Important in activating some enzymes
Selenium	Se	34	79.0	6	T	Part of an antioxidant enzyme
Molybdenum	Mo	42	95.9	1	T	Part of several enzymes

*T = Trace amount found in human body

Ionic bonds form between oppositely charged ions that are attracted to each other. For example, sodium ions having a positive charge combine with chloride ions having a negative charge (Figure 1.2). Ionic bonds are relatively weak bonds. When molecules with such bonds are put in water, the bonds easily break and the molecule **ionizes,** or forms ions. Therefore sodium chloride in body fluids exists as sodium and chloride ions.

Carbon, hydrogen, oxygen, and nitrogen atoms can be held together in molecules by **covalent bonds,** in which electrons are shared instead of being gained or lost (Figure 1.3). A carbon atom with 4 electrons in its outer shell can share an electron with each of 4 hydrogen atoms. At the same time, each of the 4 hydrogen atoms shares an electron with the carbon atom. Four pairs of electrons are shared, with each pair having an electron from carbon and an electron from hydrogen, and the outer shells of both atoms are filled. When forming covalent bonds, oxygen shares 2 electrons and nitrogen usually shares 3 electrons. Sometimes a carbon atom and another atom such as oxygen share two pairs of electrons to form a **double bond.** When writing structural formulas, chemists use a single line for a single pair of shared electrons and a double line for two pairs of shared electrons (Figure 1.3). Covalent bonds, which contain more energy than ionic bonds, hold molecules together more tightly than ionic bonds. Molecules with covalent bonds are more stable in solutions because they tend not to ionize. Many molecules in living things are stable because they contain covalent bonds.

Weak covalent bonds, called **hydrogen bonds,** are particularly important in biological structures, where they typically bind hydrogen atoms to oxygen or nitrogen atoms. In such bonds, oxygen or nitrogen atoms attract electrons. Shared electrons are pulled toward the atomic nucleus of oxygen or nitrogen and pulled away from hydrogen. Oxygen or nitrogen atoms have a partial negative charge, and hydrogen atoms have a partial positive charge.

Hydrogen bonds contribute significantly to the structure and properties of large molecules such as proteins and nucleic acids, which consist of long chains of atoms. Hydrogen bonds help to maintain each molecule in its characteristic three-dimensional shape; they also help to account for polar and nonpolar regions within large molecules. **Polar regions** have partial charges because of uneven distribution of positive and negative components of a molecule. Such regions attract other partially charged molecules, especially water. **Nonpolar regions** are uncharged and usually found below the surface of such molecules. Polar regions are **hydrophilic** (hi-dro-fil'ik), or water-loving, and nonpolar regions are **hydrophobic** (hi-dro-fo'bik), or water-fearing. Large biological molecules mix with water because of surface polar regions but do not dissolve in it because of internal nonpolar regions.

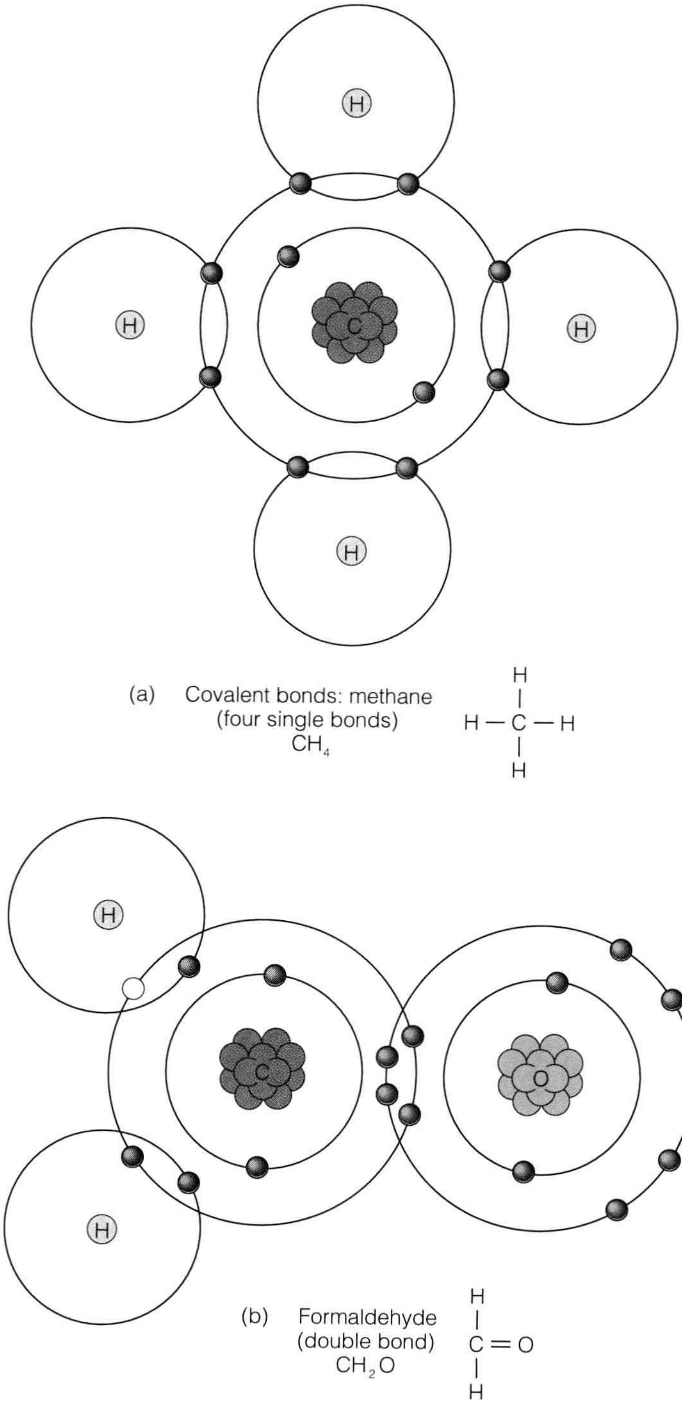


Figure 1.3

The sharing of electrons in covalent bonds: (*a*) In the gas methane, one carbon atom shares four electrons, one with each of four hydrogen atoms. The hydrogen atoms likewise share an electron with the carbon atom. (*b*) In formaldehyde, the carbon and hydrogen atoms share electrons as in methane, but carbon and oxygen each share two electrons. The sharing of two pairs of electrons forms a double bond.

Water mixes with biological molecules because of hydrogen bonds and polarity. Water molecules have a positive (hydrogen) pole and a negative (oxygen) pole because shared electrons stay closer to the oxygen than to the hydrogen atoms (Figure 1.4). The weak, partial charges allow the hydrogen side of one water molecule to form a hydrogen bond with the oxygen side of another water molecule. Water or any other compound with positive and negative regions can form hydrogen bonds and is called a **polar compound.**

See Questions—Objective 1

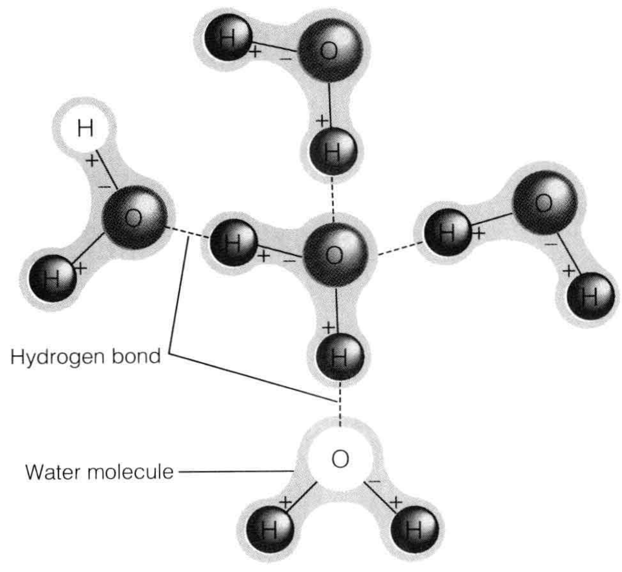


Figure 1.4

In hydrogen bonding between water molecules, the slightly negative oxygen region of one molecule is attracted to the slightly positive hydrogen region of another molecule.

Mixtures, Solutions, and Colloidal Dispersions

Unlike a chemical compound the molecules of which contain atoms in specific proportions, a **mixture** consists of two or more compounds combined in any proportion but not chemically bound. A mixture retains the properties of its substances. For example, a sugar-salt mixture of any proportions will taste both sweet and salty, but the degree of each taste depends on the relative amount of each substance in the mixture.

A **solution** is a homogeneous mixture of two or more substances in which molecules are evenly distributed and usually will not separate upon standing. In a solution, the **solvent** is the medium in which one or more substances are dissolved, and the **solute** is any dissolved substance—atoms, ions, or molecules. In the human body, water is the solvent in nearly all solutions. Typical solutes include the sugar glucose, small protein molecules, the gases carbon dioxide and oxygen, and ions.

Water, the solvent in body fluids, is so essential to life that humans live only a few days without it. As noted earlier, it comprises 55 to 60 percent of the total human body weight—more in infants and less in the elderly and more in brain tissue and less in bone and fat. Several properties of water contribute to its importance in humans and other living things (Table 1.4). Because water is a polar compound, it acts as a good solvent and forms hydrogen bonds with other molecules of both water and other substances.

Water is an especially good solvent for ions because the polar water molecules orient around ions, forming a **hydration shell.** The positive regions of the water molecules surround negative ions and the negative regions surround positive ions. Ions thereby become evenly distributed through water with water molecules interspersed between them (Figure 1.5). Ions and other substances that mix with water are easily transported through blood and other body fluids.

Table 1.4
Properties of Water

1. Good solvent ability helps to dissolve substances for transport in body fluids.
2. Ability to form layers (because of high surface tension) helps to keep membranes moist.
3. Ability to store or release large quantities of heat (high specific heat) helps to regulate body temperature.
4. Distribution throughout the body provides a medium for chemical reactions.
5. Chemical reactivity allows components of water (H^+ and OH^-) to participate in many chemical reactions.

Water forms thin layers because of its high **surface tension,** that is, it forms a thin, invisible, elastic layer on membrane surfaces. Water molecules beneath the surface are attracted to each other in all directions, but no such attraction exists between water molecules and gas molecules in the air. Attractions between water molecules cause any water layer to contract until it occupies a minimum area. Surface water molecules crowd with their hydrogen bonds projecting below the surface, thus creating sufficient tension to support waterstriders walking on a pond surface. On living membranes, high surface tension

Questions

Objective 1

(a) Define:

atom

element

molecule

compound

proton

electron

neutron

atomic number

atomic weight

cation

anion

(b) Use chemical formulas to illustrate the differences between ionic, covalent, and hydrogen bonds.

(c) What are the important properties of polar compounds?

maintains the continuity of water layers, which allows gases such as oxygen and carbon dioxide to diffuse across membranes and other membrane functions to occur.

Water has a high **specific heat;** it absorbs large quantities of energy with little change in temperature. This allows water to gain heat in the daytime and release it at night. Similarly, the high specific heat of water allows relatively large amounts of heat to be lost by the evaporation of small amounts of sweat, thereby regulating body temperature while conserving body water.

Finally, water provides a medium for chemical reactions and serves as a participant in many of these reactions. In synthetic reactions such as **condensation,** or **dehydration synthesis,** water is removed as two molecules form a larger molecule. Sugars combine to form complex carbohydrates and amino acids combine to form proteins by this kind of reaction. In degradative (breakdown) reactions such as **hydrolysis** (hi-drol'i-sis), water is added as a large molecule is broken down into smaller molecules. For example, during digestion large food molecules are broken down into simple sugars, amino acids, and other small molecules by hydrolysis.

Particles with diameters between 1 and 100 nanometers (billionths of a meter) are called **colloids** (kol'oidz). Though too large to form true solutions, colloids can form **colloidal** (kol-oid'al) **dispersions.** Such particles are suspended in a medium by opposing electrical charges, layers of water molecules around the particles, and other forces. Gelatin dessert is a colloidal dispersion with the protein gelatin dispersed in water. In the body, colloidal dispersions consist of large protein molecules dispersed in water. Much of the **cytosol** (fluid or semifluid substance around organelles in cells) is a complex colloidal system. Proteins in plasma, the fluid portion of blood, also form a colloidal dispersion. Some colloidal systems have the ability to change from a semisolid **gel,** gelatin that has "set," to a more fluid **sol** state, akin to gelatin that has melted.

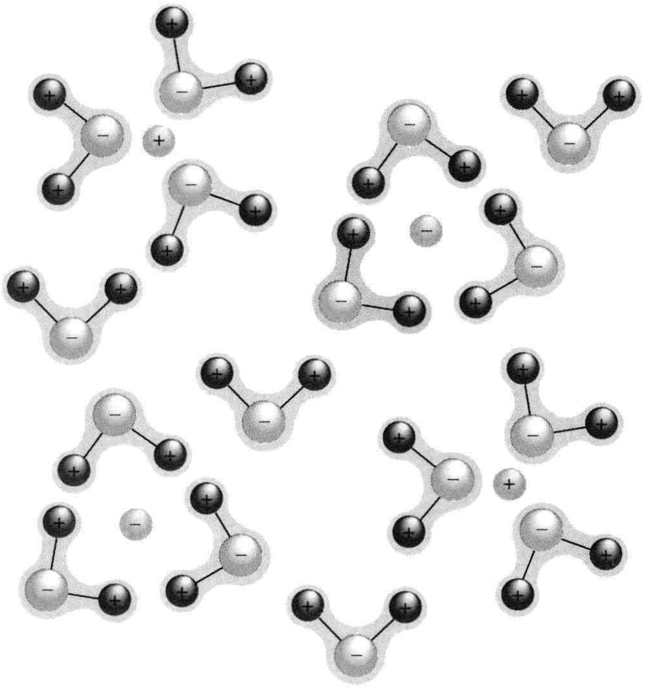


Figure 1.5

Water molecules surround positive and negative ions and help to hold these particles in solution.

The properties of chemical substances, including water, solutions, and colloidal suspensions, set limits on physiologic possibilities. The behavior of molecules in living organisms is limited by the properties of the molecules themselves.

See Questions—Objectives 2, 3, and 4

Acids, Bases, and pH

Except for the extreme acidity of the stomach, the body's external and internal environments are nearly chemically neutral—neither solidly acidic nor strongly basic (alkaline). A knowledge about acids and bases is needed to understand how the body maintains nearly neutral conditions in spite of acids that accumulate as cells use nutrients.

Acids and bases readily form ions in water. An **acid** releases or donates hydrogen ions (H^+) to a solution and is a hydrogen donor, or proton donor. (A hydrogen ion is a proton.) A **base** usually accepts hydrogen ions from a solution, but some bases release hydroxyl ions (OH^-) into solutions. A base is a proton acceptor or a hydroxyl ion donor. The acidity of a solution increases with the H^+ concentration and its alkalinity increases with the OH^- concentration. In body fluids, H^+ is often released by organic acid, or carboxyl ($-COOH$) groups ($COOH$ ionizes to COO^- and H^+). H^+ is accepted by OH^- to form water or by amino ($-NH_2$) groups to form ammonia (NH_3).

To express acidity or alkalinity, physiologists use the concept of **pH,** which is the negative log of the hydrogen ion concentration in moles per liter.

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

(Brackets [ ] denote concentration.) A solution at pH 7 is neutral, neither acidic nor basic, and contains equal numbers of H^+ and OH^- ions. Such is the case in pure, distilled water because one ten-millionth (10^{-7}) part of each mole of water is ionized, or exists as H^+ and OH^- ions. The H^+ concentration is 10^{-7} moles per liter and the solution's pH is 7.

The pH scale (Figure 1.6) relates proton concentrations to pH and is logarithmic, that is, the proton concentration changes by a factor of ten for each unit of the scale. The usual range of the pH scale is from 0 to 14, but most tissues and body fluids have a pH between 5 and 8 except in the stomach. Table 1.5 shows the pH of some body fluids, foods, and other common substances.

Table 1.5
The pH of Various Substances

Substance	pH*
Hydrochloric acid (1 molar)	0.0
Stomach hydrochloric acid (0.1 molar)	1.0
Gastric juice	1.0–3.0
Lemon juice	2.5
Vinegar, beer, wine	3.0
Orange juice	3.5
Tomatoes, grapes	4.0
Coffee	5.0
Urine	5.0–7.0
Milk	6.5
Saliva	6.3–7.3
Pure water (at 25° C)	7.0
Blood	7.35–7.45
Eggs	7.5
Ocean water	7.8–8.2
Household bleach	9.5
Milk of magnesia	10.5
Household ammonia	10.5–11.8
Oven cleaner	13.5
Sodium hydroxide (1 molar)	14.0

*pH of body fluids measured at 37° C.

Questions

Objective 2

(a) Define:

solvent

solute

solution

(b) How are solvents, solutes, and solutions related?

Objective 3

(a) In what ways is water important to living things?

(b) What disorders do you think are most likely to develop if humans are deprived of water?

Objective 4

(a) How do solutions and colloidal dispersions differ?

(b) How are solutions and colloidal dispersions alike?

Changes in the pH of body fluids have profound physiologic effects. For example, pneumonia and other diseases that interfere with gas exchange in the lungs allow carbon dioxide and H^+ to accumulate in the blood by the following reactions:

CO_2	+	H_2O	$\rightarrow$	H_2CO_3	$\rightarrow$	H^+	+	HCO_3^-
carbon dioxide		water		carbonic acid		hydrogen		ion bicarbonate

An overdose of aspirin stimulates respiratory centers in the brain and increases gas exchange, causing too much carbon dioxide and H^+ to be removed from the blood as the reactions are reversed.

Buffers, substances that resist pH change, help to prevent such changes. Carbonic acid, which can donate H^+, and bicarbonate, which can accept H^+, act as natural blood buffers helping to keep the blood pH within a narrow, tolerable range.

See Questions—Objective 5

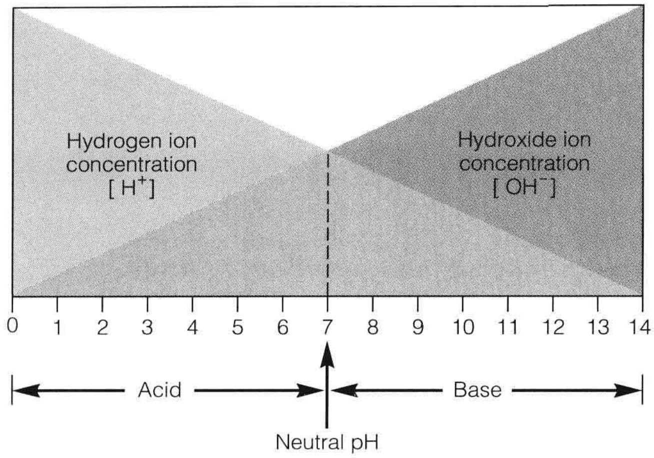


Figure 1.6

Solutions at pH 7 are neutral. Increasingly acid solutions have higher concentrations of H^+ and lower pH values. Increasingly basic solutions have lower concentrations of H^+ and higher pH values.

Complex Molecules

The study of the fundamentals of general chemistry has paved the way for considering **organic chemistry,** the study of most carbon-containing compounds. Such compounds occur in living things and their products and remains. The ability of carbon atoms to share electrons and to form long chains and rings makes the number of possible organic compounds almost infinite. Molecules that consist of chains are said to be **aliphatic** (al-eh-fat′ik) whereas those that contain rings are said to be **aromatic** (ar-o-mat′ik).

The simplest carbon compounds are hydrocarbons—chains of carbon atoms with associated hydrogen atoms. The simplest hydrocarbon, methane, has a single carbon atom, but gasoline and other petroleum products contain several carbons.

In addition to hydrogen, other atoms such as oxygen and nitrogen can bond to carbon chains, where they often form functional groups. A **functional group** is a molecular part that participates in chemical reactions and gives the molecule some of its properties. Functional groups demonstrate that structure and function are related even at the chemical level. Four categories of organic molecules with functional groups containing oxygen are alcohols, aldehydes, ketones, and organic acids (Figure 1.7). The functional groups of alcohols, called **hydroxyl** (hi-drox′il) groups, are found almost anywhere in a molecule. **Carbonyl** (kar′bon-el) groups form aldehydes at the ends of chains and ketones within chains. The functional groups of organic acids are called **carboxyl** (kar-box′il) **groups.** An **amino** (ah-me′no) **group** ($-NH_2$) contains nitrogen but no oxygen. Amino groups, as in amino acids of proteins, account for most of the body's nitrogen.

Questions

Objective 5

(a) Define:

acid

base

pH

(b) How might altering the pH of a body fluid affect body functions?

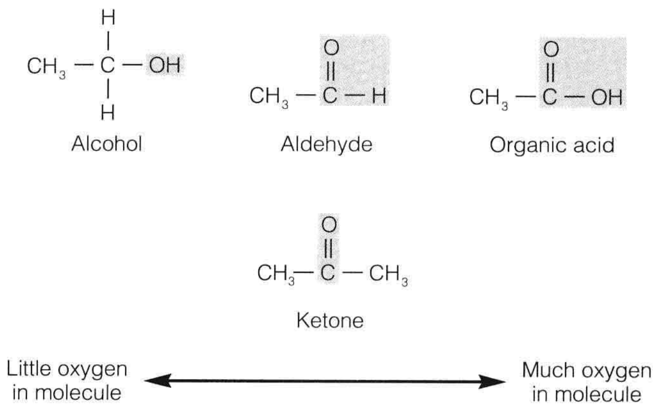


Figure 1.7

Oxygen-containing functional groups of organic molecules. The shaded portion of the molecule is the functional group. Molecules are arranged from most reduced (having the most hydrogen) to most oxidized (having the most oxygen).

The amount of oxygen in functional groups is related to the energy they contain. Alcohols, which have lots of hydrogen atoms and few oxygen atoms, contain more energy than organic acids, which have less hydrogen and more oxygen. Molecules with large amounts of hydrogen are said to be reduced and energy can be extracted from them as they are oxidized. **Reduction** is the addition of