LEARNING OUTCOMES

These Learning Outcomes correspond by number to this chapter's modules and indicate what you should be able to do after completing the chapter. They also appear at the end of each module.

Atoms, Molecules, and Compounds

2.1 Define an tom, and describe the properties of its subatomic particles. p. 93

2.2 Describe an atom and how atomic structure affe ts the mass number and atomic weight of the various chemical elements. p. 94

2.3 Explain the relationship between electrons and energy levels. p. 96

2.4 Compare the ways in which atoms combine to form molecules and compounds. p. 98

2.5 Describe the three states of matter and the importance of hydrogen bonds in liquid water. p. 100

Chemical Reactions

2.6 Define metabolism, and distinguish among ork, kinetic energy, and potential energy. p. 103

2.7 Use chemical notation to symbolize chemical reactions. p. 104

2.8 Distinguish among the major types of chemical reactions that are important for studying physiology. p. 106

2.9 Describe the crucial role of enzymes in metabolism. p. 108

Water in the Body

2.10 Describe four important properties of water and their significan e in the body. p. 111

2.11 Explain how the chemical properties of water affe t the solubility of inorganic and organic molecules. p. 112

2.12 Discuss the importance of pH and the role of buffers i body fluid . p. 114

Organic Compounds

2.13 Describe the common elements of organic compounds and how functional groups modify the properties of organic compounds. p. 117

2.14 Discuss the structures and functions of carbohydrates. p. 118

2.15 Discuss the structures and functions of lipids. p. 120

2.16 Discuss the structures and diverse functions of eicosanoids, steroids, phospholipids, and glycolipids. p. 122

2.17 Discuss protein structure and the essential functions of proteins within the body. p. 124

2.18 Explain how enzymes function within the body. p. 126

2.19 Discuss the structure and function of high-energy compounds. p. 127

2.20 Compare and contrast the structures and functions of DNA and RNA. p. 128

2 Chemical Level of Organization

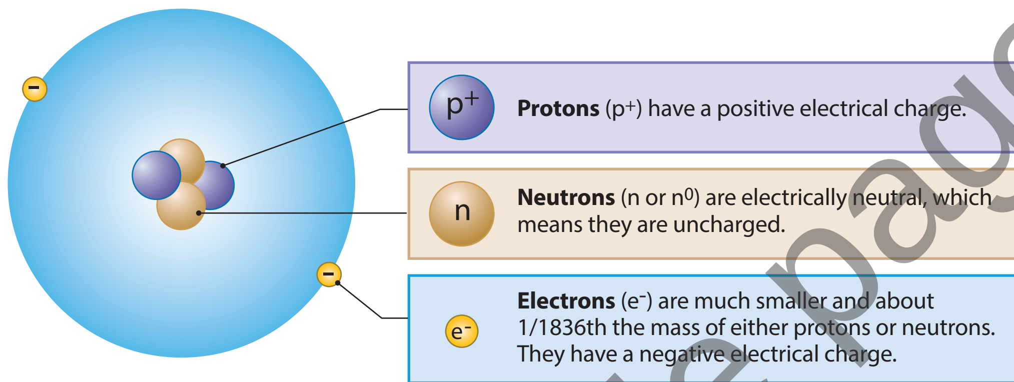
Module ˜ .°

Atoms are the basic particles of matter

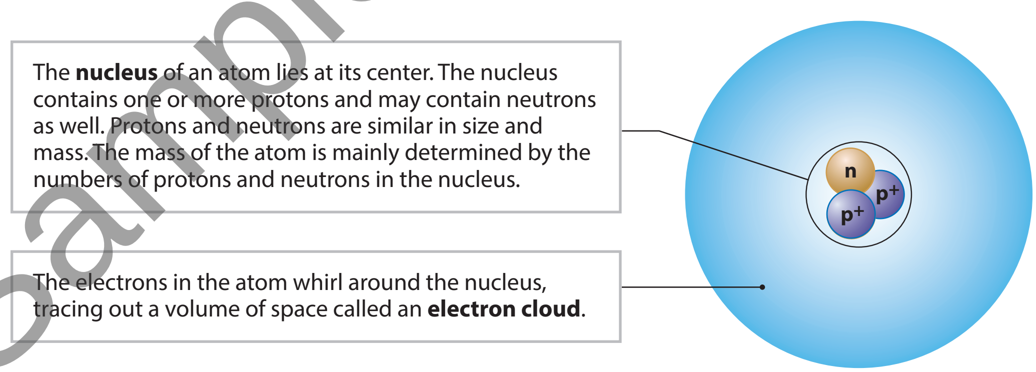
Go to MasteringA&P™
Get Ready for A&P
Chemistry

Our study of the human body begins at the chemical level of organization. Chemistry is the science that studies the structure of **matter**, which is defined as anything that takes up space and has mass. **Mass** is the quantity of matter in an object. The more matter an object contains, the greater its mass. Within Earth's gravitational field, the mass of an object determines its weight. However, the two are not always equivalent: In orbit beyond Earth's gravity, you would be weightless, but your mass would remain unchanged.

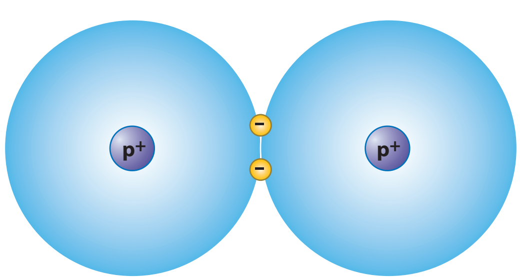
1 **Atoms** are the smallest stable units of matter. They are composed of **subatomic particles**, only three of which are important for understanding the basic chemical properties of matter.



2 Atoms can be subdivided into the nucleus and the electron cloud.



3 Atoms interact by means of their electrons and produce larger, more complex structures.



In summary, everything around us is composed of atoms in varying combinations. The unique characteristics of each object, living or nonliving, result from the types of atoms involved and the ways those atoms combine and interact.

REVIEW

A. What is the relationship between an atom and matter?

B. Which subatomic particles have a positive charge? Which are uncharged?

C. Describe the subatomic particle not in the nucleus.

INTEGRATION

D. The gravitational ÿeld of the moon is 17% of Earth's. How would the weight and mass of a 100-pound astronaut change on the moon?

LEARNING OUTCOME

Deÿne an atom, and describe the properties of its subatomic particles.

Module ˜ .˜

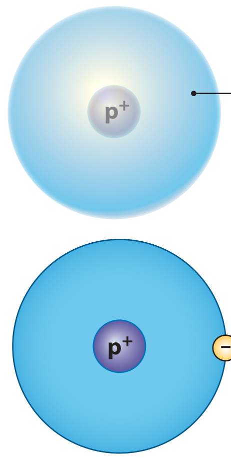
Typical atoms contain protons, neutrons, and electrons

Atoms normally contain equal numbers of protons and electrons. The number of protons in an atom is known as the **atomic number**; the total number of both protons and neutrons is its **mass number**. An **element** is a pure substance consisting only of atoms with the same atomic number.

REVIEW

A. Which is larger: an element's atomic number or mass number?

1 All atoms are electrically neutral; they contain equal numbers of protons and electrons. **Hydrogen (H)** is the simplest atom, with an atomic number of 1. Thus, an atom of hydrogen contains one proton and one electron. A hydrogen atom's proton is located in the center of the atom and forms the nucleus.



The electrons whirl around the nucleus in a space known as the **electron cloud**. One reason an electron tends to remain in the electron cloud is that the negatively charged electron is attracted to the positively charged proton. The attraction between opposite electrical charges is an example of an electrical force.

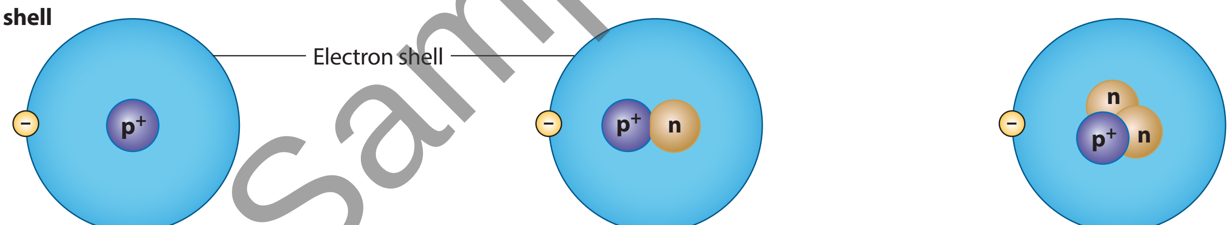
Electrons are often shown in a fi ed orbit around the nucleus, when in fact their movements are much more complex. In this simple two-dimensional model, the electron occupies a circular **electron shell**. The outermost electron shell represents the surface of the electron cloud.

2 The atoms of a single element can differ in the number of neutrons in the nucleus. Atoms whose nuclei contain the same number of protons but different numbers of neutrons are called **isotopes**. Different isotopes of an element have essentially identical chemical properties and so are indistinguishable except on the basis of mass. The mass number is therefore used to designate isotopes. Mass numbers are useful because they tell us the number of subatomic particles in the nuclei of different atoms. However, they do not tell us the actual mass of the atoms. For example, they do not take into account the masses of the electrons or the slight difference between the mass of a proton and that of a neutron. The actual mass of an atom of a specific isotope is known as its **atomic mass**. The unit used to express atomic mass is the **atomic mass unit (amu)**, or dalton. By international agreement, 1 amu is equal to one-twelfth the mass of a carbon-12 atom.

REVIEW

B. Carbon-12 (^{12}C) is the most common form of the element carbon. How is the isotope carbon-13 (^{13}C) similar to and di˜ erent from ^{12}C?

Electron shell model

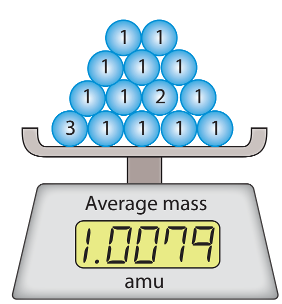


Hydrogen-1
mass number: 1

Hydrogen-2, deuterium
mass number: 2

Hydrogen-3, tritium
mass number: 3

3 The **atomic weight** of an element is an average of the different atomic masses and proportions of its different isotopes. As a result, the atomic weight of an element is very close to the mass number of the most common isotope of that element. For example, the mass number of the most common isotope of hydrogen is 1, but the atomic weight of hydrogen is 1.0079, primarily because some hydrogen atoms (0.015 percent) have a mass number of 2, and even fewer have a mass number of 3. (In most cases, the periodic table of the elements in the Appendix shows the atomic weight of each element rounded to its nearest one-hundredth decimal place. For example, the atomic weight of hydrogen is shown as 1.01, rather than 1.0079).



Atomic weight of hydrogen = 1.0079

REVIEW

C. How is it possible for two samples of hydrogen to contain the same number of atoms yet have di˜ erent weights?

Go to MasteringA&P™
Get Ready for A&P
Atomic Structure

Principal Elements of the Human Body

Element (% of total body weight)	Significance
Oxygen, O (65)	A component of water and other compounds (substances composed of two or more different elements); as a gas, essential for respiration
Carbon, C (18.6)	Found in all organic compounds
Hydrogen, H (9.7)	A component of water and most other compounds in the body
Nitrogen, N (3.2)	Found in proteins, nucleic acids, and other organic compounds
Calcium, Ca (1.8)	Found in bones and teeth; important for plasma membrane function, nerve impulses, muscle contraction, and blood clotting
Phosphorus, P (1.0)	Found in bones and teeth, nucleic acids, and high-energy compounds
Potassium, K (0.4)	Important for plasma membrane function, nerve impulses, and muscle contraction
Sodium, Na (0.2)	Important for blood volume, plasma membrane function, nerve impulses, and muscle contraction
Chlorine, Cl (0.2)	Important for blood volume, plasma membrane function, and water absorption
Magnesium, Mg (0.06)	A cofactor* for many enzymes
Sulfur, S (0.04)	Found in many proteins
Iron, Fe (0.007)	Essential for oxygen transport and energy capture
Iodine, I (0.0002)	A component of hormones of the thyroid gland
Trace elements: silicon (Si), fluorine (F), copper (Cu), manganese (Mn), zinc (Zn), selenium (Se), cobalt (Co), molybdenum (Mo), cadmium (Cd), chromium (Cr), tin (Sn), aluminum (Al), boron (B), and vanadium (V)	Some function as cofactors*; the functions of many trace elements are poorly understood

* A cofactor is a mineral or nonprotein compound. It acts with proteins called enzymes to speed up chemical reactions in living things.

REVIEW

D. Describe trace elements.

4 Our bodies consist of many elements, and the 13 most abundant elements are listed in this table. The human body also contains atoms of another 14 elements—called **trace elements**—that are present in very small amounts. Only 92 elements exist in nature, although about two dozen additional elements have been created through nuclear reactions in research laboratories. Every element has a **chemical symbol**, an abbreviation recognized by scientists everywhere. Most of the symbols are easily connected with the English names of the elements (O for oxygen, N for nitrogen, C for carbon, and so on), but a few are abbreviations of their names in other languages. For example, the symbol for sodium, Na, comes from the Latin word *natrium*.

Everyday Physiology

Why are some isotopes unstable?

The nuclei of some isotopes are unstable, or radioactive. That is, they spontaneously break down and give o° *radiation* (energy in the form of moving subatomic particles or waves). Such isotopes are called **radioisotopes**. The breakdown process is called *radioactive decay*. The decay rate of a radioisotope is commonly expressed as its **half-life**: the time required for half of a given amount of the isotope to decay. Radioisotopes di° er in how rapidly they decay; their half-lives range from fractions of a second to billions of years.

INTEGRATION

E. List the chemical symbols of the six most abundant elements in the human body and their total percentage contribution to total body weight.

LEARNING OUTCOME

Describe an atom and how atomic structure a˜ects the mass number and atomic weight of the various chemical elements.

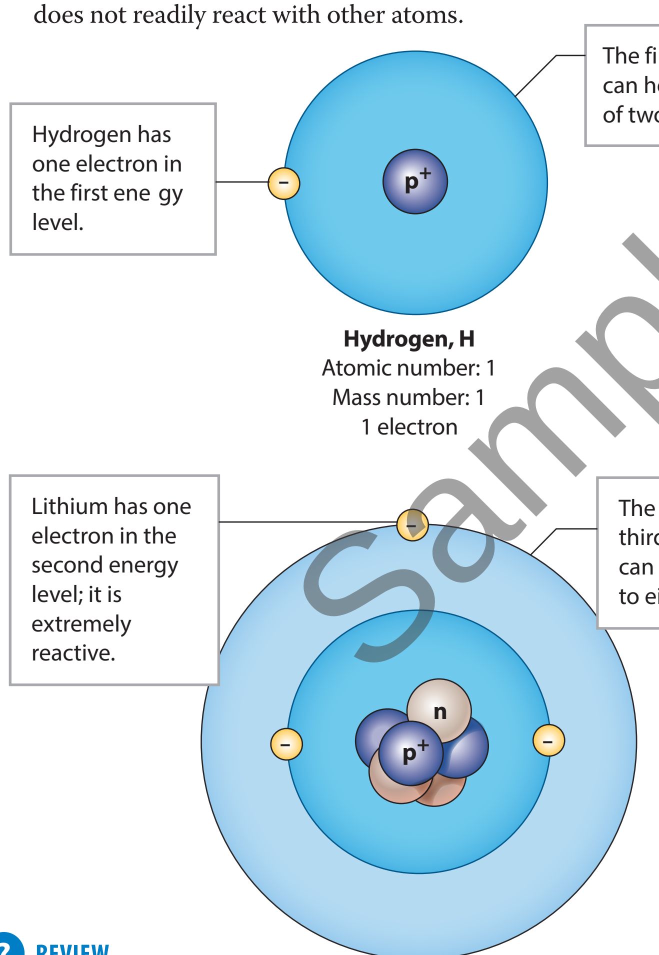
Module ˜. °

Electrons occupy various energy levels

Recall that atoms are electrically neutral; every positively charged proton is balanced by a negatively charged electron. Thus, with each increase in atomic number there is a comparable increase in the number of electrons traveling around the nucleus. Within the electron cloud, electrons occupy an orderly series of energy levels. Although the electrons in an energy level may travel in complex patterns around the nucleus, for our purposes the patterns are diagrammed as a series of concentric electron shells. The first electron shell (the one closest to the nucleus) corresponds to the lowest energy level. The number of electrons in the outermost energy level determines the atom's ability to participate in chemical reactions.

Reactive elements

1 The outermost energy level of an atom, called the **valence shell**, forms the atom's "surface." Electrons in the valence shell of an atom can be transferred to or shared with another atom. Atoms with unfilled energy levels, such as hydrogen and lithium, will react with other atoms, usually in ways that give them full valence shells. An atom with a filled valence shell is stable and does not readily react with other atoms.



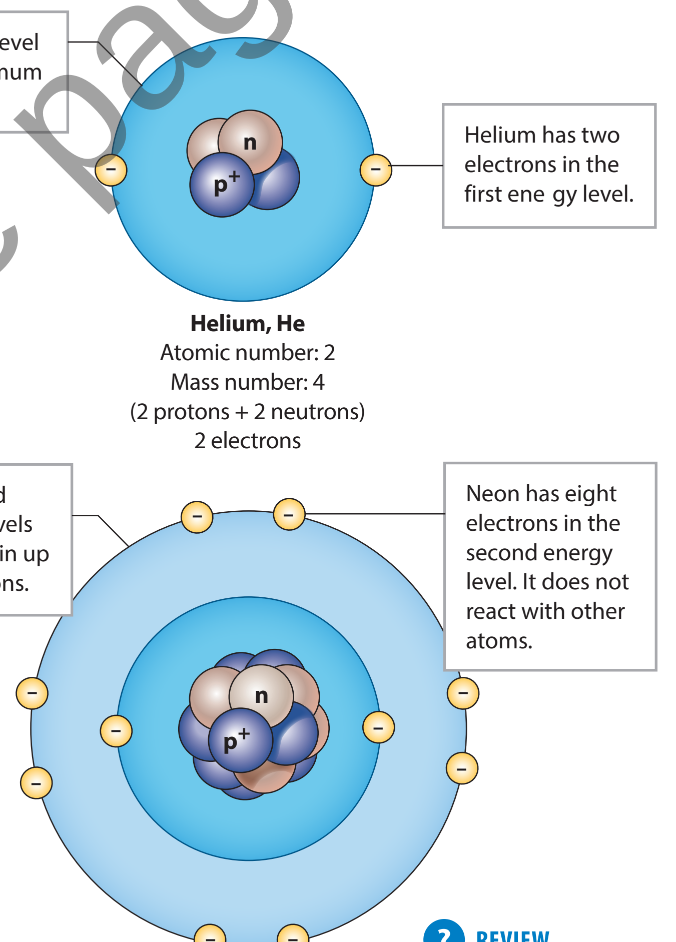
Lithium, Li
Atomic number: 3
Mass number: 6
(3 protons + 3 neutrons)
3 electrons

REVIEW

A. Indicate the maximum number of electrons that can occupy each of the ÿrst three energy levels of an atom.

Noble gases

2 Elements that do not readily participate in chemical processes are said to be **inert**. Inert elements, such as helium and neon, have filled outermost energy levels, and their atoms neither react with one another nor combine with atoms of other elements. Helium and neon are two of six such elements, called **noble gases**.

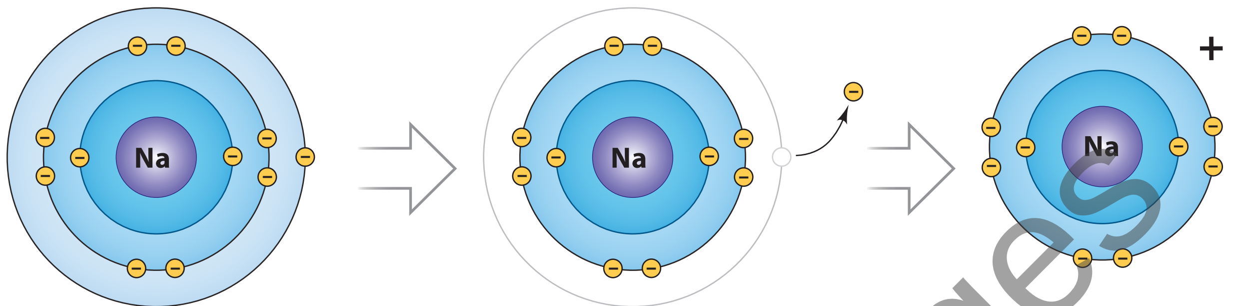


Neon, Ne
Atomic number: 10
Mass number: 20
(10 protons + 10 neutrons)
10 electrons

REVIEW

B. Explain why the atoms of inert elements do not react with one another or combine with atoms of other elements.

3 Elements with unfilled valence shells, such as hydrogen, lithium, or sodium, are called **reactive** because they readily interact or combine with other atoms. Reactive atoms become stable by gaining, losing, or sharing electrons to fill their outermost energy level. When atoms gain or lose electrons, they are no longer electrically neutral, and they become **ions**. Atoms that lose electrons from the outer energy level have more protons than electrons. The atom has a net positive charge and is called a positive ion or **cation**. A single missing electron gives the ion a charge of +1. Some ions carry charges of +2, +3, or +4, depending on how many electrons are lost to become stable.



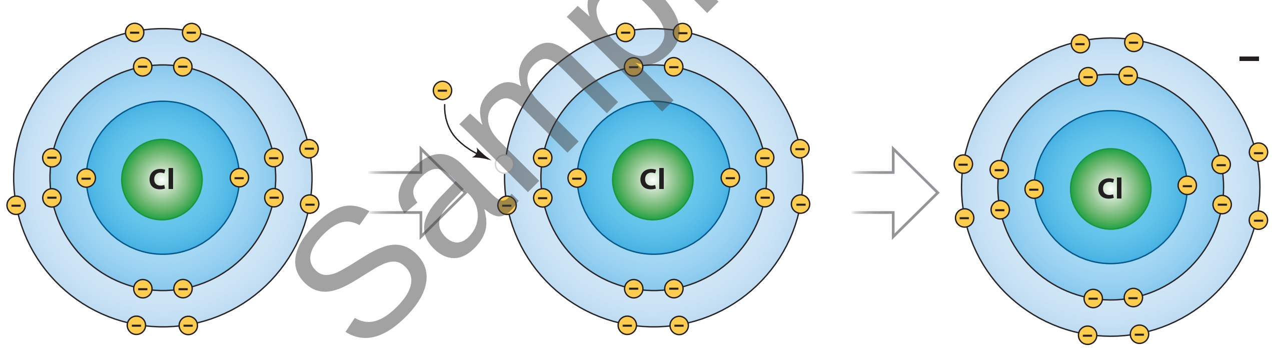
Sodium atom, Na (reactive)

Sodium ion, Na^+ (stable)

4 At other times, atoms become stable by filling their outer energy level with electrons obtained from other atoms. This also creates an atom that is no longer electrically neutral—it has more electrons than protons. The atom now has a net negative charge and is called a negative ion or **anion**. A single extra electron gives the ion a charge of –1. Some ions carry charges of –2, –3, or –4, depending on how many electrons are needed to become stable.

REVIEW

C. Explain how cations and anions form.



Chlorine atom, Cl (reactive)

Chloride ion, Cl^- (stable)

The interactions that stabilize the outer energy levels of atoms often result in **chemical bonds**. These bonds hold the participating atoms together when the reaction has ended.

INTEGRATION

D. Cations are smaller in diameter than their electrically neutral atom. Why?

LEARNING OUTCOME

Explain the relationship between electrons and energy levels.

Module ˜. °

The most common chemical bonds are ionic bonds and covalent bonds

Go to MasteringA&P™
Get Ready for A&P
Chemical Bonding

Chemical bonding forms new chemical entities called compounds and molecules. A **compound** is a chemical substance made up of atoms of two or more different elements in a fixed proportion, regardless of the type of bond joining them.

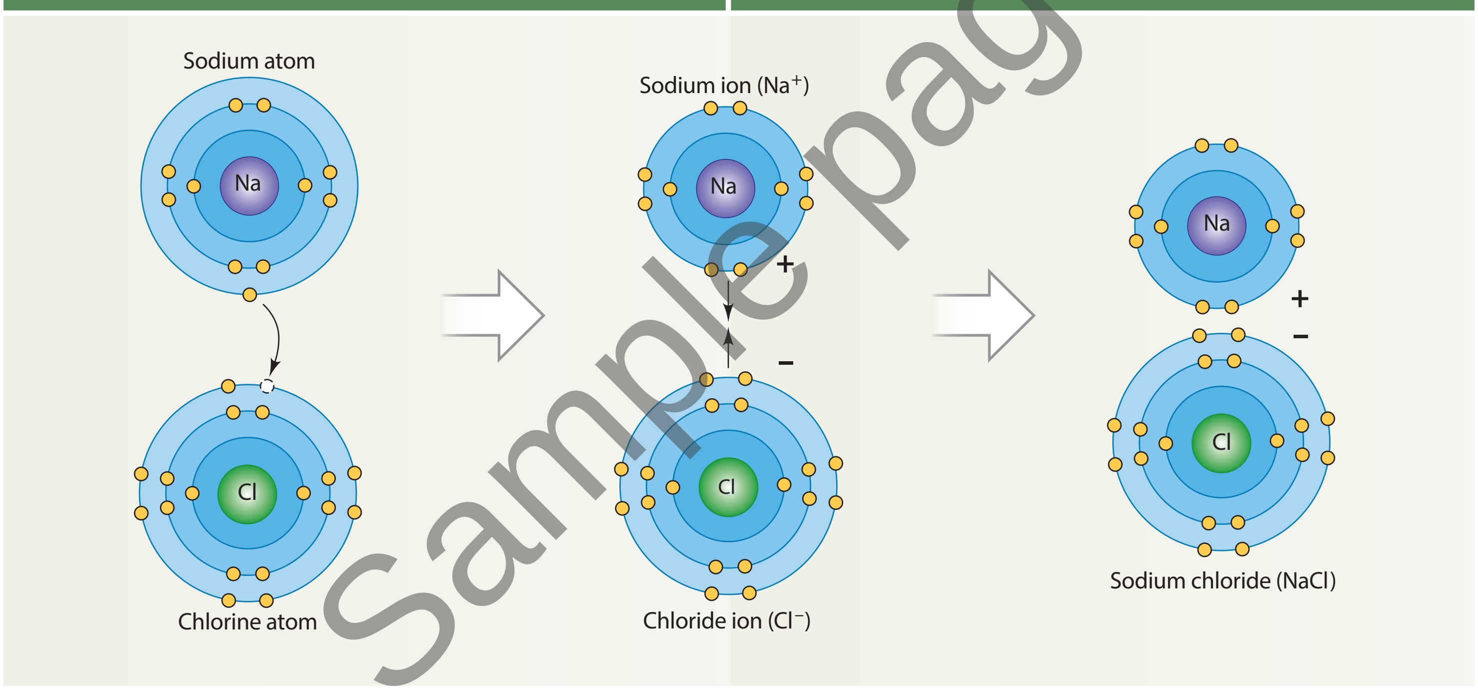
1 **Ionic bonds** are chemical bonds created by the electrical attraction between cations (positive ions) and anions (negative ions). Ionic bond formation involves the transfer of one or more electrons from an atom that can lose them to achieve stability, to another atom that can gain them to achieve stability. Here we consider formation of the ionic compound sodium chloride (table salt).

REVIEW

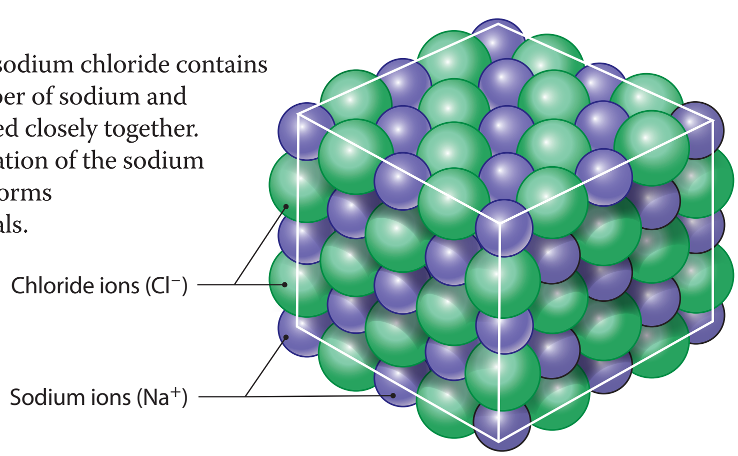
A. Describe why table salt is a compound.

Step 1
Sodium and chloride ion formation. The sodium atom loses an electron to the chlorine atom. This produces two stable ions with filled ou er energy levels.

Step 2
Ionic bond formation. Because these ions form close together and have opposite charges, they are attracted to one another. This creates NaCl, an ionic compound.



2 A crystal of sodium chloride contains a large number of sodium and chloride ions packed closely together. The packed orientation of the sodium and chloride ions forms cube-shaped crystals.

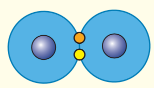
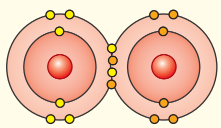
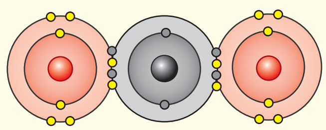


Sodium chloride crystals × 0.5

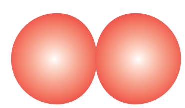
3 Some atoms can complete their outer electron shells not by gaining or losing electrons, but by sharing electrons with other atoms. Such sharing creates **covalent** (kō-VĀ-lent) **bonds** between the atoms involved. A **molecule** is a chemical structure consisting of atoms of one or more elements held together by covalent bonds.

REVIEW

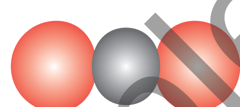
B. How many electrons are shared by the oxygen atoms in an oxygen molecule?

Molecule	Description
Hydrogen (H_2) 	Hydrogen atoms are not found as single atoms. They exist as molecules, each containing a pair of hydrogen atoms. When the 2 hydrogen atoms share their electrons, each electron whirls around both nuclei. The sharing of one pair of electrons creates a **single covalent bond**.
Oxygen (O_2) 	An oxygen atom has 6 electrons in its outer energy level. By sharing two pairs of electrons, it forms a **double covalent bond** with another oxygen atom, and an oxygen molecule is created with a stable outer energy level.
Carbon dioxide (CO_2) 	A carbon atom has 4 electrons in its outer energy level, so it needs to gain another 4 from other atoms to achieve stability. In a molecule of carbon dioxide, a carbon atom shares a pair of electrons with each of 2 oxygen atoms and forms 2 double covalent bonds.

4 These are space-filling models of oxygen and carbon dioxide molecules. The spherical diameters of the atoms are shown in proportion to each other in these models. In nonpolar covalent bonds, the participating atoms share the electrons *equally*, and there is no electrical charge on the molecule. Because of this lack of electrical charge, such molecules are called **nonpolar molecules**.

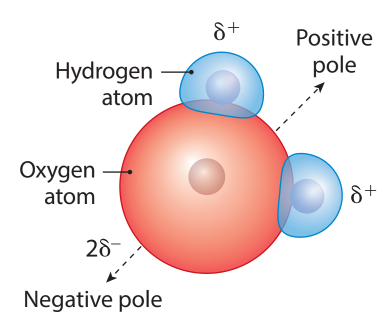


Oxygen (O_2)



Carbon dioxide (CO_2)

5 Some molecules, however, are formed by covalent bonds that involve an *unequal* sharing of electrons. In a water molecule, the electron clouds of the hydrogen atoms are distorted because the 8 protons in the oxygen atom have a much stronger attraction for the electrons than do the single protons of the hydrogen atoms. As a result, each hydrogen atom carries a slightly positive charge (δ^+), and the oxygen atom carries a slightly negative charge ($2\delta^-$). (The Greek delta symbol [δ] is used to denote partial charges.) This creates an asymmetrical **polar molecule**. Covalent bonds that produce polar molecules are called **polar covalent bonds**.



REVIEW

C. Describe the kind of bonds that hold the atoms in a water molecule together.

Clinical Note

Free radicals damage or destroy vital compounds

Covalent bonds usually form molecules in which the valence shells of the atoms involved are ÿlled. An atom, ion, or molecule that contains unpaired electrons in its valence shell is called a *free radical*. Free radicals are highly reactive. Almost as fast as it forms, a free radical enters additional reactions that are typically destructive. For example, free radicals can damage or destroy vital compounds, such as proteins. Evidence suggests that the cumulative damage from free radicals inside and outside our cells is a major factor in the aging process. Free radicals sometimes form in the course of normal metabolism, but cells have several methods of removing or inactivating them.

INTEGRATION

D. Explain why we can use the term *molecule* for the smallest particle of water but not for that of table salt.

LEARNING OUTCOME

Compare the ways in which atoms combine to form molecules and compounds.

Module ˜. °

Matter may exist as a solid, a liquid, or a gas

2

Most matter in our environment exists in one of three states: solid, liquid, or gas. Whether a particular substance is a solid, a liquid, or a gas depends on the degree of motion or vibration due to its thermal energy (temperature) and the types of interactions among its atoms or molecules. The particles of a solid are held tightly together, while those of a liquid are less so; and the particles of a gas are independent of each other.

1 Solids maintain their volume and their shape at ordinary temperatures and pressures. A lump of granite, a brick, and a textbook are solid objects.

2 Liquids have a constant volume but no fixed shape. The shape of a liquid is determined by the shape of its container. Water, brewed coffee, and soda are liquids.

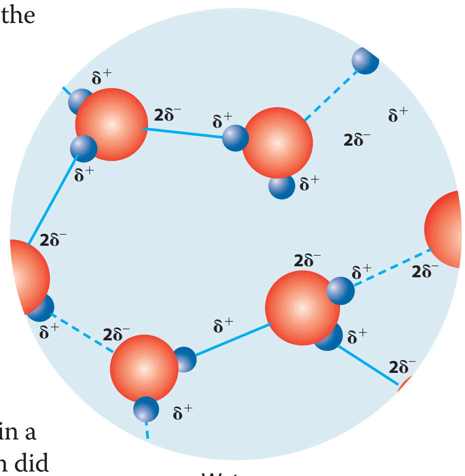
3 A gas has neither a constant volume nor a fixed shape. Gases can be compressed or expanded; unlike liquids, they will fill a container of any size. The air of our atmosphere is the gas with which we are most familiar.

? REVIEW

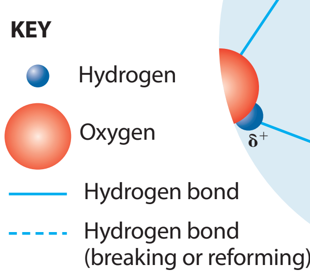
A. Describe the di˜ erent states of matter in terms of shape and volume.

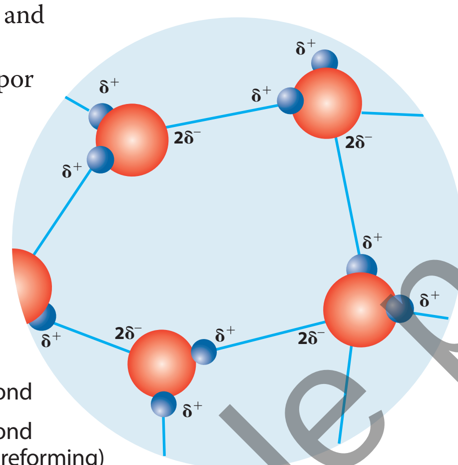
4 Water is the only substance that occurs as a solid (ice), a liquid (water), and a gas (water vapor) at temperatures compatible with life. Water exists as a liquid over a broad range of temperatures primarily because of hydrogen bonding among the water molecules.

5 The small positive charges on the hydrogen atoms of one polar molecule can be attracted to the negative charges on another polar molecule, and this can change the shapes of the molecules or pull adjacent molecules together. This weak attractive force is called a **hydrogen bond**. In the liquid state, hydrogen bonds between adjacent water molecules are continually forming and breaking. When water freezes into ice, the hydrogen bonds lock the molecules in a lattice that occupies more space than did the liquid water. This accounts for the expansion of water during freezing, and because ice is less dense than liquid water, it floats. Water becomes a vapor or gas when all of the hydrogen bonds between adjacent water molecules are broken.



Water





Ice

6 At the water surface, the hydrogen bonds between water molecules slow the rate of evaporation and form what is known as **surface tension**. Surface tension acts as a barrier that keeps small objects from entering the water. For example, it allows insects, such as these water striders, to walk across the surface of a pond or puddle. Similarly, the surface tension in a layer of tears on the eye prevents dust particles from touching the surface of the eye.

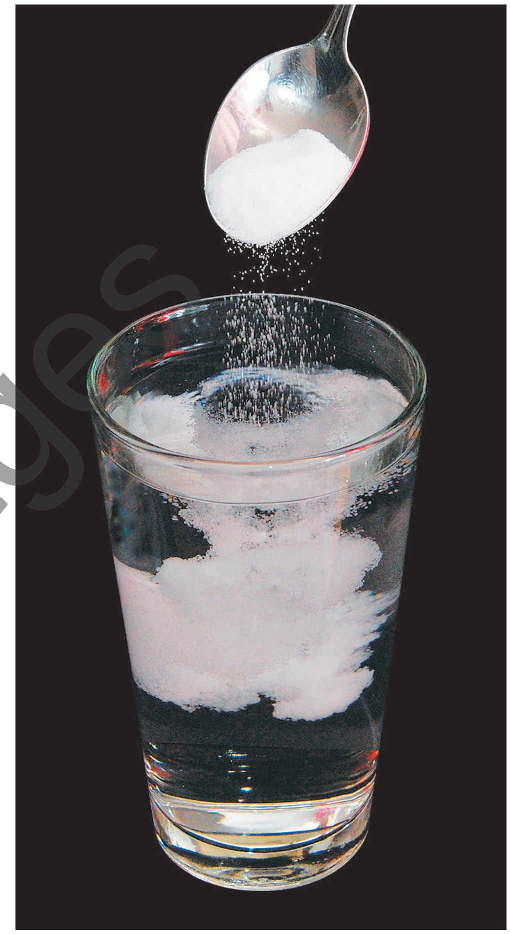
REVIEW

B. By what means are water molecules attracted to each other?

REVIEW

C. Explain why small insects can walk on the surface of a pond and why tears protect the surface of the eye from dust particles.

7 The polar charges on water molecules give water the ability to disrupt the ionic bonds of a variety of inorganic compounds and cause them to dissolve. Almost all naturally occurring elements are found in seawater, and at least 29 elements are dissolved in our body fluids.



INTEGRATION

D. Describe the relationship between thermal energy (temperature) and stability of the hydrogen bonds between water molecules in ice, in liquid water, and as a gas.

LEARNING OUTCOME

Describe the three states of matter and the importance of hydrogen bonds in liquid water.

2

Section 1 Review

Atoms , Molecules, and Compounds

Matching: Match each lettered term with the most closely related description.

a. atomic number
b. electrons
c. protons
d. neutrons
e. isotopes
f. ions
g. ionic bond
h. covalent bond
i. mass number
j. element
k. compound
l. hydrogen bond

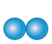
1 Atoms that have gained or lost electrons
2 Subatomic particles in the nucleus; have no electrical charge
3 Atoms of two or more different elements bonded together in a fi ed proportion
4 The number of protons in an atom
5 Attractive force between water molecules
6 Type of chemical bond within a water molecule
7 The number of subatomic particles in the nucleus
8 Substance composed only of atoms with same atomic number
9 Subatomic particles in the nucleus; have an electrical charge
10 Atoms of the same element with different masses
11 Type of chemical bond in table salt
12 Subatomic particles outside the nucleus; have an electrical charge

1 ______
2 ______
3 ______
4 ______
5 ______
6 ______
7 ______
8 ______
9 ______
10 ______
11 ______
12 ______

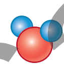
Fill-in: Fill in the missing information in the following table.

Element	Number of protons	Number of electrons	Number of neutrons	Mass number
Helium	13	2	2	14
Hydrogen	1	15	16	1
Carbon	6	17	6	18
Nitrogen	19	7	20	14
Calcium	21	22	20	40

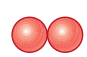
Indicate which of the following molecules are also compounds.


H_2 (hydrogen)

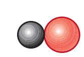
23 ______


H_2O (water)

24 ______


O_2 (oxygen)

25 ______


CO (carbon monoxide)

26 ______

Section integration: Describe how the following pairs of terms concerning atomic interactions are similar and how they are different.

27 Inert element/reactive element
28 Polar molecules/nonpolar molecules
29 Covalent bond/ionic bond

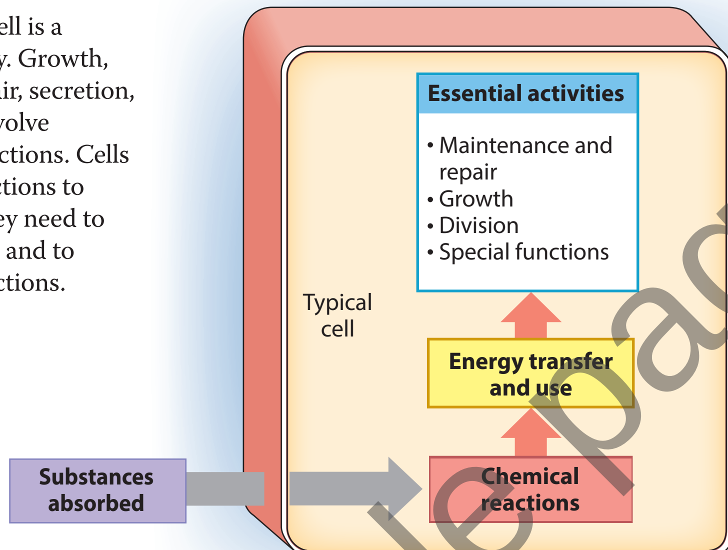
27 ______
28 ______
29 ______

Module ˜. °

Chemical reactions and energy transfer are essential to cellular functions

Cells remain alive and functional by controlling chemical reactions. In a chemical reaction, new chemical bonds form between atoms, or existing bonds between atoms are broken. These changes take place as atoms in the reacting substances, called **reactants**, are rearranged to form different substances, or **products**. All of the reactions under way in the cells and tissues of the body at any given moment make up its **metabolism** (me-TAB-ō-lizm).

1 In effect, each cell is a chemical factory. Growth, maintenance and repair, secretion, and contraction all involve complex chemical reactions. Cells also use chemical reactions to provide the energy they need to maintain homeostasis and to perform essential functions.



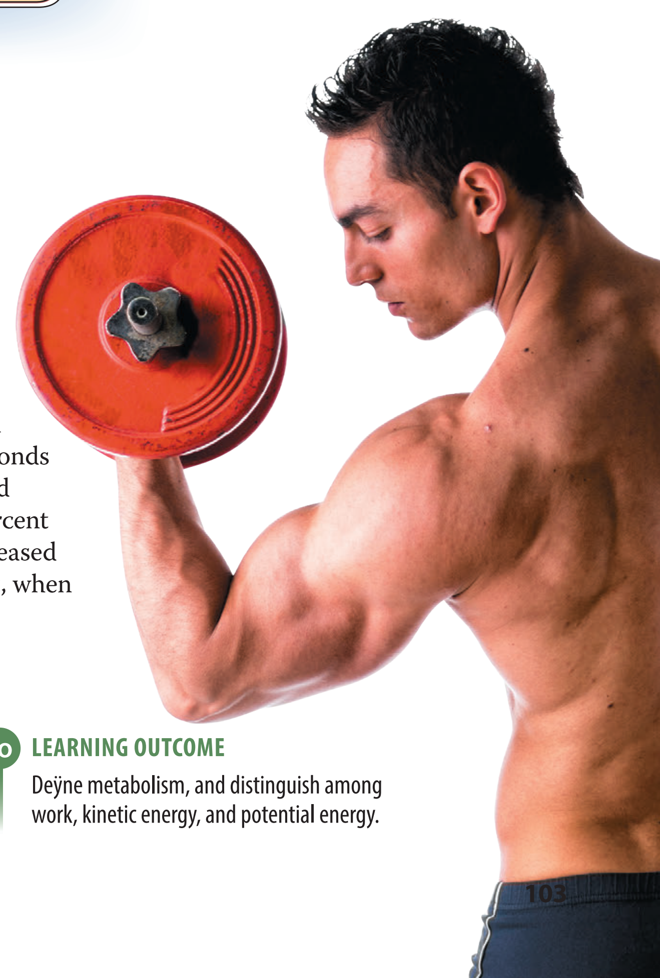
REVIEW

A. Describe how cells are chemical factories.

2 **Work** is the movement of an object or a change in the physical structure of matter. In your body, work includes movements such as walking or running, and also the synthesis of molecules and the conversion of liquid water to water vapor (evaporation).

Energy is the capacity to perform work, and movement or physical change cannot take place without energy. **Kinetic energy** is the energy of motion, energy that can be transferred to another object and do work. **Potential energy** is stored energy, energy that has the potential (capability) to do work. It may derive from an object's position (you standing on a ladder) or from its physical or chemical structure (a stretched spring or a charged battery).

Cells do work as they synthesize complex molecules and move materials into, out of, and within the cell. The cells of a skeletal muscle at rest, for example, contain potential energy in the form of the positions of protein filaments and the covalent bonds between molecules within the cells. When a muscle contracts, it performs work, and potential energy is converted into kinetic energy. Such a conversion is never 100 percent efficient. Each time an energy exchange or transfer occurs, some of the energy is released as heat. The amount of heat is proportional to the amount of work done. As a result, when you exercise, your body temperature rises.



REVIEW

B. Compare and contrast the terms *work*, *energy*, *potential energy*, and *kinetic energy*.

C. Relate the terms *work*, *energy*, *potential energy*, and *kinetic energy* to a muscle contraction at the cellular level.

LEARNING OUTCOME

Deÿne metabolism, and distinguish among work, kinetic energy, and potential energy.

Module ˜ .°

Chemical notation is a concise method of describing chemical reactions

2

Before we can consider the specific compounds found in the human body, we must be able to describe chemical compounds and reactions effectively. Using sentences to describe chemical structures and events often leads to confusion. Chemists have developed a simple form of "chemical shorthand" known as **chemical notation** that makes communication much more efficient.

REVIEW

A. Name the participants in a chemical reaction.

B. How are chemical reactions represented?

1 Chemical notation allows us to describe complex events briefly and precisely. It is relatively easy to use chemical notation to calculate the weights of the reactants involved in a particular reaction.

Atoms

The symbol of an element indicates one atom of that element. A number preceding the symbol of an element indicates more than one atom of that element.

Molecules

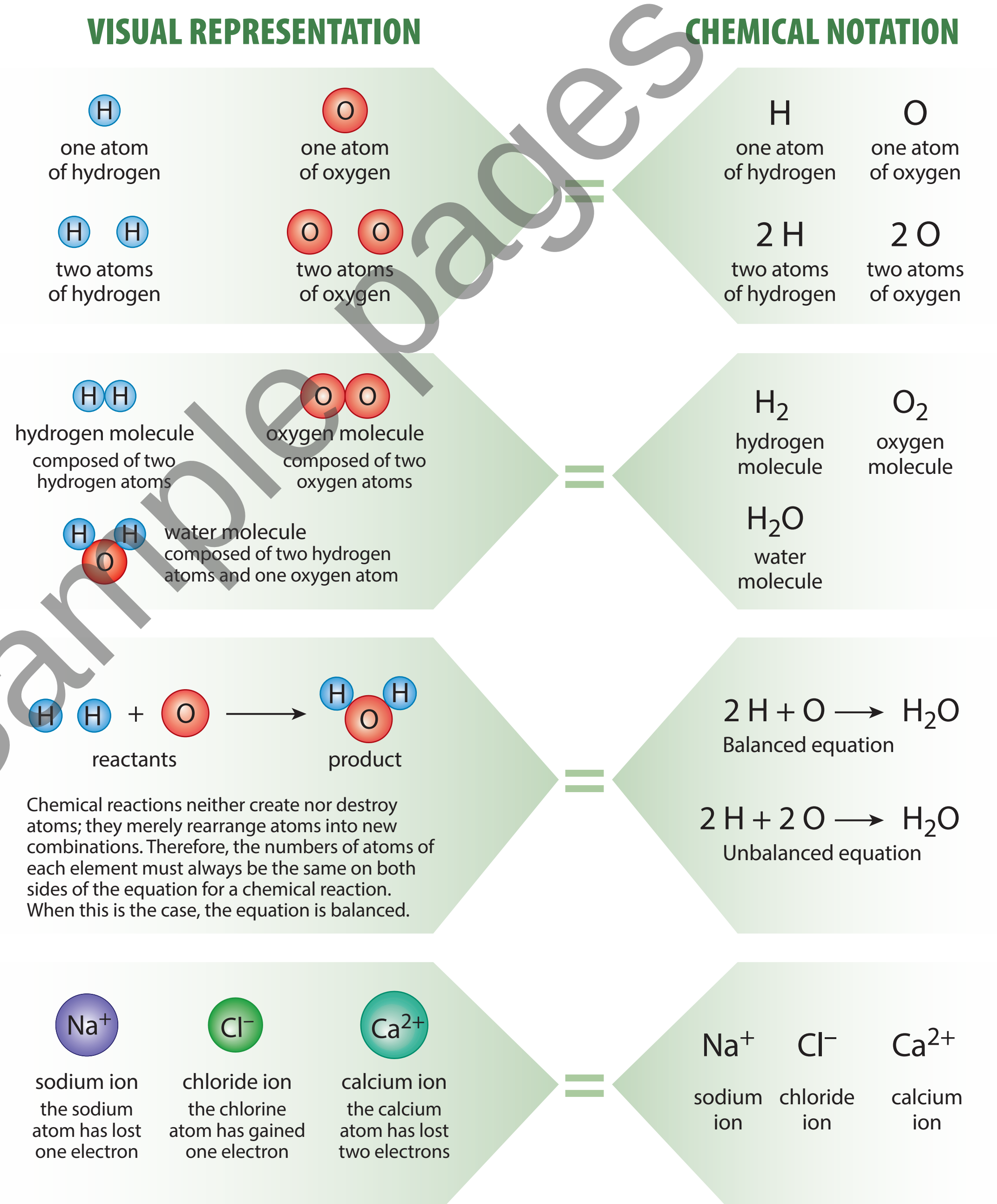
A subscript following the symbol of an element indicates a molecule with that number of atoms of that element.

Chemical Reactions

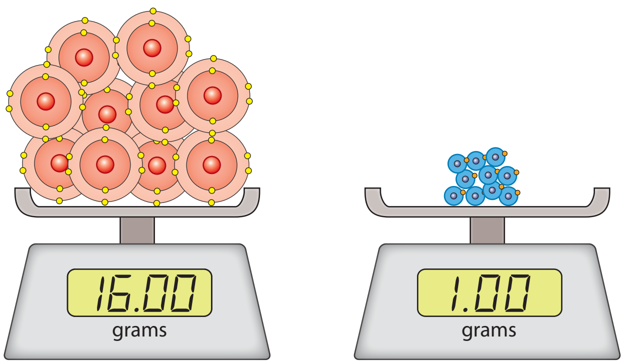
In a description of a chemical reaction, the participants at the start of the reaction are called reactants, and the reaction generates one or more products. Chemical reactions are represented by chemical equations. An arrow indicates the direction of the reaction, from reactants (usually on the left) to products (usually on the right). In the following reaction, two atoms of hydrogen combine with one atom of oxygen to produce a single molecule of water.

Ions

A superscript plus or minus sign following the symbol of an element indicates an ion. A single plus sign indicates a cation with a charge of +1. (The original atom has lost one electron.) A single minus sign indicates an anion with a charge of –1. (The original atom has gained one electron.) If more than one electron has been lost or gained, the charge on the ion is indicated by a number preceding the plus or minus sign.

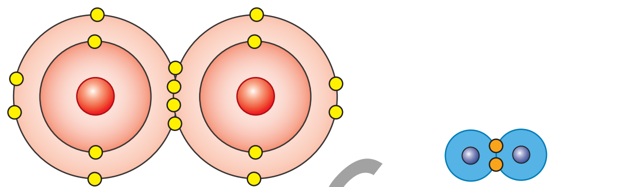


2 A **mole** (abbreviated mol) is a quantity with a weight in grams equal to an element's atomic weight. One mole of a given element always contains the same number of atoms as 1 mole of any other element. The atomic weight of oxygen is 16, and the atomic weight of hydrogen is 1. So a mole of oxygen will weigh 16 grams and contain the same number of atoms as a mole of hydrogen, which weighs 1 gram.



1 mol of oxygen   1 mol of hydrogen

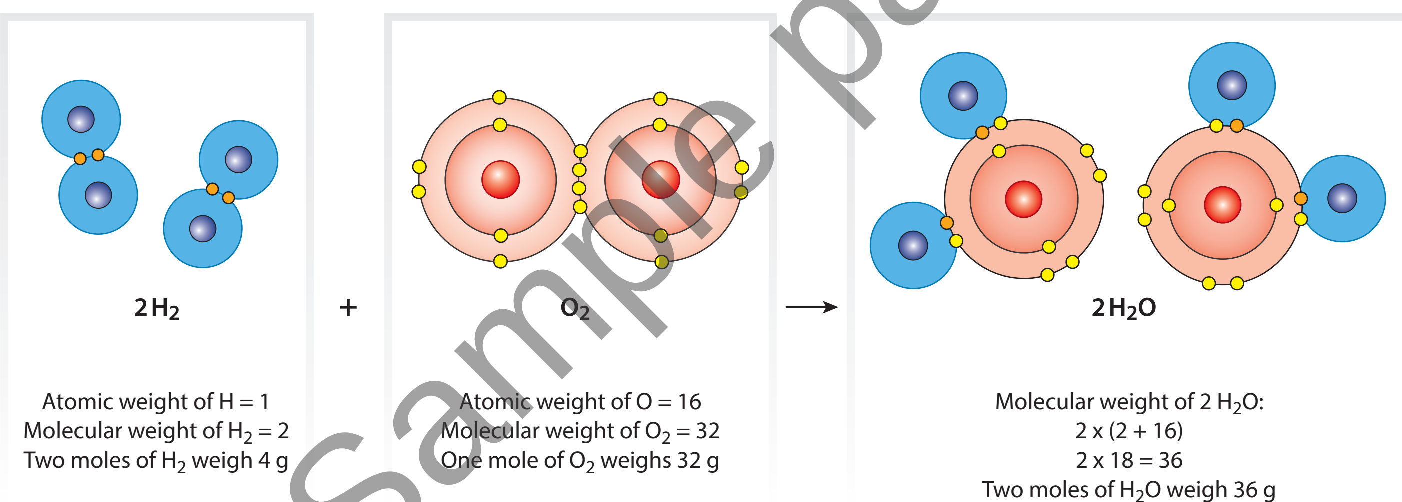
3 The **molecular weight** of a molecule or compound is the sum of the atomic weights of its component atoms. For ionic compounds (which do not form molecules), the term **formula weight** is used instead. Molecular and formula weights are important because you can neither handle individual molecules or ions nor easily count the billions of molecules or ions involved in chemical reactions in the body. To simplify our calculations of moles and molecular weights, we are rounding the atomic weights to the nearest whole number.



Molecular weight of O_2 = 32   Molecular weight of H_2 = 2

? REVIEW

C. What is formula weight?



4 Using molecular weights, you can calculate the quantities of reactants needed for a specific reaction and determine the amount of product generated. For example, suppose you want to form water from hydrogen and oxygen according to this chemical equation: $2\,H_2 + O_2 \rightarrow 2\,H_2O$. The first step is to calculate the molecular weights involved. As detailed above, combining 4 g of hydrogen with 32 g of oxygen yields 36 g of water. Although by convention we use grams, you could also work with ounces, pounds, or tons, as long as the proportions remained the same. Notice that when you do the calculation correctly, the molecular weights of reactants and products are balanced.

? INTEGRATION

D. Using chemical notation, write the molecular formula for glucose, a compound composed of 6 carbon (C) atoms, 12 hydrogen (H) atoms, and 6 oxygen (O) atoms.

E. Calculate the weight of 1 mol of glucose. (The atomic weight of carbon = 12.)

LO LEARNING OUTCOME

Use chemical notation to symbolize chemical reactions.

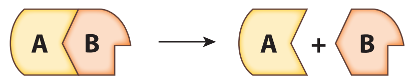
Module ˜. °

Three basic types of chemical reactions are important for understanding physiology

1 A **decomposition** reaction breaks a molecule into smaller fragments.

A simple decomposition reaction is diagrammed below:

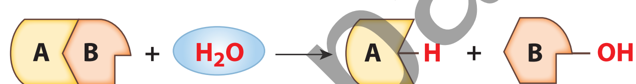
$$AB \longrightarrow A + B$$



Decomposition reactions occur outside cells as well as inside them. For example, a typical meal contains molecules of fats, sugars, and proteins that are too large and too complex to be absorbed and used by your body. Decomposition reactions in the digestive tract break these molecules down into smaller fragments so the body can absorb them.

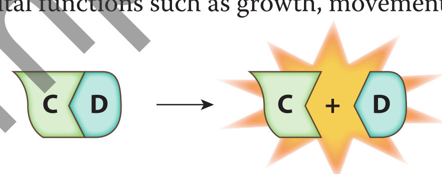
Decomposition reactions involving water are important in the breakdown of complex molecules in the body. In **hydrolysis** (hī-DROL-i-sis; *hydro-*, water + *lysis*, a loosening), one of the bonds in a complex molecule is broken, and the components of a water molecule (H and OH) are added to the resulting fragments:

$$AB + H_2O \longrightarrow AH + BOH$$



The decomposition reactions of complex molecules within the body's cells and tissues are referred to collectively as **catabolism** (ka-TAB-ō-lizm; *katabole*, a throwing down). When a covalent bond—a form of potential energy—is broken, it releases kinetic energy that can perform work. By harnessing the energy released in this way, cells carry out vital functions such as growth, movement, and reproduction.

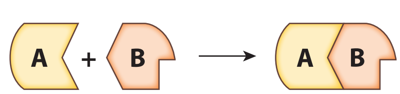
$$CD \longrightarrow C + D + \text{ENERGY}$$



2 **Synthesis** (SIN-the-sis) is the opposite of decomposition. A synthesis reaction assembles smaller molecules into larger molecules.

A simple synthetic reaction is diagrammed here:

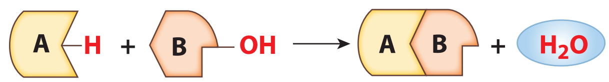
$$A + B \longrightarrow AB$$



Synthesis reactions may involve combining atoms or molecules to form even larger products. Water formation from hydrogen and oxygen molecules is a synthesis reaction. Synthesis always forms new chemical bonds, whether the reactants are atoms or molecules.

Dehydration synthesis, or condensation reaction, forms a complex molecule by removing a water molecule:

$AH + BOH \longrightarrow AB + H_2O$



Dehydration synthesis is the opposite of hydrolysis. We will see examples of both reactions in later sections.

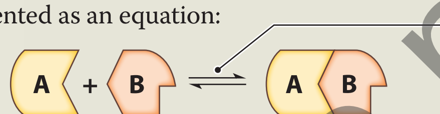
Synthesis of new molecules within the body's cells and tissues is known collectively as **anabolism** (a-NAB-ō-lizm; *anabole*, a throwing upward). Anabolism is usually considered an "uphill" process because it takes energy to create a chemical bond (just as it takes energy to push something uphill). Cells must balance their energy budgets, with catabolism providing the energy to support anabolism and other vital functions.

Chemical reactions are reversible (at least theoretically), so if

$A + B \longrightarrow AB$, then $AB \longrightarrow A + B$

Many important biological reactions are freely reversible. Such reactions can be represented as an equation:

$A + B \rightleftharpoons AB$

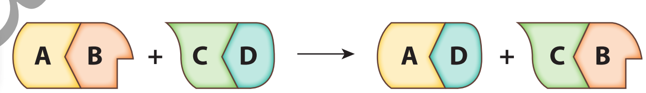


This equation indicates that, in a sense, two reactions are taking place at the same time. One is synthesis and the other decomposition. At **equilibrium**, the rates at which the two reactions proceed are in balance: As fast as one molecule of AB forms, another degrades into A + B.

3 In an **exchange reaction**, parts of the reacting molecules are shuffled around to produce new products:

A simple exchange reaction is diagrammed here:

$AB + CD \longrightarrow AD + CB$



The reactants and products contain the same components (A, B, C, and D), but those components are present in different combinations. In an exchange reaction, the reactant molecules AB and CD must break apart (a decomposition) before they can interact with each other to form AD and CB (a synthesis).

Go to Mastering A&P™
Get Ready for A&P
Chemical Reactions

2

? REVIEW

A. Compare the role of water in hydrolysis and dehydration synthesis reactions.

? REVIEW

B. Identify and describe three types of chemical reactions important in human physiology.

? INTEGRATION

C. What is the source of energy that converts glucose, a six-carbon molecule, into two three-carbon molecules in cells?

LO LEARNING OUTCOME

Distinguish among the major types of chemical reactions that are important for studying physiology.