CHAPTER OUTLINE

CHAPTER ONE

Basic Concepts About Matter

Heat and light generation, as well as numerous changes in matter, occur as wood is burned in a bonfire.

In this chapter we address the question "What exactly is chemistry about?" In addition, we consider common terminology associated with the field of chemistry. Much of this terminology is introduced in the context of the ways in which matter is classified. Like all other sciences, chemistry has its own specific language. It is necessary to restrict the meanings of some words so that all chemists (and those who study chemistry) can understand a given description of a chemical phenomenon in the same way.

1.1 Chemistry: The Study of Matter

Learning Focus

Define the term *matter* and list the aspects of matter that are of particular concern to chemists.

Chemistry *is the field of study concerned with the characteristics, composition, and transformations of matter.* What is matter? **Matter** *is anything that has mass and occupies space.* The term *mass* refers to the amount of matter present in a sample.

Matter includes all things—both living and nonliving—that can be seen (such as plants, soil, and rocks) as well as things that cannot be seen (such as air and bacteria). Not considered to be matter are the various forms of energy, such as heat, light, and electricity. However, chemists must be concerned with energy as well as matter, because almost all changes that matter undergoes involve the release or absorption of energy.

▶ The universe is composed entirely of matter and energy.

The scope of chemistry is extremely broad, and it touches every aspect of our lives. An iron gate rusting, a chocolate cake baking, the diagnosis and treatment of a heart attack, the propulsion of a jet airliner, and the digesting of food all fall within the realm of chemistry (see Figure 1.1). The key to understanding such diverse processes is an understanding

Figure 1.1 Everyday activities such as making a batch of muffins involve chemistry.

of the fundamental nature of matter, which is what we are going to talk about for the rest of this chapter.

▶ The term *chemistry* is derived from the word *alchemy*, which denotes practices carried out during the Middle Ages in an attempt to transform something common into something precious (in particular, lead into gold). Alchemy originated in Alexandrian Egypt, and the term *alchemy* is derived from the Greek *al* ("the") and *khemia* (a native name for Egypt).

Practice Questions and Problems

1.1 Classify each of the following as matter or energy (nonmatter).
a. Air b. Pizza c. Sound d. Light e. Gold f. Virus

1.2 What three aspects of matter are chemists particularly interested in?

Learning Focus

Characterize each of the three physical states of matter in terms of the definiteness or indefiniteness of its shape and volume.

1.2 Physical States of Matter

Three physical states exist for matter: solid, liquid, and gas. The classification of a given matter sample in terms of physical state is based on whether its shape and volume are definite or indefinite.

A **solid** *is the physical state characterized by a definite shape and a definite volume.* A silver dollar has the same shape and volume whether it is placed in a large container or on a table top (Figure 1.2a). For solids in powdered or granulated forms, such as sugar or salt, a quantity of the solid takes the shape of the portion of the container it occupies, but each individual particle has a definite shape and volume. A **liquid** *is the physical state characterized by an indefinite shape and a definite volume.* A liquid always takes the shape of its container to the extent that it fills the container (Figure 1.2b). A **gas** *is the physical state characterized by an indefinite shape and an indefinite volume.* A gas always completely fills its container, adopting both its volume and its shape (Figure 1.2c).

▶ The *volume* of a sample of matter is a measure of the amount of space occupied by the sample.

(a) (b) (c)

Figure 1.2 (a) A solid has a definite shape and a definite volume. (b) A liquid has an indefinite shape—it takes the shape of its container—and a definite volume. (c) A gas has an indefinite shape and an indefinite volume—it assumes the shape and volume of its container.

Figure 1.3 Water can be found in the solid, liquid, and vapor (gaseous) forms simultaneously, as shown here at Yellowstone National Park.

The state of matter observed for a particular substance depends on its temperature, the surrounding pressure, and the strength of the forces holding its structural particles together. At the temperatures and pressures normally encountered on Earth, water is one of the few substances found in all three of its physical states: solid ice, liquid water, and gaseous steam (Figure 1.3). Under laboratory conditions, states other than those commonly observed can be attained for almost all substances. Oxygen, which is nearly always thought of as a gas, becomes a liquid at −183°C and a solid at −218°C. The metal iron is a gas at extremely high temperatures (above 3000°C).

Practice Questions and Problems

1.3 Give a characteristic that distinguishes
a. liquids from solids b. gases from liquids

1.4 Give a characteristic that is the same for
a. liquids and solids b. gases and liquids

1.5 Indicate whether each of the following would take the shape of its container and also have a definite volume.
a. Copper wire b. Oxygen gas c. Granulated sugar d. Liquid water

Learning Focus

Classify a given property of a substance as a physical property or a chemical property.

1.3 Properties of Matter

Various kinds of matter are distinguished from each other by their properties. **Properties** *are the distinguishing characteristics of a substance that are used in its identification and description.* Each substance has a unique set of properties that distinguishes it from all other substances. Properties of matter are of two general types: physical and chemical.

A **physical property** *is a characteristic of a substance that can be observed without changing the basic identity of the substance.* Common physical properties include color, odor, physical state (solid, liquid, or gas), melting point, boiling point, and hardness.

During the process of determining a physical property, the physical appearance of a substance may change, but the substance's identity does not. For example, it is impossible to measure the melting point of a solid without changing the solid into a liquid. Although the liquid's appearance is much different from that of the solid, the substance is still the same; its chemical identity has not changed. Hence melting point is a physical property.

▶ *Chemical* properties describe the ability of a substance to form new substances, either by reaction with other substances or by decomposition. *Physical* properties are properties associated with a substance's physical existence. They can be determined without reference to any other substance, and their determination causes no change in the identity of the substance.

A **chemical property** *is a characteristic of a substance that describes the way the substance undergoes or resists change to form a new substance.* For example, copper objects turn green when exposed to moist air for long periods of time (Figure 1.4); this is a chemical property of copper. The green coating formed on the copper is a new substance that results from the copper's reaction with oxygen, carbon dioxide, and water present in air. The properties of this new substance (the green coating) are very different from those of metallic copper. On the other hand, gold objects resist change when exposed to air for long periods of time. The lack of reactivity of gold with air is a chemical property of gold.

Most often the changes associated with chemical properties result from the interaction (reaction) of a substance with one or more other substances. However, the presence of a second substance is not an absolute requirement. Sometimes the presence of energy (usually heat or light) can trigger the change called decomposition. The fact that hydrogen peroxide, in the presence of either heat or light, decomposes into the substances water and oxygen is a chemical property of hydrogen peroxide.

When we specify chemical properties, we usually give conditions such as temperature and pressure because they influence the interactions between substances. For example, the gases oxygen and hydrogen are unreactive toward each other at room temperature, but they interact explosively at a temperature of several hundred degrees.

Figure 1.4 The green color of the Statue of Liberty (present before it was restored) results from the reaction of the copper skin of the statue with the components of air. The fact that copper will react with the components of air is a chemical property of copper.

Practice Questions and Problems

1.6 Classify each of the following properties of the substance magnesium as a physical property or a chemical property.

a. Is a solid at room temperature
b. Ignites upon heating in air
c. Melts at 651°C
d. Does not react with cold water

1.7 Indicate whether each of the following statements describes a physical property or a chemical property.

a. Aspirin tablets can be pulverized with a hammer.
b. Mercury is a liquid at room temperature.
c. Beryllium metal vapor is extremely toxic to humans.
d. Nitric acid discolors the skin by reacting with skin protein.

Learning Focus

Classify a given change that occurs in matter as a physical change or a chemical change.

1.4 Changes in Matter

Changes in matter are common and familiar occurrences. Changes take place when food is digested, paper is burned, and a pencil is sharpened. Like properties of matter, changes in matter are classified into two categories: physical and chemical.

A **physical change** *is a process in which a substance changes its physical appearance but not its chemical composition.* A new substance is never formed as a result of a physical change.

▶ Physical changes need not involve a change of state. Pulverizing an aspirin tablet into a powder and cutting a piece of adhesive tape into small pieces are physical changes that involve only the solid state.

A change in physical state is the most common type of physical change. Melting, freezing, evaporation, and condensation are all changes of state. In any of these processes, the composition of the substance undergoing change remains the same even though its physical state and appearance change. The melting of ice does not produce a new substance; the substance is water both before and after the change (see Figure 1.5). Similarly, the steam produced from boiling water is still water.

A **chemical change** *is a process in which a substance undergoes a change in chemical composition.* Chemical changes always involve conversion of the material or materials under consideration into one or more new substances, each of which has distinctly different properties and composition from the original materials. Consider, for example, the rusting of iron objects left exposed to moist air (Figure 1.6). The reddish brown sub-

Figure 1.5 The melting of ice cream is a physical change.

stance (the rust) that forms is a new substance with chemical properties that are obviously different from those of the original iron.

Chemists study the nature of changes in matter to learn how to bring about favorable changes and prevent undesirable ones. The control of chemical change has been a major factor in attainment of the modern standard of living now enjoyed by most people in the developed world. The many plastics, synthetic fibers, and prescription drugs now in common use are the result of controlled chemical change.

On the basis of the discussion in this section and the preceding one, some generalizations concerning the use of the terms *physical* and *chemical* are in order.

1. Whenever the term *physical* is used to modify another term, as in *physical property* or *physical change,* it always conveys the ideas that the composition (chemical identity) of the substance involved *did not change.*
2. Whenever the term *chemical* is used to modify another term, as in *chemical property* or *chemical change,* it always conveys the idea that the composition (chemical identity) of the substance(s) involved either *did change* or *successfully resisted change* as the result of an external challenge to its identity.

Figure 1.6 As a result of chemical change, bright steel girders become rusty when exposed to moist air.

Example 1.1 **Correct Use of the Terms *Physical* and *Chemical***

Correctly complete each of the following sentences by placing the word *physical* or *chemical* in the blank

a. The fact that pure aspirin melts at 143°C is a _____ property of aspirin.
b. The fact that potassium metal vigorously interacts with water to produce hydrogen gas is a _____ property of potassium.
c. Straightening a bent piece of iron with a hammer is an example of a _____ change.
d. The ignition of a match is an example of a _____ change.

Solution

a. Physical. Changing solid aspirin to liquid aspirin (melting) does not produce any new substances. We still have aspirin.
b. Chemical. A new substance, hydrogen, is produced.
c. Physical. The piece of iron is still a piece of iron.
d. Chemical. New gaseous substances, as well as heat and light, are produced as the match burns.

Practice Questions and Problems

1.8 Indicate whether each of the following statements describes a physical change or a chemical change.

a. An Alka-Seltzer tablet is dropped into water.
b. A table leg is fashioned from a piece of wood.
c. Water placed in the refrigerator is converted into ice cubes.
d. Leaves turn red in the autumn.

1.9 Correctly complete each of the following sentences by placing the word *physical* or *chemical* in the blank.

a. The destruction of a newspaper through burning involves a _____ change.
b. The grating of a piece of cheese is a _____ change.
c. The heating of a blue powdered material to produce a white glassy substance and a gas is a _____ change.
d. The crushing of some ice to make some ice chips is a _____ change.

Learning Focus

List the major differences between pure substances, heterogeneous mixtures, and homogeneous mixtures.

1.5 Pure Substances and Mixtures

In addition to its classification by physical state (Section 1.2), matter can also be classified in terms of its chemical composition as a pure substance or as a mixture. A **pure substance** *is a single kind of matter that cannot be separated into other kinds of matter by any physical means.* All samples of a pure substance contain only that substance and nothing else. Pure water is water and nothing else. Pure sucrose (table sugar) contains only that substance and nothing else.

▶ *Substance* is a general term used to denote any variety of matter. *Pure substance* is a specific term that applies only to matter that contains a single substance.

A pure substance always has a definite and constant composition. This invariant composition dictates that the properties of a pure substance are always the same under a given set of conditions. Collectively, these definite and constant physical and chemical properties constitute the means by which we identify the pure substance.

▶ All samples of a pure substance, no matter what their source, have the same properties under the same conditions.

A **mixture** *is a physical combination of two or more pure substances in which each substance retains its own chemical identity.* Components of a mixture retain their identity because they are physically mixed rather than chemically combined. Consider a mixture of small rock salt crystals and ordinary sand. Mixing these two substances changes neither the salt nor the sand in any way. The larger, colorless salt particles are easily distinguished from the smaller, light-gray sand granules.

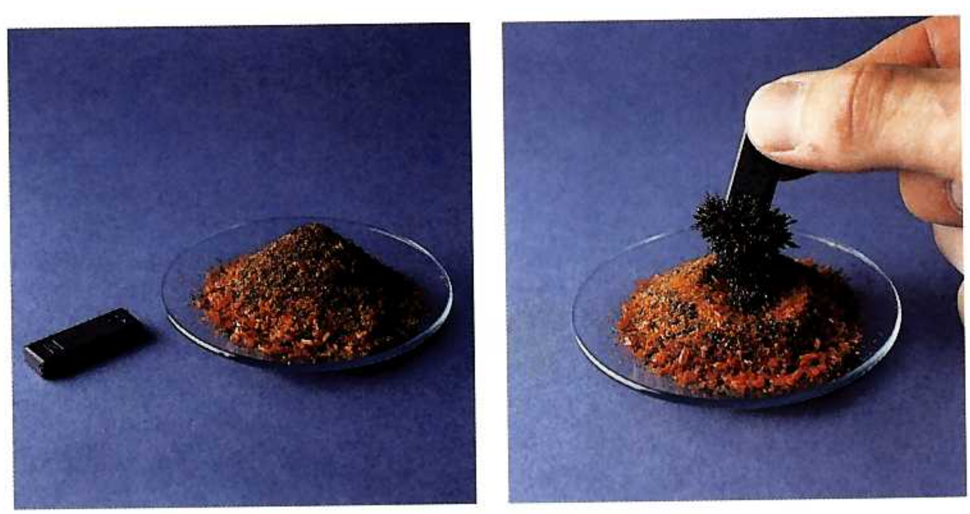
One characteristic of any mixture is that its components can be separated by using physical means. In our salt–sand mixture, the larger salt crystals could be—though very tediously—"picked out" from the sand. A somewhat easier separation method would be to dissolve the salt in water, which would leave the undissolved sand behind. The salt could then be recovered by evaporation of the water. Figure 1.7 shows a heterogeneous mixture of potassium dichromate (orange crystals) and iron filings. A magnet can be used to separate the components of this mixture.

▶ Most naturally occurring samples of matter are mixtures. Gold and diamond are two of the few naturally occurring pure substances. Despite their scarcity in nature, numerous pure substances are known. They are obtained from natural mixtures by using various types of separation techniques or are synthesized in the laboratory from naturally occurring materials.

Another characteristic of a mixture is variable composition. Numerous different salt–sand mixtures, with compositions ranging from a slightly salty sand mixture to a slightly sandy salt mixture, could be made by varying the amounts of the two components.

Mixtures are subclassified as heterogeneous or homogeneous. This subclassification is based on visual recognition of the mixture's components. A **heterogeneous mixture** *contains visibly different phases (parts), each of which has different properties.* A nonuniform appearance is a characteristic of all heterogeneous mixtures. Examples include chocolate chip cookies and blueberry muffins. Naturally occurring heterogeneous mixtures include rocks, soils, and wood.

A **homogeneous mixture** *contains only one visibly distinct phase (part), which has uniform properties throughout.* The components present in a homogeneous mixture can-



(a) (b)

Figure 1.7 (a) A magnet (on the left) and a mixture consisting of potassium dichromate (the orange crystals) and iron fillings. (b) The magnet can be used to separate the iron filings from the potassium dichromate.

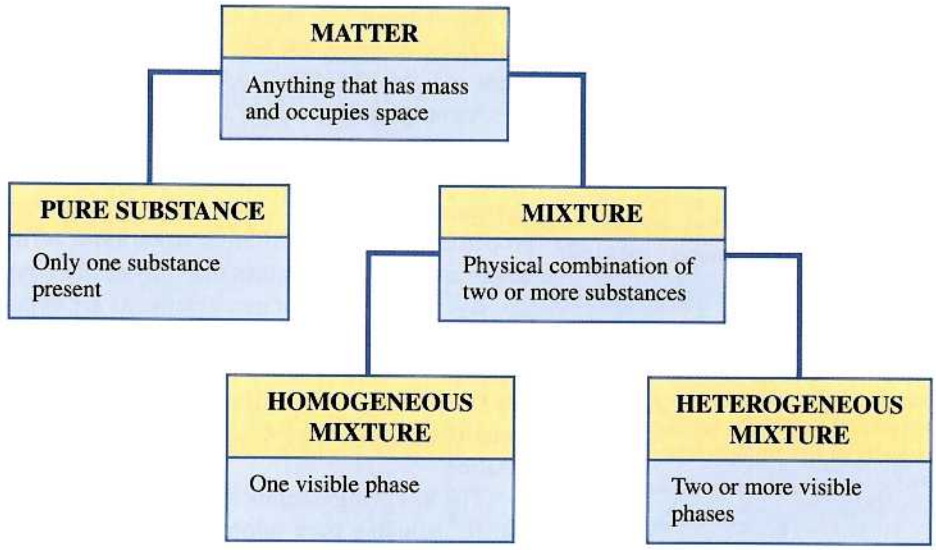


Figure 1.8 Matter falls into two basic classes: pure substances and mixtures. Mixtures, in turn, may be homogeneous or heterogeneous.

not be visually distinguished. A sugar–water mixture in which all of the sugar has dissolved has an appearance similar to that of pure water. Air is a homogeneous mixture of gases; motor oil and gasoline are multicomponent homogeneous mixtures of liquids; and metal alloys such as 14-karat gold (a mixture of copper and gold) are examples of homogeneous mixtures of solids.

Figure 1.8 summarizes what we have learned thus far about various classifications of matter.

Practice Questions and Problems

1.10 Classify each of the following statements as *true* or *false*.
a. All heterogeneous mixtures must contain three or more substances.
b. Pure substances cannot have a variable composition.
c. Substances maintain their identity in a heterogeneous mixture but not in a homogeneous mixture.
d. A homogeneous mixture contains only one visibly distinct phase.

1.11 Assign each of the following descriptions of matter to one of these categories: *heterogeneous mixture, homogeneous mixture,* or *pure substance.*
a. Two substances present, two phases present
b. Two substances present, one phase present
c. One substance present, one phase present
d. Three substances present, three phases present

1.12 Classify each of the following samples of matter as a *heterogeneous mixture, homogeneous mixture,* or *pure substance.*
a. Water and dissolved salt
b. Water and sand
c. Water, ice, and oil
d. Salt water and sugar water

Learning Focus

List the major differences between elements and compounds.

1.6 Elements and Compounds

Chemists have isolated and characterized an estimated 8.5 million pure substances. A very small number of these pure substances, 113 to be exact, are different from all of the others. They are elements. All of the rest, the remaining millions, are compounds. What distinguishes an element from a compound?

An **element** *is a pure substance that cannot be broken down into simpler pure substances by ordinary chemical means such as a reaction, an electric current, heat, or a beam of light.* The metals gold, silver, and copper are all elements.

A **compound** *is a pure substance that can be broken down into two or more simpler pure substances by chemical means.* Water is a compound. By means of an electric current, water can be broken down into the gases hydrogen and oxygen, both of which are elements. The ultimate breakdown products for any compound are elements. A compound's properties are always different from those of its component elements, because the elements are chemically rather than physically combined in the compound (Figure 1.9).

Even though two or more elements are obtained from decomposition of compounds, compounds are not mixtures. Why is this so? Remember, substances can be combined either physically or chemically. Physical combination of substances produces a mixture. Chemical combination of substances produces a compound, a substance in which combining entities are *bound* together. No such binding occurs during physical combination.

The following Chemistry at a Glance summarizes what we have learned thus far about matter, including pure substances, elements, compounds, and mixtures.

▶ Both elements and compounds are pure substances.

▶ The definition for the term *element* that is given here will do for now. After considering the concept of atomic number (Section 3.2), we will give a more precise definition.

▶ Every known compound is made up of some combination of the 113 known elements. In any given compound, the elements are combined chemically in fixed proportions by mass.

▶ There are three major property distinctions between compounds and mixtures.

1. Compounds have properties distinctly different from those of the substances that combined to form the compound. The components of mixtures retain their individual properties.
2. Compounds have a definite composition. Mixtures have a variable composition.
3. Physical methods are sufficient to separate the components of a mixture. The components of a compound cannot be separated by physical methods; chemical methods are required.

Practice Questions and Problems

1.13 Indicate whether each of the following statements is *true* or *false.*
   a. Both elements and compounds are pure substances.
   b. A compound results from the physical combination of two or more elements.
   c. Compounds, but not elements, can have a variable composition.
   d. A compound must contain at least two elements.

1.14 On the basis of the information given, classify each of the pure substances A through D as *elements* or *compounds,* or indicate that no such classification is possible because of insufficient information.
   a. Substance A cannot be broken down into simpler substances by chemical means.
   b. Substance B decomposes upon heating.
   c. Heating substance C to 1000°C causes no change in it.
   d. Substance D readily reacts with the element chlorine.

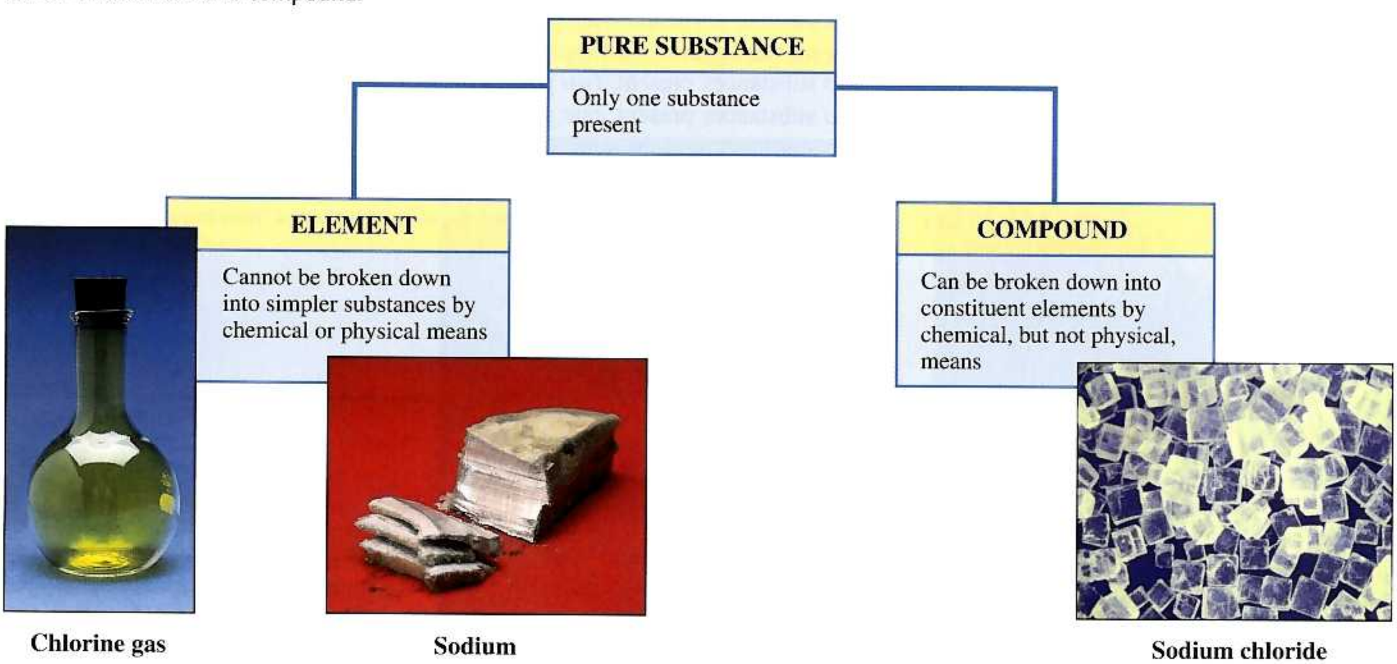


Figure 1.9 A pure substance can be either an element or a compound.

Classes of Matter

Classes of Matter

Pure Substances
- Only one substance present
- Definite and constant composition
- Properties always the same under the same conditions

Mixtures
- Physical combination of two or more substances
- Composition can vary
- Properties can vary with composition

Elements
- Cannot be broken down into simpler substances by chemical or physical means
- Building blocks for all other types of matter
- 113 elements known

Silver

Compounds
- Can be broken down into constituent elements by chemical, but not physical, means
- Chemical combination of two or more elements
- Have definite, constant, elemental composition

Emerald

Homogeneous Mixtures
- One visible phase
- Same properties throughout

Gold alloy

Heterogeneous Mixtures
- Two or more visible phases
- Different properties in different phases

Granite

1.15 From the information given in the following equations, classify each of the substances A through F as *elements* or *compounds,* or indicate that no such classification is possible because of insufficient information.

a. $A + B \longrightarrow C$

b. $D \longrightarrow E + F$

Learning Focus

List general trends concerning the discovery and abundance of the elements.

1.7 Discovery and Abundance of the Elements

The discovery and isolation of the 113 known elements, the building blocks for all matter, have taken place over a period of several centuries. Most of the discoveries have occurred since 1700, the 1800s being the most active period.

Eighty-eight of the 113 elements occur naturally, and 25 have been synthesized in the laboratory by bombarding samples of naturally occurring elements with small particles. Figure 1.10 shows samples of selected naturally occurring elements. The synthetic

Figure 1.10 Outward physical appearance of selected naturally occurring elements. *Center:* Sulfur. *From upper right, clockwise:* Arsenic, iodine, magnesium, bismuth, and mercury.

(laboratory-produced) elements are all unstable (radioactive) and usually revert quickly to the naturally occurring elements.

The naturally occurring elements are not evenly distributed on Earth and in the universe. What is startling is the nonuniformity of the distribution. A small number of elements account for the majority of elemental particles (atoms). (An atom is the smallest particle of an element that can exist. See Section 1.9.)

Studies of the radiation emitted by stars enable scientists to estimate the elemental composition of the universe (Figure 1.11a). Results indicate that two elements, hydrogen and helium, are absolutely dominant. All other elements are mere "impurities" when their abundances are compared with those of these two dominant elements. In this big picture, in which Earth is but a tiny microdot, 91% of all elemental particles (atoms) are hydrogen, and almost all of the remaining 9% are helium.

▶ A student who attended a university in the year 1700 would have been taught that 13 elements existed. In 1750 he or she would have learned about 16 elements, in 1800 about 34, in 1850 about 59, in 1900 about 82, and in 1950 about 98. Today's total of 113 elements was reached in 1999.

▶ Any increase in the number of known elements from 113 will result from the production of additional synthetic elements. Current chemical theory strongly suggests that all naturally occurring elements have been identified. The isolation of the last of the known naturally occurring elements, rhenium, occurred in 1925.

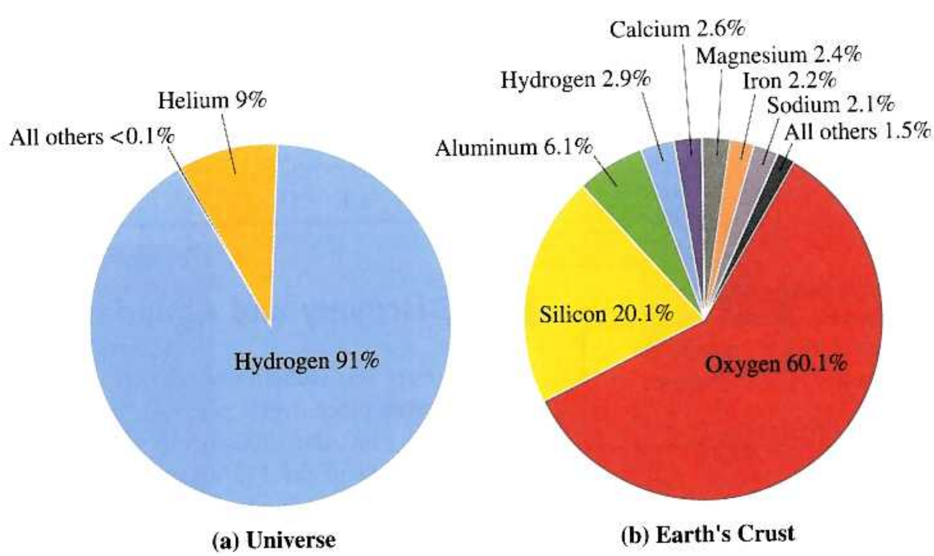


Figure 1.11 Abundance of elements in the universe and in Earth's crust (in atom percent).

If we narrow our view to the chemical world of humans—Earth's crust (its waters, atmosphere, and outer solid surface)—a different perspective emerges. Again, two elements dominate, but this time they are oxygen and silicon. Figure 1.11b provides information on elemental abundances for Earth's crust. The numbers given are atom percents—that is, the percentage of total atoms that are of a given type. Note that the eight elements listed (the only elements with atom percents greater than 1%) account for over 98% of total atoms in Earth's crust. Note also the dominance of oxygen and silicon; these two elements account for 80% of the atoms that make up the chemical world of humans.

The elements of Earth's crust are not distributed equally throughout it. Ore deposits of some elements are found only in localized regions of the crust. Thus not all countries have domestic access to all elements. Even the United States, with its wealth of natural resources, lacks domestic sources of certain elements. For example, the United States has no domestic production sources for the elements nickel, chromium, and cobalt. All new supplies of these elements must be imported from other countries.

To some observers, our nation's reliance on such imports constitutes a dangerous dependence, portending a "strategic materials crisis" equal in seriousness to the "energy crisis" associated with the importation of crude oil and petroleum products. Others see the U.S. position as manageable, though not without dangers and difficulties. All observers agree that if supplies of such imported elements were cut off, many readjustments would have to be made in lifestyles in the United States.

Chemical Portraits 1 profiles the "imported" elements nickel, chromium, and cobalt. The major use for all three of these elements is in metal alloys. (Alloys are solid-state homogeneous mixtures; see Section 1.5.) Import dependence for each of these elements is 60% or greater. (Import dependence is not 100% because significant supplies of these elements are now obtained from domestic recycling of scrap materials, such as spent metal alloys, that contain these elements.

Chemical Portraits 1 Strategic Elements–Dependence on Imports

Nickel (Ni)

Profile: The United States imports 55–65% of its nickel, of which 39% comes from Canada, 15% comes from Norway, and 13% comes from Russia.

Uses: Nickel's primary use is in stainless steel, a type of steel that is corrosion resistant. Adding nickel to steel increases its workability and strength at high temperatures. Some nickel is used in making coins; a U.S. nickel (5 cents) contains 25% nickel and 75% copper. Although nickel is relatively scarce in the Earth's crust, it is believed that large deposits of this element exist within the Earth's core.

What is the importance of the domestic recycling of scrap metals containing nickel?

Chromium (Cr)

Profile: The United States imports 75–80% of its chromium, of which 46% comes from South Africa, 14% comes from Kazakhstan, and 10% comes from Russia.

Uses: Chromium's primary use is as an ingredient in stainless steel; it is the chromium present that gives such steel its corrosion resistance. Chromium atoms near the surface of the steel react with the oxygen of air to produce a chromium-oxygen compound. This compound forms a corrosion-resistant tenacious protective coating on the surface of the steel.

What properties of chromium are responsible for the practice of chrome-plating other metal objects?

Cobalt (Co)

Profile: The United States imports 73–76% of its cobalt, of which 23% comes from Norway, 20% comes from Finland, and 13% comes from Zambia.

Uses: Cobalt's primary use is as an ingredient in superalloys (alloys that can withstand higher temperatures than stainless steel can). Such superalloys are used primarily in aircraft gas turbine engines. Cobalt, like iron, has magnetic properties and it retains them at temperatures far higher than does iron. This leads to cobalt's use in small, powerful magnets for electrical equipment.

What role does the element cobalt play in human nutrition?

See the text web site at **http://chemistry.college.hmco.com/students** for answers to the above questions and for further information.

Table 1.1
Abundance of Elements in the Human Body (in atom percent)

Element	Percent of total number of atoms in the human body
hydrogen	63
oxygen	25.5
carbon	9.5
nitrogen	1.4
calcium	0.31
phosphorus	0.22
potassium	0.06
sulfur	0.05
chlorine	0.03
sodium	0.03
magnesium	0.01

The distribution of elements in the human body and other living systems is very different from that found in Earth's crust. This distribution is the result of living systems *selectively* taking up matter from their external environment, rather than simply accumulating matter representative of their surroundings.

Eleven elements are found in the human body in atom percent levels of 0.01 or greater, as shown in Table 1.1. The high abundances of hydrogen and oxygen in the body reflect its high water content. Hydrogen is over twice as abundant as oxygen, largely because water contains hydrogen and oxygen in a 2-to-1 atom ratio.

Practice Questions and Problems

1.16 Indicate whether each of the following statements about the known elements is *true* or *false*.

a. The majority of the known elements have been discovered since 1900.
b. At present, 108 elements are known.
c. Elements that do not occur in nature can be produced in a laboratory setting.
d. New elements have been identified within the last 10 years.

1.17 Indicate whether each of the following statements about elemental abundances is *true* or *false*.

a. Silicon is the second most abundant element in Earth's crust.
b. Oxygen is the most abundant element both in Earth's crust and in the human body.
c. Hydrogen is the most abundant element in the universe but not in Earth's crust.
d. Two elements account for over three-fourths of the atoms in Earth's crust.

1.8 Names and Chemical Symbols of the Elements

Learning Focus

For the common elements, given the name of the element write its chemical symbol, or given its chemical symbol write its name.

▶ Learning the symbols of the more common elements is an important key to success in studying chemistry. Knowledge of chemical symbols is essential for writing chemical formulas (Section 1.10) and chemical equations (Section 5.6).

Each element has a unique name that, in most cases, was selected by its discoverer. Abbreviations called chemical symbols also exist for the names of the elements. A **chemical symbol** *is a one- or two-letter designation for an element derived from the name of the element.* These symbols are used more frequently than the elements' names. They can be written more quickly than the names, and they occupy less space. A complete list of the known elements and their chemical symbols is given in Table 1.2. The chemical symbols and names of the more frequently encountered elements are shown in color in this table.

Note that the first letter of a chemical symbol is always capitalized and that the second is not. Two-letter symbols are often, but not always, the first two letters of the element's name.

Eleven elements have symbols that bear no relationship to the element's English-language name. In ten of these cases, the symbol is derived from the Latin name of the

Table 1.2
The Chemical Symbols for the Elements[a]
The symbols and names of the more frequently encountered elements are shown in red.

Ac	actinium	Ge	germanium	Pr	praseodymium
Ag	silver*	H	hydrogen	Pt	platinum
Al	aluminum	He	helium	Pu	plutonium
Am	americium	Hf	hafnium	Ra	radium
Ar	argon	Hg	mercury*	Rb	rubidium
As	arsenic	Ho	holmium	Re	rhenium
At	astatine	Hs	hassium	Rf	rutherfordium
Au	gold*	I	iodine	Rh	rhodium
B	boron	In	indium	Rn	radon
Ba	barium	Ir	iridium	Ru	ruthenium
Be	beryllium	K	potassium*	S	sulfur
Bh	bohrium	Kr	krypton	Sb	antimony*
Bi	bismuth	La	lanthanum	Sc	scandium
Bk	berkelium	Li	lithium	Se	selenium
Br	bromine	Lu	lutetium	Sg	seaborgium
C	carbon	Lr	lawrencium	Si	silicon
Ca	calcium	Md	mendelevium	Sm	samarium
Cd	cadmium	Mg	magnesium	Sn	tin*
Ce	cerium	Mn	manganese	Sr	strontium
Cf	californium	Mo	molybdenum	Ta	tantalum
Cl	chlorine	Mt	meitnerium	Tb	terbium
Cm	curium	N	nitrogen	Tc	technetium
Co	cobalt	Na	sodium*	Te	tellurium
Cr	chromium	Nb	niobium	Th	thorium
Cs	cesium	Nd	neodymium	Ti	titanium
Cu	copper*	Ne	neon	Tl	thallium
Db	dubnium	Ni	nickel	Tm	thulium
Dy	dysprosium	No	nobelium	U	uranium
Er	erbium	Np	neptunium	V	vanadium
Es	einsteinium	O	oxygen	W	tungsten*
Eu	europium	Os	osmium	Xe	xenon
F	fluorine	P	phosphorus	Y	yttrium
Fe	iron*	Pa	protactinium	Yb	ytterbium
Fm	fermium	Pb	lead*	Zn	zinc
Fr	francium	Pd	palladium	Zr	zirconium
Ga	gallium	Pm	promethium		
Gd	gadolinium	Po	polomium		

[a]Only 109 elements are listed in this table. Elements 110–112 and 114 discovered (synthesized) in the period 1994–1999, are yet to be named.

*These elements have symbols that were derived from non-English names.

element; in the case of the element tungsten, a German name is the symbol's source. Most of these elements have been known for hundreds of years and date back to the time when Latin was the language of scientists. Elements whose symbols are derived from non-English names are marked with an asterisk in Table 1.2.

Practice Questions and Problems

1.18 In which of the following sequences of elements do all of the elements have two-letter chemical symbols?
a. Magnesium, nitrogen, phosphorus
b. Bromine, iron, calcium
c. Aluminum, copper, chlorine
d. Boron, barium, beryllium

1.19 In which of the following sequences of elements do all of the elements have chemical symbols that start with a letter that is not the first letter of the element's English name?
a. Silver, gold, mercury
b. Copper, helium, neon
c. Cobalt, chromium, sodium
d. Potassium, iron, lead

1.9 Atoms and Molecules

Learning Focus

Define the term *atom* and be familiar with the various general types of *molecules* that exist.

Consider the process of subdividing a sample of the element gold (or any other element) into smaller and smaller pieces. It seems reasonable that eventually a "smallest possible piece" of gold would be reached that could not be divided further and still be the element gold. This smallest possible unit of gold is called a gold atom. An **atom** *is the smallest particle of an element that can exist and still have the properties of the element.*

A sample of any element is composed of atoms of a single type, those of that element. In contrast, a compound must have two or more types of atoms present, because by definition at least two elements must be present (Section 1.6).

No one ever has seen or ever will see an atom with the naked eye; they are simply too small for such observation. However, sophisticated electron microscopes, with magnification factors in the millions, have made it possible to photograph "images" of individual atoms (Figure 1.12).

Atoms are incredibly small particles. Atomic dimensions, although not directly measurable, can be calculated from measurements made on large-size samples of elements. The diameter of an atom is approximately four-billionths of an inch. If atoms of such diameter were arranged in a straight line, it would take 254 million of them to extend a distance of 1 inch (see Figure 1.13).

Free atoms are rarely encountered in nature. Instead, under normal conditions of temperature and pressure, atoms are nearly always found together in aggregates or clusters ranging in size from two atoms to numbers too large to count. When the group or cluster of atoms is relatively small and bound together tightly, the resulting entity is called a molecule. A **molecule** *is a group of two or more atoms that functions as a unit because the atoms are tightly bound together.* This resultant "package" of atoms behaves in many ways as a single, distinct particle would.

▶ Reasons for the tendency of atoms to aggregate into molecules and information on the binding forces involved are considered in Chapter 4.

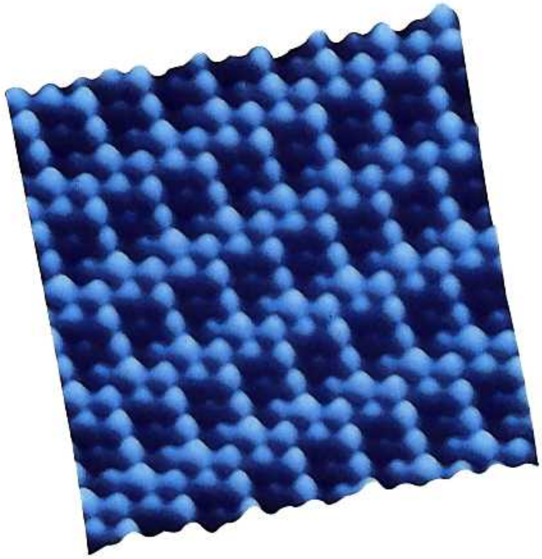


Figure 1.12 A computer reconstruction of the surface of a sample of a solid as observed with a scanning tunneling microscope. The image reveals the regular pattern of individual atoms. The color was added to the image by computer.

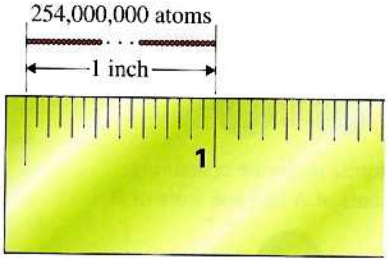


Figure 1.13 254 million atoms arranged in a straight line would extend a distance of approximately 1 inch.

▶ The Latin word *mole* means "a mass." The word *molecule* denotes a "little mass."

A **diatomic molecule** *is a molecule that contains two atoms.* It is the simplest type of molecule that can exist. Next is complexity are *triatomic* molecules. A **triatomic molecule** *is a molecule that contains three atoms.* The molecule present in water, the most common of all compounds, is triatomic; it contains two hydrogen atoms and one oxygen atom. Continuing on numerically, we have *tetratomic* molecules, *pentatomic* molecules, and so on.

The atoms contained in a molecule may all be of the same kind, or two or more kinds may be present. In accordance with this observation, molecules are classified into the two categories of *homoatomic* and *heteroatomic.* A **homoatomic molecule** *is a molecule in which all atoms present are of the same kind.* A substance containing homoatomic molecules must be an element. A **heteroatomic molecule** *is a molecule in which two or more kinds of atoms are present.* Substances that contain heteroatomic molecules must be compounds, because the presence of two or more kinds of atoms reflects the presence of two or more kinds of elements.

The fact that homoatomic molecules exist indicates that individual atoms are not always the preferred structural unit for an element. Nearly all of the oxygen present in air is in the form of diatomic molecules. Several other elements, including nitrogen (the other major constituent of air) and hydrogen, are also diatomic in the gaseous state. Chemical Portraits 2 profiles the "diatomic" elements oxygen, nitrogen, and hydrogen. The diatomic nature of these elements can be specified by using the notations O_2, N_2, and H_2 to represent molecules of these elements.

Figure 1.14 shows general models for four simple types of heteroatomic molecules. Comparison of parts (c) and (d) of this figure shows that molecules with the same number of atoms need not have the same arrangement of atoms.

Chemical Portraits 2 — Three Well-Known Gaseous Diatomic Elements

Oxygen (O_2)

Profile: Oxygen, the second most abundant gas in air, constitutes 21% by volume of clean, dry air. This colorless, odorless, tasteless gas is often referred to as the "life-giving" element because a person can live weeks without food, days without water, but only minutes without oxygen. To commercially obtain pure oxygen, air is liquefied at low temperatures, and its various components are separated according to their different boiling points.

Uses: The steel industry is the dominant outlet for industrial O_2. Here, impurities are removed from the steel by their reaction with O_2. Medical and life-support uses for oxygen consume less than 2% of commercial oxygen production.

What is the major use for liquid oxygen in the United States's space program?

Nitrogen (N_2)

Profile: Nitrogen, the most abundant gas in air, constitutes 78% by volume of clean, dry air. Like O_2, it is colorless, odorless, and tasteless, and it is obtained in the pure state through low-temperature extraction from liquid air. Unlike O_2, however, N_2 is a very unreactive gas.

Uses: The major industrial use for N_2 gas is as the nitrogen source for making nitrogen-containing fertilizers such as liquid ammonia and ammonium nitrate. Nitrogen is a nutrient required by all plants and plants cannot obtain it from air. Because of its unreactivity, another major use for N_2 is that of a "blanketing agent." Here it is used to protect substances that would react with O_2 or moisture in air.

When was nitrogen discovered and by whom?

Hydrogen (H_2)

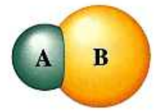
Profile: Hydrogen, unlike N_2 and O_2, is not a constituent of air. Hydrogen molecules are the least massive of all molecules. Because of their small mass, gaseous H_2 molecules are able to acquire velocities sufficient for them to overcome the gravitational forces of the earth and escape to outer space; thus no H_2 is present in the atmosphere. Like O_2 and N_2, H_2 gas is colorless, odorless, and tasteless; like O_2, H_2 molecules are relatively reactive.

Uses: About 40% of commercial H_2 production is used to make ammonia, the starting material for nitrogen-fertilizer production. Decomposition of hydrogen-containing compounds such as water and methane is the source of such hydrogen.

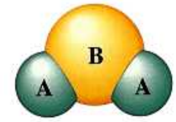
What is the state of development for hydrogen-powered cars?

See the text web site at **http://chemistry.college.hmco.com/students** for answers to the above questions and for further information.

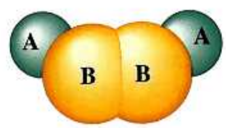
Figure 1.14 Depictions of various simple heteroatomic molecules using models. Spheres of different sizes and colors represent different kinds of atoms.



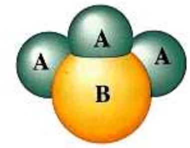
(a) A diatomic molecule containing one atom of A and one atom of B



(b) A triatomic molecule containing two atoms of A and one atom of B



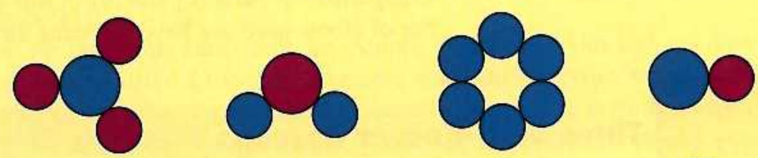
(c) A tetratomic molecule containing two atoms of A and two atoms of B



(d) A tetratomic molecule containing three atoms of A and one atom of B

Example 1.2 Classifying Molecules Based on Numbers of and Types of Atoms

Classify each of the following molecules as *diatomic, triatomic,* etc., and also as *homoatomic* or *heteroatomic.*



(a) **(b)** **(c)** **(d)**

Solution

a. Tetratomic and heteroatomic (four atoms; two kinds of atoms)
b. Triatomic and heteroatomic (three atoms; two kinds of atoms)
c. Hexatomic and homoatomic (six atoms; only one kind of atom)
d. Diatomic and heteroatomic (two atoms; two kinds of atoms)

▶ The concept that heteroatomic molecules are the building blocks for *all* compounds will have to be modified when certain solids, called ionic solids, are considered in Section 4.6.

A molecule is the smallest particle of a compound capable of a stable independent existence. Continued subdivision of a quantity of table sugar to yield smaller and smaller amounts would ultimately lead to the isolation of one single "unit" of table sugar: a molecule of table sugar. This table sugar molecule could not be broken down any further and still exhibit the physical and chemical properties of table sugar. The table sugar molecule could be broken down further by chemical (not physical) means to produce atoms, but if that occurred, we would no longer have table sugar. The *molecule* is the limit of *physical* subdivision. The *atom* is the limit of *chemical* subdivision.

Practice Questions and Problems

1.20 Indicate whether each of the following statements is *true* or *false.*
a. Triatomic molecules must contain at least two kinds of atoms.
b. A molecule of a compound must be heteroatomic.
c. Heteroatomic molecules do not maintain the properties of their constituent elements.
d. A molecule of an element may be homoatomic or heteroatomic, depending on which element is involved.

1.21 Which of the terms *heteroatomic, homoatomic, diatomic, triatomic, element,* and *compound* apply to each of the following molecules? (More than one term applies in each situation.)

a. (Q—X) b. (Q—Z—X) c. (X—X) d. (X—Q—X)

Learning Focus

Interpret a chemical formula in terms of the number of elements and the number of atoms present.

1.10 Chemical Formulas

Information about compound composition can be presented in a concise way by using a chemical formula. A **chemical formula** *is a notation made up of the symbols of the elements present in a compound and numerical subscripts (located to the right of each symbol) that indicate the number of atoms of each element present in a molecule of the compound.*

The chemical formula for the compound aspirin is $C_9H_8O_4$. This chemical formula conveys the information that an aspirin molecule contains three different elements—carbon (C), hydrogen (H), and oxygen (O)—and 21 atoms—9 carbon atoms, 8 hydrogen atoms, and 4 oxygen atoms.

When only one atom of a particular element is present in a molecule of a compound, that element's symbol is written without a numerical subscript in the formula for the compound. The formula for rubbing alcohol, C_3H_6O, reflects this practice for the element oxygen.

In order to write formulas correctly, one must follow the capitalization rules for elemental symbols (Section 1.8). Making the error of capitalizing the second letter of an element's symbol can dramatically alter the meaning of a chemical formula. The formulas $CoCl_2$ and $COCl_2$ illustrate this point; the symbol Co stands for the element cobalt, whereas CO stands for one atom of carbon and one atom of oxygen.

▶ Further information about the use of parentheses in formulas (when and why) will be presented in Section 4.19. The important concern now is being able to interpret formulas that contain parentheses in terms of total atoms present.

Sometimes chemical formulas contain parentheses; an example is $Al_2(SO_4)_3$. The interpretation of this formula is straightforward; in a formula unit, there are present 2 aluminum (Al) atoms and 3 SO_4 groups. The subscript following the parentheses always indicates the number of units in the formula of the polyatomic entity inside the parentheses. In terms of atoms, the formula $Al_2(SO_4)_3$ denotes 2 aluminum (Al) atoms, $3 \times 1 = 3$ sulfur (S) atoms, and $3 \times 4 = 12$ oxygen (O) atoms. Example 1.3 contains further comments about chemical formulas that contain parentheses.

Example 1.3 **Interpreting Chemical Formulas**

For each of the following chemical formulas, state how many atoms of each element are present in one molecule of the substance.

a. HCN—hydrogen cyanide, a poisonous gas
b. $C_{18}H_{21}NO_3$—codeine, a pain-killing drug
c. $Ca_{10}(PO_4)_6(OH)_2$—hydroxyapatite, present in tooth enamel

Solution

a. One atom each of the elements hydrogen, carbon, and nitrogen is present. Remember that the subscript 1 is implied when no subscript is written.
b. This formula indicates that 18 carbon atoms, 21 hydrogen atoms, 1 nitrogen atom, and 3 oxygen atoms are present in one molecule of the compound.
c. There are 10 calcium atoms. The amounts of phosphorus, hydrogen, and oxygen are affected by the subscripts outside the parentheses. There are 6 phosphorus atoms and 2 hydrogen atoms present. Oxygen atoms are present in two locations in the formula. There are a total of 26 oxygen atoms: 24 from the PO_4 subunits (6×4) and 2 from the OH subunits (2×1).

Practice Questions and Problems

1.22 On the basis of its formula, classify each of the following substances as an element or a compound.
a. $LiCO_3$ b. CO c. Co d. O_3 e. $CoCl_2$ f. $COCl_2$

1.23 Determine the number of elements and the number of atoms present in molecules represented by the following formulas.
a. H_2CO_3 b. NH_4ClO_4 c. $CaSO_4$ d. C_4H_{10} e. $Be(CN)_2$ f. $Cu(NO_3)_2$

1.24 Write a chemical formula for each of the following substances using the information given for the substance.
a. A molecule of nicotine contains 10 atoms of carbon, 14 atoms of hydrogen, and 2 atoms of nitrogen.
b. A molecule of vitamin C contains 6 atoms of carbon, 8 atoms of hydrogen, and 6 atoms of oxygen.

1.25 What is the chemical formula for each of the following molecules?
a. (X—Q) b. (X—Q—Q) c. (Q—Q—Q) d. (X—X—Q)

CONCEPTS TO REMEMBER

Chemistry. Chemistry is the field of study that is concerned with the characterization, composition, and transformations of matter.

Matter. Matter, the substances of the physical universe, is anything that has mass and occupies space. Matter exists in three physical states: solid, liquid, and gas.

Properties of matter. Properties, the distinguishing characteristics of a substance that are used in its identification and description, are of two types: physical and chemical. Physical properties are properties that we can observe without changing a substance into another substance. Chemical properties are properties that matter exhibits as it undergoes or resists changes in chemical composition. The failure of a substance to undergo change in the presence of another substance is considered a chemical property.

Changes in matter. Changes that can occur in matter are classified into two types: physical and chemical. A physical change is a process that does not alter the basic nature (chemical composition) of the substance under consideration. No new substances are ever formed as a result of a physical change. A chemical change is a process that involves a change in the basic nature (chemical composition) of the substance. Such changes always involve conversion of the material or materials under consideration into one or more new substances that have properties and composition distinctly different from those of the original materials.

Pure substances and mixtures. All specimens of matter are either pure substances or mixtures. A pure substance is a form of matter that always has a definite and constant composition. A mixture is a physical combination of two or more pure substances in which the pure substances retain their identity.

Types of mixtures. Mixtures can be classified as heterogeneous or homogeneous on the basis of the visual recognizability of the components present. A heterogeneous mixture contains visibly different parts or phases, each of which has different properties. A homogeneous mixture contains only one phase, which has uniform properties throughout it.

Types of pure substances. A pure substance can be classified as either an element or a compound on the basis of whether it can be broken down into two or more simpler substances by ordinary chemical means. Elements cannot be broken down into simpler substances. Compounds yield two or more simpler substances when broken down. There are 113 pure substances that qualify as elements. There are millions of compounds.

Atoms and molecules. An atom is the smallest particle of an element that can exist and still have the properties of the element. Free isolated atoms are rarely encountered in nature. Instead, atoms are almost always found together in aggregates or clusters. A molecule is a group of two or more atoms that functions as a unit because the atoms are tightly bound together.

Types of molecules. Molecules are of two types: homoatomic and heteroatomic. Homoatomic molecules are molecules in which all atoms present are of the same kind. A pure substance containing homoatomic molecules is an element. Heteroatomic molecules are molecules in which two or more different kinds of atoms are present. Pure substances that contain heteroatomic molecules must be compounds.

Chemical symbols. Chemical symbols are a shorthand notation for the names of the elements. Most consist of two letters; a few involve a single letter. The first letter of a chemical symbol is always capitalized, and the second letter is always lower-case.

Chemical formulas. Chemical formulas are used to specify compound composition in a concise manner. They consist of the symbols of the elements present in the compound and numerical subscripts (located to the right of each symbol) that indicate the number of atoms of each element present in a molecule of the compound.

KEY TERMS

Atom (1.9)
Chemical change (1.4)
Chemical formula (1.10)
Chemical property (1.3)
Chemical symbol (1.8)
Chemistry (1.1)
Compound (1.6)
Diatomic molecule (1.9)
Element (1.6)
Gas (1.2)
Heteroatomic molecule (1.9)
Heterogeneous mixture (1.5)
Homoatomic molecule (1.9)
Homogeneous mixture (1.5)
Liquid (1.2)
Matter (1.1)
Mixture (1.5)
Molecule (1.9)
Physical change (1.4)
Physical property (1.3)
Properties (1.3)
Pure substance (1.5)
Solid (1.2)
Triatomic molecule (1.9)

ADDITIONAL PROBLEMS

1.26 Assign each of the following descriptions of matter to one of the following categories: *element, compound,* or *mixture.*
a. One substance present, one phase present, substance cannot be decomposed by chemical means
b. One substance present, three elements present
c. Two substances present, two phases present
d. Two elements present, composition is definite and constant

1.27 Assign each of the following descriptions of matter to one of the following categories: *element, compound,* or *mixture.*
a. One substance present, one phase present, one kind of homoatomic molecule present
b. Two substances present, two phases present, all molecules are heteroatomic
c. One phase present, two kinds of homoatomic molecules present
d. One phase present, all molecules are triatomic, all molecules are heteroatomic, all molecules are identical

1.28 Indicate whether each of the following samples of matter is a *heterogeneous mixture,* a *homogeneous mixture,* a *compound,* or an *element.*
a. A colorless gas, only part of which reacts with hot iron
b. A "cloudy" liquid that separates into two layers upon standing for 2 hours
c. A green solid, all of which melts at the same temperature to produce a liquid that decomposes upon further heating
d. A colorless gas that cannot be separated into simpler substances using physical means and that reacts with copper to produce both a copper–nitrogen and a copper–oxygen compound

1.29 Classify each of the following pairs of substances as (1) two elements, (2) two compounds, (3) an element and a compound, or (4) a single pure substance.
a. (Q—X) and (Q—Q)   b. (Q—X) and (X)
c. (Q) and (X)   d. (Q—X) and (Q—X)

1.30 Write a formula for each of the following substances by using the information given about molecules of the substance.
a. Molecules are triatomic and contain the elements hydrogen, carbon, and nitrogen.
b. Molecules are heptatomic and contain 2 atoms of hydrogen, 1 atom of sulfur, and the element oxygen.
c. Molecules are triatomic and contain twice as many atoms of nitrogen as of oxygen.
d. Molecules are pentatomic and contain the elements hydrogen and nitrogen and 3 atoms of oxygen.

1.31 In each of the following pairs of formulas, indicate whether the first formula listed denotes *more total atoms, the same number of total atoms,* or *fewer total atoms* than the second formula listed.
a. HN_3 and NH_3
b. $CaSO_4$ and $Mg(OH)_2$
c. $NaClO_3$ and $Be(CN)_2$
d. $Be_3(PO_4)_2$ and $Mg(C_2H_3O_2)_2$

1.32 On the basis of the given information, determine the numerical value of the subscript x in each of the following chemical formulas.
a. BaS_2O_x; formula unit contains 6 atoms
b. $Al_2(SO_x)_3$; formula unit contains 17 atoms
c. SO_xCl_x; formula unit contains 5 atoms
d. $C_xH_{2x}Cl_x$; formula unit contains 8 atoms

1.33 A mixture contains the following five pure substances: N_2, N_2H_4, NH_3, CH_4, and CH_3Cl.
a. How many different kinds of molecules that contain four or fewer atoms are present in the mixture?
b. How many different kinds of atoms are present in the mixture?
c. How many total atoms are present in a mixture sample containing five molecules of each component?
d. How many total hydrogen atoms are present in a mixture sample containing four molecules of each component?

PRACTICE TEST ▶ True/False

1.34 An *indefinite* volume is a property of both gases and liquids.

1.35 When a substance undergoes a *chemical* change, it is always true that one or more new substances are produced.

1.36 The description "two substances present, two phases present" applies to all types of mixtures.

1.37 Scientists "suspect" that there are more *naturally occurring* elements yet to be discovered.

1.38 The chemical symbol for an element is always the first one or two letters in the element's name.

1.39 A compound results from the *physical* combination of two or more elements.

1.40 The most abundant elements in the universe and in Earth's crust are, respectively, hydrogen and oxygen.

1.41 Both homogeneous mixtures and heterogeneous mixtures can have a *variable* composition.

1.42 The descriptors *homoatomic* and *triatomic* both apply to molecules of the compound H_2O.

1.43 The properties "melts at 73°C" and "decomposes upon heating" are both examples of *chemical* properties of a substance.

1.44 A pure substance can never be decomposed into simpler pure substances by *chemical* means.

1.45 The elements gold, silver, and aluminum all have two-letter chemical symbols.

1.46 The chemical formulas NH_3 and HN_3 both denote the same compound.

1.47 The total number of atoms present in one formula unit of $(NH_4)_3PO_4$ is 18.

1.48 A *physical* change is a process in which a substance changes its physical appearance but not its chemical composition.

PRACTICE TEST ▶ Multiple Choice

1.49 Which of the following is a property of *both* liquids and solids?
a. Definite shape
b. Definite volume
c. Indefinite shape
d. Indefinite volume

1.50 In which of the following pairs of properties are both properties *chemical* properties?
a. Freezes at 5°C, flammable
b. Decomposes at 75°C, reacts with chlorine
c. Good reflector of light, blue in color
d. Has a high density, is very hard

1.51 When a substance undergoes a *chemical* change, it is always true that
a. it melts
b. it changes physical state
c. its chemical composition changes
d. heat is evolved

1.52 Which of the following statements is *correct?*
a. Elements, but not compounds, are pure substances.
b. Compounds, but not elements, are pure substances.
c. Both elements and compounds are pure substances.
d. Neither elements nor compounds are pure substances.

1.53 A pure substance A is found to change upon heating into two new pure substances B and C. Both B and C may be decomposed by chemical means. From this, we may conclude that
a. A is an element, and B and C are compounds
b. A is a compound, and B and C are elements
c. A, B, and C are all elements
d. A, B, and C are all compounds

1.54 In which of the following sequences of elements do each of the elements have a one-letter chemical symbol?
a. Lead, nitrogen, zinc
b. Potassium, fluorine, carbon
c. Tin, hydrogen, iodine
d. Oxygen, silicon, chlorine

1.55 Which one of the following statements is *incorrect*?
a. An atom is the smallest "piece" of an element that can exist and still have the properties of the element.
b. Free isolated atoms are rarely encountered in nature.
c. Atoms may be decomposed using chemical change.
d. Only one kind of atom may be present in a homoatomic molecule.

1.56 Which of the following pairings of terms is *incorrect*?
a. Element — homoatomic molecules
b. Pure substance — variable composition
c. Heterogeneous mixture — two or more regions with differing properties
d. Homogeneous mixture — two or more substances present

1.57 Which of the following classifications of matter could *not* contain heteroatomic molecules?
a. Heterogeneous mixture
b. Homogeneous mixture
c. Pure substance
d. Element

1.58 In which of the following pairs of formulas do the two members of the pair contain the same number of elements as well as the same number of atoms?
a. Hf and HF
b. $CoCl_2$ and $COCl_2$
c. SO_2 and SO_3
d. NH_4Cl and $BaSO_4$