CHEMISTRY IN PRACTICE One of the most malleable of metals is gold. It can be hammered into sheets so thin that they are only about 1/280,000 of an inch thick, which corresponds to a thickness of only several hundred atoms. (The sheets are so thin that some light can pass through.) Thin gold sheets are sold as "gold leaf" and are used for applying gold in a variety of decorative ways. For example, gold lettering is applied to doors by first painting the letters using a varnish and then, while the varnish is still tacky, applying the gold. Gold leaf is also used as a decorative finish on various objects, such as the statue of Prometheus that overlooks the skating rink at Rockefeller Center in New York City.

point (357 °C) make it useful as a fluid in thermometers. Most of the other metals have much higher melting points, and some are used primarily because of this. Tungsten, for example, has the highest melting point of any metal (3400 °C, or 6150 °F), which explains its use as filaments that glow white-hot in electric light bulbs.

We use the term *free element* to mean an element that is not chemically combined with any other element.

The chemical properties of metals vary tremendously. Some, such as gold and platinum, are very unreactive toward almost all chemical agents. This property, plus their natural beauty and rarity, makes them highly prized for use in jewelry. Other metals, however, are so reactive that few people except chemists and chemistry students ever get to see them in their "free" states. For instance, the metal sodium reacts very quickly with oxygen or moisture in the air, and its bright metallic surface tarnishes almost immediately. In contrast, compounds of sodium, such as table salt and baking soda, are quite stable and very common.

FIGURE 1.18 ***Sodium is a metal.*** The freshly exposed surface of a bar of sodium reveals its shiny metallic luster. The metal reacts quickly with moisture and oxygen to form a white coating. Sodium's high reactivity makes it dangerous to touch with bare skin.

Nonmetals

Substances such as plastics, wood, and glass that lack the properties of metals are said to be *nonmetallic,* and an element that has nonmetallic properties is called a **nonmetal.** Most often, we encounter the nonmetals in the form of compounds or mixtures of compounds. There are some nonmetals, however, that are very important to us in their elemental forms. The air we breathe, for instance, contains mostly nitrogen and oxygen. Both are gaseous, colorless, and odorless nonmetals. Since we can't see, taste, or smell them, however, it's difficult to experience their existence. (Although if you step into an atmosphere without oxygen, your body will soon tell you that something is missing!) Probably the most commonly *observed* nonmetallic element is carbon. We find it as the graphite in pencils, as coal, and as the charcoal used for barbecues. It also occurs in a more valuable form as diamond (Figure 1.22). Although diamond and graphite differ in appearance, each is a form of elemental carbon.

Many of the nonmetals are solids at room temperature and atmospheric pressure, while many others are gases. Photographs of some of the nonmetallic elements appear in Figure 1.23. Their properties are almost completely opposite those of metals. Each of these elements lacks the characteristic appearance of a metal. They are poor conductors of heat and, with the exception of the graphite form of carbon, are also poor conductors of electricity. The electrical conductivity of graphite appears to be an accident of molecular structure, since the structures of metals and graphite are completely different.

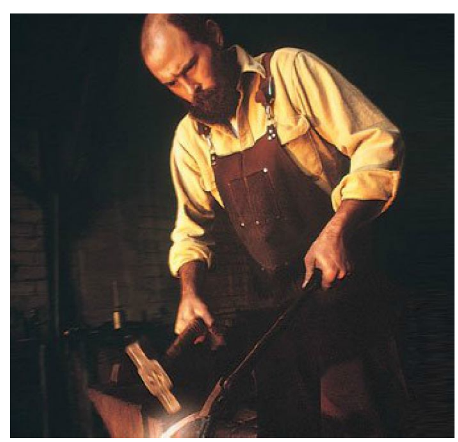

FIGURE 1.19 ***Malleability of iron.*** A blacksmith uses the malleability of hot iron to fashion horseshoes from an iron bar.

The nonmetallic elements lack the malleability and ductility of metals. A lump of sulfur crumbles when hammered and breaks apart when pulled on. Diamond cutters rely on the brittle nature of carbon when they split a gem-quality stone by carefully striking a quick blow with a sharp blade.

As with metals, nonmetals exhibit a broad range of chemical reactivity. Fluorine, for instance, is extremely reactive. It reacts readily with almost all the other elements. At the other extreme is helium, the gas used to inflate children's balloons and the Goodyear blimp. This element does not react with anything, a fact that chemists find useful when they want to provide a totally *inert* (unreactive) atmosphere inside some apparatus.

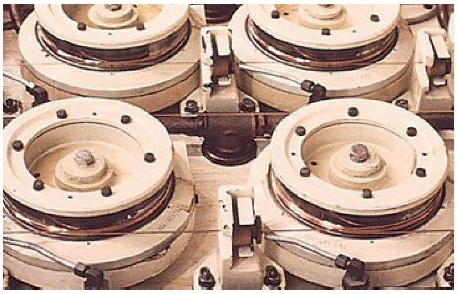

FIGURE 1.20 ***The ductility of copper.*** This property allows the metal to be drawn into wire. Here copper wire passes through one die after another as it is drawn into thinner and thinner wire.

FIGURE 1.21 ***Mercury.*** The metal mercury (once known as quicksilver) is a liquid at room temperature, unlike other metals, which are solids.

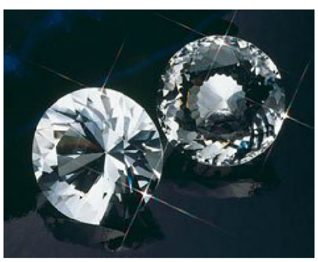

FIGURE 1.22 ***Diamonds.*** Gems such as these are simply another form of the element carbon.

Metalloids

The properties of metalloids lie between those of metals and nonmetals. This shouldn't surprise us since the metalloids are located between the metals and the nonmetals in the periodic table. In most respects, metalloids behave as nonmetals, both chemically and physically. However, in their most important physical property, electrical conductivity, they somewhat resemble metals. Metalloids tend to be **semiconductors;** they conduct electricity, but not nearly so well as metals. This property, particularly as found in silicon and germanium, is responsible for the remarkable progress made during the last four decades in the field of solid-state electronics. The operation of every computer, hi-fi stereo system, TV receiver, VCR, CD player, and AM-FM radio relies on transistors made from semiconductors. Perhaps the most amazing advance of all has been the fantastic reduction in the size of electronic components that semiconductors have allowed (Figure 1.24). To it, we owe the development of small and versatile cell phones, TV cameras, compact disc players, hand-held calculators, and microcomputers. The heart of these devices is a microcircuit embedded in the surface of a tiny silicon chip.

Trends within the periodic table help us remember facts

The occurrence of the metalloids between the metals and the nonmetals is our first example of trends in properties within the periodic table. We will frequently see that as we move from position to position across a period or down a group, chemical and physical properties change in a more or less regular way. There are few abrupt changes in the characteristics of the elements as we scan across a period or down a group. The location of the metalloids can be seen, then, as an example of the gradual transition between metallic and nonmetallic properties. From left to right across Period 3, we go from aluminum, an element that has every appearance of a metal, to silicon, a semiconductor, to phosphorus, an element with clearly nonmetallic properties. A similar gradual change is seen going down Group IVA. Carbon is certainly a nonmetal, silicon and germanium are metalloids, and tin and lead are metals. Trends such as these are useful to spot because they help us remember properties.

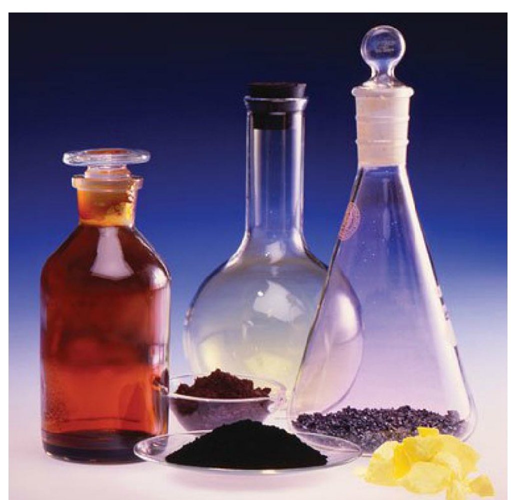

FIGURE 1.23 ***Some nonmetallic elements.*** In the bottle on the left is dark-red liquid bromine, which vaporizes easily to give a deeply colored orange vapor. Pale green chlorine fills the round flask in the center. Solid iodine lines the bottom of the flask on the right and gives off a violet vapor. Powdered red phosphorus occupies the dish in front of the flask of chlorine, and black powdered graphite is in the watch glass. Also shown are lumps of yellow sulfur.

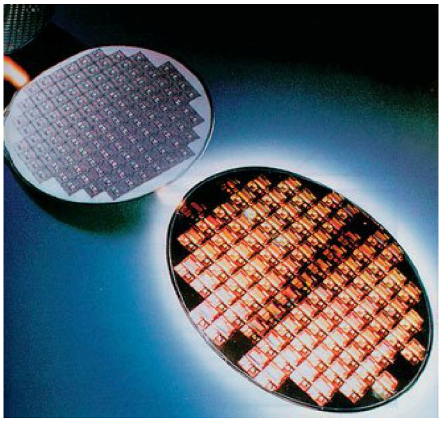

FIGURE 1.24 ***Modern electronic circuits rely on the semiconductor properties of silicon.*** The silicon wafer shown here contains more electronic components (10 billion) than there are people on our entire planet (about 6 billion)!

SUMMARY

Chemistry and Its Place among the Sciences **Chemistry** is a science that studies the properties and composition of **matter,** which is anything that has **mass** and occupies space. Mass is a measure of the amount of matter in an object and is commonly measured in units of **grams** (symbol **g**). Some knowledge of chemistry is needed by all scientists because all tangible things, living or not, are composed of chemicals. Chemists and scientists in other disciplines often study the same things; they simply view them from different perspectives. Today, as in the past, chemistry plays a crucial role in fulfilling the needs of society.

Scientific Method This is the general procedure by which science advances. **Observations** are made, and the **empirical facts** or **data** that are collected from many experiments are often summarized in **scientific laws,** which frequently are expressed in equation form. Scientists formulate mental images or models of nature to explain observed behavior. Models begin as **hypotheses,** and those that survive repeated testing become known as **theories.** Although the general pattern in the development of science is the cycle of observation–explanation–observation–explanation . . . , many discoveries are made accidentally by people who have learned to be observant through scientific training. The **atomic theory** proposes that matter is made of tiny particles **(atoms)** that combine to form more complex substances. **Molecules** are particles that contain two or more atoms.

Properties of Materials When studying matter we are concerned with its physical and chemical properties. **Physical properties** can be measured without changing the chemical makeup of the sample. Physical changes are changes that take place without altering the chemical composition of the sample. A **chemical property** describes a **chemical change** and relates to how substances change into other substances in **chemical reactions. Intensive properties** are independent of sample size; **extensive properties** depend on sample size. For identification purposes, intensive properties are more useful than extensive properties because they don't depend on the size of the sample.

Types of Materials **Solid, liquid,** and **gas** are the most common **states of matter.** Their properties can be related to the different ways the individual atomic-size particles are organized. In a solid, they are tightly packed and cannot easily move; in a liquid, they are less tightly packed and can move past each other; and in a gas, they are widely spaced with much empty space between them.

An **element** is a substance that cannot be decomposed into something simpler by a chemical reaction. Each element has an internationally agreed-upon **chemical symbol.** Symbols are used in place of the name of an element and also to represent an atom of the element. Elements combine in fixed proportions to form **compounds.** Elements and compounds are **pure substances** that may be combined in *varying* proportions to give **mixtures.** A one-phase mixture is called a **solution** and is **homogeneous.** If a mixture consists of two or more **phases** it is **heterogeneous.** Formation or separation of a mixture into its components can be accomplished by a physical change; formation or decomposition of a compound takes place by a chemical change.

Elements and Atoms When accurate masses of all the reactants and products in a reaction are measured and compared, no observable changes in mass accompany chemical reactions (the **law of conservation of mass**). The mass ratios of the elements in any compound are constant regardless of the source of the compound or how it is prepared (the **law of definite proportions**). **Dalton's atomic theory** explained the laws of chemical combination by proposing that matter consists of indestructible atoms with masses that do not change during chemical reactions. During a chemical reaction, atoms may change partners, but they are neither created nor destroyed. After Dalton had proposed his theory, it was discovered that whenever two elements form more than one compound, the different masses of one element that combine with a fixed mass of the other are in a ratio of small whole numbers (the **law of multiple proportions**). Using modern instruments such as the scanning tunneling microscope, scientists are able to "see" atoms on the surfaces of solids.

An element's **atomic mass (atomic weight)** is the relative mass of its atoms on a scale in which atoms of carbon-12 have a mass of exactly 12 u **(atomic mass units).** Most elements occur in nature as uniform mixtures of a small number of **isotopes,** whose masses differ slightly. However, all isotopes of an element have very nearly identical chemical properties, and the percentages of the isotopes that make up an element are generally so constant throughout the world that we can say that the average mass of their atoms is a constant.

Atomic Structure Atoms can be split into **subatomic particles,** such as **electrons, protons,** and **neutrons. Nucleons** are particles that make up the atomic **nucleus** and include the protons, each of which carries a single unit of **positive charge** (charge = 1+) and neutrons (no charge). The number of protons is called the **atomic number (*Z*)** of the element. Each element has a different atomic number. The electrons, each with a unit of **negative charge** (charge = 1−) are found outside the nucleus; their number equals the atomic number in a neutral atom. Isotopes of an element have identical atomic numbers but different numbers of neutrons. In more modern terms, an **element** can be defined as a substance whose atoms all have the same number of protons in their nuclei.

The Periodic Table The search for similarities and differences among the properties of the elements led Mendeleev to discover that when the elements are placed in (approximate) order of increasing atomic mass, similar properties recur at regular, repeating intervals. In the modern **periodic table** the elements are arranged in rows, called **periods,** in order of increasing atomic number. The rows are stacked so that elements in the columns, called **groups** or **families,** have similar chemical and physical properties. The A-group elements (IUPAC Groups 1, 2, and 13–18) are called **representative elements;** the B-group elements (IUPAC Groups 3–12) are called **transition elements.** The two long rows of **inner transition elements** located below the main body of the table consist of the **lanthanides,** which follow La (Z = 57), and the **actinides,** which follow Ac (Z = 89). Certain groups are given family names: Group IA (Group 1), except for hydrogen, are the **alkali metals** (the alkalis); Group IIA (Group 2), the **alkaline earth metals;** Group VIIA (Group 17), the **halogens;** Group VIIIA (Group 18), the **noble gases.**

Metals, Nonmetals, and Metalloids Most elements are **metals;** they occupy the lower left-hand region of the periodic table (to the left of a line drawn approximately from boron, B, to astatine, At). **Nonmetals** are found in the upper right-hand region of the table. **Metalloids** occupy a narrow band between the metals and nonmetals.

Metals exhibit a **metallic luster,** tend to be **ductile** and **malleable,** and conduct electricity. Nonmetals tend to be brittle, lack metallic luster, and are nonconductors of electricity. Many nonmetals are gases. Bromine (a nonmetal) and mercury (a metal) are the two elements that are liquids at ordinary room temperature. **Metalloids** have properties intermediate between those of metals and nonmetals and are **semiconductors** of electricity.

TOOLS YOU HAVE LEARNED

The table below lists the concepts that you've learned in this chapter that can be applied as tools in solving problems. Study each one carefully so that you know what each is used for. When faced with solving a problem, recall what each tool does and consider whether it will be helpful in finding a solution. This will aid you in selecting the tools you need. If necessary, refer to this table when working on the Thinking-It-Through problems and the Review Exercises that follow.

TOOL	HOW IT WORKS
Law of definite proportions (page 13)	If we know the mass ratio of the elements in one sample of a compound, we know the ratio will be the same in a different sample of the same compound.
Law of conservation of mass (page 13)	The total mass of chemicals present before a reaction starts equals the total mass after the reaction is finished. We can use this law to check whether we have accounted for all the substances formed in a reaction.
Periodic Table (page 30)	From an element's position in the periodic table, we can tell whether it's a metal, nonmetal, or metalloid.

THINKING IT THROUGH

Need extra help? Visit the Brady/ Senese web site at www.wiley.com/ college/brady

ON-LINE HELP

The first step in solving a problem is to *analyze* the information available and plan what has to be done to obtain the answer. This is the most difficult part, because once you've figured out what you need to do, working through the *solution* is usually relatively easy. The goal for each of the following problems is to encourage you to separate the *analysis* and *solution* parts of problem solving. Therefore, for each of these problems we just ask you to think about the information required and to figure out the necessary steps needed to find the answer. We are *not* asking you to find the answer itself; instead, just assemble the information needed to obtain it, state what additional data (if any) are needed, and describe how you would use the data to answer the question.

The problems are divided into two groups. Those in Level 2 are more challenging than those in Level 1 and provide an opportunity to really hone your problem-solving skills. Detailed answers to these problems can be found on the web site.

Level 1 Problems

1. Aluminum combines with oxygen to form a compound called aluminum oxide, which is the principal constituent of the gem ruby. In an experiment, a chemist found that 15.0 g of aluminum combined with 13.3 g of oxygen. If this experiment were repeated with 25.0 g of aluminum and 13.3 g of oxygen, explain how you would determine the number of grams of aluminum oxide that would be formed. Which of the tools described in this chapter are needed to solve this problem?

2. How many times heavier than an atom of ^{12}C is the average atom of iron? (Explain how you can obtain the answer.)

3. Suppose the atomic mass unit had been defined as $\frac{1}{10}$ of the mass of an atom of phosphorus. Describe how you would calculate the atomic mass of carbon on this scale.

4. How do we find the chemical symbol for an atom that has a nucleus containing 45 protons and 58 neutrons?

5. How can you tell whether the element that has a nucleus which contains 49 protons is a metal, a nonmetal, or a metalloid?

6. Suppose you learned that scientists had discovered a new element with an atomic number of 117. How could you determine which group it belongs to in the periodic table?

Level 2 Problems

7. Carbon forms a compound with element *X* in which there are four atoms of *X* for each atom of carbon. A sample of this compound was analyzed and found to contain 1.50 g of C and 39.95 g of *X*. Explain how you would calculate the atomic mass of *X*.

8. In an experiment, it was found that 3.50 g of phosphorus combines with 12.0 g of chlorine to form a compound in which there are three chlorine atoms for each phosphorus atom. Explain how you would calculate the number of grams of chlorine that would combine with 8.50 g of phosphorus to form this same compound. Which of the tools described in this chapter are needed to solve this problem?

9. The element phosphorus burns easily in air and is used to produce some of the effects in fireworks. When phosphorus burns it is found that 2.40 g of phosphorus combines with 2.89 g of oxygen to form a compound. If this combustion were repeated using 5.60 g of phosphorus, explain how you would calculate (a) the number of grams of oxygen that would react, and (b) the number of grams of the compound that would be formed. Which of the tools described in this chapter are needed to solve this problem?

10. Arsenic forms two compounds with sulfur. In 6.00 g of one of these compounds, there were 3.62 g of As. In 6.00 g of the other compound, there were 2.89 g of As. Explain in detail how you would show that these compounds exhibit the law of multiple proportions.

11. When magnesium burns in oxygen, a brilliant light is given off, so the reaction is often used in fireworks displays. In an experiment, 1.0 g of magnesium was combined with 2.0 g of oxygen and after the reaction was complete, 1.6 g of a white solid, magnesium oxide, was collected and no magnesium metal remained. Explain how you would determine whether all of the oxygen reacted and, if any remained, how you could calculate the amount. Which of the tools described in this chapter are needed to solve this problem?

REVIEW QUESTIONS

Introduction

1.1 After some thought, give two reasons why a course in chemistry will benefit *you* in the pursuit of your particular major.

1.2 What does the science of chemistry seek to study?

1.3 Define *matter.* Which of the following are examples of matter? (a) air, (b) a pencil, (c) a cheese sandwich, (d) a squirrel, (e) your mother.

1.4 Look around your room and list ten items you see that are made of synthetic materials, that is, materials not found in nature.

1.5 In answering the preceding question, what have you learned about the contribution of chemistry to modern life?

Scientific Method

1.6 What steps are involved in the scientific method?

1.7 What is the function of a laboratory?

1.8 Define (a) data, (b) hypothesis, (c) law, and (d) theoretical model.

1.9 What role does luck play in the advancement of science?

Properties of Substances

1.10 What is *a physical property*? What is *a chemical property*? What is the chief distinction between physical and chemical properties? Define the terms *intensive property* and *extensive property*. Give two examples of each.

1.11 How does a physical change differ from a chemical change? When a solid melts, is the change a physical or a chemical change?

1.12 "A sample of calcium (an electrically conducting white metal that is shiny, relatively soft, melts at 850 °C, and boils at 1440 °C) was placed into liquid water that was at 25 °C. The calcium reacted slowly with the water to give bubbles of gaseous hydrogen and a solution of the substance calcium hydroxide." In this description, what physical properties and what chemical properties are described?

1.13 What is a chemical reaction?

1.14 Lye is a common name for a substance called sodium hydroxide. Muriatic acid is the common name for hydrochloric acid. Either of these chemicals can cause severe burns if left in contact with the skin, but when water solutions of them are mixed in just the right proportions, the resulting solution contains only sodium chloride. From this description, how do you know that a chemical reaction occurs between sodium hydroxide and hydrochloric acid?

1.15 If you swallow a water solution of baking soda, a gas (carbon dioxide) forms in your stomach, which causes you to burp. Has a chemical reaction occurred? Explain your answer.

1.16 In places like Saudi Arabia, freshwater is scarce and is recovered from seawater. When seawater is boiled, the water evaporates and the steam can be condensed to give pure water that people can drink. If all the water is evaporated, solid salt is left behind. Are the changes described here chemical or physical?

1.17 Suppose you were told that behind a screen there were two samples of liquid, one of them water and the other gasoline. You are told that Sample 1 occupies 3 fluid ounces and Sample 2 occupies 7 fluid ounces.
(a) What kind of property (intensive or extensive) is volume?
(b) Can you use the information given to you in this question to determine which sample is water and which is gasoline? (Explain.)

1.18 Name two intensive properties that you *could* use to distinguish between water and gasoline. Give one chemical property you could use.

1.19 Many reference books list physical properties that can aid in the identification of substances. One such book is the *Handbook of Chemistry and Physics*, which no doubt is available in your school library.
(a) Use the Table of Physical Constants of Inorganic Compounds in the *Handbook of Chemistry and Physics* to tabulate the melting points, boiling points, and colors of cadmium iodide, lead iodide, and bismuth tribromide.
(b) Which of these tabulated properties could you use to distinguish among these three substances?
(c) A chemist who was asked to analyze a sample was able to isolate a yellow solid from an experiment. This substance was found to melt at 402 °C and boil at 954 °C. Which of the chemicals described in part (a) of this question could the chemist have obtained from the experiment?

Types of Materials

1.20 What are the three states of matter?

1.21 How does the atomic model explain the differences in the properties of solids, liquids, and gases?

Elements, Compounds, and Mixtures

1.22 Define (a) element, (b) compound, (c) mixture, (d) homogeneous, (e) heterogeneous, (f) phase, (g) solution.

1.23 What kind of change (chemical or physical) is needed to separate a compound into its elements?

1.24 What kind of change (chemical or physical) is needed to separate a mixture into its components?

Chemical Symbols

1.25 What is the chemical symbol for each of the following elements? (a) chlorine, (b) sulfur, (c) iron, (d) silver, (e) sodium, (f) phosphorus, (g) iodine, (h) copper, (i) mercury, (j) calcium.

1.26 What is the name of each of the following elements? (a) K, (b) Zn, (c) Si, (d) Sn, (e) Mn, (f) Mg, (g) Ni, (h) Al, (i) C, (j) N.

1.27 Describe two ways that chemical symbols are used.

Laws of Chemical Combination and Dalton's Theory

1.28 Name and state the two laws of chemical combination discussed in this chapter.

1.29 Which postulate of Dalton's theory is based on the law of conservation of mass? Which is based on the law of definite proportions?

1.30 Why didn't the existence of isotopes affect the apparent validity of the atomic theory?

1.31 In your own words, describe how Dalton's theory explains the law of conservation of mass and the law of definite proportions.

1.32 Which of the laws of chemical combination is used to define the term *compound*?

Atomic Masses and Atomic Structure

1.33 Write the symbol for the isotope that forms the basis of the atomic mass scale. What is the mass of this atom expressed in atomic mass units?

1.34 What are the names, symbols, electrical charges, and masses (expressed in u) of the three subatomic particles introduced in this chapter?

1.35 Where in an atom is nearly all of its mass concentrated? Explain your answer in terms of the particles that contribute to this mass.

1.36 What is a *nucleon*? Which ones have we studied?

1.37 Define the terms *atomic number* and *mass number*.

1.38 In terms of the structures of atoms, how are isotopes of the same element alike? How do they differ?

1.39 Name one property that atoms of two *different* elements might possibly have in common.

1.40 Consider the symbol ${}^{a}_{b}X$, where X stands for the chemical symbol for an element. What information is given in locations (a) a and (b) b?

1.41 Write the symbols of the isotopes that contain the following. (Use the table of atomic masses and numbers printed inside the front cover for additional information, as needed.)
(a) An isotope of iodine whose atoms have 78 neutrons.
(b) An isotope of strontium whose atoms have 52 neutrons.
(c) An isotope of cesium whose atoms have 82 neutrons.
(d) An isotope of fluorine whose atoms have 9 neutrons.

The Periodic Table

1.42 In the compounds formed by Li, Na, K, Rb, and Cs with chlorine, how many atoms of Cl are there per atom of the metal? In the compounds formed by Be, Mg, Ca, Sr, and Ba with chlorine, how many atoms of Cl are there per atom of metal? How did this kind of information lead Mendeleev to develop his periodic table?

1.43 On what basis did Mendeleev construct his periodic table? On what basis are the elements arranged in the modern periodic table?

1.44 In the periodic table, what is a "period"? What is a "group"?

1.45 Why did Mendeleev leave gaps in his periodic table?

1.46 In the text, we identified two places in the modern periodic table where the atomic mass order was reversed. Using the table on the inside front cover, locate two other places where this occurs.

1.47 Which is better related to the chemistry of an element, its mass number or its atomic number? Give a brief explanation in terms of the basis for the periodic table.

1.48 On the basis of their positions in the periodic table, why is it not surprising that strontium-90, a dangerous radioactive isotope of strontium, replaces calcium in newly formed bones?

1.49 In the refining of copper, sizable amounts of silver and gold are recovered. Why is this not surprising?

1.50 Why would you reasonably expect cadmium to be a contaminant in zinc but not in silver?

1.51 Make a rough sketch of the periodic table and mark off those areas where you would find (a) the representative elements, (b) the transition elements, and (c) the inner transition elements.

1.52 What group numbers are used to designate the representative elements following (a) the North American system for designating groups and (b) the IUPAC system?

1.53 Supply the IUPAC group numbers that correspond to the following North American designations: (a) Group IA, (b) Group VIIA, (c) Group IIIB, (d) Group IB, (e) Group IVA.

1.54 Based on discussions in this chapter, explain why it is unlikely that scientists will discover a new element, never before observed, having an atomic mass of approximately 73.

1.55 Which of the following is
(a) an alkali metal: Ca, Cu, In, Li, S?
(b) a halogen: Ce, Hg, Si, O, I?
(c) a transition element: Pb, W, Ca, Cs, P?
(d) a noble gas: Xe, Se, H, Sr, Zr?
(e) a lanthanide element: Th, Sm, Ba, F, Sb?
(f) an actinide element: Ho, Mn, Pu, At, Na?
(g) an alkaline earth metal: Mg, Fe, K, Cl, Ni?

Physical Properties of Metals, Nonmetals, and Metalloids

1.56 Name five physical properties that we usually observe for metals.

1.57 Why is mercury used in thermometers? Why is tungsten used in light bulbs?

1.58 What property of metals allows them to be drawn into wire?

1.59 Gold can be hammered into sheets so thin that some light can pass through them. What property of gold allows such thin sheets to be made?

1.60 Only two metals are colored (the rest are "white," like iron or lead). You have surely seen both of them. Which metals are they?

1.61 Which nonmetals occur as monatomic gases (gases whose particles consist of single atoms)?

1.62 Which two elements exist as liquids at room temperature and pressure?

1.63 Which physical property of metalloids distinguishes them from metals and nonmetals?

1.64 Sketch the shape of the periodic table and mark off those areas where we find (a) metals, (b) nonmetals, and (c) metalloids.

1.65 Which metals can you think of that are commonly used to make jewelry? Why isn't iron used to make jewelry?

REVIEW PROBLEMS

Answers to problems whose numbers are printed in color are given in Appendix B. More challenging questions are marked with asterisks. **ILW** = Interactive LearningWare solution is available at *www.wiley.com/college/brady.*

Laws of Chemical Combination

1.66 Laughing gas is a compound formed from nitrogen and oxygen in which there are 1.75 g of nitrogen for every 1.00 g of oxygen. The compositions of several nitrogen–oxygen compounds follow. Which of these is laughing gas?
(a) 6.35 g nitrogen, 7.26 g oxygen
(b) 4.63 g nitrogen, 10.58 g oxygen
(c) 8.84 g nitrogen, 5.05 g oxygen
(d) 9.62 g nitrogen, 16.5 g oxygen
(e) 14.3 g nitrogen, 40.9 g oxygen

1.67 One of the substances used to melt ice on sidewalks and roadways in cold climates is calcium chloride. In this compound calcium and chlorine are combined in a ratio of 1.00 g of calcium to 1.77 g of chlorine. Which of the following calcium–chlorine mixtures will give calcium chloride with no calcium or chlorine left over after the reaction is complete?
(a) 3.65 g calcium, 4.13 g chlorine
(b) 0.856 g calcium, 1.56 g chlorine
(c) 2.45 g calcium, 4.57 g chlorine
(d) 1.35 g calcium, 2.39 g chlorine
(e) 5.64 g calcium, 9.12 g chlorine

1.68 Ammonia is composed of hydrogen and nitrogen in a ratio of 9.33 g of nitrogen to 2.00 g of hydrogen. If a sample of ammonia contains 6.28 g of hydrogen, how many grams of nitrogen does it contain?

1.69 A compound of phosphorus and chlorine used in the manufacture of a flame retardant treatment for fabrics contains 1.20 grams of phosphorus for every 4.12 g of chlorine. Suppose a sample of this compound contains 6.22 g of chlorine. How many grams of phosphorus does it contain?

1.70 Refer to the data about ammonia in Problem 1.68. If 4.56 g of nitrogen combined completely with hydrogen to form ammonia, how many grams of ammonia would be formed?

1.71 Refer to the data about the phosphorus–chlorine compound in Problem 1.69. If 12.5 g of phosphorus combined completely with chlorine to form this compound, how many grams of the compound would be formed?

1.72 Molecules of a certain compound of nitrogen and oxygen contain one atom each of N and O. In this compound there are 1.143 g of oxygen for each 1.000 g of nitrogen. Molecules of a different compound of nitrogen and oxygen contain one atom of N and two atoms of O. How many grams of oxygen would be combined with each 1.000 g of nitrogen in the second compound?

1.73 Tin forms two compounds with chlorine. In one of them (compound 1), there are two Cl atoms for each Sn atom; in the other (compound 2), there are four Cl atoms for each Sn atom. When combined with the same mass of tin, what would be the ratio of the masses of chlorine in the two compounds? In compound 1, 0.597 g of chlorine is combined with each 1.000 g of tin. How many grams of chlorine would be combined with 1.000 g of tin in compound 2?

Atomic Masses and Isotopes

1.74 The mass in grams of 1 atomic mass unit is $1.6605402 \times 10^{-24}$ g. Use this value to calculate the mass in grams of one atom of carbon-12.

1.75 Use the mass in grams of the atomic mass unit given in the preceding problem to calculate the average mass of one atom of sodium.

1.76 The chemical substance in natural gas is a compound called methane. Its molecules are composed of carbon and hydrogen and each molecule contains four atoms of hydrogen and one atom of carbon. In this compound, 0.33597 g of hydrogen is combined with 1.0000 g of carbon-12. Use this information to calculate the atomic mass of the element hydrogen.

1.77 A certain element *X* forms a compound with oxygen in which there are two atoms of *X* for every three atoms of O. In this compound, 1.125 g of *X* are combined with 1.000 g of oxygen. Use the average atomic mass of oxygen to calculate the average atomic mass of *X*. Use your calculated atomic mass to identify the element *X*.

1.78 If an atom of carbon-12 had been assigned a relative mass of 24.0000 u, what would be the average atomic mass of hydrogen relative to this mass?

1.79 One atom of ^{109}Ag has a mass that is 9.0754 times that of a ^{12}C atom. What is the atomic mass of this isotope of silver expressed in atomic mass units?

Atomic Structure

ILW 1.80 Naturally occurring copper is composed of 69.17% of ^{63}Cu, with an atomic mass of 62.9396 u, and 30.83% of ^{65}Cu, with an atomic mass of 64.9278 u. Use these data to calculate the average atomic mass of copper.

1.81 Naturally occurring magnesium (one of the elements in milk of magnesia) is composed of 78.99% of ^{24}Mg (atomic mass, 23.9850 u), 10.00% of ^{25}Mg (atomic mass, 24.9858 u), and 11.01% of ^{26}Mg (atomic mass, 25.9826 u). Use these data to calculate the average atomic mass of magnesium.

ILW 1.82 Give the numbers of neutrons, protons, and electrons in the atoms of each of the following isotopes. (Use the table of atomic masses and numbers printed inside the front cover for additional information, as needed.)
(a) radium-226 (c) $^{206}_{82}$Pb
(b) carbon-14 (d) $^{23}_{11}$Na

1.83 Give the numbers of electrons, protons, and neutrons in the atoms of each of the following isotopes. (As necessary, consult the table of atomic masses and numbers printed inside the front cover.)
(a) cesium-137 (c) $^{238}_{92}$U
(b) iodine-131 (d) $^{197}_{79}$Au

ADDITIONAL EXERCISES

1.84 An atom of an element has 25 protons in its nucleus.
(a) Is the element a metal, a nonmetal, or a metalloid?
(b) On the basis of the average atomic mass, write the symbol for the element's most abundant isotope.
(c) How many neutrons are in the isotope you described in part b?
(d) How many electrons are in atoms of this element?
(e) How many times heavier than ^{12}C is the average atom of this element?

*__1.85__ Elements *X* and *Y* form a compound in which there is one atom of *X* for every four atoms of *Y*. When these elements react, it is found that 1.00 g of *X* combines with 5.07 g of *Y*. When 1.00 g of *X* combines with 1.14 g of O, it forms a compound containing two atoms of O for each atom of *X*. Calculate the atomic mass of *Y*.

1.86 An iron nail is composed of four isotopes with the percentage abundances and atomic masses given in the following table. Calculate the average atomic mass of iron.

Isotope	Percentage Abundance	Atomic Mass (u)
^{54}Fe	5.80	53.9396
^{56}Fe	91.72	55.9349
^{57}Fe	2.20	56.9354
^{58}Fe	0.28	57.9333

*__1.87__ Bromine (shown in Figure 1.23, page 32) is a dark red liquid that vaporizes easily and is very corrosive to the skin. It is used commercially as a bleach for fibers and silk. Naturally occurring bromine is composed of two isotopes, ^{79}Br, with a mass of 78.9183 u, and ^{81}Br, with a mass of 80.9163 u. Use this information and the average atomic mass of bromine given in the table on the inside front cover of the book to calculate the percentage abundances of these two isotopes.

*__1.88__ Rust contains an iron–oxygen compound in which there are three oxygen atoms for each two iron atoms. In this compound, the iron to oxygen mass ratio is 2.325 g Fe to 1.000 g O. Another compound of iron and oxygen contains these elements in the ratio of 2.616 g Fe to 1.000 g O. What is the ratio of iron to oxygen atoms in this other iron–oxygen compound?

1.89 One atomic mass unit has a mass of $1.6605402 \times 10^{-24}$ g. Calculate the mass, in grams, of one atom of magnesium. What is the mass of one atom of iron, expressed in grams? Use these two answers to determine how many atoms of Mg are in 24.305 g of magnesium and how many atoms of Fe are in 55.847 g of iron. Compare your answers. What conclusions can you draw from the results of these calculations? Without actually performing any calculations, how many atoms do you think would be in 40.078 g of calcium?