1 FOCUS

Section Objectives

2.1 **Explain** how elements are related to minerals.
2.2 **Identify** the kinds of particles that make up atoms.
2.3 **Explain** the differences between ions and isotopes.
2.4 **Explain** what compounds are and **describe** why they form.
2.5 **Compare and contrast** the three major types of chemical bonds.

Reading Focus

Build Vocabulary L2

Concept Map Have students construct a concept map using the terms *chemical bond*, *ionic bond*, *covalent bond*, and *metallic bond*. The main concept (*chemical bond*) should be at the top. Tell students to place the terms in ovals and list the characteristics of each type of bond underneath the oval. For each type of bond, students should include some examples and their properties.

Reading Strategy L2

Differences: Electron is much less massive than proton and neutron; electron is negatively charged, proton is positively charged, neutron is not charged.
Similarities: All are subatomic particles.

2 INSTRUCT

Elements and the Periodic Table

Build Reading Literacy L1

Refer to **p. 392D** in **Chapter 14**, which provides guidelines for this strategy.

Preview Have students preview the section (pp. 34–43), focusing their attention on headings, visuals, and boldfaced material. Ask: **Based on your preview, which figure in the section do you think contains the most information?** *(Figure 1 on pp. 36–37)* **Based on your preview, name three classes of elements.** *(metals, nonmetals, and metalloids)*
Visual, Verbal

2.1 Matter

Reading Focus

Key Concepts

- What is an element?
- What particles make up atoms?
- What are isotopes?
- What are compounds and why do they form?
- How do chemical bonds differ?

Vocabulary

- element
- atomic number
- energy level
- isotope
- mass number
- compound
- chemical bond
- ion
- ionic bond
- covalent bond
- metallic bond

Reading Strategy

Comparing and Contrasting Copy the graphic organizer. As you read, complete the organizer to compare and contrast protons, neutrons, and electrons.

Protons	Electrons	Neutrons
Differences		
Similarities		

You and everything else in the universe are made of matter. Matter is anything that has volume and mass. On Earth, matter usually exists in one of three states—solid, liquid, or gas. A solid is a type of matter that has a definite shape and a definite volume. Rocks and minerals are solids. A liquid is matter that has a definite volume, but not a definite shape. Earth's oceans, rivers, and lakes are liquids. A gas is matter that has neither a definite shape nor a definite volume. Most of Earth's atmosphere is composed of the gases nitrogen and oxygen. Though matter can be classified by its physical state: solid, liquid, or gas, it is more useful to look at its chemical composition and structure. Each of Earth's nearly 4000 minerals is a unique substance. The building blocks of minerals are **elements.**

Elements and the Periodic Table

The names of many elements are probably very familiar to you. Many common metals are elements, such as copper, iron, silver, and gold. **An element is a substance that cannot be broken down into simpler substances by chemical or physical means.** There are more than 112 known elements, and new elements continue to be discovered. Of these, 95 occur naturally; the others are produced in laboratories.

The elements have been organized by their properties in a document called the periodic table, which is shown in Figure 1 on pages 36 and 37. You see from the table that the name of each element is represented by a symbol consisting of one, two, or three letters. Symbols provide a shorthand way of representing an element. Each element is

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also known by its atomic number, which is shown above each symbol on the table. Look at the block for sulfur, element 16, and gold, element 79. Sulfur and gold are minerals made of one element. Most elements are not stable enough to exist in pure form in nature. Thus, most minerals are combinations of elements.

The rows in the periodic table are called periods. The number of elements in a period varies. Period 1, for example, contains only two elements. These elements are hydrogen (H) and helium (He). Period 2 contains the elements lithium (Li) through neon (Ne). Periods 4 and 5 each contain 18 elements while Period 6 includes 32 elements.

The columns in the periodic table are called groups. Note that there are 18 groups in the periodic table shown on pages 36 and 37. Elements within a group have similar properties.

Of the known elements, only eight make up most of Earth's continental crust. These eight elements are listed in Table 1. Notice that six of the eight elements in Table 1 are classified as metals. Metals have specific properties such as the ability to be shaped and drawn into wire. Metals are also good conductors of heat and electricity. They combine in thousands of ways to form compounds, the building blocks of most Earth materials. To understand how elements form compounds we need to review their building blocks which are atoms.

Table 1 Relative Abundance of the Most Common Elements in Earth's Continental Crust

Element	Approximate Percentage by Weight
Oxygen (O)	46.6
Silicon (Si)	27.7
Aluminum (Al)	8.1
Iron (Fe)	5.0
Calcium (Ca)	3.6
Sodium (Na)	2.8
Potassium (K)	2.6
Magnesium (Mg)	2.1
All others	1.7

Source: Data from Brian Mason.

Atoms

As you might already know, all elements are made of atoms. **An atom is the smallest particle of matter that contains the characteristics of an element.**

The central region of an atom is called the nucleus. The nucleus contains protons and neutrons. Protons are dense particles with positive electrical charges. Neutrons are equally dense particles that have no electrical charge. Electrons, which are small particles with little mass and negative electrical charges, surround an atom's nucleus.

Protons and Neutrons A proton has about the same mass as a neutron. Hydrogen atoms have only a single proton in their nuclei. Other atoms contain more than 100 protons. The number of protons in the nucleus of an atom is called the **atomic number.** All atoms with six protons, for example, are carbon atoms. The atomic number of carbon is 6. Likewise, every atom with eight protons is an oxygen atom. The atomic number of oxygen is 8.

Atoms have the same number of protons and electrons. Carbon atoms have six protons and therefore six electrons. Oxygen atoms have eight protons in their nuclei and have eight electrons surrounding the nucleus.

Build Math Skills L2

Using Tables and Graphs Have students convert Table 1 into a circle graph. Ask: **Why would a circle graph be a good alternative way to show the information in Table 1?** *(A circle graph shows the parts that make up a whole, just as the elements listed in the table make up a whole—100 percent of the elements in the continental crust.)* Suggest that students first estimate the size of each wedge of the circle graph and draw the graph accordingly. Then have them precisely draw the graph by first multiplying each percent by 360° to find the central angle of each wedge. They can then use a protractor to draw each central angle on a circle. Students can compare their estimates with their precise graphs. Some students may wish to create their graphs using software. Ask: **What advantage does a circle graph have over a table of percentages?** *(The sizes of the wedges of the graph often make it easier to compare different quantities.)*
Visual, Logical

Atoms

Integrate Biology L2

Cell Nucleus Students may know that most cells in living organisms also have a structure called a nucleus. Inform students that the cell's nucleus contains the cell's genetic, or hereditary, material. Ask: **How are an atom's nucleus and a cell's nucleus similar?** *(They are both central structures of a basic unit.)* **How are the two nuclei different?** *(The cell nucleus controls the activities of the cell. The atomic nucleus does not have a similar function.)*
Logical

Address Misconceptions L2

Although the text says that all matter is made of atoms, this is not strictly true everywhere in the universe. For example, the solar wind produced by the sun consists of a stream of protons and electrons. Also, in a neutron star, enormous pressure forces electrons and protons in the atoms in a star to combine with each other, leaving only a very dense ball of neutrons.
Logical

Customize for English Language Learners

To help students understand the idea of energy levels, have them work in pairs to think of everyday situations that involve different levels. Examples might include dresser drawers, shelves in a bookshelf, and bleachers in a gym. Ask students how these analogies are different from energy levels in atoms. *(Energy levels are not physical objects and are not evenly spaced.)* If you have a bookshelf in the class, have students place marbles on different levels to represent electrons.

Use Visuals **L1**

Figure 1 Use this figure to discuss how information is shown on a periodic table. Ask: **What are the boldfaced single or double letters, such as *H* and *Li*?** *(symbols for each element)* **What is the number above each symbol?** *(the element's atomic number)* **What is the number below each symbol?** *(the element's atomic mass)* **What do the colors of the boxes indicate?** *(They show whether an element is a metal, transition metal, nonmetal, noble gas, lanthanide, or actinide.)*
Visual, Logical

Build Science Skills **L2**

Using Tables and Graphs Use the data in Figure 1 to show the advantage of arranging elements by atomic number instead of atomic mass. Make a large graph with atomic number on the horizontal axis and atomic mass on the vertical axis for elements 1 through 20. Draw straight lines between the points. Ask: **What does the graph show about the general relationship between atomic number and atomic mass?** *(As the atomic number increases, so does the atomic mass.)* **Are there any points on the graph that do not follow the pattern?** *(Yes, the atomic mass of element 18, argon, is greater than the atomic mass of element 19, potassium.)* Point out that arranging the elements strictly by increasing atomic mass would result in some elements with unlike properties being grouped together.
Visual, Logical

Periodic Table of the Elements

Figure 1

Nonmetals	Metals	Metalloids	
C	Li	B	Solid
Br	Hg		Liquid
H			Gas
	Tc		Not found in nature

Period	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B
1	1 H Hydrogen 1.0079								
2	3 Li Lithium 6.941	4 Be Beryllium 9.0122							
3	11 Na Sodium 22.990	12 Mg Magnesium 24.305							
4	19 K Potassium 39.098	20 Ca Calcium 40.08	21 Sc Scandium 44.956	22 Ti Titanium 47.90	23 V Vanadium 50.941	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.933
5	37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.22	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91
6	55 Cs Cesium 132.91	56 Ba Barium 137.33	71 Lu Lutetium 174.97	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.85	75 Re Rhenium 186.21	76 Os Osmium 190.2	77 Ir Iridium 192.22
7	87 Fr Francium (223)	88 Ra Radium (226)	103 Lr Lawrencium (262)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (264)	108 Hs Hassium (265)	109 Mt Meitnerium (268)

Lanthanide Series

57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.4

Actinide Series

89 Ac Actinium (227)	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)

Metals—elements that are good conductors of heat and electric current

Nonmetals—elements that are poor conductors of heat and electric current

Metalloids—elements with properties that are somewhat similar to metals and nonmetals

Facts and Figures

Although plutonium is classified as a synthetic element, traces of plutonium isotopes Pu-238 and Pu-239 appear at low concentrations (about one part per 1011) in pitchblende, a uranium ore. In 1971, Darlene Hoffman, a scientist at Los Alamos National Laboratory, discovered traces of Pu-244 in Precambrian rocks. Because this isotope has a half-life of about 82 million years, it probably existed when Earth formed.

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Key	
Atomic number	6
Element symbol	C
Element name	Carbon
Atomic mass	12.011

10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
								2 He Helium 4.0026
			5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.179
			13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.453	18 Ar Argon 39.948
28 Ni Nickel 58.71	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.59	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
46 Pd Palladium 106.4	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.69	51 Sb Antimony 121.75	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.30
78 Pt Platinum 195.09	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.37	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
110 *Uun Ununnilium (269)	111 *Uuu Unununium (272)	112 *Uub Ununbium (277)		114 *Uuq Ununquadium				

*Name not officially assigned.

63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04
95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)

Integrate Language Arts L2

Elements 110, 111, 112, and 114 have not been named yet. Scientists can propose names for new elements, but the International Union of Pure and Applied Chemistry has final approval. Until new elements receive official names, chemists refer to them by their Latin-based atomic numbers. For example, element 114 is called ununquadium, Latin for one-one-four. Increase students' familiarity with the periodic table by discussing some of the strategies used to name elements (scientists, geographic locations, mythological characters).
Verbal, Portfolio

Build Science Skills L2

Comparing and Contrasting For this activity, use a periodic table that is several years old to display or distribute to students. You might use one from an older textbook. To illustrate the dynamic nature of science, have students compare Figure 1 to the older periodic table. Ask: **What differences do you notice between the two periodic tables?** *(Depending on when the older table was printed, the number of elements may vary and some elements in Period 7 may not have assigned names. Some values for atomic mass are likely to vary.)* Make a list of responses on the board. Then ask: **How will the periodic table change in the future?** *(Unnamed elements will be assigned official names and more elements may be discovered.)*
Visual, Verbal

Section 2.1 (continued)

Use Visuals
L1

Figure 2 Use this diagram to show a model of the atom. Explain to students that each energy level contains a certain number of electrons.
Visual

Build Math Skills
L2

Calculating An electron has a mass of 9.11×10^{-28} g. Have students calculate a more exact ratio between the mass of a proton and the mass of an electron. If necessary, review the idea of a ratio: a dimensionless number used to compare two values. *(The mass of a proton is 1.674×10^{-24} g. 1.674×10^{-24} g/9.11×10^{-28} g = 1838)* The ratio is actually 1836:1. The error is due to rounding.
Logical

Build Science Skills
L2

Using Models Have students build models of atoms similar to Figure 2 using materials found at home or in the classroom. Models do not have to be exactly to scale but should show the relationships among the particles clearly.
Visual, Logical

Isotopes
Build Science Skills
L2

Calculating Oxygen-18 has a mass number of 18 and 10 neutrons in its nucleus. Oxygen-17 has a mass number of 17 and 9 neutrons in its nucleus. Ask: **What is the atomic number of oxygen?** *(8)*
Logical

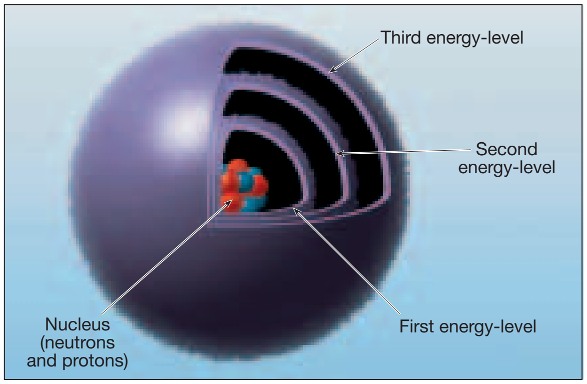

Figure 2 Model of an Atom The electrons that move about an atom's nucleus occupy distinct regions called energy levels.

Electrons An electron is the smallest of the three fundamental particles in an atom. An electron has a mass of about 1/1836 the mass of a proton or a neutron. Electrons move about the nucleus so rapidly that they create a sphere-shaped negative zone. You can picture moving electrons by imagining a cloud of negative charges surrounding the nucleus, as shown in Figure 2.

Electrons are located in regions called **energy levels.** Each energy level contains a certain number of electrons. Interactions among electrons in the outermost energy levels explains how atoms form compounds, as you will find out later in the chapter.

Reading Checkpoint *How are electrons, protons, and neutrons alike and how are they different?*

Isotopes

Atoms of the same element always have the same number of protons. For example, every carbon atom has 6 protons. Carbon is element number 6 on the periodic table. But the number of neutrons for atoms of the same element can vary. **Atoms with the same number of protons but different numbers of neutrons are isotopes of an element.** Isotopes of the same element are labeled using a convention called the mass number and with the element's name or symbol. The **mass number** of an atom is the total mass of the atom (protons plus neutrons) expressed in atomic mass units. The proton and the neutron each have a mass that is slightly larger than the atomic mass unit. Recall that the mass of an electron is so small that the number of electrons has no effect on the mass number of an atom.

Carbon has 15 different isotopes. Models for three of these are shown in Figure 3. Carbon-12 makes up almost 99 percent of all carbon on Earth. Carbon-12 has 6 protons and 6 neutrons. Carbon-13 makes up much of the remaining naturally occurring carbon atoms on Earth. Carbon-13 has 6 protons and 7 neutrons.Though only traces of carbon-14 are found in nature, the presence of this isotope is often used to determine the age of once-living things. Carbon-14 has 6 protons and 8 neutrons

The nuclei of most atoms are stable. However, many elements have atoms whose nuclei are unstable. Such atoms disintegrate through a process called radioactive decay. Radioactive decay occurs because the forces that hold the nucleus together are not strong enough.

Facts and Figures

Carbon-14 can be used to find the ages of some objects. Carbon-14 is formed continuously by natural processes in the atmosphere. Carbon in the atmosphere reacts with oxygen to form carbon dioxide. Plants take in carbon dioxide during photosynthesis, the process by which they use energy in sunlight to make food. Initially, the ratio of carbon-14 to carbon-12 is the same in plants as it is in the atmosphere. The same is true for an animal that eats a plant. After a plant or animal dies, though, it no longer takes in carbon. The carbon-14 gradually undergoes radioactive decay to form nitrogen-14 with a half-life of 5730 years. The age of an object containing plant or animal material can be determined by comparing the ratio of carbon-14 to carbon-12 in the object to the ratio of these isotopes in the atmosphere. If the ratio of carbon-14 to carbon-12 in the object is one-quarter the ratio of carbon-14 to carbon-12 in the atmosphere, for example, then two half-lives, or 11,460 years, have passed since the plant or animal was alive.

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During radioactive decay, unstable atoms radiate energy and particles. Some of this energy powers the movements of Earth's crust and upper mantle. The rates at which unstable atoms decay are measurable. Therefore certain radioactive atoms can be used to determine the ages of fossils, rocks, and minerals.

Reading Checkpoint *What are isotopes?*

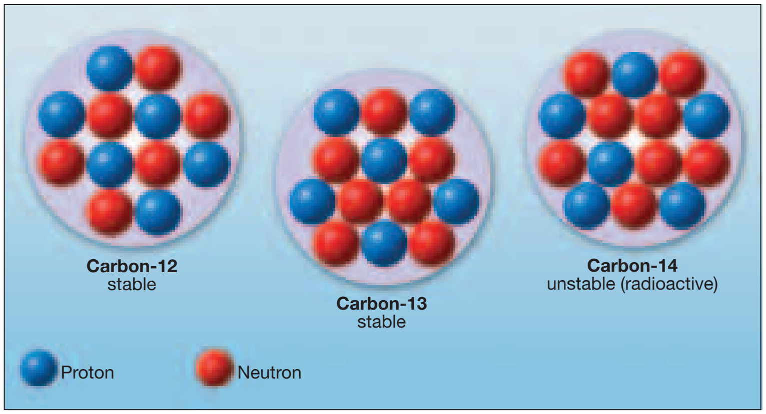


Figure 3 Nuclei of Isotopes of Carbon Carbon has many isotopes. Of these, three occur in nature. **Comparing and Contrasting** ***How are the nuclei of these isotopes the same, and how do they differ?***

Why Atoms Bond

Most elements exist combined with other elements to form substances with properties that are different from the elements themselves. Sodium is often found combined with the element chlorine as the mineral halite. Lead is found in the mineral galena, which is made up of the element lead combined with the element sulfur. Chemical combinations of the atoms of elements are called **compounds.** **A compound is a substance that consists of two or more elements that are chemically combined in specific proportions.** Compounds form when atoms are more stable (exist at a lower energy state) in a combined form. The chemical process, called bonding, centers around the electron arrangements of atoms. Thus, when atoms combine with others to form compounds, they gain, lose, or share electrons.

Scientists have discovered that the most stable elements are found on the right side of the periodic table in Group 8A (18). These elements have a very low reactivity and exist in nature as single atoms. Scientists explain why atoms form compounds by considering how an atom undergoes changes to its electron structure to be more like atoms in Group 8A.

Teacher Demo

Isotopes and Numbers **L2**

Purpose Students will observe the relationships among number of protons, number of neutrons, atomic number, and mass number for different isotopes.

Materials overhead projector, red and green gummy candies

Procedure Explain that the green candies represent neutrons and the red candies represent protons. Model a carbon-12 nucleus by placing a group of 6 red candies and 6 green candies on the overhead. Ask students to count the number of candies (particles) to determine the mass number of the carbon atom *(12)*. Then ask students what the atomic number is for carbon *(6)*. Then remove a red candy (proton) and ask if the atom is still carbon *(no)*. Replace the red candy and add a green candy (neutron). Ask students if the atom is still carbon *(yes)*. Then ask: **How is this atom different from the original one?** *(The atom has a different isotope, carbon-13.)* Show students the appropriate notation to represent isotopes: element name with mass number or element symbol with mass number and atomic number.

carbon-13 or $^{13}_{6}C$

Expected Outcome Students should gain a familiarity with mass numbers, atomic numbers, and isotopes.
Visual

Answer to . . .

Figure 3 *The isotopes all have the same number of protons, and thus, the same atomic number, but each has a different number of neutrons.*

Reading Checkpoint *They all are subatomic particles that make up atoms. Protons have positive electrical charges, neutrons have no charge, and electrons have negative charges. Protons and neutrons are found in an atom's nucleus. Electrons move about the nucleus.*

Reading Checkpoint *Isotopes are atoms of the same element with the same number of protons but different numbers of neutrons.*

Section 2.1 (continued)

Build Science Skills L2

Predicting Emphasize that, except for hydrogen and helium, the dots in an electron dot diagram do not represent all of the electrons in an atom, just the valence electrons.

Have students look at Figure 4. Ask them to predict the electron dot diagrams for rubidium, strontium, indium, tin, antimony, tellurium, iodine, and xenon. *(These elements—Rb, Sr, In, Sn, Sb, Te, I, and Xe—have the same valence electron configurations as the elements directly above them in the periodic table.)*
Logical, Visual

Types of Chemical Bonds

Address Misconceptions

Many students think that atoms become positively charged as a result of gaining protons. Challenge this misconception by explaining that electrons are the only subatomic particles that can be removed from or added to an atom during a chemical reaction. Remind students that protons are bound into the nuclei of atoms and cannot be removed or added during chemical reactions.
Logical

Integrate Chemistry L2

Ionic Compounds and Conduction
Why are solid ionic compounds poor conductors of electricity whereas melted ionic compounds are good conductors? Tell students that for an electric current to flow through a substance, charged particles must be able to move from one place to another. In a solid ionic crystal, the ions are fixed in a lattice. Ask: **Why can't ionic solids conduct electricity?** *(Since the ions are in fixed positions, they cannot conduct current.)* **What happens if the solid is melted?** *(The ions are freed from the lattice.)* **Why is the melted solid a good conductor of electricity?** *(The ions can move around and conduct a current.)*
Logical

Look at Figure 4. It shows the shorthand way of representing the number of electrons in the outer energy level. Recall that electrons move about the nucleus of an atom in a region called an electron cloud. Within this cloud, only a certain number of electrons can occupy each energy level. For example, a maximum of two electrons can occupy the first energy level. From Figure 4, you see that helium (He) is shown with two electrons. A maximum of eight electrons can be found in the second energy level. You also see from the figure that neon (Ne) is shown with eight electrons. **When an atom's outermost energy level does not contain the maximum number of electrons, the atom is likely to form a chemical bond with one or more other atoms. Chemical bonds** can be thought of as the forces that hold atoms together in a compound. The principal types of chemical bonds are ionic bonds, covalent bonds, or metallic bonds.

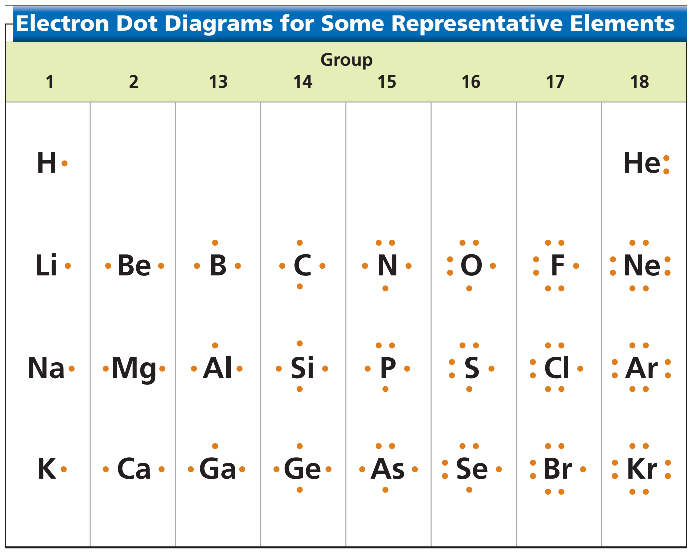


Figure 4 In an electron dot diagram, each dot represents an electron in the atom's outer energy level. These electrons are sometimes called valence electrons.
Observing ***How many electrons do sodium and chlorine have in their outer energy levels?***

Types of Chemical Bonds

Ionic Bonds An atom that gains electrons becomes negatively charged. This happens because the atom now has more electrons than protons. An atom that loses electrons becomes positively charged. This happens because the atom now has more protons than electrons. An atom that has an electrical charge because of a gain or loss of one or more electrons is called an **ion.** Oppositely charged ions attract each other to form crystalline compounds. **Ionic bonds form between positive and negative ions.**

Some common compounds on Earth have both a chemical name and a mineral name. For example, table salt has a chemical name, sodium chloride, and a mineral name, halite. Salt forms when sodium (Na) reacts with chlorine (Cl) as shown in Figure 5A. Sodium is very unstable and reactive. Sodium atoms lose one electron and become positive ions. Chlorine atoms gain one electron and become negative ions. These oppositely charged ions are attracted to each other and form the compound called sodium chloride.

The properties of a compound are different from the properties of the elements in the compound. Sodium is a soft, silvery metal that reacts vigorously with water. If you held it in your hand, sodium could burn your skin. Chlorine is a green poisonous gas. Chemically combined these atoms produce table salt, the familiar crystalline solid that is essential to health.

Reading Checkpoint ***What happens when two or more atoms react?***

Formation of Sodium Chloride

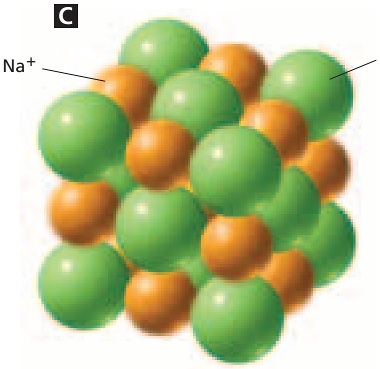
Figure 5 **A** When sodium metal comes in contact with chlorine gas, a violent reaction occurs. **B** Sodium atoms transfer one electron to the outer energy levels of chlorine atoms. Both ions now have filled outer energy levels **C** The positive and negative ions formed attract each other to form a crystalline solid with a rigid structure.

A

B

$$Na\cdot + \cdot\ddot{\underset{\cdot\cdot}{Cl}}: \rightarrow Na^{+}\ :\ddot{\underset{\cdot\cdot}{Cl}}:^{-}$$

C



Use Visuals L1

Figure 5 Use this diagram to explain how an ionic compound forms. Ask: **What happens to the sodium atom when it loses an electron?** *(It becomes a positive ion.)* **What happens to a chlorine atom when it gains an electron?** *(It becomes a negative ion.)* **What happens to the two ions?** *(They are attracted to each other and form a compound.)*
Visual, Logical

Integrate Health L2

Sodium and Chlorine in the Body Sodium chloride, or table salt, is an essential nutrient for human beings. Tell students that sodium and chlorine both help maintain the acid-base balance in the body. Sodium is also involved in maintaining the water balance of the body and in nerve function. Chlorine is needed for the formation of gastric juice for digestion of food. The average American gets about 20 times the required intake of sodium.
Logical

Answer to . . .

Figure 4 *Sodium has one electron in its outer energy level (valence electron) and chlorine has seven.*

Reading Checkpoint *Electrons are gained, lost, or shared when two or more atoms react to form a compound.*

Build Reading Literacy L1

Refer to **p. 502** in **Chapter 18**, which provides guidelines for this strategy.

Visualize Tell students that forming a mental image of concepts they are learning helps them remember new concepts. After students have read about ionic, covalent, and metallic bonds, have them visualize models for each type of bond. Then encourage students to draw diagrams that demonstrate the differences among these three types of bonds.
Visual

Teacher Demo

Comparing Bonds L2

Purpose Students observe differences in the properties of substances with different bonds.

Materials rock salt, chalk, copper wire, hammer, goggles

Procedure Take students outside to an open area. Allow them to examine the samples of rock salt, chalk, and copper wire. Have students stand back a safe distance. Put on goggles, then place each sample on a hard surface and hit it with a hammer. Invite students to observe how each sample looks after being pounded with the hammer.

Expected Outcome The rock salt and chalk shatter because they are ionic and covalent substances, respectively. The copper wire changes shape instead of shattering because metals are malleable.
Visual

Address Misconceptions L2

Many students do not differentiate among atoms, molecules, and ions in their perceptions of particles. Challenge this misconception by having students make drawings to represent an atom, a molecule, and an ion. Students should draw a single sphere for an atom, at least two spheres joined in some way for a molecule, and one sphere with either a plus or a minus sign for an ion.
Visual

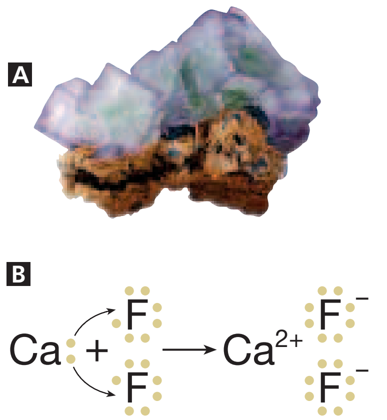


Figure 6 Ionic Compound A Fluorite is an ionic compound that forms when calcium reacts with fluorine. **B** The dots shown with the element's symbol represent the electrons in the outermost levels of the ions.
Explaining *Explain what happens to the electrons in calcium atoms and fluorine atoms when fluorite forms.*

Compounds that contain ionic bonds are called ionic compounds. Figure 6 shows calcium fluoride, a common ionic compound. Our model for ionic bonding suggests that one calcium atom transfers two electrons from its outermost energy level to two atoms of fluorine. This transfer gives all atoms the right numbers of electrons in their outer energy levels. The compound that forms is known as the mineral fluorite.

Ionic compounds are rigid solids with high melting and boiling points. These compounds are poor conductors of electricity in their solid states. When melted, however, many ionic compounds are good conductors of electricity. Most ionic compounds consist of elements from groups 1 and 2 on the periodic table reacting with elements from groups 16 and 17 of the table.

Reading Checkpoint *How do ionic bonds form, and what are some properties of ionic compounds?*

Covalent Bonds

Covalent bonds form when atoms share electrons. Compounds with covalent bonds are called covalent compounds. Figure 7 shows silicon dioxide, one of the most common covalent compounds on Earth. Silicon dioxide forms when one silicon atom and two oxygen atoms share electrons in their outermost energy levels. Silicon dioxide is also known as the mineral quartz.

The bonding in covalent compounds results in properties that differ from those of ionic compounds. Unlike ionic compounds, many covalent compounds have low melting and boiling points. For example, water, a covalent compound, boils at 100°C at standard pressure. Sodium chloride, an ionic compound, boils at 1413°C at standard pressure. Covalent compounds also are poor conductors of electricity, even when melted.

The smallest particle of a covalent compound that shows the properties of that compound is a molecule. A molecule is a neutral group of atoms joined by one or more covalent bonds. Water, for example, consists of molecules. These molecules are made of two hydrogen atoms covalently-bonded to one oxygen atom. The many gases that make up Earth's atmosphere, including hydrogen, oxygen, nitrogen, and carbon dioxide, also consist of molecules.

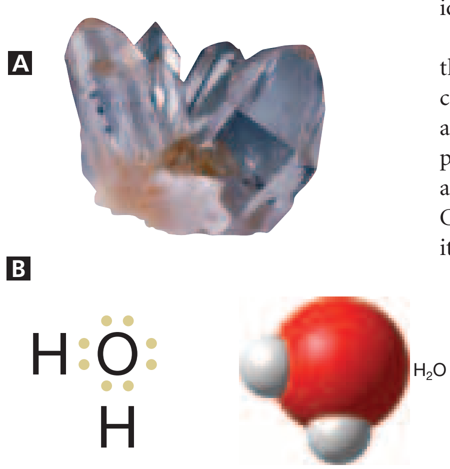


Figure 7 Covalent Compounds A Quartz is a covalent compound that forms when silicon and oxygen atoms bond. **B** Water consists of molecules formed when hydrogen and oxygen share electrons.

Facts and Figures

Unlike ionic and covalent compounds, metals are malleable and ductile. Instead, metal ions are held together in a "sea of electrons" referred to as the metallic bond. When a piece of metal is deformed, the ions move to new positions. The piece of metal does not break because the ions are still held attracted to the electrons.

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Metallic Bonds Metals are malleable, which means that they can be easily shaped. You've observed this property when you wrapped aluminum foil around food or crushed an aluminum can. Metals are also ductile, meaning that they can be drawn into thin wires without breaking. The wiring in your school or home is probably made of the metal copper. Metals are excellent conductors of electricity.

Metallic bonds form when electrons are shared by metal ions. Figure 8 shows a model for this kind of bond. The sharing of an electron pool gives metals their characteristic properties. Using the model you can see how an electrical current is easily carried through the pool of electrons. Later in this chapter, you will learn about some metals that are classified as minerals.

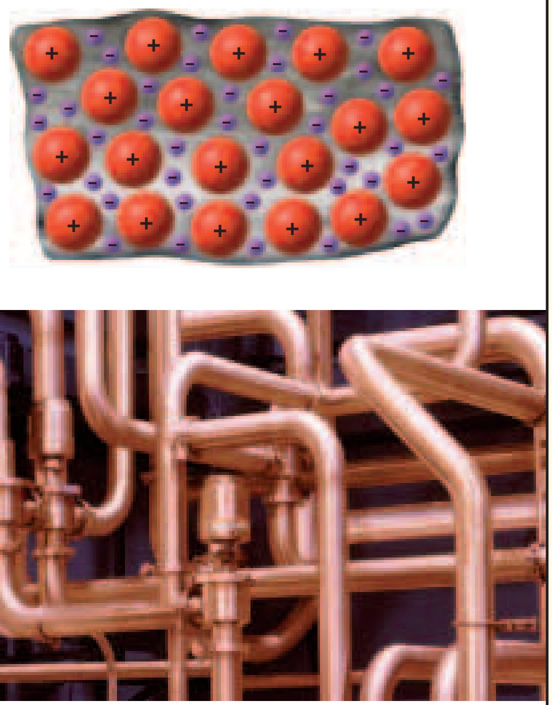

Figure 8 Metallic Bonds A Metals form bonds with one another by sharing electrons. **B** Such bonds give metals, such as this copper, their characteristic properties. Metals can be easily formed and shaped.

Section 2.1 Assessment

Reviewing Concepts

1. What is an element?
2. What kinds of particles make up atoms?
3. What are isotopes?
4. What are compounds and why do they form?
5. Contrast ionic, covalent, and metallic bonds.

Critical Thinking

6. **Comparing and Contrasting** Compare and contrast solids, liquids, and gases.
7. **Applying Concepts** What elements in Table 1 are metals?
8. **Applying Concepts** A magnesium atom needs two electrons to fill its outermost energy level. A chlorine atom needs one electron to fill its outermost shell. If magnesium reacts with chlorine, what type of bond will most likely form? Explain.
9. **Applying Concepts** Which elements in the periodic table might combine with oxygen to form compounds similar to magnesium dioxide (MgO_2)?

Math Practice

10. The isotopes of carbon have from 2 to 16 neutrons. Use this information to make a table that shows the 15 isotopes of carbon and the atomic number and mass number of each.

3 ASSESS

Evaluate Understanding L2

Have students describe why substances form ionic, covalent, and metallic bonds.

Reteach L1

Use Figures 5 and 6 to review the formation of ions and ionic bonds. Be sure students understand that the ionic bond is the electrostatic attraction between ions of opposite charge. Ionic compounds do not exist as discrete pairs of ions, but as aggregates of ions.

Math Practice

Solutions

10. The atomic number, which is the number of protons in an element, is the same for each isotope of carbon. The mass number varies from 8 (6 protons + 2 neutrons) to 24 (6 protons + 18 neutrons).

Answer to . . .

Figure 6 *Calcium transfers its two electrons to two fluorine atoms, forming two fluoride ions.*

Reading Checkpoint *Ionic bonds form when electrons are transferred from one atom to another. Ionic compounds are rigid solids with high melting and boiling points and are poor conductors of electricity in their solid states. When melted, many ionic compounds are good conductors of electricity.*

Section 2.1 Assessment

1. An element is a class of matter that contains only one type of atom. An element cannot be broken down, chemically or physically, into a simpler substance with the same properties.
2. Protons and neutrons are found in an atom's nucleus, while electrons move about this central core.
3. Isotopes are atoms of the same element that have the same number of protons but different numbers of neutrons.
4. A compound is a substance that consists of two or more elements. Compounds form as the result of changes in the arrangement of electrons in the outermost shells of the bonded atoms.
5. Ionic bonds are those that form when electrons are transferred. Covalent bonds involve the sharing of electrons. Metallic bonds exist when electrons are shared by metallic ions.
6. All are forms of matter, and thus all are made of atoms. A solid has a definite shape and definite volume. A liquid has a definite volume, but not a definite shape. A gas has neither a definite volume nor a definite shape.
7. aluminum, iron, calcium, sodium, potassium, magnesium
8. An ionic bond forms because magnesium will give up or transfer its two electrons to two chlorine ions.
9. Elements in groups 1 and 2 have similar properties to those of magnesium and often combine with oxygen to form compounds.