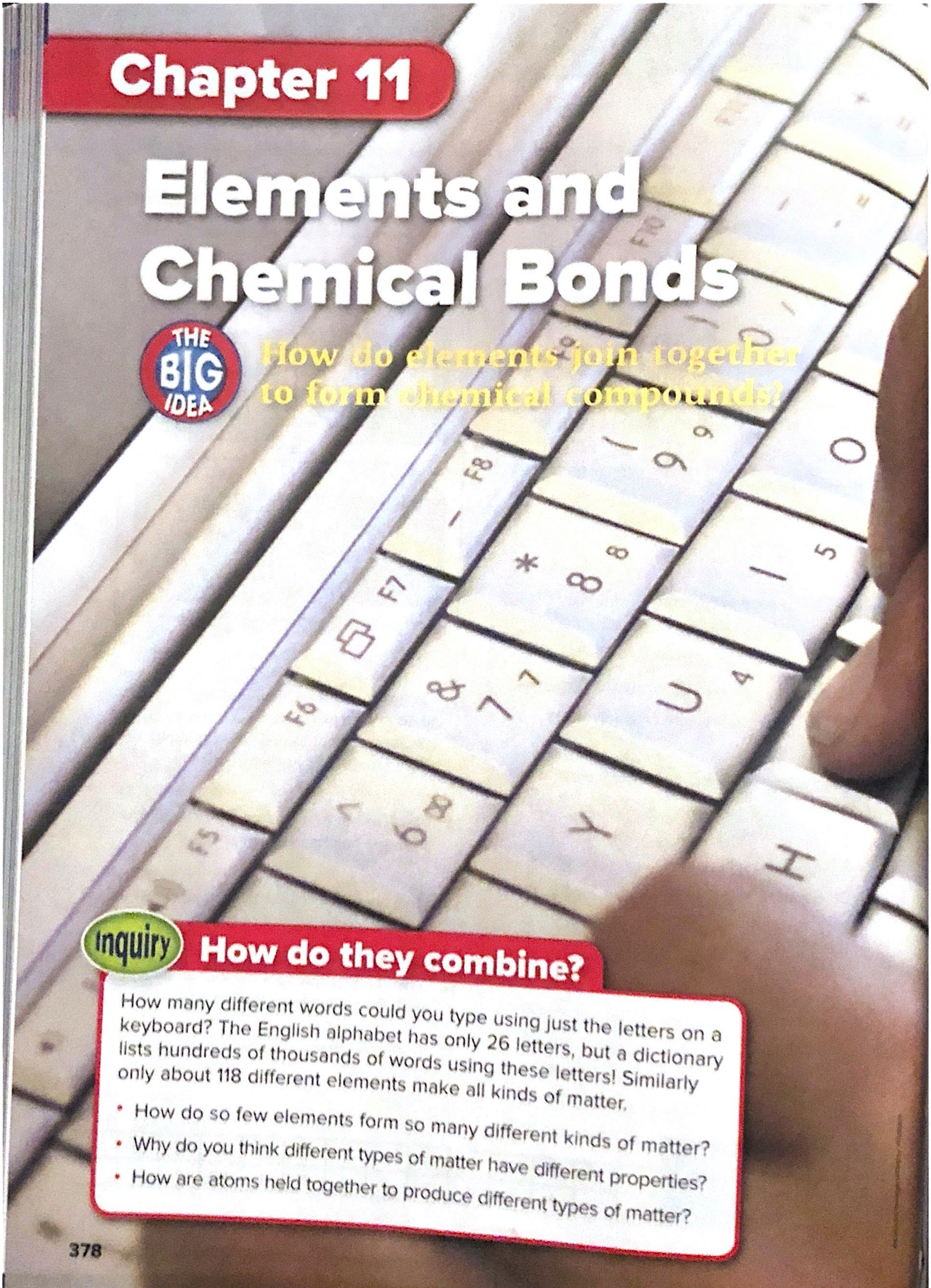


Chapter 11

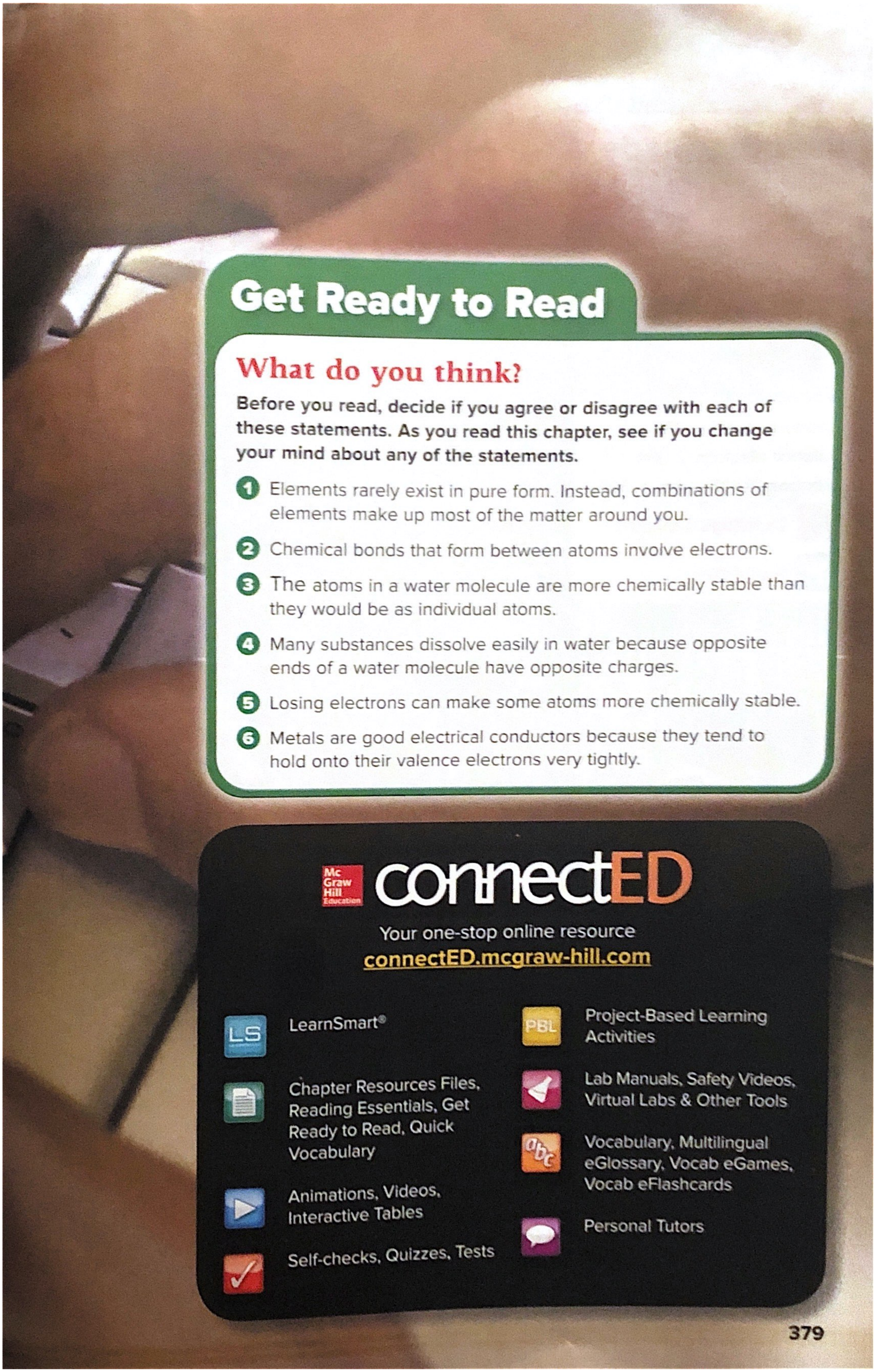
Elements and Chemical Bonds

THE BIG IDEA How do elements join together to form chemical compounds?

Inquiry How do they combine?

How many different words could you type using just the letters on a keyboard? The English alphabet has only 26 letters, but a dictionary lists hundreds of thousands of words using these letters! Similarly only about 118 different elements make all kinds of matter.

- How do so few elements form so many different kinds of matter?
- Why do you think different types of matter have different properties?
- How are atoms held together to produce different types of matter?



Get Ready to Read

What do you think?

Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

1. Elements rarely exist in pure form. Instead, combinations of elements make up most of the matter around you.
2. Chemical bonds that form between atoms involve electrons.
3. The atoms in a water molecule are more chemically stable than they would be as individual atoms.
4. Many substances dissolve easily in water because opposite ends of a water molecule have opposite charges.
5. Losing electrons can make some atoms more chemically stable.
6. Metals are good electrical conductors because they tend to hold onto their valence electrons very tightly.

Lesson 1

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- How is an electron's energy related to its distance from the nucleus?
- Why do atoms gain, lose, or share electrons?

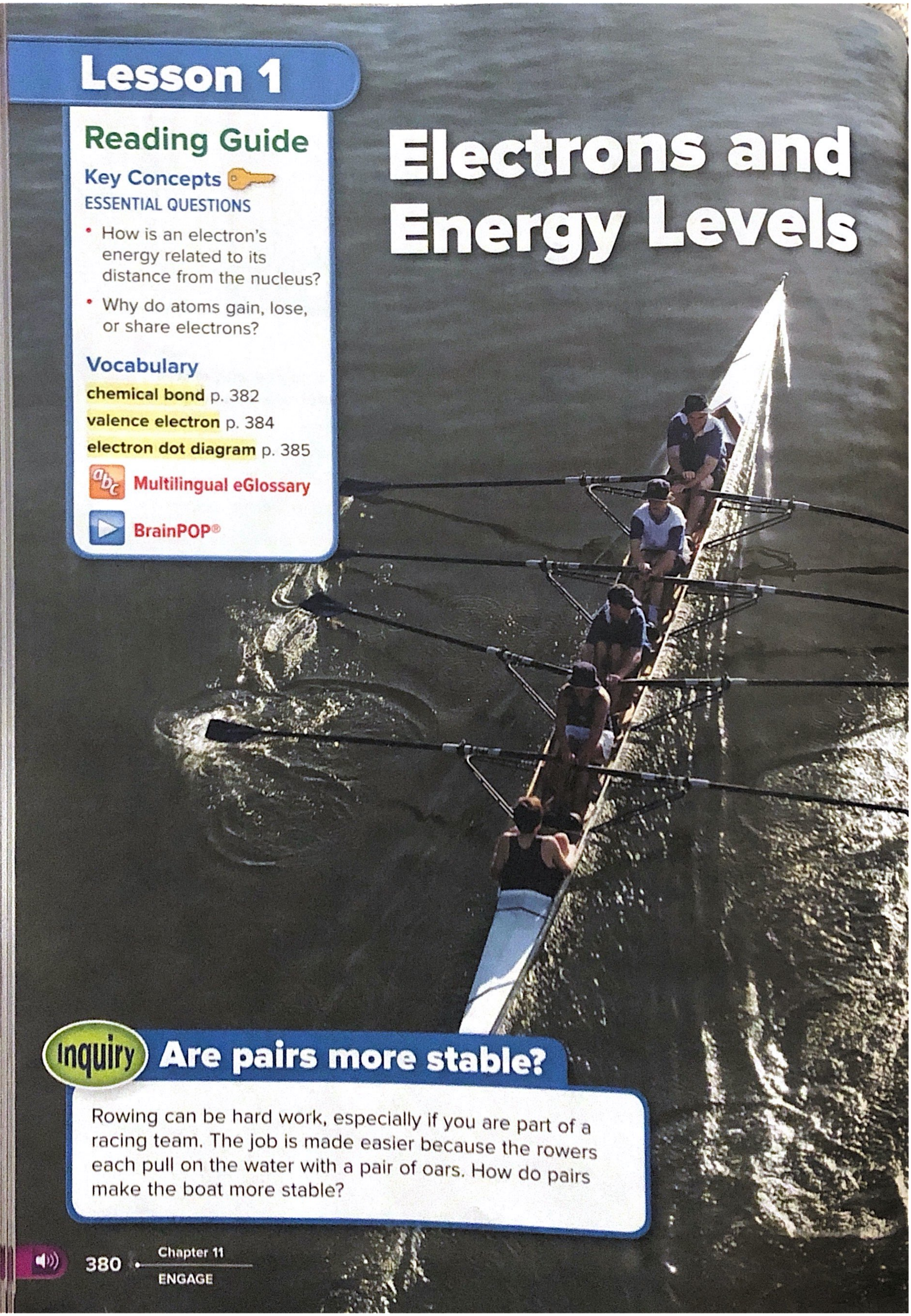
Vocabulary

chemical bond p. 382
valence electron p. 384
electron dot diagram p. 385

Multilingual eGlossary

BrainPOP®

Electrons and Energy Levels



Inquiry Are pairs more stable?

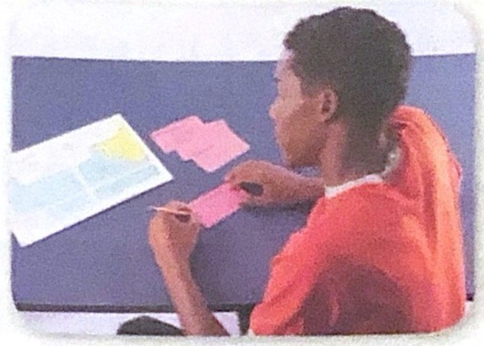
Rowing can be hard work, especially if you are part of a racing team. The job is made easier because the rowers each pull on the water with a pair of oars. How do pairs make the boat more stable?

Launch Lab

20 minutes

How is the periodic table organized?

How do you begin to put together a puzzle of a thousand pieces? You first sort similar pieces into groups. All edge pieces might go into one pile. All blue pieces might go into another pile. Similarly, scientists placed the elements into groups based on their properties. They created the periodic table, which organizes information about all the elements.



1. Obtain six **index cards** from your teacher. Using one card for each element name, write the names *beryllium, sodium, iron, zinc, aluminum,* and *oxygen* at the top of a card.
2. Open your textbook to the periodic table printed on the inside back cover. Locate the element key for each element written on your cards.
3. For each element, find the following information and write it on the index card: symbol, atomic number, atomic mass, state of matter, and element type.

Think About This

1. What do the elements in the blue blocks have in common? In the green blocks? In the yellow blocks?
2. **Key Concept** Each element in a column on the periodic table has similar chemical properties and forms bonds in similar ways. Based on this, for each element you listed on a card, name another element on the periodic table that has similar chemical properties.

The Periodic Table

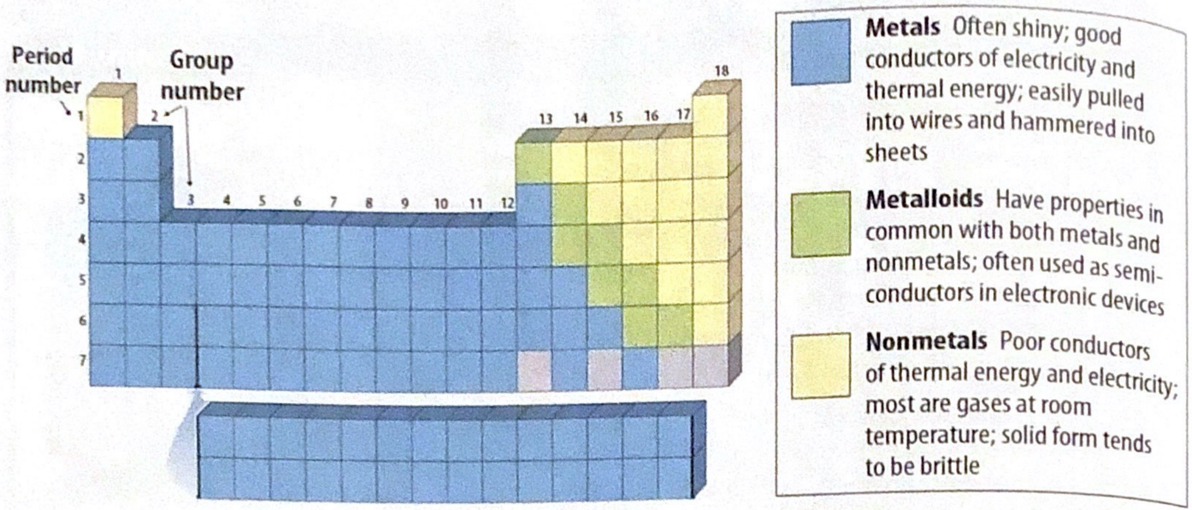
Imagine trying to find a book in a library if all the books were unorganized. Books are organized in a library to help you easily find the information you need. The periodic table is like a library of information about all chemical elements.

A copy of the periodic table is on the inside back cover of this book. The table has more than 100 blocks–one for each known element. Each block on the periodic table includes basic properties of each element such as the element's state of matter at room temperature and its atomic number. The atomic number is the number of protons in each atom of the element. Each block also lists an element's atomic mass, or the average mass of all the different isotopes of that element.

Periods and Groups

You can learn about some properties of an element from its position on the periodic table. Elements are organized in periods (rows) and groups (columns). The periodic table lists elements in order of atomic number. The atomic number increases from left to right as you move across a period. Elements in each group have similar chemical properties and react with other elements in similar ways. In this lesson, you will read more about how an element's position on the periodic table can be used to predict its properties.

Reading Check How is the periodic table organized?



▲ **Figure 1** Elements on the periodic table are classified as metals, nonmetals, or metalloids.

Animation

Metals, Nonmetals, and Metalloids

The three main regions of elements on the periodic table are shown in **Figure 1.** Except for hydrogen, elements on the left side of the table are metals. Nonmetals are on the right side of the table. Metalloids form the narrow stair-step region between metals and nonmetals.

Reading Check Where are metals, nonmetals, and metalloids on the periodic table?

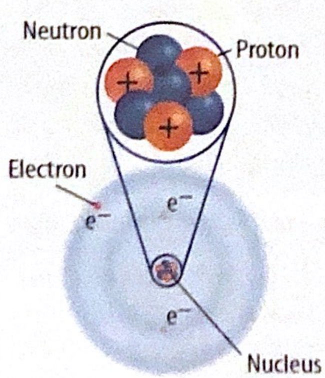
REVIEW VOCABULARY

compound
matter that is made up of two or more different kinds of atoms joined together by chemical bonds

Atoms Bond

In nature, pure elements are rare. Instead, atoms of different elements chemically combine and form **compounds.** Compounds make up most of the matter around you, including living and nonliving things. There are only about 118 elements, but these elements combine and form millions of compounds. Chemical bonds hold them together. *A* **chemical bond** *is a force that holds two or more atoms together.*

Figure 2 Protons and neutrons are in an atom's nucleus. Electrons move around the nucleus. ▼



Lithium Atom

Electron Number and Arrangement

Recall that atoms contain protons, neutrons, and electrons, as shown in **Figure 2.** Each proton has a positive charge; each neutron has no charge; and each electron has a negative charge. The atomic number of an element is the number of protons in each atom of that element. In a neutral (uncharged) atom, the number of protons equals the number of electrons.

The exact position of electrons in an atom cannot be determined. This is because electrons are in constant motion around the nucleus. However, each electron is usually in a certain area of space around the nucleus. Some are in areas close to the nucleus, and some are in areas farther away.

Electrons and Energy Different electrons in an atom have different amounts of energy. An electron moves around the nucleus at a distance that corresponds to its amount of energy. Areas of space in which electrons move around the nucleus are called energy levels. Electrons closest to the nucleus have the least amount of energy. They are in the lowest energy level. Electrons farthest from the nucleus have the greatest amount of energy. They are in the highest energy level. The energy levels of an atom are shown in **Figure 3.** Notice that only two electrons can be in the lowest energy level. The second energy level can hold up to eight.

Key Concept Check How is an electron's energy related to its position in an atom?

Electrons and Bonding Imagine two magnets. The closer they are to each other, the stronger the attraction of their opposite ends. Negatively charged electrons have a similar attraction to the positively charged nucleus of an atom. The electrons in energy levels closest to the nucleus of the same atom have a strong attraction to that nucleus. However, electrons farther from that nucleus are weakly attracted to it. These outermost electrons can easily be attracted to the nucleus of other atoms. This attraction between the positive nucleus of one atom and the negative electrons of another is what causes a chemical bond.

FOLDABLES

Make two quarter-sheet note cards from a sheet of paper. Use them to organize your notes on valence electrons and electron dot diagrams.

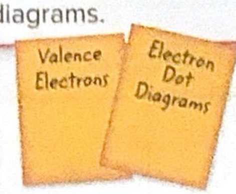
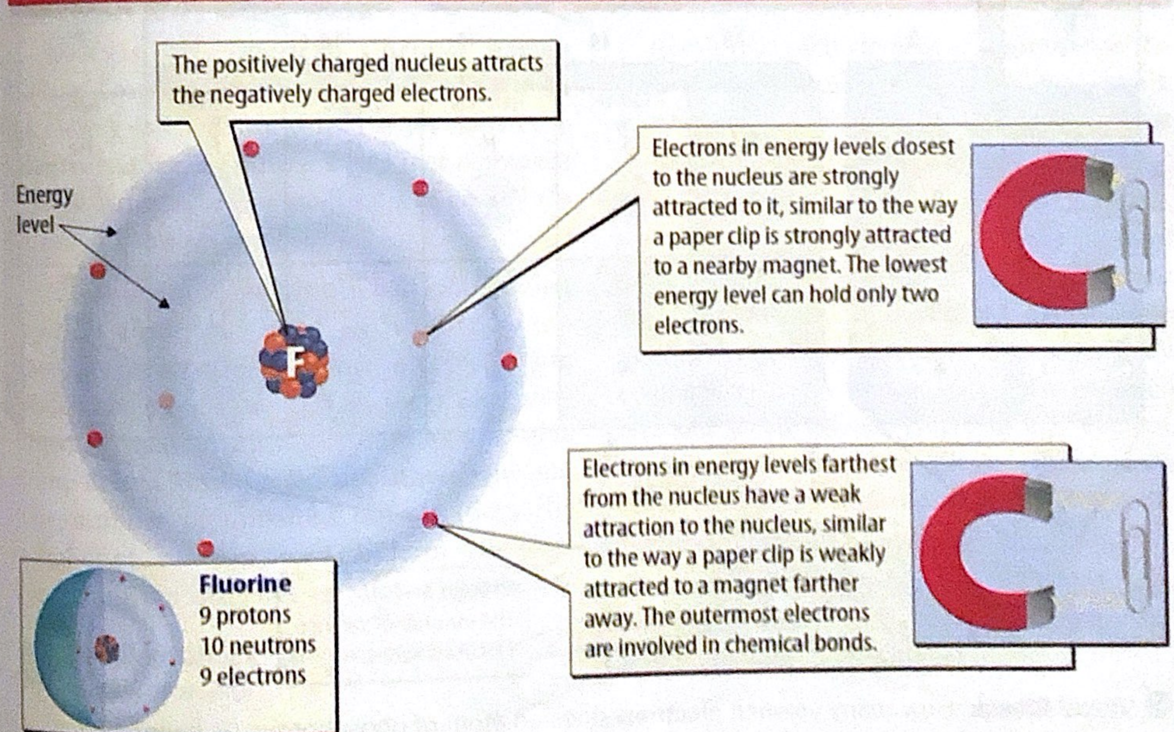


Figure 3 Electrons are in certain energy levels within an atom.

Personal Tutor

Electron Energy Levels



Valence Electrons

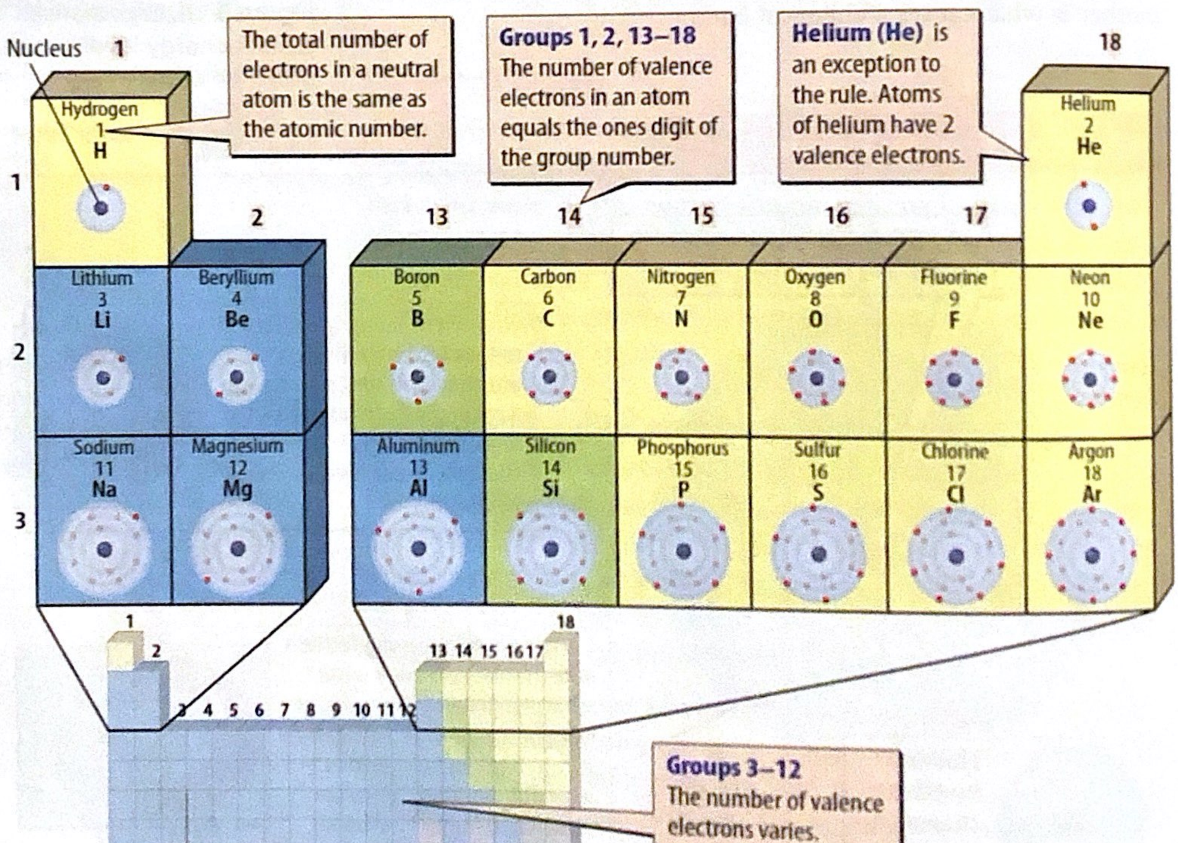
You have read that electrons farthest from their nucleus are easily attracted to the nuclei of nearby atoms. These outermost electrons are the only electrons involved in chemical bonding. Even atoms that have only a few electrons, such as hydrogen or lithium, can form chemical bonds. This is because these electrons are still the outermost electrons and are exposed to the nuclei of other atoms. A **valence electron** *is an outermost electron of an atom that participates in chemical bonding.* Valence electrons have the most energy of all electrons in an atom.

WORD ORIGIN

valence
from Latin *valentia,* means "strength, capacity"

The number of valence electrons in each atom of an element can help determine the type and the number of bonds it can form. How do you know how many valence electrons an atom has? The periodic table can tell you. Except for helium, elements in certain groups have the same number of valence electrons. **Figure 4** illustrates how to use the periodic table to determine the number of valence electrons in the atoms of groups 1, 2, and 13–18. Determining the number of valence electrons for elements in groups 3–12 is more complicated. You will learn about these groups in later chemistry courses.

Figure 4 You can use the group numbers at the top of the columns to determine the number of valence electrons in atoms of groups 1, 2, and 13–18.

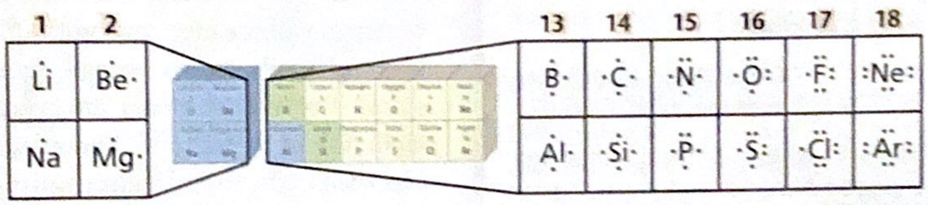


Visual Check How many valence electrons does an atom of phosphorous (P) have?

Writing and Using Electron Dot Diagrams

Figure 5 Electron dot diagrams show the number of valence electrons in an atom.

Steps for writing a dot diagram	Beryllium	Carbon	Nitrogen	Argon
1 Identify the element's group number on the periodic table.	2	14	15	18
2 Identify the number of valence electrons. • This equals the ones digit of the group number.	2	4	5	8
3 Draw the electron dot diagram. • Place one dot at a time on each side of the symbol (top, right, bottom, left). Repeat until all dots are used.	Be·	·C·	·N·	:Ar:
4 Determine if the atom is chemically stable. • An atom is chemically stable if all dots on the electron dot diagram are paired.	Chemically Unstable	Chemically Unstable	Chemically Unstable	Chemically Stable
5 Determine how many bonds this atom can form. • Count the dots that are unpaired.	2	4	3	0



Electron Dot Diagrams

In 1916 an American Chemist named Gilbert Lewis developed a method to show an element's valence electrons. He developed the **electron dot diagram,** *a model that represents valence electrons in an atom as dots around the element's chemical symbol.*

Electron dot diagrams can help you predict how an atom will bond with other atoms. Dots, representing valence electrons, are placed one-by-one on each side of an element's chemical symbol until all the dots are used. Some dots will be paired up, others will not. The number of unpaired dots is often the number of bonds an atom can form. The steps for writing dot diagrams are shown in **Figure 5.**

Reading Check Why are electron dot diagrams useful?

Recall that each element in a group has the same number of valence electrons. As a result, every element in a group has the same number of dots in its electron dot diagram.

Notice in **Figure 5** that an argon atom, Ar, has eight valence electrons, or four pairs of dots, in the diagram. There are no unpaired dots. Atoms with eight valence electrons do not easily react with other atoms. They are chemically stable. Atoms that have between one and seven valence electrons are reactive, or chemically unstable. These atoms easily bond with other atoms and form chemically stable compounds.

Atoms of hydrogen and helium have only one energy level. These atoms are chemically stable with two valence electrons.

MiniLab
20 minutes

How does an electron's energy relate to its position in an atom?

Electrons in energy levels closest to the nucleus are strongly attracted to it. You can use paper clips and a magnet to model a similar attraction.

1. Read and complete a lab safety form.
2. Pick up a **paper clip** with a **magnet.** Use the first paper clip to pick up another one.
3. Continue picking up paper clips in this way until you have a chain of paper clips and no more will attach.
4. Gently pull off the paper clips one by one.

Analyze and Conclude

1. **Observe** Which paper clip was the easiest to remove? Which was the most difficult?
2. **Use Models** In what way do the magnet and the paper clips act as a model for an atom?
3. **Key Concept** How does an electron's position in an atom affect its ability to take part in chemical bonding?

Noble Gases

The elements in Group 18 are called noble gases. With the exception of helium, noble gases have eight valence electrons and are chemically stable. Chemically stable atoms do not easily react, or form bonds, with other atoms. The electron structures of two noble gases–neon and helium–are shown in Figure 6. Notice that all dots are paired in the dot diagrams of these atoms.

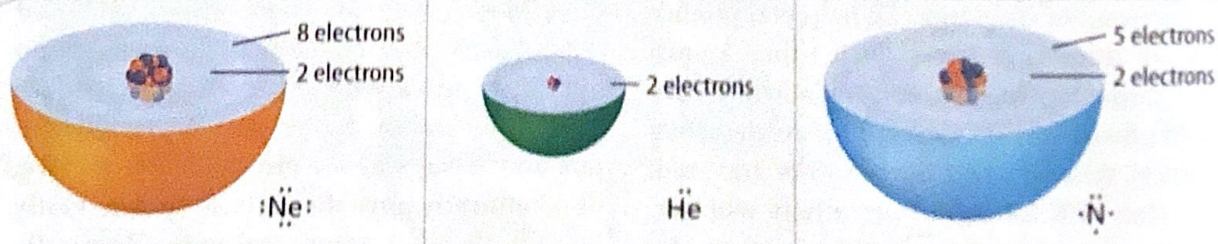
Stable and Unstable Atoms

Atoms with unpaired dots in their electron dot diagrams are reactive, or chemically unstable. For example, nitrogen, shown in Figure 6, has three unpaired dots in its electron dot diagram, and it is reactive. Nitrogen, like many other atoms, becomes more stable by forming chemical bonds with other atoms.

When an atom forms a bond, it gains, loses, or shares valence electrons with other atoms. By forming bonds, atoms become more chemically stable. Recall that atoms are most stable with eight valence electrons. Therefore, atoms with less than eight valence electrons form chemical bonds and become stable. In Lessons 2 and 3, you will read which atoms gain, lose, or share electrons when forming stable compounds.

Key Concept Check Why do atoms gain, lose, or share electrons?

Figure 6 Atoms gain, lose, or share valence electrons and become chemically stable.



Neon has 10 electrons: 2 inner electrons and 8 valence electrons. A neon atom is chemically stable because it has 8 valence electrons. All dots in the dot diagram are paired.

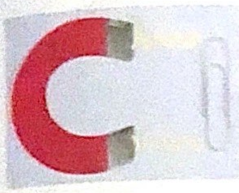
Helium has 2 electrons. Because an atom's lowest energy level can hold only 2 electrons, the 2 dots in the dot diagram are paired. Helium is chemically stable.

Nitrogen has 7 electrons: 2 inner electrons and 5 valence electrons. Its dot diagram has 1 pair of dots and 3 unpaired dots. Nitrogen atoms become more stable by forming chemical bonds.

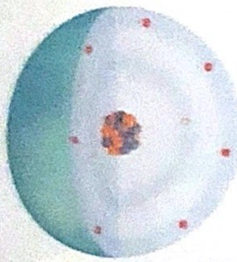
Lesson 1 Review

Online Quiz
Virtual Lab

Visual Summary



Electrons are less strongly attracted to a nucleus the farther they are from it, similar to the way a magnet attracts a paper clip.



Electrons in atoms are in energy levels around the nucleus. Valence electrons are the outermost electrons.

All noble gases, except He, have four pairs of dots in their electron dot diagrams. Noble gases are chemically stable.

FOLDABLES

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

1. Elements rarely exist in pure form. Instead, combinations of elements make up most of the matter around you.
2. Chemical bonds that form between atoms involve electrons.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

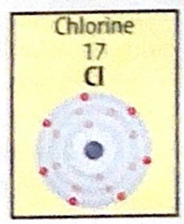
1. **Use the term** *chemical bond* in a complete sentence.
2. **Define** *electron dot diagram* in your own words.
3. The electrons of an atom that participate in chemical bonding are called ________.

Understand Key Concepts

4. **Identify** the number of valence electrons in each atom: calcium, carbon, and sulfur.
5. Which part of the atom is shared, gained, or lost when forming a chemical bond?
   - **A.** electron
   - **B.** neutron
   - **C.** nucleus
   - **D.** proton
6. **Draw** electron dot diagrams for oxygen, potassium, iodine, nitrogen, and beryllium.

Interpret Graphics

7. **Determine** the number of valence electrons in each diagram shown below.



8. **Organize Information** Copy and fill in the graphic organizer below to describe one or more details for each concept: electron energy, valence electrons, stable atoms.

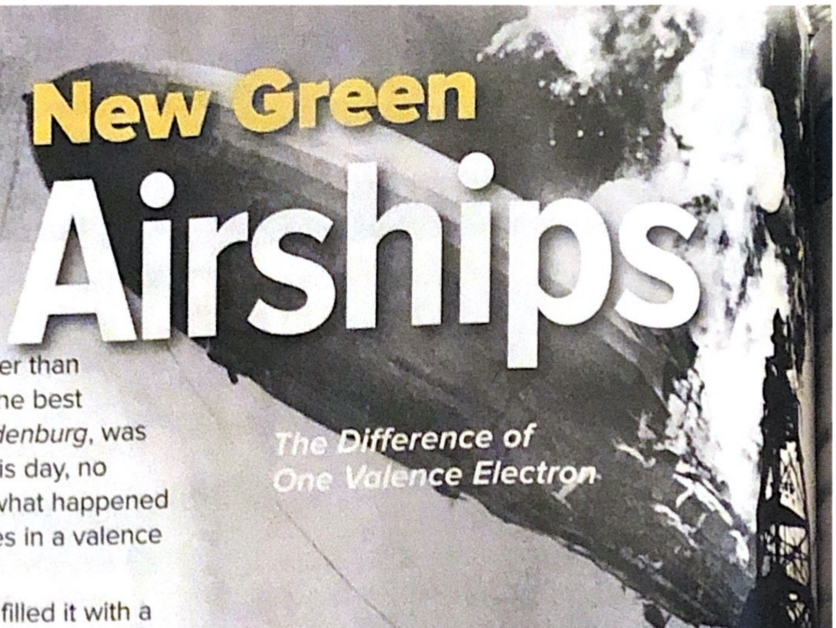
Concept	Description

Critical Thinking

9. **Compare** krypton and bromine in terms of chemical stability.
10. **Decide** An atom of nitrogen has five valence electrons. How could a nitrogen atom become more chemically stable?

GREEN SCIENCE

New Green Airships

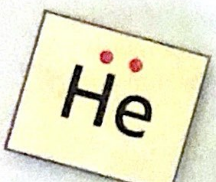


The Difference of One Valence Electron

Faster than ocean liners and safer than airplanes, airships used to be the best way to travel. The largest, the *Hindenburg*, was nearly the size of the *Titanic*. To this day, no larger aircraft has ever flown. So, what happened to the giant airship? The answer lies in a valence electron.

The builders of the *Hindenburg* filled it with a lighter-than-air gas, hydrogen, so that it would float. Their plan was to use helium, a noble gas. However, helium was scarce. They knew hydrogen was explosive, but it was easier to get. For nine years, hydrogen airships floated safely back and forth across the Atlantic. But in 1937, disaster struck. Just before it landed, the *Hindenburg* exploded in flames. The age of the airship was over.

Since the *Hindenburg*, airplanes have become the main type of air transportation. A big airplane uses hundreds of gallons of fuel to take off and fly. As a result, it releases large amounts of pollutants into the atmosphere. Some people are looking for other types of air transportation that will be less harmful to the environment. Airships may be the answer. An airship floats and needs very little fuel to take off and stay airborne. Airships also produce far less pollution than other aircraft.



Today, however, airships use helium not hydrogen. With two valence electrons instead of one, as hydrogen has, helium is unreactive. Thanks to helium's chemical stability, someday you might be a passenger on a new, luxurious, but not explosive, version of the *Hindenburg*.

▲ **A new generation of big airships might soon be hauling freight and carrying passengers.**

It's Your Turn

RESEARCH Precious documents deteriorate with age as their surfaces react with air. Parchment turns brown and crumbles. Find out how our founding documents have been saved from this fate by noble gases.