Atoms, Bonding, and the Periodic Table

Reading Preview

Key Concepts

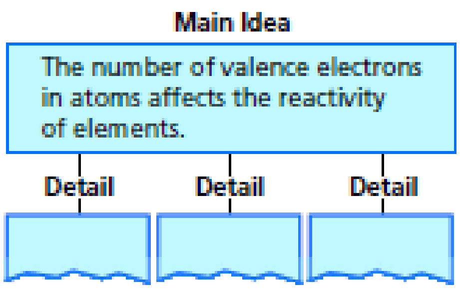
- How is the reactivity of elements related to valence electrons in atoms?
- What does the periodic table tell you about atoms and the properties of elements?

Key Terms

- valence electron
- electron dot diagram
- chemical bond

Target Reading Skill

Identifying Main Ideas As you read *How the Periodic Table Works,* write the main idea in a graphic organizer like the one below. Then write three supporting details that give examples of the main idea.



Lab zone Discover Activity

What Are the Trends in the Periodic Table?

1. Examine the periodic table of the elements that your teacher provides. Look in each square for the whole number located above the symbol of the element. As you read across a row from left to right, what trend do you see?
2. Now look at a column from top to bottom. What trend do you see in these numbers?

Think It Over

Interpreting Data Can you explain why one row ends and a new row starts? Why are certain elements in the same column?

Why isn't the world made only of elements? How do the atoms of different elements combine to form compounds? The answers to these questions are related to electrons and their energy levels. And the roadmap to understanding how electrons determine the properties of elements is the periodic table.

Valence Electrons and Bonding

You learned earlier about electrons and energy levels. An atom's **valence electrons** (VAY luns) are those electrons that have the highest energy level and are held most loosely. **The number of valence electrons in an atom of an element determines many properties of that element, including the ways in which the atom can bond with other atoms.**

FIGURE 1
Valence Electrons
Skydivers in the outer ring are less securely held to the group than are members of the inner ring. Similarly, valence electrons are more loosely held by an atom than are electrons of lower energy levels.

Electron Dot Diagrams Each element has a specific number of valence electrons, ranging from 1 to 8. Figure 2 shows one way to depict the number of valence electrons in an element. An **electron dot diagram** includes the symbol for the element surrounded by dots. Each dot stands for one valence electron.

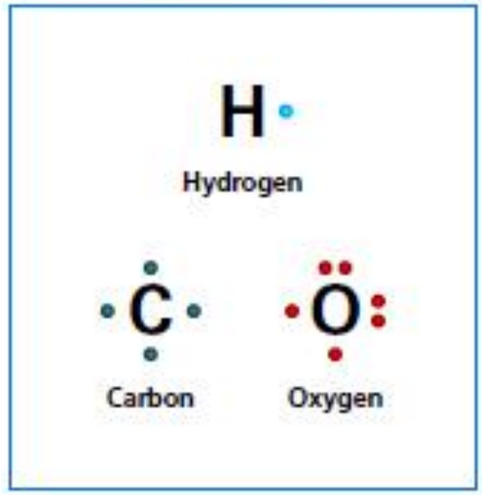
Chemical Bonds and Stability Atoms of most elements are more stable—less likely to react—when they have eight valence electrons. For example, atoms of neon, argon, krypton, and xenon all have eight valence electrons and are very unreactive. These elements do not easily form compounds. Some small atoms, such as helium, are stable with just two valence electrons in their first and only energy level.

Atoms usually react in a way that makes each atom more stable. One of two things can happen: Either the number of valence electrons increases to eight (or two, in the case of hydrogen). Or, the atom gives up loosely held valence electrons. Atoms that react this way can become chemically combined, that is, bonded to other atoms. A **chemical bond** is the force of attraction that holds two atoms together as a result of the rearrangement of electrons between them.

Chemical Bonds and Chemical Reactions When atoms bond, electrons may be transferred from one atom to another, or they may be shared between the atoms. In either case, the change results in a chemical reaction—that is, new substances form. Later in this chapter, you will learn which elements are likely to gain electrons, which are likely to give up electrons, and which are likely to share electrons. You will also learn how the periodic table of the elements can help you predict how atoms of different elements react.

Reading Checkpoint **What information does an electron dot diagram show?**

FIGURE 2
Electron Dot Diagrams
An atom's valence electrons are shown as dots around the symbol of the element. Notice that oxygen atoms have six valence electrons. **Predicting** *How many more electrons are needed to make an oxygen atom stable?*



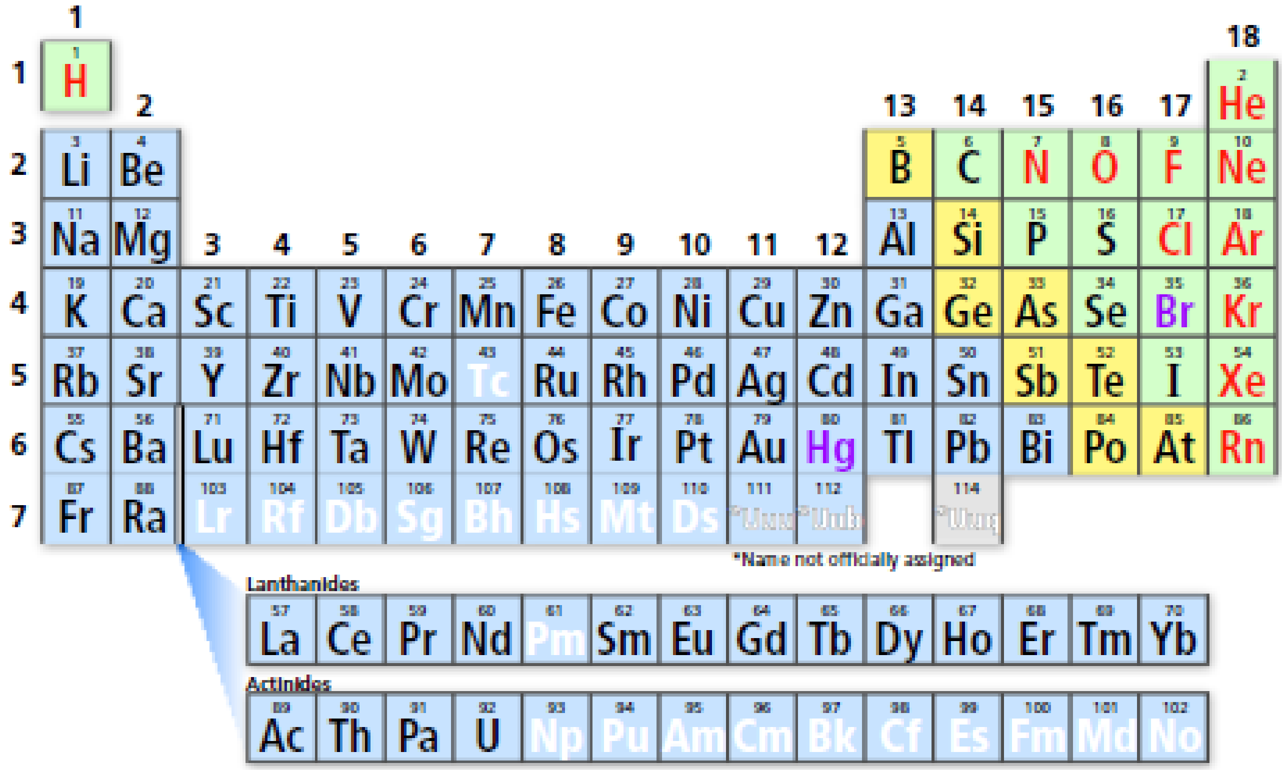


FIGURE 3
Periodic Table of the Elements
The periodic table is a system used worldwide for organizing the elements. Clues to an element's properties relate to its position in the table.

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How the Periodic Table Works

Recall that the periodic table is organized by atomic number—the number of protons in the nucleus of an atom. **The periodic table gives you information about the arrangement of electrons in atoms.** If you know the number of valence electrons that atoms of different elements have, you have a clue as to which elements combine and how.

Relating Periods and Groups Look at Figure 3 and think about how atoms change from left to right across a period, or row. As the atomic number increases, the number of electrons also increases. A period ends when the highest energy level has eight electrons. Valence electrons of atoms in the next period are of a higher energy level. This repeating pattern means that the elements within a group, or column, always have the same number of valence electrons.

Figure 4 compares the electron dot diagrams of elements in Periods 2 and 3. Notice that each element has one more valence electron than the element to its left. For example, Group 1 elements have one valence electron. The elements in Group 2 have two. Elements in Group 13 have three valence electrons, elements in Group 14 have four, and so on. (Elements in Groups 3 to 12 follow a slightly different pattern.) **The elements within a group have similar properties because they all have the same number of valence electrons in their atoms.**

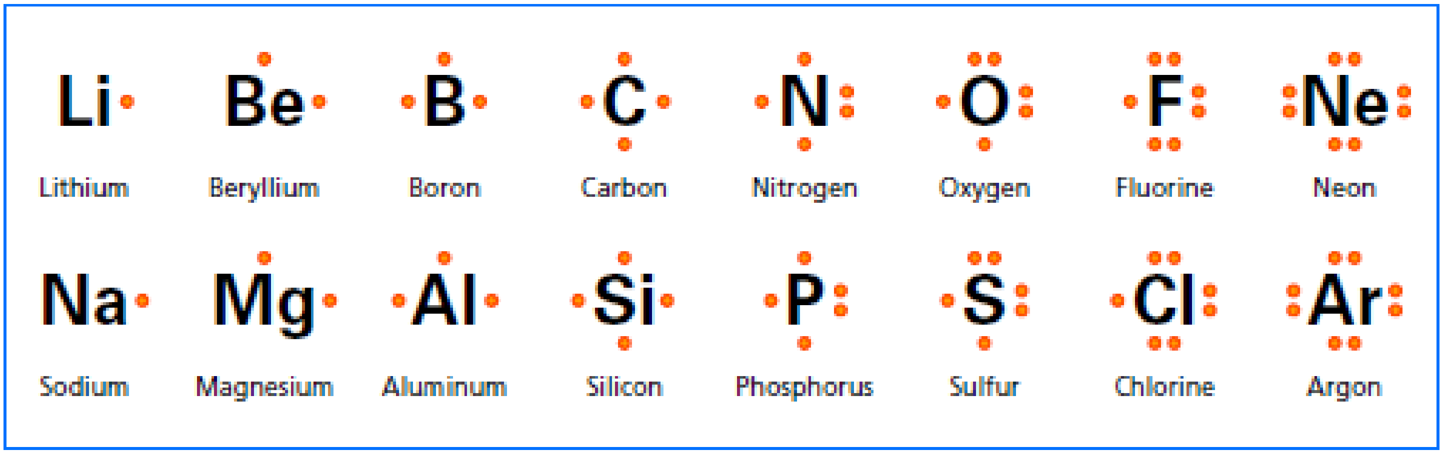


FIGURE 4
Patterns of Valence Electrons
After the number of valence electrons reaches 8, a new period begins.

Noble Gases The Group 18 elements are the noble gases. Atoms of these elements have eight valence electrons, except for helium, which has two. As you have read, atoms with eight valence electrons (or two, in the case of helium) are stable. Such atoms are unlikely to transfer electrons to other atoms or to share electrons with other atoms. As a result, noble gases do not react easily with other elements. Even so, chemists have been able to make noble gases form compounds with a few other elements.

Reactive Nonmetals and Metals Now look at the elements in the column just to the left of the noble gases. The elements in Group 17, the halogens, have atoms with seven valence electrons. A gain of just one more electron gives these atoms the stable number of eight electrons, as in the noble gases. As a result, the halogens react easily with other elements whose atoms can give up or share electrons.

At the far left side of the periodic table is Group 1, the alkali metal family. Atoms of the alkali metals have only one valence electron. Except for lithium, the next lowest energy level has a stable set of eight electrons. (Lithium atoms have a stable set of two electrons at the next lowest energy level.) Therefore, alkali metal atoms can become chemically more stable by losing their one valence electron. This property makes the alkali metals very reactive.

Reading Checkpoint How are atoms of the elements in Group 1 similar?

FIGURE 5
Reactivity of Chlorine
Chlorine is so reactive that steel wool burns when exposed to the chlorine gas in this jar.
Relating Cause and Effect *Why is chlorine so reactive?*

Atoms and Bonding

Video Preview
▶ Video Field Trip
Video Assessment

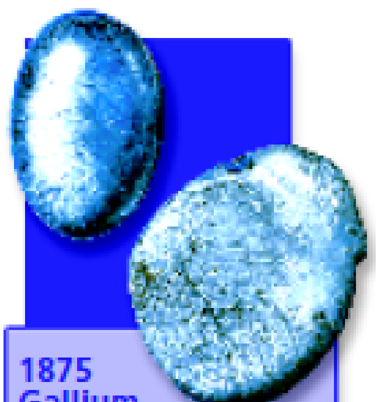
Other Metals Look at the elements in Groups 2 through 12 of the periodic table. Like the Group 1 elements, these elements are metals. Most have one, two, or three valence electrons. They react by losing these electrons, especially when they combine with oxygen or one of the halogens.

How reactive a metal is depends on how easily its atoms lose valence electrons. Some metals, such as those in Group 2 (the alkaline earth metals), lose electrons easily and are almost as reactive as the alkali metals of Group 1. Other metals, such as platinum (Pt) in Group 10 and gold (Au) in Group 11, are unreactive. In general, the reactivity of metals decreases from left to right across the periodic table. Among Groups 1 and 2, reactivity increases from top to bottom.

Science and History

Discovery of the Elements

In 1869, Dmitri Mendeleev published the first periodic table. At that time, 63 elements were known. Since then, scientists have discovered or created about 50 new elements.



1875
Gallium
The French chemist Paul-Émile Lecoq de Boisbaudran discovered an element that he called gallium. It had properties predicted by Mendeleev for an unknown element that would fit directly below aluminum in the periodic table.

1894
Argon, Neon, Krypton, and Xenon
British chemist William Ramsay discovered an element he named argon, after the Greek word for "lazy." The name fits because argon does not react with other elements. Ramsay looked for other nonreactive gases and discovered neon, krypton, and xenon.

1898
Polonium and Radium
Polish chemist Marie Curie started with three tons of uranium ore before she eventually isolated a few grams of two new elements. She named them polonium and radium.

1830 — 1865 — 1900

Other Nonmetals Elements in the green section of the periodic table are the nonmetals. Notice that, unlike the metals, most nonmetals are gases at room temperature. Five nonmetals are solids, and one is a liquid. All of the nonmetals have four or more valence electrons. Like the halogens, other nonmetals become stable when they gain or share enough electrons to have a set of eight valence electrons.

The nonmetals combine with metals usually by gaining electrons. But nonmetals can also combine with other nonmetals by sharing electrons. Of the nonmetals, oxygen and the halogens are highly reactive. In fact, fluorine is the most reactive element known. It even forms compounds with some of the noble gases.

Writing in Science

Research and Write Select three elements that interest you and find out more about them. Who identified or discovered the elements? How did the elements get their names? How are the elements used? To answer these questions, look up the elements in reference books.

1941
Plutonium
American chemist Glenn Seaborg was the first to isolate plutonium, which is found in small amounts in uranium ores. Plutonium is used as fuel in certain nuclear reactors. It has also been used to power equipment used in space exploration.

1939
Francium
Although Mendeleev predicted the properties of an element he called "eka-cesium," the element was not discovered until 1939. French chemist Marguerite Perey named her discovery francium, after the country France.

1997
Elements 101 to 109
The International Union of Pure and Applied Chemists (IUPAC) agreed on names for elements 101 to 109. Many of the names honor scientists, such as Lise Meitner, shown here in 1946. All of the new elements were created in laboratories, and none is stable enough to exist in nature.

2003 to Present
Darmstadtium
Element 110, first created in the mid-1990s, is named darmstadtium. Research to produce and study new synthetic elements continues.

1935 1970 2005

The quartz movement of the watch

FIGURE 6
A Metalloid at Work
This quartz-movement watch keeps time with a small quartz crystal, a compound made of the metalloid silicon and the nonmetal oxygen. The crystal vibrates at about 32,000 vibrations per second when a voltage is applied.

Metalloids Several elements known as metalloids lie along a zigzag line between the metals and nonmetals. The metalloids have from three to six valence electrons. They can either lose or share electrons when they combine with other elements. So, depending on the conditions, these elements can behave as either metals or nonmetals.

Hydrogen Notice that hydrogen is located above Group 1 in the periodic table. It is placed there because it has only one valence electron. However, hydrogen is considered to be a nonmetal. It is a reactive element, but its properties differ greatly from those of the alkali metals.

Reading Checkpoint **Why is hydrogen grouped above the Group 1 elements even though it is not a metal?**

Section 1 Assessment

Target Reading Skill Identifying Main Ideas Use your graphic organizer to help you answer Question 2 below.

Reviewing Key Concepts

1. a. **Defining** What are valence electrons?
   b. **Reviewing** What role do valence electons play in the formation of compounds from elements?
   c. **Comparing and Contrasting** Do oxygen atoms become more stable or less stable when oxygen forms compounds? Explain.
2. a. **Summarizing** Summarize how the periodic table is organized, and tell why this organization is useful.
   b. **Explaining** Why do the properties of elements change in a regular way across a period?
   c. **Relating Cause and Effect** How reactive are the elements in Group 18? Explain this reactivity in terms of the number of valence electrons.

Lab zone At-Home Activity

Looking for Elements Find some examples of elements at home. Then locate the elements on the periodic table. Show your examples and the periodic table to your family. Point out the positions of the elements on the table and explain what the periodic table tells you about the elements. Include at least two nonmetals in your discussion. (*Hint:* The nonmetals may be invisible.)