

Nonmetals and Metalloids

Reading Preview

Key Concepts

- What are the properties of nonmetals?
- How are the metalloids useful?

Key Terms

- nonmetal
- diatomic molecule
- halogen
- noble gas
- metalloid
- semiconductor

Target Reading Skill

Using Prior Knowledge Before you read, write what you know about the properties of nonmetals and metalloids in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. Nonmetals are not shiny.
2.


What You Learned
1.
2.

These bears, the grass behind them, and all life on Earth are based on carbon, a nonmetal. ▶

Lab
zone

Discover Activity

What Are the Properties of Charcoal?

1. Break off a piece of charcoal and roll it between your fingers. Record your observations.
2. Rub the charcoal on a piece of paper. Describe what happens.
3.  Strike the charcoal sharply with the blunt end of a fork. Describe what happens.
4. When you are finished with your investigation, return the charcoal to your teacher and wash your hands.

Think It Over

Classifying Charcoal is a form of the element carbon. Would you classify carbon as a metal or a nonmetal? Use your observations from this activity to explain your answer.

Life on Earth depends on certain nonmetal elements. The air you and other animals breathe contains several nonmetals, including oxygen. And all living organisms are made from compounds of the nonmetal carbon. Yet, while many compounds containing nonmetals are useful to life, some nonmetals by themselves are poisonous and highly reactive. Still other nonmetals are completely unreactive. Compared to metals, nonmetals have a much wider variety of properties. However, nonmetals do have several properties in common.



FIGURE 27

Physical Properties of Nonmetals

Nonmetals have properties that are the opposite of metals.

Comparing and Contrasting

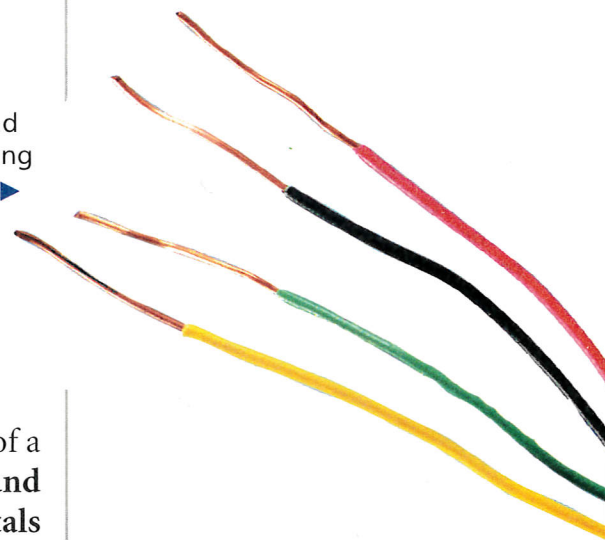
Contrast the properties of these nonmetals with those of metals.



◀ Sulfur crumbles into a powder.

▲ The helium filling this blimp is a gas at room temperature.

Nonmetals are good insulators. Carbon compounds are found in the plastic insulating these copper wires. ▶



Properties of Nonmetals

A **nonmetal** is an element that lacks most of the properties of a metal. **Most nonmetals are poor conductors of electricity and heat and are reactive with other elements. Solid nonmetals are dull and brittle.** Look at the periodic table again. All of the elements in green-tinted boxes are nonmetals. Many of the nonmetals are common elements on Earth.

Physical Properties Ten of the 16 nonmetals are gases at room temperature. The air you breathe is mostly a mixture of two nonmetals, nitrogen (N) and oxygen (O). Other nonmetal elements, such as carbon (C), iodine (I), and sulfur (S), are solids at room temperature. Bromine (Br) is the only nonmetal that is liquid at room temperature.

Look at examples of nonmetals in Figure 27. In general, the physical properties of nonmetals are the opposite of those of the metals. Solid nonmetals are dull, meaning not shiny, and brittle, meaning not malleable or ductile. If you hit most solid nonmetals with a hammer, they break or crumble into a powder. Nonmetals usually have lower densities than metals. And nonmetals are also poor conductors of heat and electricity.

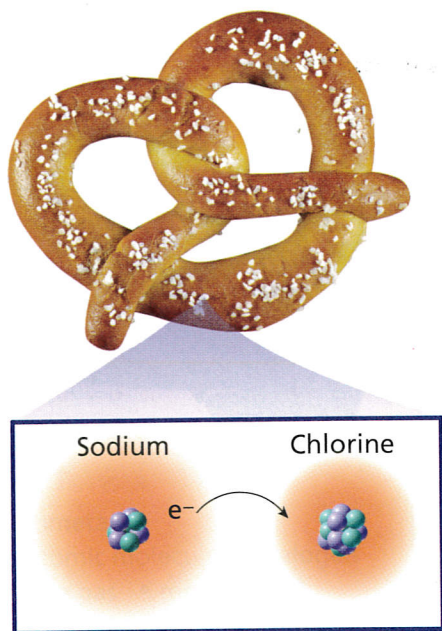


FIGURE 28
Reactions of Nonmetals
 The table salt on a pretzel is mined from deposits found on Earth. The same compound can also be formed from a reaction between the metal sodium and the nonmetal chlorine.

14
6 C Carbon
14 Si Silicon
32 Ge Germanium
50 Sn Tin
82 Pb Lead



Chemical Properties Most nonmetals are reactive, so they readily form compounds. In fact, fluorine (F) is the most reactive element known. Yet, Group 18 elements hardly ever form compounds.

Atoms of nonmetals usually gain or share electrons when they react with other atoms. When nonmetals and metals react, electrons move from the metal atoms to the nonmetal atoms, as shown by the formation of salt, shown in Figure 28. Another example is rust—a compound made of iron and oxygen (Fe_2O_3). It's the reddish, flaky coating you might see on an old piece of steel or an iron nail.

Many nonmetals can also form compounds with other nonmetals. The atoms share electrons and become bonded together into molecules.



In which portion of the periodic table do you find nonmetals?

Families of Nonmetals

Look again at the periodic table. Notice that only Group 18 contains elements that are all nonmetals. In Groups 14 through 17, there is a mix of nonmetals and other kinds of elements.

The Carbon Family Each element in the carbon family has atoms that can gain, lose, or share four electrons when reacting with other elements. In Group 14, only carbon is a nonmetal. What makes carbon especially important is its role in the chemistry of life. Compounds made of molecules containing long chains of carbon atoms are found in all living things.

Most of the fuels that are burned to yield energy contain carbon. Coal, for example, is mostly the element carbon. Gasoline is made from crude oil, a mixture of carbon compounds with chains of 5 to 50 or more carbon atoms in their molecules.

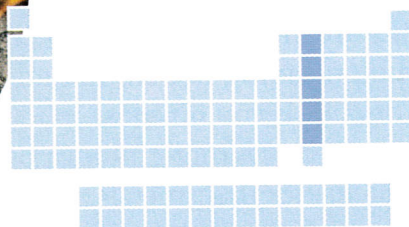


FIGURE 29
Carbon
 Charcoal is one form of carbon, the only nonmetal in Group 14.

The Nitrogen Family Group 15, the nitrogen family, contains two nonmetals, nitrogen and phosphorus. These nonmetals usually gain or share three electrons when reacting with other elements. To introduce yourself to nitrogen, take a deep breath. The atmosphere is almost 80 percent nitrogen gas (N_2). Nitrogen does not readily react with other elements, so you breathe out as much nitrogen as you breathe in.

Nitrogen is an example of an element that occurs in nature in the form of diatomic molecules, as N_2 . A **diatomic molecule** consists of two atoms. In this form, nitrogen is not very reactive. Although living things need nitrogen, most of them are unable to use nitrogen from the air. However, certain kinds of bacteria can use this nitrogen to form compounds. This process is called nitrogen fixation. Plants can then take up these nitrogen compounds formed in the soil by the bacteria. Farmers also add nitrogen compounds to the soil in the form of fertilizers. Like all animals, you get the nitrogen you need from the food you eat—from plants, or from animals that ate plants.

Phosphorus is the other nonmetal in the nitrogen family. Phosphorus is much more reactive than nitrogen, so phosphorus in nature is always found in compounds. A compound containing phosphorus is used to make matches, because it can react with oxygen in the air.

7	N	Nitrogen
15	P	Phosphorus
33	As	Arsenic
51	Sb	Antimony
83	Bi	Bismuth

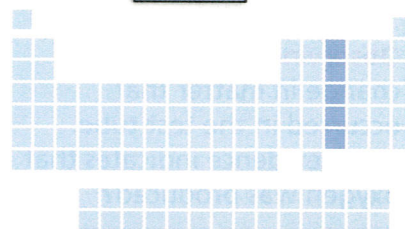


FIGURE 30
The Nitrogen Family

Nitrogen and phosphorus are grouped in the same family of the periodic table, Group 15. **Making Generalizations**
How do atoms of both these elements change when they react?



▼ Nitrogen is a key ingredient of fertilizers.



▲ Match heads contain a highly reactive phosphorus compound that ignites easily.

Show Me the Oxygen

How can you test for the presence of oxygen?

1.  Pour about a 3-cm depth of hydrogen peroxide (H_2O_2) into a test tube.
2. Add a pea-sized amount of manganese dioxide (MnO_2) to the test tube.
3. Observe the test tube for about 1 minute.
4.  When instructed by your teacher, set a wooden splint on fire.
5. Blow the splint out after 5 seconds and immediately plunge the glowing splint into the mouth of the test tube. Avoid getting the splint wet.

Observing Describe the change in matter that occurred in the test tube. What evidence indicates that oxygen was produced?

The Oxygen Family Group 16, the oxygen family, contains three nonmetals—oxygen, sulfur, and selenium. These elements usually gain or share two electrons when reacting with other elements.

You are using oxygen right now. With every breath, oxygen travels into your lungs. There, it is absorbed into your bloodstream, which distributes it all over your body. You could not live without a steady supply of oxygen. Like nitrogen, the oxygen you breathe is a diatomic molecule (O_2). In addition, oxygen sometimes forms a triatomic (three-atom) molecule, which is called ozone (O_3). Ozone collects in a layer in the upper atmosphere, where it screens out harmful radiation from the sun. However, ozone is a dangerous pollutant at ground level because it is highly reactive.

Because oxygen is highly reactive, it can combine with almost every other element. It also is the most abundant element in Earth's crust and the second-most abundant element in the atmosphere. (The first is nitrogen.)

Sulfur is the other common nonmetal in the oxygen family. If you have ever smelled the odor of a rotten egg, then you are already familiar with the smell of some sulfur compounds. Sulfur is used in the manufacture of rubber for rubber bands and automobile tires. Most sulfur is used to make sulfuric acid (H_2SO_4), one of the most important chemicals used in industry.

FIGURE 31

The Oxygen Family

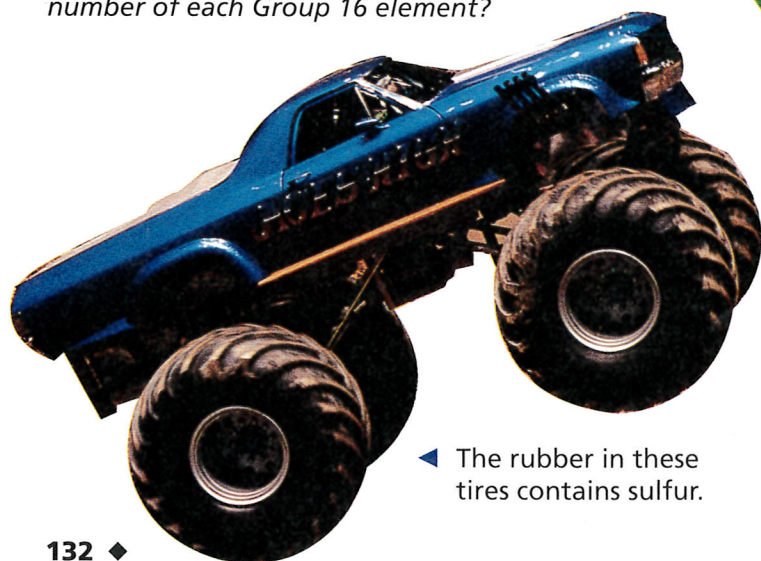
Oxygen and sulfur are the most common of the three nonmetals in Group 16.

Interpreting Tables What is the atomic number of each Group 16 element?



▲ Some of the oxygen needed by a frog enters through its skin.

16
8
O
Oxygen
16
S
Sulfur
34
Se
Selenium
52
Te
Tellurium
84
Po
Polonium



◀ The rubber in these tires contains sulfur.

The Halogen Family Group 17 contains fluorine, chlorine, bromine, iodine, and astatine. These elements are also known as the **halogens**, which means “salt forming.” All but astatine are nonmetals, and all share similar properties. A halogen atom typically gains or shares one electron when it reacts with other elements.

All of the halogens are very reactive, and the uncombined elements are dangerous to humans. Fluorine is so reactive that it reacts with almost every other known substance. Even water and powdered glass will burn in fluorine. Chlorine gas is extremely dangerous, but it is used in small amounts to kill bacteria in water supplies.

Though the halogen elements are dangerous, many of the compounds that halogens form are quite useful. Compounds of carbon and fluorine make up the nonstick coating on cookware. Small amounts of fluorine compounds that are added to water supplies help prevent tooth decay. Chlorine is one of the elements in ordinary table salt (the other is sodium). Another salt of chlorine, calcium chloride, is used to help melt ice on roads and walkways. Bromine reacts with silver to form silver bromide, which is used in photographic film.

Go Online

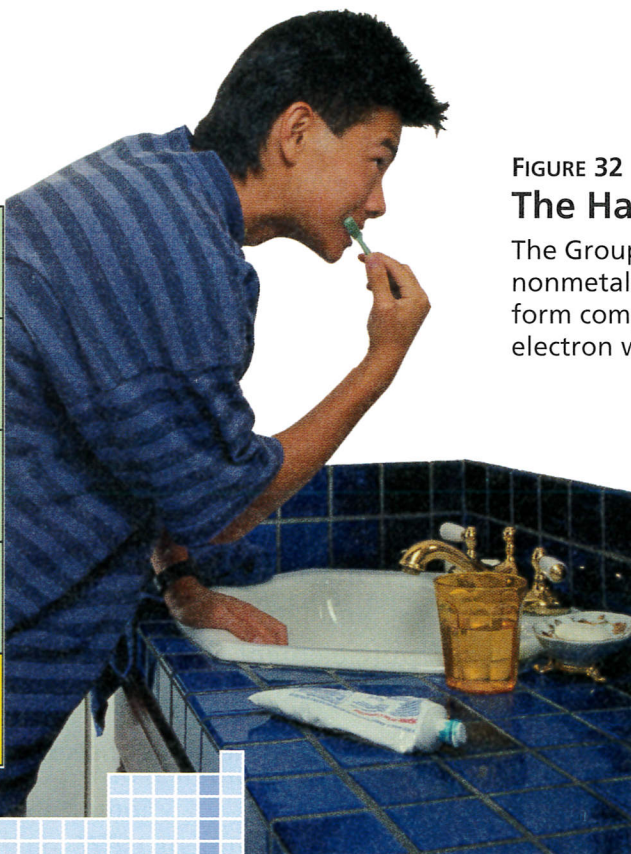
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17
9 F Fluorine
17 Cl Chlorine
35 Br Bromine
53 I Iodine
85 At Astatine



▲ Fluorine-containing compounds are found in toothpaste.

FIGURE 32 The Halogens

The Group 17 elements are the most reactive nonmetals. Atoms of these elements easily form compounds by sharing or gaining one electron with atoms of other elements.



◀ Bromine is highly reactive, and will burn skin on contact.

FIGURE 33 The Noble Gases
Electricity makes the Group 18 elements glow brightly inside glass tubes. **Applying Concepts**
Why are neon and the other noble gases so unreactive?

2	He Helium
10	Ne Neon
18	Ar Argon
36	Kr Krypton
54	Xe Xenon
86	Rn Radon



The Noble Gases The elements in Group 18 are known as the **noble gases**. They do not ordinarily form compounds because atoms of noble gases do not usually gain, lose, or share electrons. As a result, the noble gases are usually unreactive. Even so, scientists have been able to form some compounds of the heavy noble gases (Kr, Xe) in the laboratory.

All the noble gases exist in Earth's atmosphere, but only in small amounts. Because they are so unreactive, the noble gases were not discovered until the late 1800s. Helium was discovered by a scientist who was studying not the atmosphere but the sun.

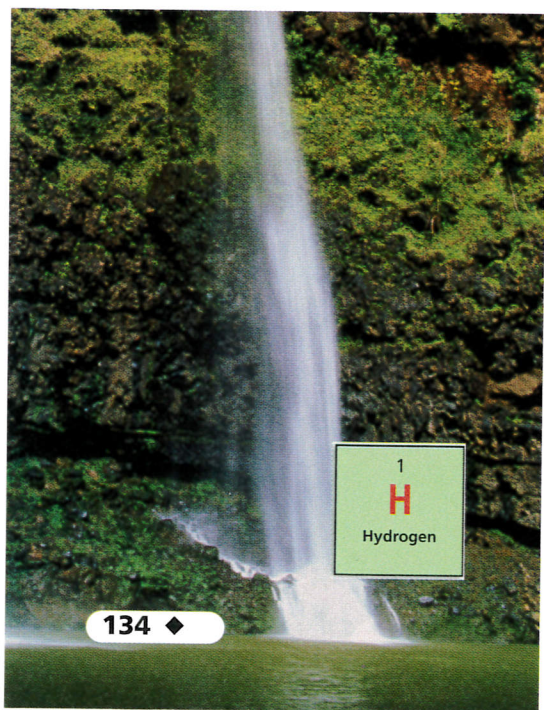
Have you made use of a noble gas? You have if you have ever purchased a floating balloon filled with helium. Noble gases are also used in glowing electric lights. These lights are commonly called neon lights, even though they are often filled with argon, xenon, or other noble gases.

Hydrogen Alone in the upper left corner of the periodic table is hydrogen—the element with the simplest and smallest atoms. Each hydrogen atom has one proton and one electron. Some hydrogen atoms also have neutrons. Because the chemical properties of hydrogen differ very much from those of the other elements, it really cannot be grouped into a family. Although hydrogen makes up more than 90 percent of the atoms in the universe, it makes up only 1 percent of the mass of Earth's crust, oceans, and atmosphere. Hydrogen is rarely found on Earth as a pure element. Most hydrogen is combined with oxygen in water (H_2O).



Reading Checkpoint

Why were the noble gases undiscovered until the late 1800s?



1	H Hydrogen
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FIGURE 34

Importance of Hydrogen

Water is a compound of hydrogen and oxygen.

Without liquid water, life on Earth would be impossible.

The Metalloids

Along the border between the metals and the nonmetals are seven elements called metalloids. These elements are shown in the yellow squares in the periodic table. The **metalloids** have some characteristics of both metals and nonmetals. All are solids at room temperature. They are brittle, hard, and somewhat reactive.

The most common metalloid is silicon (Si). Silicon combines with oxygen to form silicon dioxide (SiO_2). Ordinary sand, which is mostly SiO_2 , is the main component of glass. A compound of boron (B) and oxygen is added during the process of glassmaking to make heat-resistant glass. Compounds of boron are also used in some cleaning materials.

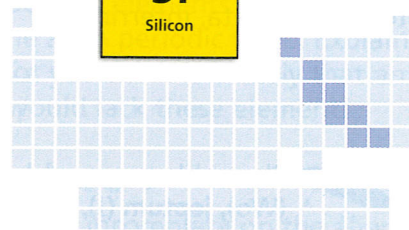
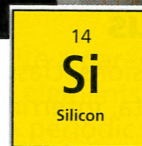
The most useful property of the metalloids is their **varying ability to conduct electricity**. Whether or not a metalloid conducts electricity can depend on temperature, exposure to light, or the presence of small amounts of impurities. For this reason, metalloids such as silicon, germanium (Ge), and arsenic (As) are used to make semiconductors. **Semiconductors** are substances that can conduct electricity under some conditions but not under other conditions. Semiconductors are used to make computer chips, transistors, and lasers.



What is the most common metalloid, and where is it found?

FIGURE 35 Silicon

A silicon computer chip is dwarfed by an ant, but the chip's properties as a semiconductor make it a powerful part of modern computers.



Section 4 Assessment

Target Reading Skill Using Prior Knowledge Review your graphic organizer about nonmetals and metalloids, and revise it based on what you learned in the section.

Reviewing Key Concepts

- Reviewing** What physical and chemical properties are found among the nonmetals?
 - Making Generalizations** What happens to the atoms of most nonmetals when they react with other elements?
 - Comparing and Contrasting** How do the physical and chemical properties of the halogens compare with those of the noble gases?
- Identifying** Where in the periodic table are the metalloids found?
 - Describing** What are three uses of metalloids?
 - Applying Concepts** What property makes certain metalloids useful as “switches” to turn a small electric current on and off?

Lab
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At-Home Activity

Halogen Hunt Identify compounds in your home that contain halogens. Look at labels on foods, cooking ingredients, cleaning materials, medicines, and cosmetics. The presence of a halogen is often indicated by the words *fluoride*, *chloride*, *bromide*, and *iodide* or the prefixes *fluoro-*, *chloro-*, *bromo-*, and *iodo-*. Show your family these examples and describe properties of the halogens.