

Lesson 3

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- Where are nonmetals and metalloids on the periodic table?
- What are the properties of nonmetals and metalloids?

Vocabulary

nonmetal p. 363

halogen p. 365

noble gas p. 366


metalloid p. 367

semiconductor p. 367



Multilingual eGlossary

Nonmetals and Metalloids



Inquiry

Why don't they melt?

What do you expect to happen to something when a flame is placed against it? As you can see, the nonmetal material this flower sits on protects the flower from the flame. Some materials conduct thermal energy. Other materials, such as this one, do not.



Launch Lab

20 minutes

What are some properties of nonmetals?



You now know what the properties of metals are. What properties do nonmetals have?

- 1 Read and complete a lab safety form.
- 2 Examine pieces of **copper, carbon, aluminum, and sulfur**. Describe the appearance of these elements in your Science Journal.
- 3 Use a **conductivity tester** to check how well these elements conduct electricity. Record your observations.
- 4 Wrap each element sample in a **paper towel**. Carefully hit the sample with a **hammer**. Unwrap the towel and observe the sample. Record your observations.



Think About This

1. Locate these elements on the periodic table. From their locations, which elements are metals? Which elements are nonmetals?
2. **Key Concept** Using your results, compare the properties of metals and nonmetals.
3. **Key Concept** What property of a nonmetal makes it useful to insulate electrical wires?

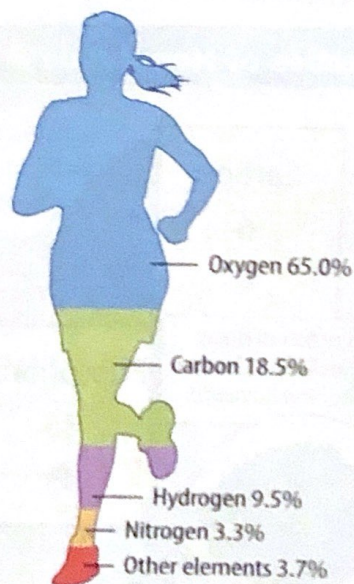
The Elements of Life

Would it surprise you to learn that more than 96 percent of the mass of your body comes from just four elements? As shown in **Figure 12**, all four of these elements—oxygen, carbon, hydrogen, and nitrogen—are nonmetals. **Nonmetals** are elements that have no metallic properties.

Of the remaining elements in your body, the two most common elements also are nonmetals—phosphorus and sulfur. These six elements form the compounds in proteins, fats, nucleic acids, and other large molecules in your body and in all other living things.

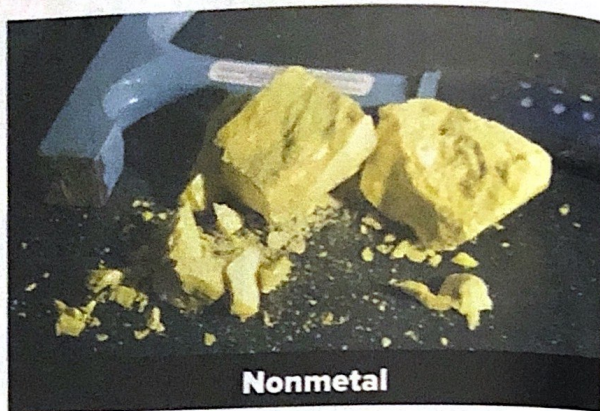
- Reading Check** What are the six most common elements in the human body?

Figure 12 Like other living things, this woman's mass comes mostly from nonmetals.





Metal



Nonmetal

▲ **Figure 13** Solid metals, such as copper, are malleable. Solid nonmetals, such as sulfur, are brittle.

How are nonmetals different from metals?

Recall that metals have luster. They are ductile, malleable, and good conductors of electricity and thermal energy. All metals except mercury are solids at room temperature.



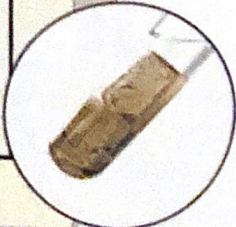
The properties of nonmetals are different from those of metals. Many nonmetals are gases at room temperature. Those that are solid at room temperature have a dull surface, which means they have no luster. Because nonmetals are poor conductors of electricity and thermal energy, they are good insulators. For example, nose cones on space shuttles are insulated from the intense thermal energy of reentry by a material made from carbon, a nonmetal. **Figure 13** and **Figure 14** show several properties of nonmetals.

Figure 14 Nonmetals have properties that are different from those of metals. Phosphorus and carbon are dull, brittle solids that do not conduct thermal energy or electricity. ▼



Key Concept Check What properties do nonmetals have?

Properties of Nonmetals

Carbon 6 C	Oxygen 8 O	2 He
Carbon occurs in many forms, including charcoal, graphite, and diamond.	Phosphorus 15 P	9 Fluorine Fe
	There are two common forms of phosphorus. The white form, shown here, is stored in a liquid because it bursts into flames when exposed to oxygen.	10 Neon Ne
		
		
	11 Ga	12 Zn
	32 Germanium Ge	33 Arsenic As
		34 Selenium Se
		35 Bromine Br

Visual Check Compare the properties of oxygen to those of carbon and phosphorus.



Figure 15 These glass containers each hold a halogen gas. Although they are different colors in their gaseous state, they react similarly with other elements.

Visual Check Compare the colors of these halogens.

Nonmetals in Groups 14–16

Look back at the periodic table in **Figure 4**. Notice that groups 14–16 contain metals, nonmetals, and metalloids. The chemical properties of the elements in each group are similar. However, the physical properties of the elements can be quite different.

Carbon is the only nonmetal in group 14. It is a solid that has different forms. Carbon is in most of the compounds that make up living things. Nitrogen, a gas, and phosphorus, a solid, are the only nonmetals in group 15. These two elements form many different compounds with other elements, such as oxygen. Group 16 contains three nonmetals. Oxygen is a gas that is essential for many organisms. Sulfur and selenium are solids that have the physical properties of other solid nonmetals.

Group 17: The Halogens

An element in group 17 of the periodic table is called a **halogen** (HA luh jun). **Figure 15** shows the halogens fluorine, chlorine, bromine, and iodine. The term *halogen* refers to an element that can react with a metal and form a salt. For example, chlorine gas reacts with solid sodium and forms sodium chloride, or table salt. Calcium chloride is another salt often used on icy roads.

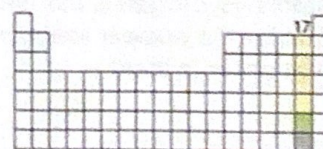
Halogens react readily with other elements and form compounds. They react so readily that halogens only can occur naturally in compounds. They do not exist as free elements. They even form compounds with other nonmetals, such as carbon. In general, the halogens are less reactive as you move down the group.

Reading Check Will bromine react with sodium? Explain your answer.

FOLDABLES

Fold a sheet of paper to make a table with three columns and three rows. Label it as shown. Use it to organize information about nonmetals and metalloids.

	Nonmetals	Metalloids
Properties		
Uses		



WORD ORIGIN

halogen
from Greek *hals*, means "salt";
and *-gen*, means "to produce"



Group 18: The Noble Gases

The elements in group 18 are known as the **noble gases**. The elements helium, neon, argon, krypton, xenon, and radon are the noble gases. Unlike the halogens, the only way elements in this group react with other elements is under special conditions in a laboratory. These elements were not yet discovered when Mendeleev **constructed** his periodic table because they do not form compounds naturally. Once they were discovered, they fit into a group at the far right side of the table.

ACADEMIC VOCABULARY

construct

(verb) to make by combining and arranging parts

Hydrogen

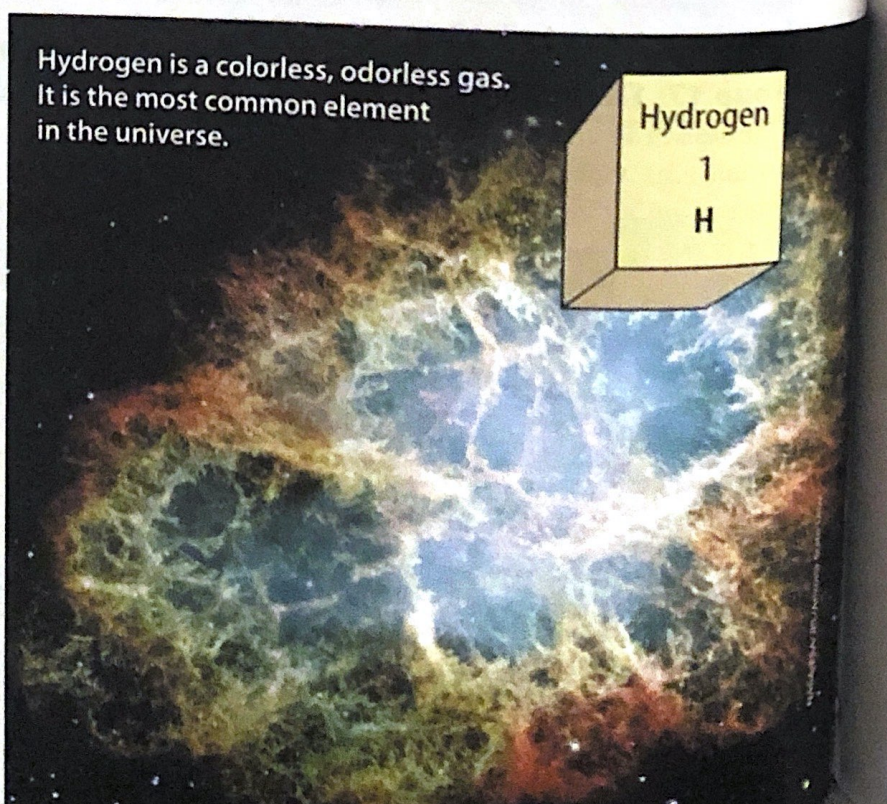
Figure 16 shows the element key for hydrogen. Of all the elements, hydrogen has the smallest atomic mass. It is also the most common element in the universe.

Is hydrogen a metal or a nonmetal? Hydrogen is most often classified as a nonmetal because it has many properties like those of nonmetals. For example, like some nonmetals, hydrogen is a gas at room temperature. However, hydrogen also has some properties similar to those of the group 1 alkali metals. In its liquid form, hydrogen conducts electricity just like a metal does. In some chemical reactions, hydrogen reacts as if it were an alkali metal. However, under conditions on Earth, hydrogen usually behaves like a nonmetal.




Reading Check Why is hydrogen usually classified as a nonmetal?

Figure 16 More than 90 percent of all the atoms in the universe are hydrogen atoms. Hydrogen is the main fuel for the nuclear reactions that occur in stars.



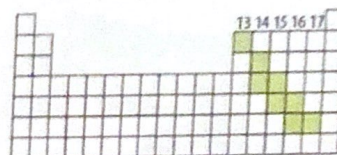
Metalloids

Between the metals and the nonmetals on the periodic table are elements known as metalloids. A **metalloid** (MEH tul oyd) is an element that has physical and chemical properties of both metals and nonmetals. The elements boron, silicon, germanium, arsenic, antimony, tellurium, polonium, and astatine are metalloids. Silicon is the most abundant metalloid in the universe. Most sand is made of a compound containing silicon. Silicon is also used in many different products, some of which are shown in Figure 17.

 **Key Concept Check** Where are metalloids on the periodic table?

Semiconductors

Recall that metals are good conductors of thermal energy and electricity. Nonmetals are poor conductors of thermal energy and electricity but are good insulators. A property of metalloids is the ability to act as a semiconductor. A **semiconductor** conducts electricity at high temperatures, but not at low temperatures. At high temperatures, metalloids act like metals and conduct electricity. But at lower temperatures, metalloids act like nonmetals and stop electricity from flowing. This property is useful in electronic devices such as computers, televisions, and solar cells.

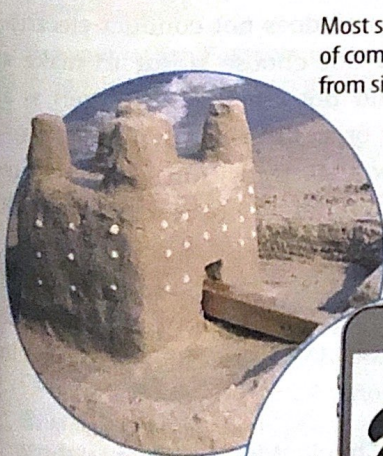


WORD ORIGIN

semiconductor
from Latin *semi-*, means "half"; and *conducere*, means "to bring together"

Figure 17 The properties of silicon make it useful for many different products.

Uses of Silicon



Most sand is composed of compounds formed from silicon and oxygen.



Silicon is a major ingredient in glass.



Silicon is used in the parts of many electronic devices.



Silicon is an important ingredient used to make medical tubing.



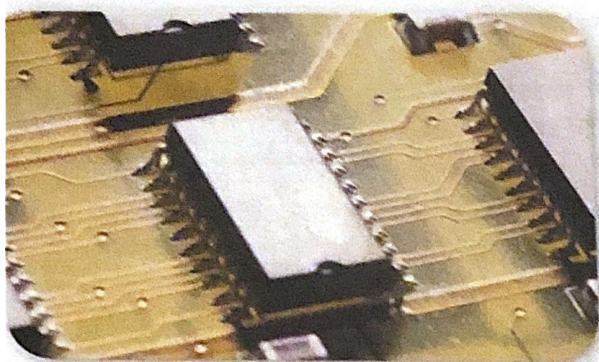


Figure 18 This microchip conducts electricity at high temperatures using a semiconductor.



Personal Tutor



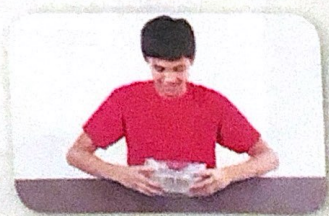
MiniLab

15 minutes


Which insulates better?

In this lab, you will compare how well a metal bowl and a nonmetal ball containing a mixture of nonmetals conduct thermal energy.

- 1 Read and complete a lab safety form.
- 2 Pour **very warm water** into a **pitcher**.
- 3 Pour half of the warm water into a **metal bowl**. In your Science Journal, describe how the outside of the bowl feels.
- 4 Inflate a **beach ball** until it is one-third full. Mold the partially filled beach ball into the shape of a bowl. Pour the remaining warm water into your beach ball bowl. Feel the outside of the bowl. Describe how it feels.



Analyze and Conclude

1. **Explain** the difference in the outside temperatures of the two bowls.
2. **Predict** the results of putting ice in each of the bowls.
3.  **Key Concept** Make a statement about how well a nonmetal conducts thermal energy.


Properties and Uses of Metalloids

Pure silicon is used in making semiconductor devices for computers and other electronic products. Germanium is also used as a semiconductor as shown in **Figure 18**. Other metalloids have different uses. Boron is used in water softeners and laundry products. Boron also glows bright green in fireworks. Silicon is one of the most abundant elements on Earth. Sand, clay, and many rocks and minerals are made of silicon compounds.

Metals, Nonmetals, and Metalloids


You have read that all metallic elements have common characteristics, such as malleability, conductivity, and ductility. However, each metal has unique properties that make it different from other metals. The same is true for nonmetals and metalloids. How can knowing the properties of an element help you evaluate its uses?

Look again at the periodic table. An element's position on the periodic table tells you a lot about the element. By knowing that sulfur is a nonmetal, for example, you know that it breaks easily and does not conduct electricity. You would not choose sulfur to make a wire. You would not try to use oxygen as a semiconductor or sodium as a building material. You know that transition elements are strong, malleable, and do not react easily with oxygen or water. Because of these characteristics, these metals make good building materials. Understanding the properties of elements can help you decide which element to use in a given situation.

-  **Reading Check** Why would you not use an element on the right side of the periodic table as a building material?



Lesson 3 Review

 Online Quiz

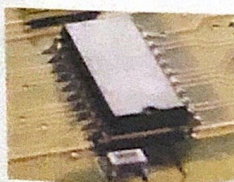
Visual Summary



A nonmetal is an element that has no metallic properties. Solid nonmetals are dull, brittle, and do not conduct thermal energy or electricity.



Halogens and noble gases are nonmetals. These elements are found in group 17 and group 18 of the periodic table.



Metalloids have some metallic properties and some nonmetallic properties. The most important use of metalloids is as semiconductors.

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.

5. Most of the elements in living things are nonmetals.
6. Even though they look very different, oxygen and sulfur share some similar properties.

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

Use Vocabulary

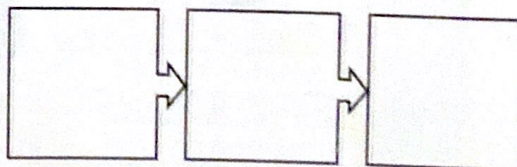
- 1 **Distinguish** between a nonmetal and a metalloid.
- 2 An element in group 17 of the periodic table is called a(n) _____.
- 3 An element in group 18 of the periodic table is called a(n) _____.

Understand Key Concepts

- 4 The ability of a halogen to react with a metal to form a salt is an example of a _____ property.
A. chemical C. periodic
B. noble gas D. physical
- 5 **Classify** each of the following elements as a metal, a nonmetal, or a metalloid: boron, carbon, aluminum, and silicon.
- 6 **Infer** which group you would expect to contain element 120. Use the periodic table to help you answer this question.

Interpret Graphics

- 7 **Sequence** nonmetals, metals, and metalloids in order from left to right across the periodic table by copying and completing the graphic organizer below.



Critical Thinking

- 8 **Hypothesize** how your classroom would be different if there were no metalloids.
- 9 **Analyze** why hydrogen is sometimes classified as a metal.
- 10 **Determine** whether there are more nonmetals in group 14 or in group 16. Explain your answer.