



LESSON

4

Nonmetals and Metalloids



- What Are the Properties of Nonmetals?
- What Are the Families Containing Nonmetals?



my planet DiARY

MISCONCEPTION

Something in the Air

A common misconception is that the air in the atmosphere is mostly oxygen.

Fact: At sea level, air is actually only about 21 percent oxygen by volume. Nitrogen makes up about 78 percent of the atmosphere. The remaining one percent is made up of several gases, including argon and carbon dioxide.

Evidence: Oxygen is actually toxic at high concentrations. If you breathed in pure oxygen, you would eventually get very sick.



Communicate Write your answer to each question below. Then discuss your answers with a partner.

1. Why don't scuba divers fill their tanks with pure oxygen?

2. Can you think of anything else that is good for you in small amounts but bad for you in large amounts?

PLANET DIARY Go to Planet Diary to learn more about nonmetals.



Do the Inquiry Warm-Up What Are the Properties of Charcoal?

Vocabulary

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

Skills

- 🎯 Reading: Summarize
- 🔍 Inquiry: Classify

What Are the Properties of Nonmetals?

Life on Earth depends on many nonmetals. For example, carbon (C), nitrogen (N), phosphorus (P), hydrogen (H), and oxygen (O) are all nonmetal elements found in your body's DNA. A model of DNA is shown in **Figure 1**. While many compounds made with nonmetals are essential to life, some nonmetals are poisonous and highly reactive. Still others are nonreactive. Compared to metals, nonmetals have a much wider variety of properties. However, nonmetals do have several properties in common.

Physical Properties A **nonmetal** is an element that lacks most of the properties of a metal. Except for hydrogen, the nonmetals are found on the right side of the periodic table. 🗝️ **In general, most nonmetals are poor conductors of electric current and heat. Solid nonmetals tend to be dull and brittle.** If you were to hit most solid nonmetals with a hammer, they would break or crumble into a powder. Also, nonmetals usually have lower densities than metals.

Many nonmetals are gases at room temperature. The air you breathe contains mostly nitrogen and oxygen. Some nonmetal elements, such as carbon, sulfur (S), and iodine (I), are solids at room temperature. Bromine (Br) is the only nonmetal that is a liquid at room temperature.

FIGURE 1

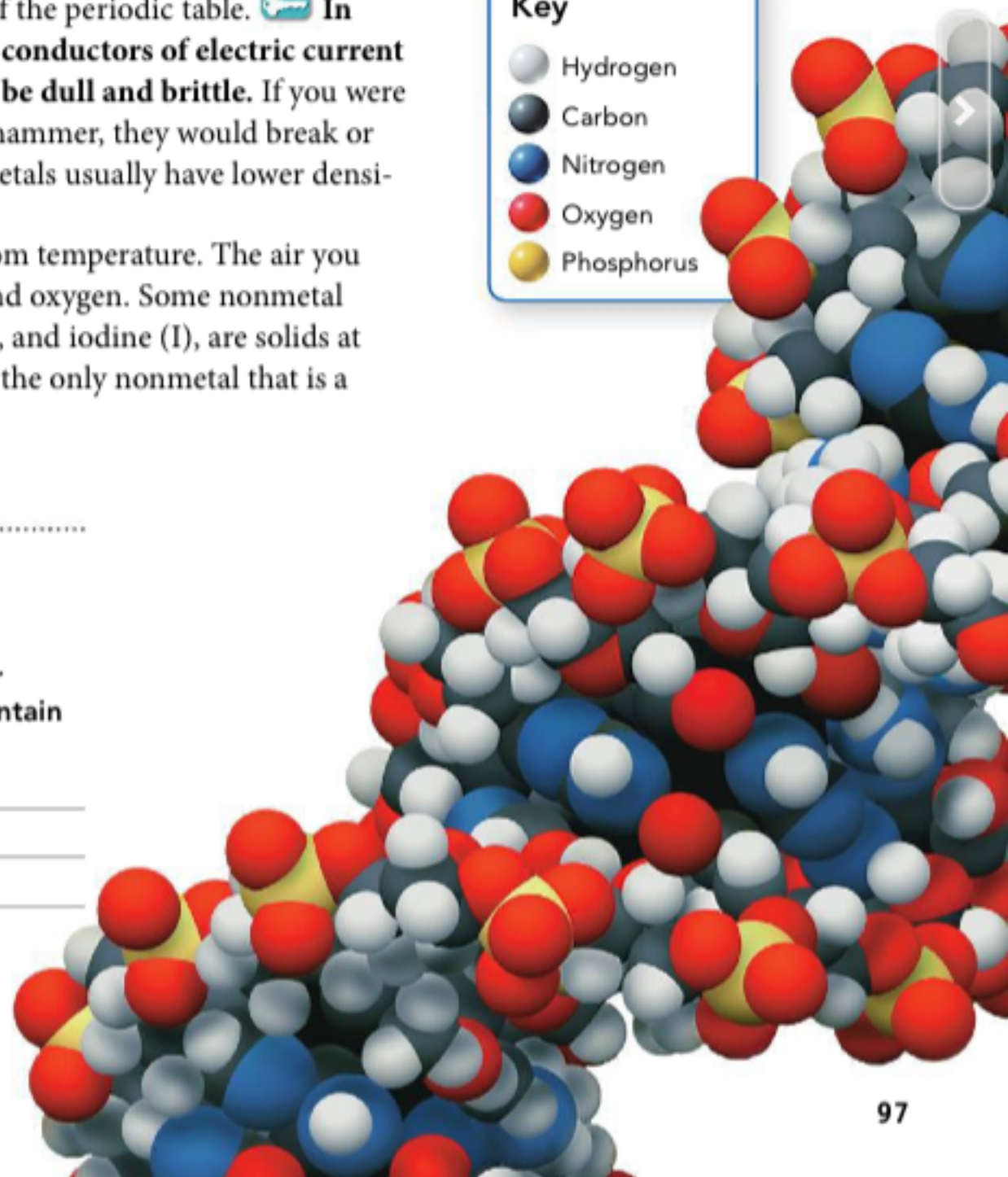
DNA

DNA, which is made up of atoms of nonmetals, is essential to life.

🖋️ **Identify** Can you think of other substances essential to life that contain nonmetals?

Key

- 👉 Hydrogen
- 👉 Carbon
- 👉 Nitrogen
- 👉 Oxygen
- 👉 Phosphorus





Chemical Properties 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. For example, when sodium and chlorine react to form table salt (NaCl), an electron moves from the sodium atom to the chlorine atom.

Many nonmetals can form compounds with other nonmetals. In these types of compounds, the atoms share their electrons to form bonds. When two or more atoms bond this way, they form a molecule. A water (H₂O) molecule consists of two hydrogen atoms and one oxygen atom.

apply it!

Most properties of nonmetals are the opposite of the properties of metals.

1 Compare and Contrast Complete the table about the properties of metals and nonmetals.

2 Observe Sulfur, shown at the right, is a nonmetal. What properties can you observe from the photo? What additional properties can you predict?

Properties of Metals	Properties of Nonmetals
Shiny	Dull
Malleable	_____
Good conductors of electric current	_____
_____	Poor conductors of heat



Do the Quick Lab
Carbon—A Nonmetal.

Assess Your Understanding

1a. Identify What property of nonmetals is the opposite of being *malleable* and *ductile*?

b. Make Generalizations What happens to the atoms of most nonmetals when they react with other elements?


got it?

I get it! Now I know that the physical properties of nonmetals are that _____

I need extra help with _____

Go to **my science** **COACH** online for help with this subject.

What Are the Families Containing Nonmetals?

Look back at the periodic table. There are nonmetals in Group 1 and in Groups 14–18.  **The families containing nonmetals include the carbon family, the nitrogen family, the oxygen family, the halogen family, the noble gases, and hydrogen.**


Before you read about the families containing nonmetals, refer to the periodic table to complete the table below.

Family	Group	Nonmetals in Family
Carbon family	14	_____
Nitrogen family	15	_____
Oxygen family	16	_____
Halogen family	17	_____
Noble gases	18	_____
Hydrogen	1	_____

The Carbon Family In Group 14, only carbon is a non-metal. Carbon is especially important in its role in the chemistry of life. Proteins, DNA, and fats all contain carbon.

Most of the fuels that are burned to yield energy contain carbon. Coal contains large amounts of carbon. Gasoline is made from crude oil, a mixture of carbon compounds with one carbon atom to chains of several hundred carbon atoms. A diamond, which is shown in **Figure 2**, is made of pure carbon.



 **Shade in the nonmetal in Group 14 on the periodic table.**

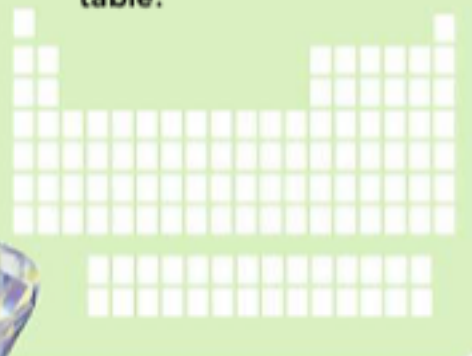


FIGURE 2
Diamond
Diamonds are made of pure carbon.

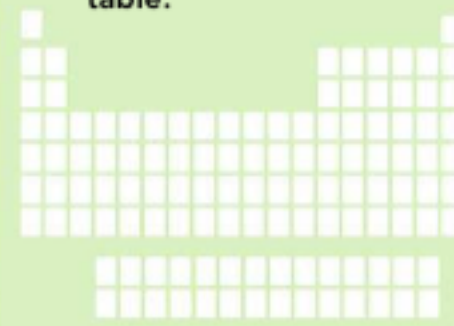


The Nitrogen Family

Group 15, the nitrogen family, contains two nonmetals, nitrogen and phosphorus. Nitrogen makes up about 78 percent of Earth's atmosphere by volume. In nature, nitrogen exists as two nitrogen atoms bonded together to form a diatomic molecule, N_2 . A **diatomic molecule** is made up of two atoms. In this form, nitrogen is not very reactive.



Shade in the nonmetals in Group 15 on the periodic table.



Although living things need nitrogen, most of them are unable to use nitrogen from the air. However, certain kinds of bacteria can use the nitrogen from the air to form compounds. This process is called nitrogen fixation. Plants can then take in these nitrogen compounds formed by the bacteria in the soil. Farmers also add nitrogen compounds to the soil in the form of fertilizers. Lightning, shown in **Figure 3**, also converts nitrogen in the atmosphere into a form that can be used by plants.

Phosphorus is the other nonmetal in the nitrogen family. Much more reactive than nitrogen, phosphorus in nature is always found in compounds.

FIGURE 3

Lightning

The energy released in the atmosphere in the form of lightning is able to break the bonds between nitrogen atoms, causing them to react with oxygen. Plants are able to use the nitrogen in this form.



CHALLENGE How do you get the nitrogen you need?

7

N

Nitrogen
14.007

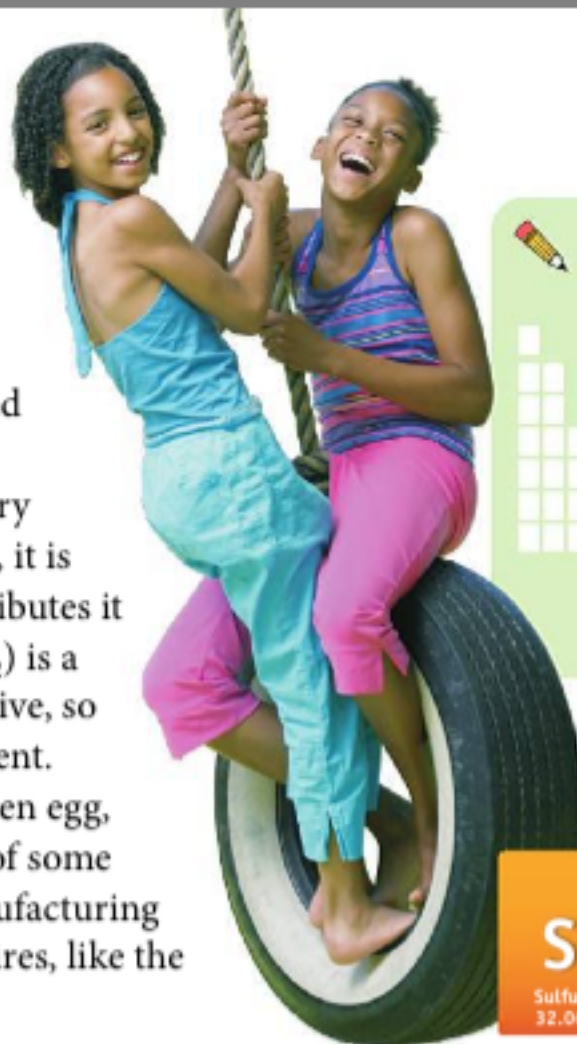




The Oxygen Family Group 16, the oxygen family, contains three nonmetals—oxygen, sulfur, and selenium (Se). Oxygen is a gas at room temperature, whereas sulfur and selenium are both solids.

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. Like nitrogen, oxygen (O_2) is a diatomic molecule. Oxygen is relatively reactive, so it can combine with almost every other element.

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 manufacturing of rubber for rubber bands and automobile tires, like the one shown in **Figure 4**.



Shade in the nonmetals in Group 16 on the periodic table.

FIGURE 4
Rubber Tires
Automobile tires are made out of rubber that contains sulfur compounds.

The Halogen Family Group 17 contains the nonmetals fluorine (F), chlorine (Cl), bromine, and iodine. These elements are also known as the **halogens**, which means “salt forming.” The properties of astatine (At) are unknown because it is extremely rare.

All of the halogens are very reactive. Fluorine is the most reactive of all the elements. It is so reactive that it reacts with almost every known substance, including water. 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 fluorine make up the nonstick coating on cookware. Fluorine compounds are also found in toothpaste, which is shown in **Figure 5**, because they help prevent tooth decay.

Shade in the nonmetals in Group 17 on the periodic table.

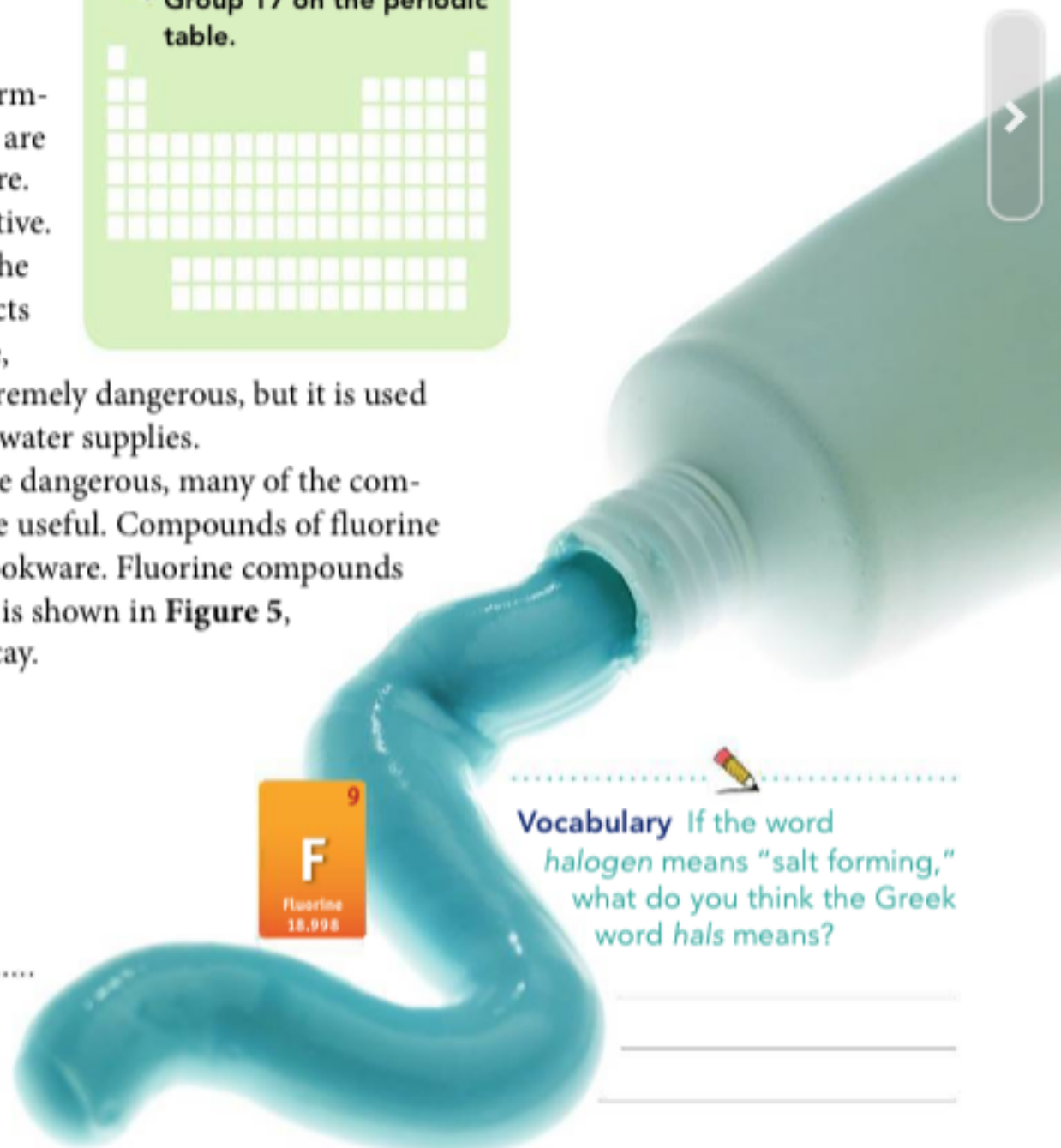


FIGURE 5
Toothpaste
Toothpastes often contain fluorine compounds.

Vocabulary If the word *halogen* means “salt forming,” what do you think the Greek word *hals* means?

He Ne Ar Kr Xe

FIGURE 6

Neon Lights

Glowing electric lights are often called “neon lights” even though they are usually filled with other noble gases or mixtures of them. The lights above show the symbols for helium (He), neon (Ne), argon (Ar), krypton (Kr), and xenon (Xe).

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 nonreactive. Even so, scientists have been able to synthesize some noble gas compounds in the laboratory.

You have probably seen a floating balloon filled with helium (He). Noble gases are also used in glowing electric lights, such as the ones shown in Figure 6.



Shade in the noble gases on the periodic table.



Shade in hydrogen on the periodic table.



Hydrogen Alone in the upper left corner of the periodic table is hydrogen—the element with the simplest atoms. The chemical properties of hydrogen are very different from those of the other elements, so it cannot be grouped in with a family.

Hydrogen makes up more than 90 percent of the atoms in the universe. Stars—like the sun, shown in Figure 7—contain massive amounts of hydrogen. But, hydrogen 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.

FIGURE 7

The Sun

The sun fuses hydrogen atoms together to form helium.

Explain Why isn’t hydrogen considered an alkali metal?



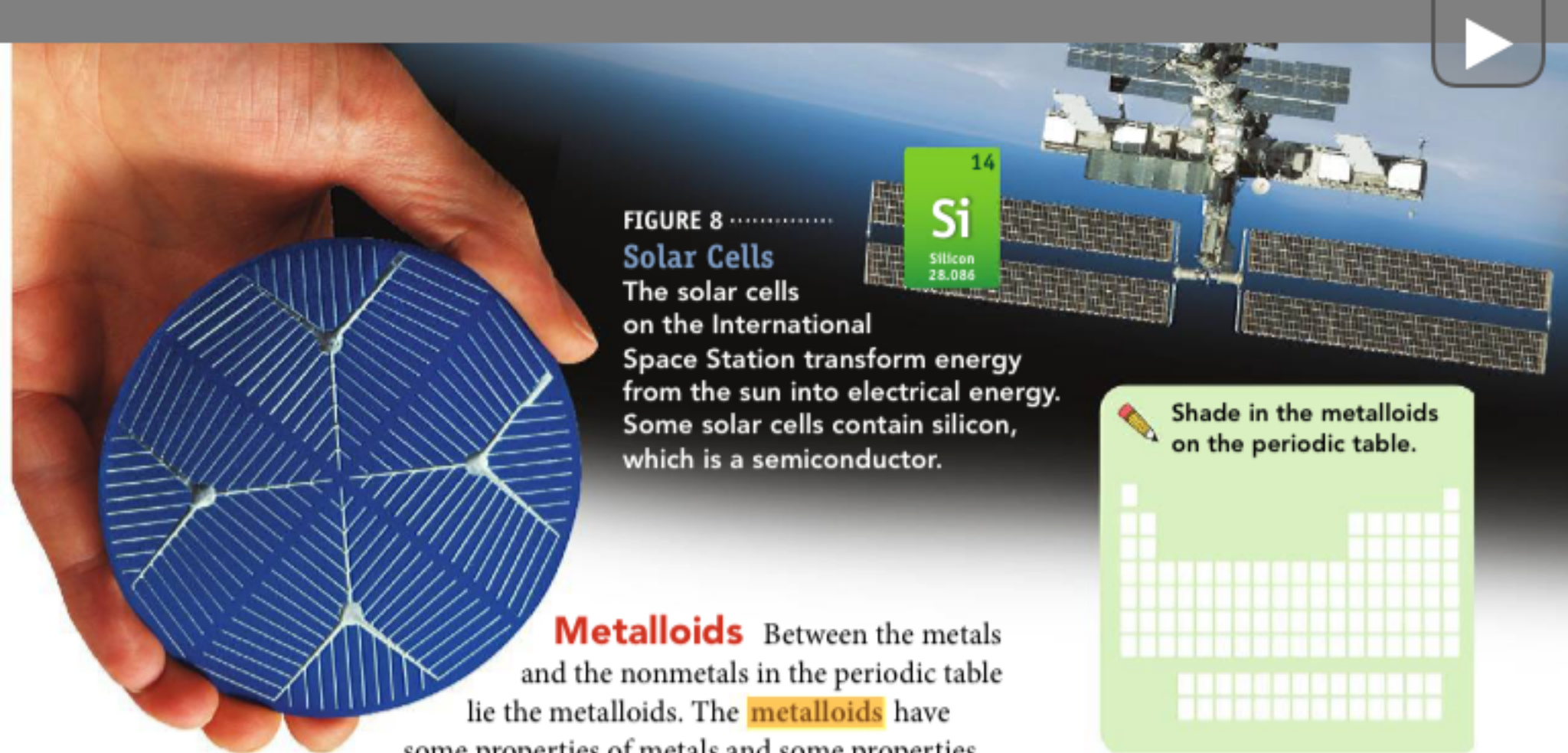


FIGURE 8
Solar Cells
 The solar cells on the International Space Station transform energy from the sun into electrical energy. Some solar cells contain silicon, which is a semiconductor.

Metalloids Between the metals and the nonmetals in the periodic table lie the metalloids. The **metalloids** have some properties of metals and some properties of nonmetals. All metalloids are solids at room temperature. The metalloids are brittle, hard, and somewhat reactive.

The most common metalloid is silicon (Si). Ordinary sand, which is mostly silicon dioxide (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.

A metalloid's most useful property is the ability to conduct electric current. The conductivity of a metalloid can depend on temperature, exposure to light, or the presence of impurities. For this reason, metalloids such as silicon and germanium (Ge) are used to make semiconductors. **Semiconductors** are substances that can conduct electric current under some conditions but not under other conditions. Semiconductors are used to make computer chips, transistors, and lasers. Semiconductors are also used in solar cells, such as the ones shown in **Figure 8**.

Shade in the metalloids on the periodic table.

Summarize Summarize the properties of the metalloids.

apply it!

Use this portion of the periodic table to answer the questions.

- Classify** List the chemical symbols of the nonmetals: _____ . The remaining elements are classified as _____ .
- 2** Selenium has properties similar to (sulfur/bromine) because they are in the same (period/group).

14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.453
32 Ge Germanium 72.59	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904



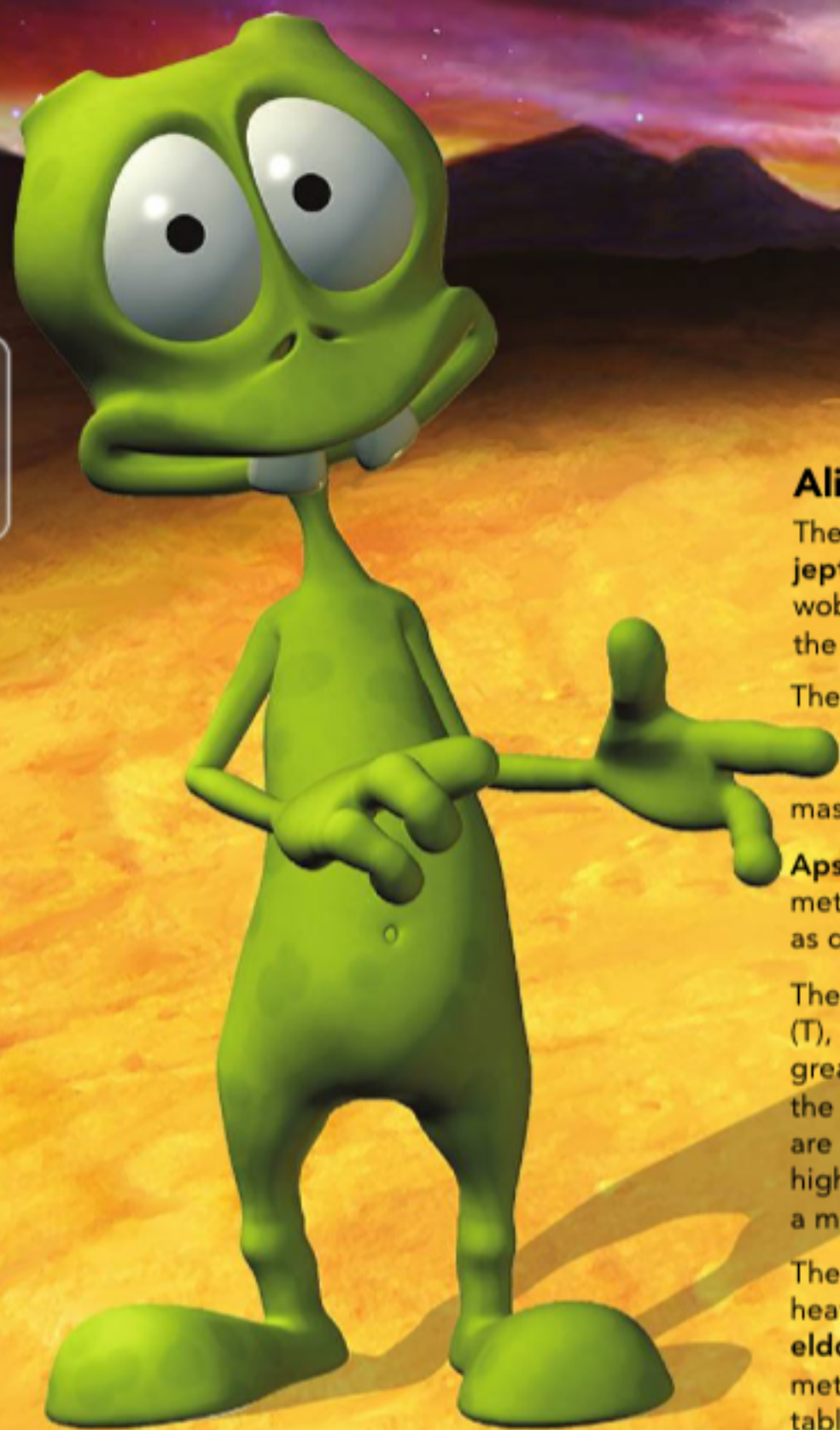
Alien Periodic Table

How is the periodic table organized?

FIGURE 9

VIRTUAL LAB Imagine that inhabitants of another planet send a message to Earth that contains information about 30 elements. However, the message contains different names and symbols for these elements than those used on Earth. **Infer** Using the clues provided, fill in the periodic table with these "alien" names.

	1	
1	<input type="text"/>	
2	<input type="text"/>	2 <input type="text"/>
3	<input type="text"/>	<input type="text"/>
4	<input type="text"/>	<input type="text"/>
5	<input type="text"/>	<input type="text"/>



Alien Elements

The noble gases are **bombal** (Bo), **wobble** (Wo), **jeptum** (J), and **logon** (L). Among these gases, wobble has the greatest atomic mass and bombal the least. Logon is lighter than jeptum.

The most reactive group of metals are **xtalt** (X), **byyou** (By), **chow** (Ch), and **quackzil** (Q). Of these metals, chow has the lowest atomic mass. Quackzil is in the same period as wobble.

Apstrom (A), **vulcania** (Vc), and **kratt** (Kt) are non-metals in Group 17. Vulcania is in the same period as quackzil and wobble.

The metalloids are **ernst** (E), **highho** (Hi), **terriblum** (T), and **sississ** (Ss). Sississ is the metalloid with the greatest atomic mass. Ernst is the metalloid with the lowest atomic mass. Highho and terriblum are in Group 14. Terriblum has more protons than highho. **Yazzer** (Yz) touches the zigzag line, but it's a metal, not a metalloid.

The lightest element of all is called **pfsst** (Pf). The heaviest element in the group of 30 elements is **eldorado** (El). The most chemically active non-metal is apstrom. Kratt reacts with byyou to form table salt.

					18
13	14	15	16	17	

The element **doggone** (D) has only 4 protons in its atoms.

Floxxit (Fx) is important in the chemistry of life. It forms compounds made of long chains of atoms. **Rhaatrap** (R) and **doadeer** (Do) are metals in the fourth period, but rhaatrap is less reactive than doadeer.

Magnificon (M), **goldy** (G), and **sississ** are all members of Group 15. Goldy has fewer electrons than magnificon.

Urrp (Up), **oz** (Oz), and **nuutye** (Nu) are in Group 16. Nuutye is found as a diatomic molecule and has the same properties as a gas found in Earth's atmosphere. Oz has a lower atomic number than urrp.

The element **anatom** (An) has atoms with a total of 49 electrons. **Zapper** (Z) and **pie** (Pi) are both members of Group 2. Zapper has fewer protons than pie.

Assess Your Understanding

2a. **List** What are the nonmetals in Group 16 of the periodic table?

b. **Compare and Contrast** How do the chemical properties of the halogens compare to those of the noble gases?

c. **ANSWER THE BIG QUESTION** How is the periodic table organized?



got it?

I get it! Now I know that the families containing nonmetals include _____

I need extra help with _____

Go to **my science COACH** online for help with this subject.