

Grouping the Elements

You probably know a family with several members who look a lot alike. The elements in a family or group in the periodic table often—but not always—have similar properties.

The properties of the elements in a group are similar because the atoms of the elements have the same number of electrons in their outer energy level. Atoms will often take, give, or share electrons with other atoms in order to have a complete set of electrons in their outer energy level. Elements whose atoms undergo such processes are called *reactive* and can combine to form compounds.

What You Will Learn

- Explain why elements in a group often have similar properties.
- Describe the properties of the elements in the groups of the periodic table.

Vocabulary

alkali metal
alkaline-earth metal
halogen
noble gas

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.



Although the element hydrogen appears above the alkali metals on the periodic table, it is not considered a member of Group 1. It will be described separately at the end of this section.

Group 1: Alkali Metals

3
Li
Lithium

11
Na
Sodium

19
K
Potassium

37
Rb
Rubidium

55
Cs
Cesium

87
Fr
Francium

Group contains: metals

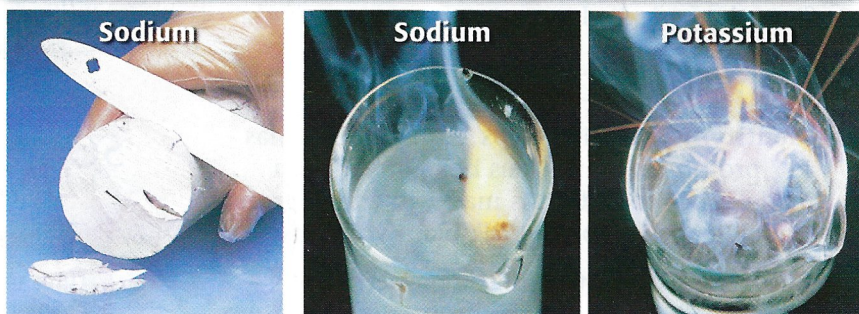
Electrons in the outer level: 1

Reactivity: very reactive

Other shared properties: softness; color of silver; shininess; low density

Alkali metals (AL kuh LIE MET uhlz) are elements in Group 1 of the periodic table. They share physical and chemical properties, as shown in **Figure 1**. Alkali metals are the most reactive metals because their atoms can easily give away the one outer-level electron. Pure alkali metals are often stored in oil. The oil keeps them from reacting with water and oxygen in the air. Alkali metals are so reactive that in nature they are found only combined with other elements. Compounds formed from alkali metals have many uses. For example, sodium chloride (table salt) is used to flavor your food. Potassium bromide is used in photography.

Figure 1 Properties of Alkali Metals



▲ Alkali metals are soft enough to be cut with a knife.

▲ Alkali metals react with water to form hydrogen gas.

Group 2: Alkaline-Earth Metals

4
Be
Beryllium

12
Mg
Magnesium

20
Ca
Calcium

38
Sr
Strontium

56
Ba
Barium

88
Ra
Radium

Group contains: metals

Electrons in the outer level: 2

Reactivity: very reactive but less reactive than alkali metals

Other shared properties: color of silver; higher densities than alkali metals

Alkaline-earth metals (AL kuh LIEN UHRTH MET uh lz) are less reactive than alkali metals are. Atoms of alkaline-earth metals have two outer-level electrons. It is more difficult for atoms to give two electrons than to give one when joining with other atoms. Group 2 elements and their compounds have many uses. For example, magnesium can be mixed with other metals to make low-density materials used in airplanes. And compounds of calcium are found in cement, chalk, and even you, as shown in **Figure 2**.



Figure 2 Calcium, an alkaline-earth metal, is an important part of a compound that keeps your bones and teeth healthy.

Groups 3–12: Transition Metals

21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn
39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd
57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg
89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Uuu	112 Uub

Group contains: metals

Electrons in the outer level: 1 or 2

Reactivity: less reactive than alkaline-earth metals

Other shared properties: shininess; good conductors of thermal energy and electric current; higher densities and melting points than elements in Groups 1 and 2 (except for mercury)

alkali metal one of the elements of Group 1 of the periodic table (lithium, sodium, potassium, rubidium, cesium, and francium)

alkaline-earth metal one of the elements of Group 2 of the periodic table (beryllium, magnesium, calcium, strontium, barium, and radium)

Groups 3–12 do not have individual names. Instead, all of these groups are called *transition metals*. The atoms of transition metals do not give away their electrons as easily as atoms of the Group 1 and Group 2 metals do. So, transition metals are less reactive than alkali metals and alkaline-earth metals are.

✓ Reading Check Why are alkali metals more reactive than transition metals are? (See the Appendix for answers to Reading Checks.)

Figure 3 Properties of Transition Metals

Mercury is used in thermometers. Unlike the other transition metals, mercury is liquid at room temperature.



Many transition metals—but not all—are silver colored! This **gold** ring proves it!

Some transition metals, such as **titanium** in the artificial hip at right, are not very reactive. But others, such as **iron**, are reactive. The iron in the steel trowel on the left has reacted to form rust.

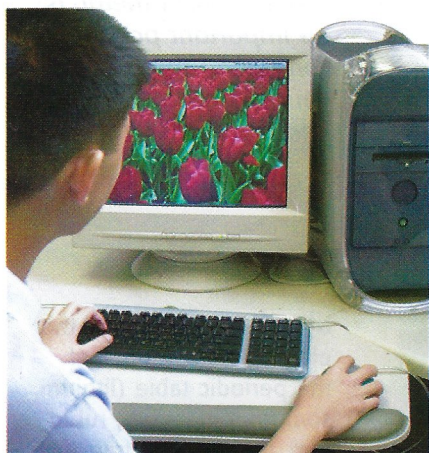


Figure 4 Do you see red? The color red appears on a computer monitor because of a compound formed from europium that coats the back of the screen.

Properties of Transition Metals

The properties of the transition metals vary widely, as shown in **Figure 3**. But, because these elements are metals, they share the properties of metals. Transition metals tend to be shiny and to conduct thermal energy and electric current well.

Lanthanides and Actinides

Some transition metals from Periods 6 and 7 appear in two rows at the bottom of the periodic table to keep the table from being too wide. The elements in each row tend to have similar properties. Elements in the first row follow lanthanum and are called *lanthanides*. The lanthanides are shiny, reactive metals. Some of these elements are used to make steel. An important use of a compound of one lanthanide element is shown in **Figure 4**.

Elements in the second row follow actinium and are called *actinides*. All atoms of actinides are radioactive, or unstable. The atoms of a radioactive element can change into atoms of another element. Elements listed after plutonium, element 94, do not occur in nature. They are made in laboratories. Very small amounts of americium (AM uhr ISH ee uhm), element 95, are used in some smoke detectors.

✓ Reading Check Are lanthanides and actinides transition metals?

57	La
Lanthanum	
89	Ac
Actinium	

Lanthanides	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinides	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Group 13: Boron Group

5

B

Boron

13

Al

Aluminum

31

Ga

Gallium

49

In

Indium

81

Tl

Thallium

113

Uut

Ununtrium

Group contains: one metalloid and five metals

Electrons in the outer level: 3

Reactivity: reactive

Other shared properties: solids at room temperature

The most common element from Group 13 is aluminum. In fact, aluminum is the most abundant metal in Earth's crust. Until the 1880s, however, aluminum was considered a precious metal because the process used to make pure aluminum was very expensive. During the 1850s and 1860s, Emperor Napoleon III of France used aluminum dinnerware because aluminum was more valuable than gold.

Today, the process of making pure aluminum is easier and less expensive than it was in the 1800s. Aluminum is now an important metal used in making aircraft parts. Aluminum is also used to make lightweight automobile parts, foil, cans, and siding.

Like the other elements in the boron group, aluminum is reactive. Why can it be used in so many things? A thin layer of aluminum oxide quickly forms on aluminum's surface when aluminum reacts with oxygen in the air. This layer prevents further reaction of the aluminum.

CONNECTION TO Environmental Science

WRITING SKILL

Recycling Aluminum

Aluminum recycling is a very successful program. In your **science journal**, write a one-page report that describes how aluminum is processed from its ore. In your report, identify the ore and compare the energy needed to extract aluminum from the ore with the energy needed to process recycled aluminum.

Group 14: Carbon Group

6

C

Carbon

14

Si

Silicon

32

Ge

Germanium

50

Sn

Tin

82

Pb

Lead

114

Uuq

Ununquadium

Group contains: one nonmetal, two metalloids, and three metals

Electrons in the outer level: 4

Reactivity: varies among the elements

Other shared properties: solids at room temperature

The nonmetal carbon can be found uncombined in nature, as shown in **Figure 5**. Carbon also forms a wide variety of compounds. Some of these compounds, such as proteins, fats, and carbohydrates, are necessary for living things on Earth.

The metalloids silicon and germanium, also in Group 14, are used to make computer chips. The metal tin is useful because it is not very reactive. For example, a tin can is really made of steel coated with tin. Because the tin is less reactive than the steel is, the tin keeps the iron in the steel from rusting.


 **Reading Check** What metalloids from Group 14 are used to make computer chips?

Figure 5 Diamond and soot have very different properties, yet both are natural forms of carbon.

Diamond is the hardest material known. It is used as a jewel and on cutting tools, such as saws, drills, and files.



Soot is formed from burning oil, coal, and wood and is used as a pigment in paints and crayons.

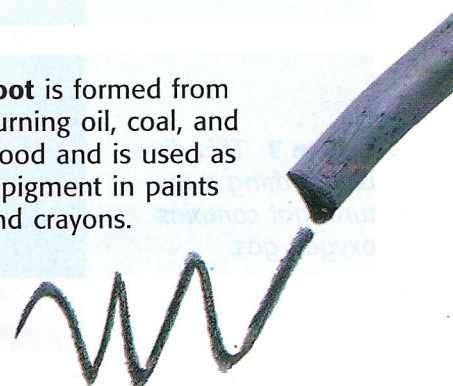




Figure 6 Simply striking a match on the side of this box causes chemicals on the match to react with phosphorus on the box and begin to burn.

Group 15: Nitrogen Group

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

Group contains: two nonmetals, two metalloids, and two metals

Electrons in the outer level: 5

Reactivity: varies among the elements

Other shared properties: solids at room temperature (except for nitrogen)

Nitrogen, which is a gas at room temperature, makes up about 80% of the air you breathe. Nitrogen removed from air can be reacted with hydrogen to make ammonia for fertilizers.

Although nitrogen is not very reactive, phosphorus is extremely reactive, as shown in **Figure 6**. In fact, in nature phosphorus is only found combined with other elements.

Group 16: Oxygen Group

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

Group contains: three nonmetals, one metalloid, and one metal

Electrons in the outer level: 6

Reactivity: Reactive

Other shared properties: All but oxygen are solid at room temperature.

Oxygen makes up about 20% of air. Oxygen is necessary for substances to burn. Oxygen is also important to most living things, such as the diver in **Figure 7**. Sulfur is another commonly found member of Group 16. Sulfur can be found as a yellow solid in nature. It is used to make sulfuric acid, the most widely used compound in the chemical industry.

✓ Reading Check Which gases from Groups 15 and 16 make up most of the air you breathe?

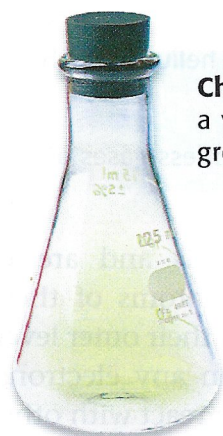
INTERNET ACTIVITY

For another activity related to this chapter, go to go.hrw.com and type in the keyword **HP5PRTW**.

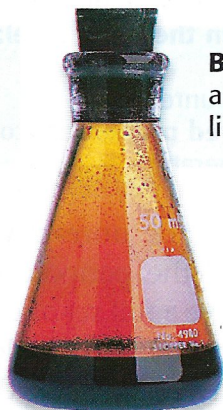


Figure 7 This diver is breathing a mixture that contains oxygen gas.

Figure 8 Physical Properties of Some Halogens



Chlorine is a yellowish green gas.



Bromine is a dark red liquid.



Iodine is a dark gray solid.

Group 17: Halogens

9

F

Fluorine

17

Cl

Chlorine

35

Br

Bromine

53

I

Iodine

85

At

Astatine

Group contains: nonmetals

Electrons in the outer level: 7

Reactivity: very reactive

Other shared properties: poor conductors of electric current; violent reactions with alkali metals to form salts; never in uncombined form in nature

Halogens (HAL oh juh-nz) are very reactive nonmetals because their atoms need to gain only one electron to have a complete outer level. The atoms of halogens combine readily with other atoms, especially metals, to gain that missing electron. The reaction of a halogen with a metal makes a salt, such as sodium chloride. Both chlorine and iodine are used as disinfectants. Chlorine is used to treat water. Iodine mixed with alcohol is used in hospitals.

Although the chemical properties of the halogens are similar, the physical properties are quite different, as shown in **Figure 8**.

halogen one of the elements of Group 17 of the periodic table (fluorine, chlorine, bromine, iodine, and astatine); halogens combine with most metals to form salts

CONNECTION TO Biology

Water Treatment Chlorine has been used to treat drinking water since the early 20th century. Chlorinating water helps protect people from many diseases by killing the organisms in water that cause the diseases. But there is much more to water treatment than just adding chlorine. Research how a water treatment plant purifies water for your use. Construct a model of a treatment plant. Use labels to describe the role of each part of the plant in treating the water you use each day.

ACTIVITY



Figure 9 In addition to neon, other noble gases can be used to make “neon” lights.

noble gas one of the elements of Group 18 of the periodic table (helium, neon, argon, krypton, xenon, and radon); noble gases are unreactive

Group 18: Noble Gases

2
He
Helium

10
Ne
Neon

18
Ar
Argon

36
Kr
Krypton

54
Xe
Xenon

86
Rn
Radon

Group contains: nonmetals

Electrons in the outer level: 8 (except helium, which has 2)

Reactivity: unreactive

Other shared properties: colorless, odorless gases at room temperature

Noble gases are unreactive nonmetals and are in Group 18 of the periodic table. The atoms of these elements have a full set of electrons in their outer level. So, they do not need to lose or gain any electrons. Under normal conditions, they do not react with other elements. Earth’s atmosphere is almost 1% argon. But all the noble gases are found in small amounts.

The unreactivity of the noble gases makes them useful. For example, ordinary light bulbs last longer when they are filled with argon. Because argon is unreactive, it does not react with the metal filament in the light bulb even when the filament gets hot. A more reactive gas might react with the filament, causing the light to burn out. The low density of helium makes blimps and weather balloons float. Another popular use of noble gases is shown in **Figure 9**.

Reading Check Why are noble gases unreactive?

Hydrogen

1
H
Hydrogen

Electrons in the outer level: 1

Reactivity: reactive

Other properties: colorless, odorless gas at room temperature; low density; explosive reactions with oxygen

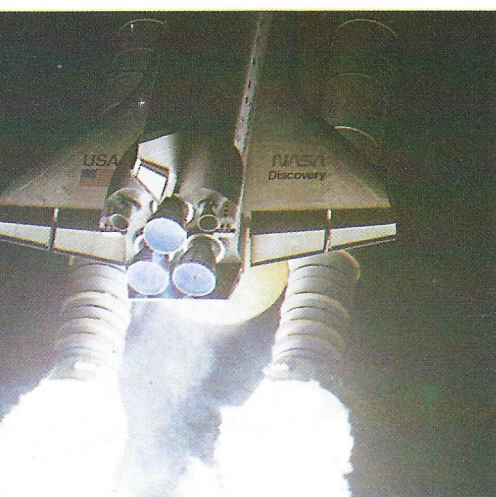


Figure 10 Hydrogen reacts violently with oxygen. The hot water vapor that forms as a result of this reaction helps guide the space shuttle into orbit.

The properties of hydrogen do not match the properties of any single group, so hydrogen is set apart from the other elements in the table. Hydrogen is above Group 1 because atoms of the alkali metals also have only one electron in their outer level. Atoms of hydrogen can give away one electron when they join with other atoms. However, the physical properties of hydrogen are more like those of nonmetals than those of metals. So, hydrogen really is in a group of its own. Hydrogen is found in stars. In fact, it is the most abundant element in the universe. Its reactive nature makes it useful as a fuel in rockets, as shown in **Figure 10**.

SECTION Review

Summary

- Alkali metals (Group 1) are the most reactive metals. Atoms of the alkali metals have one electron in their outer level.
- Alkaline-earth metals (Group 2) are less reactive than the alkali metals are. Atoms of the alkaline-earth metals have two electrons in their outer level.
- Transition metals (Groups 3–12) include most of the well-known metals and the lanthanides and actinides.
- Groups 13–16 contain the metalloids and some metals and nonmetals.
- Halogens (Group 17) are very reactive nonmetals. Atoms of the halogens have seven electrons in their outer level.
- Noble gases (Group 18) are unreactive nonmetals. Atoms of the noble gases have a full set of electrons in their outer level.
- Hydrogen is set off by itself in the periodic table. Its properties do not match the properties of any one group.



Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

noble gas alkaline-earth metal
halogen alkali metal

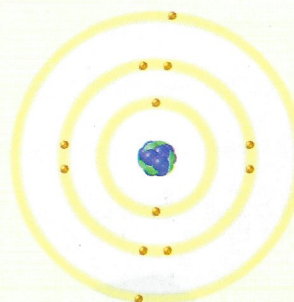
1. An atom of a(n) ___ has a full set of electrons in its outermost energy level.
2. An atom of a(n) ___ has one electron in its outermost energy level.
3. An atom of a(n) ___ tends to gain one electron when it combines with another atom.
4. An atom of a(n) ___ tends to lose two electrons when it combines with another atom.

Understanding Key Ideas

5. Which group contains elements whose atoms have six electrons in their outer level?
a. Group 2 c. Group 16
b. Group 6 d. Group 18
6. What are two properties of the alkali metals?
7. What causes the properties of elements in a group to be similar?
8. What are two properties of the halogens?
9. Why is hydrogen set apart from the other elements in the periodic table?
10. Which group contains elements whose atoms have three electrons in their outer level?

Interpreting Graphics

11. Look at the model of an atom below. Does the model represent a metal atom or a nonmetal atom? Explain your answer.



Critical Thinking

12. **Making Inferences** Why are neither the alkali metals nor the alkaline-earth metals found uncombined in nature?
13. **Making Comparisons** Compare the element hydrogen with the alkali metal sodium.

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Topic: Alkali Metals; Halogens and Noble Gases

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Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

group period
alkali metals halogens
alkaline-earth metals noble gases

- 1 Elements in the same vertical column on the periodic table belong to the same ____.
- 2 Elements in the same horizontal row on the periodic table belong to the same ____.
- 3 The most reactive metals are ____.
- 4 Elements that are unreactive are called ____.

UNDERSTANDING KEY IDEAS

Multiple Choice

- 5 Mendeleev's periodic table was useful because it
 - a. showed the elements arranged by atomic number.
 - b. had no empty spaces.
 - c. showed the atomic number of the elements.
 - d. allowed for the prediction of the properties of missing elements.
- 6 Most nonmetals are
 - a. shiny.
 - b. poor conductors of electric current.
 - c. flattened when hit with a hammer.
 - d. solids at room temperature.

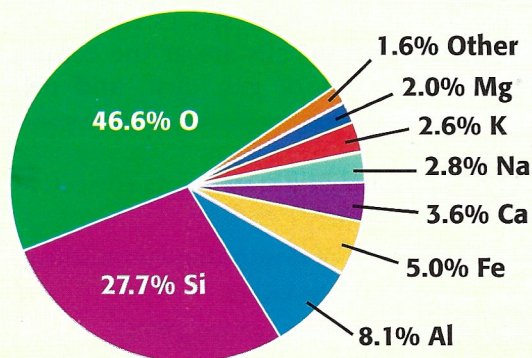
- 7 Which of the following items is NOT found on the periodic table?
 - a. the atomic number of each element
 - b. the name of each element
 - c. the date that each element was discovered
 - d. the atomic mass of each element
- 8 Which of the following statements about the periodic table is false?
 - a. There are more metals than nonmetals on the periodic table.
 - b. Atoms of elements in the same group have the same number of electrons in their outer level.
 - c. The elements at the far left of the periodic table are nonmetals.
 - d. Elements are arranged by increasing atomic number.
- 9 Which of the following statements about alkali metals is true?
 - a. Alkali metals are generally found in their uncombined form.
 - b. Alkali metals are Group 1 elements.
 - c. Alkali metals should be stored underwater.
 - d. Alkali metals are unreactive.
- 10 Which of the following statements about elements is true?
 - a. Every element occurs naturally.
 - b. All elements are found in their uncombined form in nature.
 - c. Each element has a unique atomic number.
 - d. All of the elements exist in approximately equal quantities.

Short Answer

- 11 How is Moseley's basis for arranging the elements different from Mendeleev's?
- 12 How is the periodic table like a calendar?

Math Skills

Examine the chart of the percentages of elements in the Earth's crust below. Then, answer the questions that follow.



- 13 Excluding the "Other" category, what percentage of the Earth's crust are alkali metals?
- 14 Excluding the "Other" category, what percentage of the Earth's crust are alkaline-earth metals?

CRITICAL THINKING

- 15 **Concept Mapping** Use the following terms to create a concept map: *periodic table, elements, groups, periods, metals, nonmetals, and metalloids.*
- 16 **Forming Hypotheses** Why was Mendeleev unable to make any predictions about the noble gas elements?

- 17 **Identifying Relationships** When an element that has 115 protons in its nucleus is synthesized, will it be a metal, a nonmetal, or a metalloid? Explain your answer.

- 18 **Applying Concepts** Your classmate offers to give you a piece of sodium that he found on a hiking trip. What is your response? Explain.

- 19 **Applying Concepts** Identify each element described below.

- a. This metal is very reactive, has properties similar to those of magnesium, and is in the same period as bromine.
- b. This nonmetal is in the same group as lead.

INTERPRETING GRAPHICS

- 20 Study the diagram below to determine the pattern of the images. Predict the missing image, and draw it. Identify which properties are periodic and which properties are shared within a group.

