Section 2
Grouping the Elements

Key Concept Elements within each group, or column, on the periodic table have similar properties.

What You Will Learn
- Elements in a group often have similar properties because their atoms have the same number of electrons in their outer energy level.
- Hydrogen is set off by itself in the periodic table because its properties do not match the properties of any one group.
- Metals are in Groups 1–16. Metalloids are in Groups 13–16. Nonmetals are in Groups 14–18. Noble gases are in Group 18.

Why It Matters
By knowing which group an element is in, you can predict some of the element's properties.

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 are similar because the atoms of the elements in a group 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.* They can combine to form compounds.

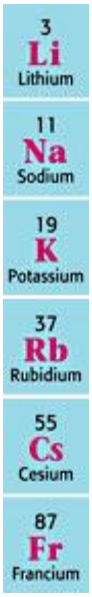
Group 1: Alkali Metals

Group contains: metals

Electrons in the outer level: 1

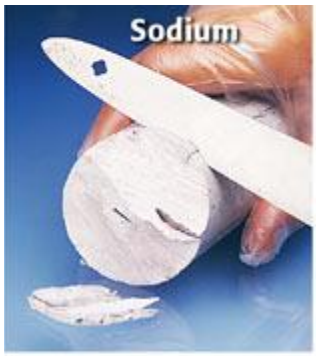
Reactivity: very reactive

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

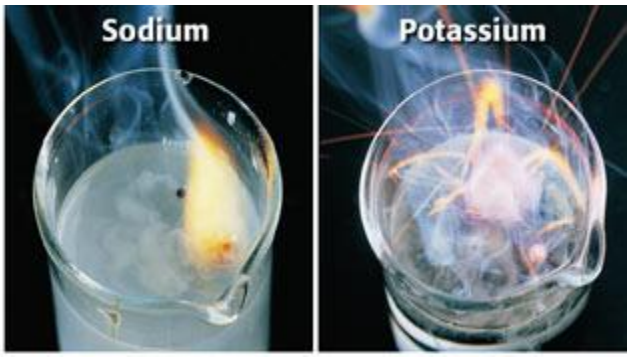


Alkali metals are elements in Group 1 of the periodic table. **Figure 1** shows some of the properties they share. Alkali metals are the most reactive metals. Their atoms can easily give away their one outer-level electron. Pure alkali metals are often stored in oil. The oil keeps them from reacting 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. Sodium chloride (table salt) flavors food.

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.

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 2: Alkaline-Earth Metals

Group contains: metals

Electrons in the outer level: 2

Reactivity: very reactive but less reactive than alkali metals

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

Alkaline-earth metals 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 away two electrons than to give away 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 conductivity of thermal energy and electric current; density and melting points higher than those of elements in Groups 1 and 2 (except for mercury)

Elements of Groups 3–12 are all 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.

The lanthanides and the actinides make up two rows of transition metals that are placed at the bottom of the table to save space. However, you should still read them as you read the rest of the table, from left to right and then down. The elements in each of these two rows tend to have similar properties.

Properties of Transition Metals

The number of outer-level electrons in atoms of transition metals can vary. So, 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.

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 are silver colored. The **gold** that this ring is made out of is an exception.

Some transition metals in the artificial hip at ri reactive. But others, su reactive. The iron in th the left has reacted to

Standards Check Why are transition metals not as reactive as alkali metals and alkaline-earth metals?

Group 13: Boron Group

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. Pure aluminum was very expensive to make. Today, making pure aluminum is easier and cheaper than it was in the 1800s. Aluminum is useful because it is such a lightweight metal. It is now an important metal used in making aircraft parts, lightweight automobile parts, foil, cans, and siding.

Like the other elements in the boron group, aluminum is reactive. However, when aluminum reacts with oxygen in the air, a thin layer of aluminum oxide quickly forms on aluminum's surface. This layer prevents further reaction of the aluminum.

Group 14: Carbon Group

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

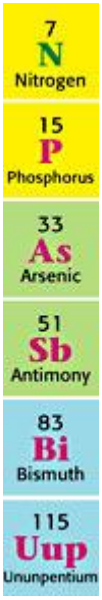
The nonmetal carbon can be found uncombined in nature, as shown in **Figure 4.** Carbon also forms a wide variety of compounds. Some of these compounds, such as proteins, fats, and carbohydrates, are necessary for living things on Earth.

Figure 4 Diamond and soot have very different properties, yet both are natural forms of carbon.

The metalloids silicon and germanium are used in semiconductors, which are needed to make computer chips. The metal tin is useful because it is not very reactive. A layer of tin helps prevent iron in steel cans from rusting.

Standards Check What three types of elements are found in Group 14 of the periodic table?

Group 15: Nitrogen Group



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 nitrogen)

Nitrogen, which is a gas at room temperature, makes up about 80% of the air that 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 5.** In fact, in nature, phosphorus is found only combined with other elements.

Figure 5 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 16: Oxygen Group

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

Electrons in the outer level: 6

Reactivity: reactive

Other shared properties: solids at room temperature (except oxygen)

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 shown in **Figure 6.** It is even found dissolved in ocean water, which is where fish get the oxygen they need.

Figure 6 This diver is breathing a mixture that contains oxygen gas.

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.

Group 17: Halogens

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 are very reactive 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 extra 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 7.**

Figure 7 The physical properties of some halogens are shown above.
How does the state of matter change as you move from top to bottom in Group 17?

Group 18: Noble Gases

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. In fact, these elements were first called *inert gases* because scientists thought that these elements would not react at all! However, scientists have made compounds from some elements in Group 18. So, the name *noble gases* is more correct. 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 hot metal filament in the light bulb. 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 8.**

Figure 8 In addition to neon, other noble gases can be used to make "neon" lights.

Standards Check Where are the noble gases located on the periodic table?

Hydrogen

Electrons in the outer level: 1

Reactivity: reactive

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

Hydrogen is the most abundant element in the universe. It is found in large amounts in stars. Atoms of hydrogen can give away one electron when they join with other atoms. Hydrogen reacts with many elements, and is found in many compounds. Hydrogen's reactive nature makes it useful as a fuel in rockets, as shown in **Figure 9.**

Figure 9 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 Uniqueness of Hydrogen

Most atoms of hydrogen have just one proton and one electron. The properties of hydrogen do not match the properties of any single group, so hydrogen is set apart in the table. Hydrogen is above Group 1 because atoms of the alkali metals also have only one electron in their outer level. 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.

Standards Check Why is hydrogen classified apart from the other elements in the periodic table?

Section Summary

- Elements that are classified as alkali metals (Group 1) are the most reactive metals. Atoms of the alkali metals have one electron in their outer level.
- Elements that are classified as 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.
- Elements that are classified as 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.

Chapter Summary

The Big Idea

Elements are organized on the periodic table according to their properties.

Section 1

Arranging the Elements

Key Concept Elements are arranged on the periodic table according to their atomic number and their chemical properties.

- Elements on the periodic table are arranged in order of increasing atomic number.
- Elements on the periodic table are classified as metals, nonmetals, or metalloids.
- Elements in a horizontal row, or period, are listed in order of increasing atomic number.
- Elements in a vertical column, or group, usually have similar chemical properties.
- The periodic law states that the properties of el ements form a pattern according to increasing atomic number.

Mendeleev first arranged elements based on the property of atomic mass.

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- Metals are in Groups 1–16. Metalloids are in Groups 13–16. Nonmetals are in Groups 14–18. Noble gases are in Group 18.

Solid iodine and liquid bromine are in Group 17 of the periodic table and are reactive nonmetals.

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