

The Periodic Table

chapter preview

sections

- 1 Introduction to the Periodic Table
- 2 Representative Elements
- 3 Transition Elements
 - Lab** *Metals and Nonmetals*
 - Lab** *Health Risks from Heavy Metals*



Virtual Lab *How is an atom's structure related to its position on the periodic table?*

Skyscrapers, Neon Lights, and the Periodic Table

Many cities have distinctive skylines. What is truly amazing is that everything in this photograph is made from 90 naturally occurring elements. In this chapter, you will learn more about the elements and the table that organizes them.

Science Journal Think of an element that you have heard about. Make a list of the properties you know and the properties you want to learn about.

Start-Up Activities



Make a Model of a Periodic Pattern

Every 29.5 days, the Moon begins to cycle through its phases from full moon to new moon and back again to full moon. Events that follow a predictable pattern are called periodic events. What other periodic events can you think of?

1. On a blank sheet of paper, make a grid with four squares across and four squares down.
2. Your teacher will give you 16 pieces of paper with different shapes and colors. Identify properties you can use to distinguish one piece of paper from another.
3. Place a piece of paper in each square on your grid. Arrange the pieces on the grid so that each column contains pieces that are similar.
4. Within each column, arrange the pieces to show a gradual change in their appearance.
5. **Think Critically** In your Science Journal, describe how the properties change in the rows across the grid and in the columns down the grid.



Preview this chapter's content and activities at bookk.msscience.com

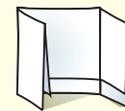
FOLDABLES™ Study Organizer

Periodic Table Make the following Foldable to help you classify the elements in the periodic table as metals, nonmetals, and metalloids.

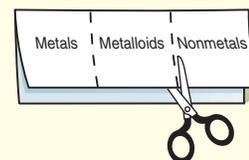
- STEP 1** **Fold** a vertical sheet of paper from side to side. Make the front edge about 1.25 cm shorter than the back edge.



- STEP 2** **Turn** lengthwise and **fold** into thirds.



- STEP 3** **Unfold and cut** only the top layer along both folds to make three tabs. **Label** each tab as shown.



Find Main Ideas As you read the chapter, write information about the three types of elements under the appropriate tabs. Use the information in your Foldable to explain how metalloids have properties between those of metals and nonmetals.

Introduction to the Periodic Table

as you read

What You'll Learn

- **Describe** the history of the periodic table.
- **Interpret** an element key.
- **Explain** how the periodic table is organized.

Why It's Important

The periodic table makes it easier for you to find information that you need about the elements.

Review Vocabulary

element: a substance that cannot be broken down into simpler substances

New Vocabulary

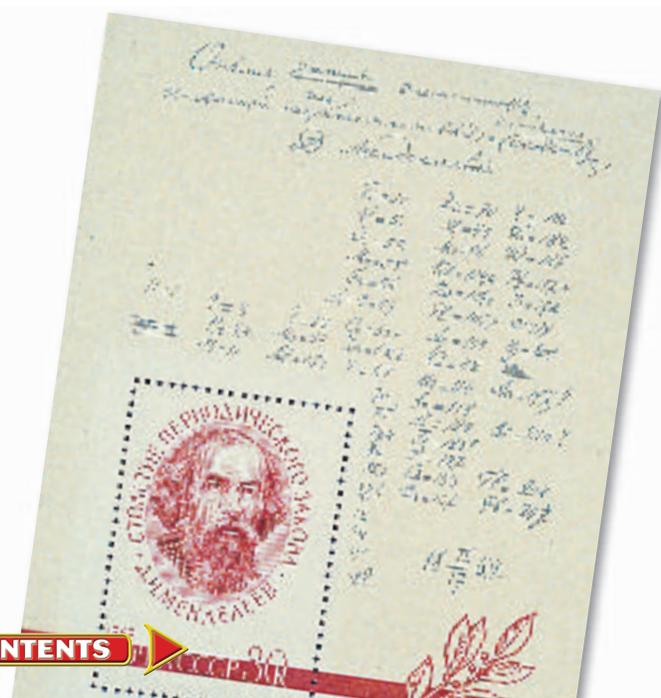
- period
- group
- representative element
- transition element
- metal
- nonmetal
- metalloid

Development of the Periodic Table

Early civilizations were familiar with a few of the substances now called elements. They made coins and jewelry from gold and silver. They also made tools and weapons from copper, tin, and iron. In the nineteenth century, chemists began to search for new elements. By 1830, they had isolated and named 55 different elements. The list continues to grow today.

Mendeleev's Table of Elements A Russian chemist, Dmitri Mendeleev (men duh LAY uhf), published the first version of his periodic table in the *Journal of the Russian Chemical Society* in 1869. His table is shown in **Figure 1**. When Mendeleev arranged the elements in order of increasing atomic mass, he began to see a pattern. Elements with similar properties fell into groups on the table. At that time, not all the elements were known. To make his table work, Mendeleev had to leave three gaps for missing elements. Based on the groupings in his table, he predicted the properties for the missing elements. Mendeleev's predictions spurred other chemists to look for the missing elements. Within 15 years, all three elements—gallium, scandium, and germanium—were discovered.

Figure 1 Mendeleev published his first periodic table in 1869. This postage stamp, with his table and photo, was issued in 1969 to commemorate the event. Notice the question marks that he used to mark his prediction of yet-undiscovered elements.



Moseley's Contribution Although Mendeleev's table correctly organized most of the elements, a few elements seemed out of place. In the early twentieth century, the English physicist Henry Moseley, before age 27, realized that Mendeleev's table could be improved by arranging the elements according to atomic number rather than atomic mass. Moseley revised the periodic table by arranging the elements in order of increasing number of protons in the nucleus. With Moseley's table, it was clear how many elements still were undiscovered.

Today's Periodic Table

In the modern periodic table on the next page, the elements still are organized by increasing atomic number. The rows or periods are labeled 1–7. A **period** is a row of elements in the periodic table whose properties change gradually and predictably. The periodic table has 18 columns of elements. Each column contains a group, or family, of elements. A **group** contains elements that have similar physical or chemical properties.

Zones on the Periodic Table The periodic table can be divided into sections, as you can see in **Figure 2**. One section consists of the first two groups, Groups 1 and 2, and the elements in Groups 13–18. These eight groups are the **representative elements**. They include metals, metalloids, and nonmetals. The elements in Groups 3–12 are **transition elements**. They are all metals. Some transition elements, called the inner transition elements, are placed below the main table. These elements are called the lanthanide and actinide series because one series follows the element lanthanum, element 57, and the other series follows actinium, element 89.

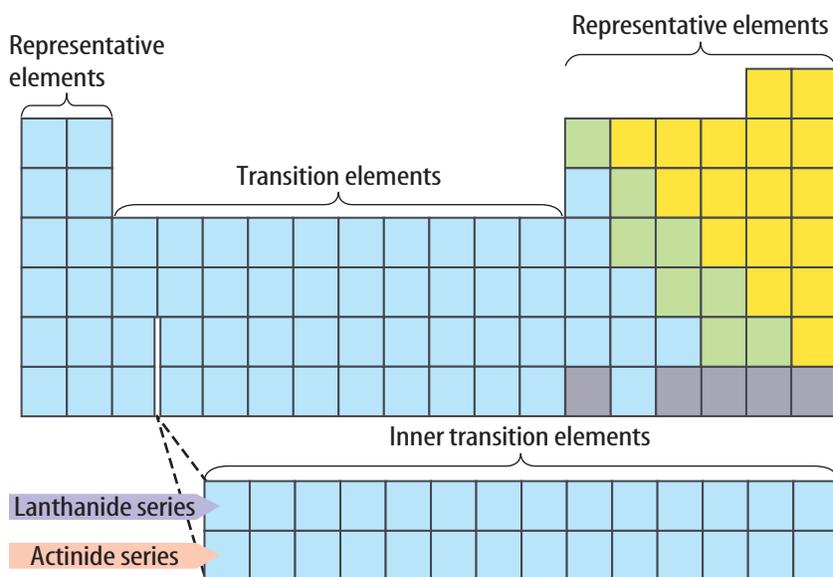


Figure 2 The periodic table is divided into sections. Traditionally, the lanthanides and actinides are placed below the table so that the table will not be as wide. These elements have similar properties.

Designing a Periodic Table

Procedure

1. Collect **pens and pencils** from everyone in your class.
2. Decide which properties of the pens and pencils you will use to organize them into a periodic table. Consider properties such as color, mass, or length. Then create your table.

Analysis

1. Explain how your periodic table is similar to the periodic table of the elements.
2. If your classmates brought different pens or pencils to class tomorrow, how would you organize them on your periodic table?

PERIODIC TABLE OF THE ELEMENTS

Columns of elements are called groups. Elements in the same group have similar chemical properties.

-  Gas
-  Liquid
-  Solid
-  Synthetic

1	1		2		3		4		5		6		7		8		9					
1	Hydrogen 1 H 1.008		Lithium 3 Li 6.941		Beryllium 4 Be 9.012		Scandium 21 Sc 44.956		Titanium 22 Ti 47.867		Vanadium 23 V 50.942		Chromium 24 Cr 51.996		Manganese 25 Mn 54.938		Iron 26 Fe 55.845		Cobalt 27 Co 58.933			
2	Sodium 11 Na 22.990		Magnesium 12 Mg 24.305		Rubidium 37 Rb 85.468		Strontium 38 Sr 87.62		Yttrium 39 Y 88.906		Zirconium 40 Zr 91.224		Niobium 41 Nb 92.906		Molybdenum 42 Mo 95.94		Technetium 43 Tc (98)		Ruthenium 44 Ru 101.07		Rhodium 45 Rh 102.906	
3	Potassium 19 K 39.098		Calcium 20 Ca 40.078		Cesium 55 Cs 132.905		Barium 56 Ba 137.327		Lanthanum 57 La 138.906		Hafnium 72 Hf 178.49		Tantalum 73 Ta 180.948		Tungsten 74 W 183.84		Rhenium 75 Re 186.207		Osmium 76 Os 190.23		Iridium 77 Ir 192.217	
4	Francium 87 Fr (223)		Radium 88 Ra (226)		Actinium 89 Ac (227)		Rutherfordium 104 Rf (261)		Dubnium 105 Db (262)		Seaborgium 106 Sg (266)		Bohrium 107 Bh (264)		Hassium 108 Hs (277)		Meitnerium 109 Mt (268)					

Element — Hydrogen
 Atomic number — 1
 Symbol — H
 Atomic mass — 1.008
 State of matter — Gas

The first three symbols tell you the state of matter of the element at room temperature. The fourth symbol identifies elements that are not present in significant amounts on Earth. Useful amounts are made synthetically.

The number in parentheses is the mass number of the longest-lived isotope for that element.

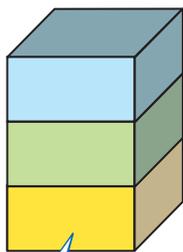
Rows of elements are called periods. Atomic number increases across a period.

The arrow shows where these elements would fit into the periodic table. They are moved to the bottom of the table to save space.

Lanthanide series

Actinide series

Cerium 58 Ce 140.116	Praseodymium 59 Pr 140.908	Neodymium 60 Nd 144.24	Promethium 61 Pm (145)	Samarium 62 Sm 150.36
Thorium 90 Th 232.038	Protactinium 91 Pa 231.036	Uranium 92 U 238.029	Neptunium 93 Np (237)	Plutonium 94 Pu (244)



Metal
Metalloid
Nonmetal

The color of an element's block tells you if the element is a metal, nonmetal, or metalloid.



			13	14	15	16	17	18	
			Boron 5 B 10.811	Carbon 6 C 12.011	Nitrogen 7 N 14.007	Oxygen 8 O 15.999	Fluorine 9 F 18.998	Helium 2 He 4.003	
			Aluminum 13 Al 26.982	Silicon 14 Si 28.086	Phosphorus 15 P 30.974	Sulfur 16 S 32.065	Chlorine 17 Cl 35.453	Neon 10 Ne 20.180	
10	11	12							Argon 18 Ar 39.948
Nickel 28 Ni 58.693	Copper 29 Cu 63.546	Zinc 30 Zn 65.409	Gallium 31 Ga 69.723	Germanium 32 Ge 72.64	Arsenic 33 As 74.922	Selenium 34 Se 78.96	Bromine 35 Br 79.904	Krypton 36 Kr 83.798	
Palladium 46 Pd 106.42	Silver 47 Ag 107.868	Cadmium 48 Cd 112.411	Indium 49 In 114.818	Tin 50 Sn 118.710	Antimony 51 Sb 121.760	Tellurium 52 Te 127.60	Iodine 53 I 126.904	Xenon 54 Xe 131.293	
Platinum 78 Pt 195.078	Gold 79 Au 196.967	Mercury 80 Hg 200.59	Thallium 81 Tl 204.383	Lead 82 Pb 207.2	Bismuth 83 Bi 208.980	Polonium 84 Po (209)	Astatine 85 At (210)	Radon 86 Rn (222)	
Darmstadtium 110 Ds (281)	Unununium * 111 Uuu (272)	Ununbium * 112 Uub (285)		Ununquadium * 114 Uuq (289)		** 116		** 118	

* The names and symbols for elements 111–114 are temporary. Final names will be selected when the elements' discoveries are verified.

** Elements 116 and 118 were thought to have been created. The claim was retracted because the experimental results could not be repeated.

Europium 63 Eu 151.964	Gadolinium 64 Gd 157.25	Terbium 65 Tb 158.925	Dysprosium 66 Dy 162.500	Holmium 67 Ho 164.930	Erbium 68 Er 167.259	Thulium 69 Tm 168.934	Ytterbium 70 Yb 173.04	Lutetium 71 Lu 174.967
Americium 95 Am (243)	Curium 96 Cm (247)	Berkelium 97 Bk (247)	Californium 98 Cf (251)	Einsteinium 99 Es (252)	Fermium 100 Fm (257)	Mendelevium 101 Md (258)	Nobelium 102 No (259)	Lawrencium 103 Lr (262)

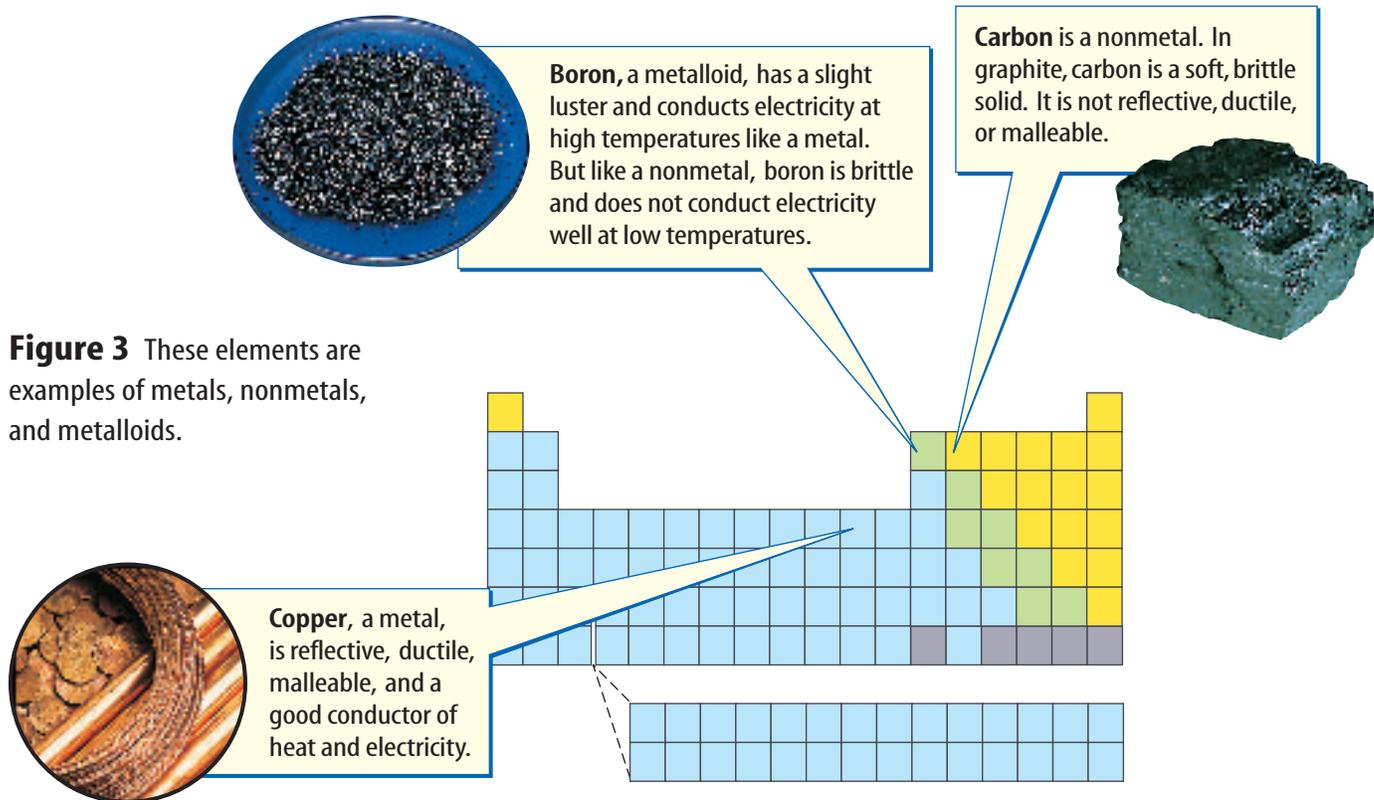


Figure 3 These elements are examples of metals, nonmetals, and metalloids.

Metals If you look at the periodic table, you will notice it is color coded. The colors represent elements that are metals, nonmetals, or metalloids. Examples of a metal, a nonmetal, and a metalloid are illustrated in **Figure 3**. With the exception of mercury, all the metals are solids, most with high melting points. A **metal** is an element that has luster, is a good conductor of heat and electricity, is malleable, and is ductile. The ability to reflect light is a property of metals called luster. Many metals can be pressed or pounded into thin sheets or shaped into objects because they are malleable (MAL yuh bul). Metals are also ductile (DUK tul), which means that they can be drawn out into wires. Can you think of any items that are made of metals?

Nonmetals and Metalloids **Nonmetals** are usually gases or brittle solids at room temperature and poor conductors of heat and electricity. There are only 17 nonmetals, but they include many elements that are essential for life—carbon, sulfur, nitrogen, oxygen, phosphorus, and iodine.

The elements between metals and nonmetals on the periodic table are called metalloids (ME tuh loydz). As you might expect from the name, a **metalloid** is an element that shares some properties with metals and some with nonmetals. These elements also are called semimetals.

Scienceonline
Topic: Elements
 Visit bookk.msscience.com for Web links to information about how the periodic table was developed.
Activity Select an element and write about how, when, and by whom it was discovered.

Reading Check How many elements are nonmetals?

The Element Keys Each element is represented on the periodic table by a box called the element key. An enlarged key for hydrogen is shown in **Figure 4**. An element key shows you the name of the element, its atomic number, its symbol, and its average atomic mass. Element keys for elements that occur naturally on Earth include a logo that tells whether the element is a solid, a liquid, or a gas at room temperature. All the gases except hydrogen are on the right side of the table. They are marked with a balloon logo. Most of the other elements are solids at room temperature and are marked with a cube. Two elements on the periodic table are liquids at room temperature. Their logo is a drop. Elements that do not occur naturally on Earth are marked with a bull's-eye logo. These are synthetic elements.

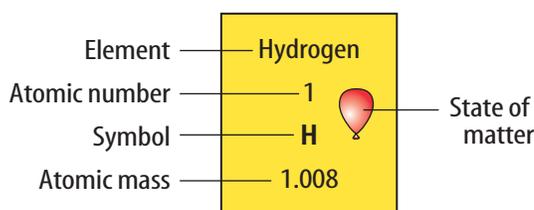


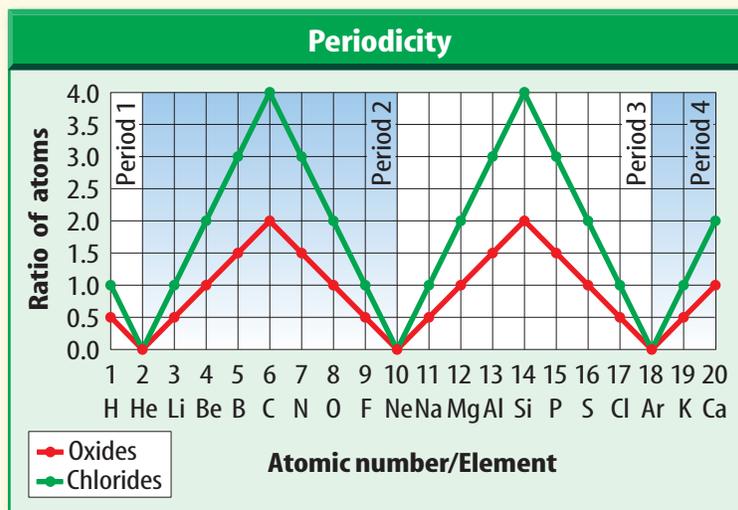
Figure 4 As you can see from the element key, a lot of information about an element is given on the periodic table.

Identify the two elements that are liquids at room temperature.

Applying Science

What does *periodic* mean in the periodic table?

Elements often combine with oxygen to form oxides and chlorine to form chlorides. For example, two hydrogen atoms combine with one oxygen atom to form oxide, H_2O or water. One sodium atom combines with one chlorine atom to form sodium chloride, $NaCl$ or table salt. The location of an element on the periodic table is an indication of how it combines with other elements.



Identifying the Problem

The graph shows the number of oxygen atoms (red) and chlorine atoms (green) that will combine with the first 20 elements. What pattern do you see?

Solving the Problem

1. Find all of the elements in Group 1 on the graph. Do the same with the elements in Groups 14 and 18. What do you notice about their positions on the graph?
2. This relationship demonstrates one of the properties of a group of elements. Follow the elements in order on the periodic table and on the graph. Write a statement using the word *periodic* that describes what occurs with the elements and their properties.

Table 1 Chemical Symbols and Their Origins

Name	Symbol	Origin of Name
Mendelevium	Md	For Dimitri Mendeleev
Lead	Pb	The Latin name for lead is <i>plumbum</i> .
Thorium	Th	The Norse god of thunder is Thor.
Polonium	Po	For Poland, where Marie Curie, a famous scientist, was born
Hydrogen	H	From Greek words meaning "water former"
Mercury	Hg	<i>Hydrargyrum</i> means "liquid silver" in Greek.
Gold	Au	<i>Aurum</i> means "shining dawn" in Latin.
Ununium	Uuu	Named using the IUPAC naming system

Symbols for the Elements The symbols for the elements are either one- or two-letter abbreviations, often based on the element name. For example, V is the symbol for vanadium, and Sc is the symbol for scandium. Sometimes the symbols don't match the names. Examples are Ag for silver and Na for sodium. In those cases, the symbol might come from Greek or Latin names for the elements. Some elements are named for scientists such as Lise Meitner (meitnerium, Mt). Some are named for geographic locations such as France (francium, Fr).

Newly synthesized elements are given a temporary name and 3-letter symbol that is related to the element's atomic number. The International Union of Pure and Applied Chemistry (IUPAC) adopted this system in 1978. Once the discovery of the element is verified, the discoverers can choose a permanent name. **Table 1** shows the origin of some element names and symbols.

section 1 review

Summary

Development of the Periodic Table

- Dmitri Mendeleev published the first version of the periodic table in 1869.
- Mendeleev left three gaps on the periodic table for missing elements.
- Moseley arranged Mendeleev's table according to atomic number, not by atomic mass.

Today's Periodic Table

- The periodic table is divided into sections.
- A period is a row of elements whose properties change gradually and predictably.
- Groups 1 and 2 along with Groups 13–18 are called representative elements.
- Groups 3–12 are called transition elements.

Self Check

1. **Evaluate** the elements in period 4 to show how the physical state changes as the atomic number increases.
2. **Describe** where the metals, nonmetals, and metalloids are located in the periodic table.
3. **Classify** each of the following elements as metal, nonmetal, or metalloid: Fe, Li, B, Cl, Si, Na, and Ni.
4. **Define** what an element key contains.
5. **Think Critically** How would the modern periodic table be different if elements were arranged by average atomic mass instead of by atomic number?

Applying Math

6. **Solve One-Step Equations** What is the difference in atomic mass of iodine and magnesium?

Group 14—The Carbon Group

If you look at Group 14, you can see that carbon is a nonmetal, silicon and germanium are metalloids, and tin and lead are metals. The non-metal carbon exists as an element in several forms. You're familiar with two of them—diamond and graphite. Carbon also is found in all living things. Carbon is followed by the metalloid silicon, an abundant element contained in sand. Sand contains ground-up particles of minerals such as quartz, which is composed of silicon and oxygen. Glass is an important product made from sand.

Silicon and its Group 14 neighbor, germanium, are metalloids. They are used in electronics as semiconductors. A **semiconductor** doesn't conduct electricity as well as a metal, but does conduct electricity better than a nonmetal. Silicon and small amounts of other elements are used for computer chips as shown in **Figure 7**.

Tin and lead are the two heaviest elements in Group 14. Lead is used in the apron, shown in **Figure 7**, to protect your torso during dental X rays. It also is used in car batteries, low-melting alloys, protective shielding around nuclear reactors, particle accelerators, X-ray equipment, and containers used for storing and transporting radioactive materials. Tin is used in pewter, toothpaste, and the coating on steel cans used for food.

Group 14
The Carbon Group

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

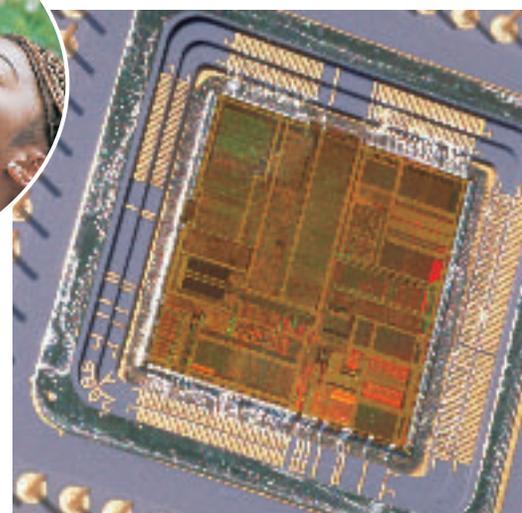
Figure 7 Members of Group 14 include one nonmetal, two metalloids, and two metals.



Lead is used to shield your body from unwanted X-ray exposure.

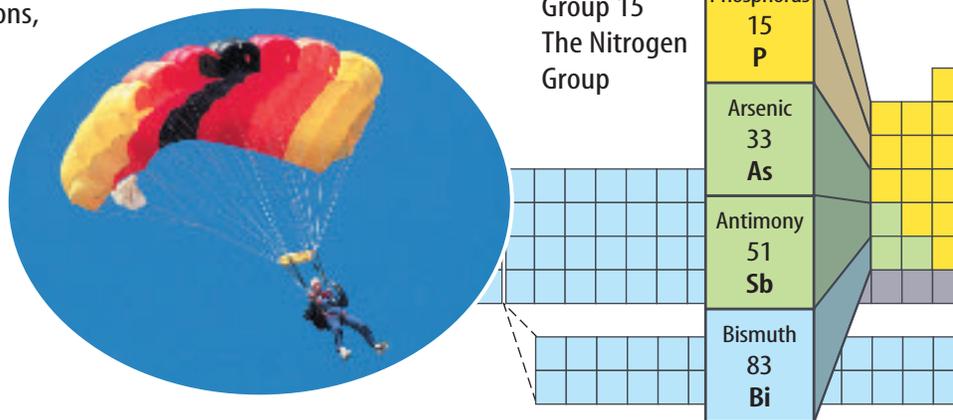


All living things contain carbon compounds.



Silicon crystals are used to make computer chips.

Figure 8 Ammonia is used to make nylon, a tough, light fiber capable of replacing silk in many applications, including parachutes.



Farmers Each year farmers test their soil to determine the level of nutrients, the matter needed for plants to grow. The results of the test help the farmer decide how much nitrogen, phosphorus, and potassium to add to the fields. The additional nutrients increase the chance of having a successful crop.

Group 15—The Nitrogen Group At the top of Group 15 are the two nonmetals—nitrogen and phosphorus. Nitrogen and phosphorus are required by living things and are used to manufacture various items. These elements also are parts of the biological materials that store genetic information and energy in living organisms. Although almost 80 percent of the air you breathe is nitrogen, you can't get the nitrogen your body needs by breathing nitrogen gas. Bacteria in the soil must first change nitrogen gas into substances that can be absorbed through the roots of plants. Then, by eating the plants, nitrogen becomes available to your body.



Reading Check *Can your body obtain nitrogen by breathing air? Explain.*

Figure 9 Nitrogen and phosphorus are required for healthy green plants. This synthetic fertilizer label shows the nitrogen and phosphorous compounds that provide these.



Ammonia is a gas that contains nitrogen and hydrogen. When ammonia is dissolved in water, it can be used as a cleaner and disinfectant. Liquid ammonia is sometimes applied directly to soil as a fertilizer. Ammonia also can be converted into solid fertilizers. It also is used to freeze-dry food and as a refrigerant. Ammonia also is used to make nylon for parachutes, as shown in **Figure 8**.

The element phosphorus comes in two forms—white and red. White phosphorus is so active it can't be exposed to oxygen in the air or it will burst into flames. The heads of matches contain the less active red phosphorus, which ignites from the heat produced by friction when the match is struck. Phosphorous compounds are essential ingredients for healthy teeth and bones. Plants also need phosphorus, so it is one of the nutrients in most fertilizers. The fertilizer label in **Figure 9** shows the compounds of nitrogen and phosphorus that are used to give plants a synthetic supply of these elements.

Group 16—The Oxygen Family The first two members of Group 16, oxygen and sulfur, are essential for life. The heavier members of the group, tellurium and polonium, are both metalloids.

About 20 percent of Earth's atmosphere is the oxygen you breathe. Your body needs oxygen to release the energy from the foods you eat. Oxygen is abundant in Earth's rocks and minerals because it readily combines with other elements. Oxygen also is required for combustion to occur. Foam is used in fire fighting to keep oxygen away from the burning item, as shown in **Figure 10**. Ozone, a less common form of oxygen, is formed in the upper atmosphere through the action of electricity during thunderstorms. The presence of ozone is important because it shields living organisms from some harmful radiation from the Sun.

Sulfur is a solid, yellow nonmetal. Large amounts of sulfur are used to manufacture sulfuric acid, one of the most commonly used chemicals in the world. Sulfuric acid is a combination of sulfur, hydrogen, and oxygen. It is used in the manufacture of paints, fertilizers, detergents, synthetic fibers, and rubber.

Selenium conducts electricity when exposed to light, so it is used in solar cells, light meters, and photographic materials. Its most important use is as the light-sensitive component in photocopier machines. Traces of selenium are also necessary for good health.

Group 16
The Oxygen
Family

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



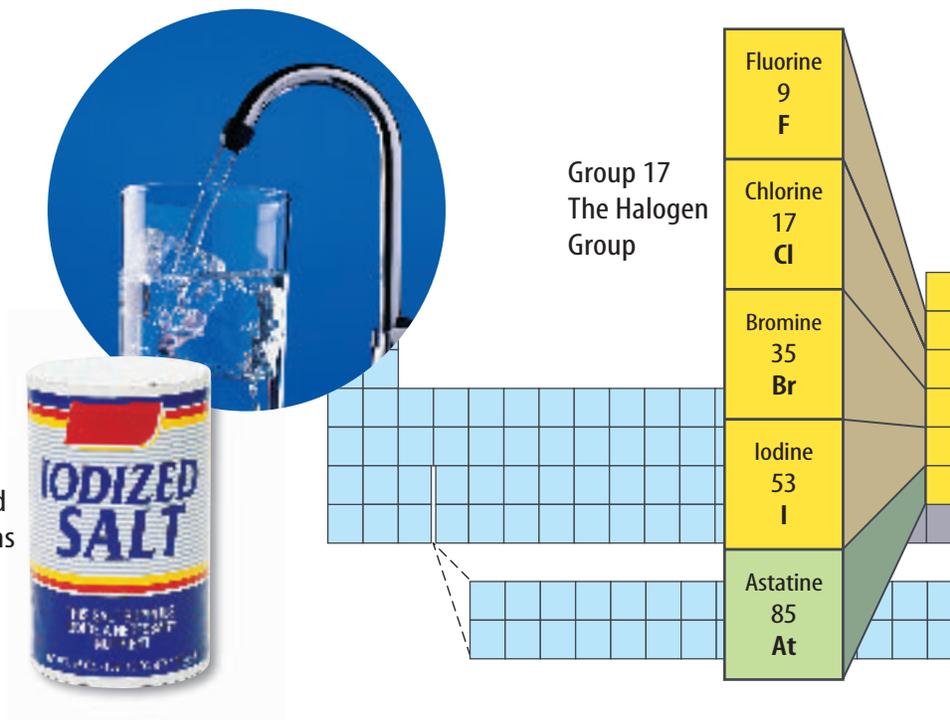
Poison Buildup Arsenic disrupts the normal function of an organism by disrupting cellular metabolism. Because arsenic builds up in hair, forensic scientists can test hair samples to confirm or disprove a case of arsenic poisoning. Tests of Napoleon's hair suggest that he was poisoned with arsenic. Use reference books to find out who Napoleon I was and why someone might have wanted to poison him.



Figure 10 The foam used in aircraft fires forms a film of water over the burning fuel which suffocates the fire.

Figure 11 The halogens are a group of elements that are important to us in a variety of ways. Chlorine is added to drinking water to kill bacteria.

Iodine is needed by many systems in your body.



Group 17—The Halogen Group All the elements in Group 17 are nonmetals except for astatine, which is a radioactive metalloid. These elements are called **halogens**, which means “salt-former.” Table salt, sodium chloride, is a substance made from sodium and chlorine. All of the halogens form similar salts with sodium and with the other alkali metals.

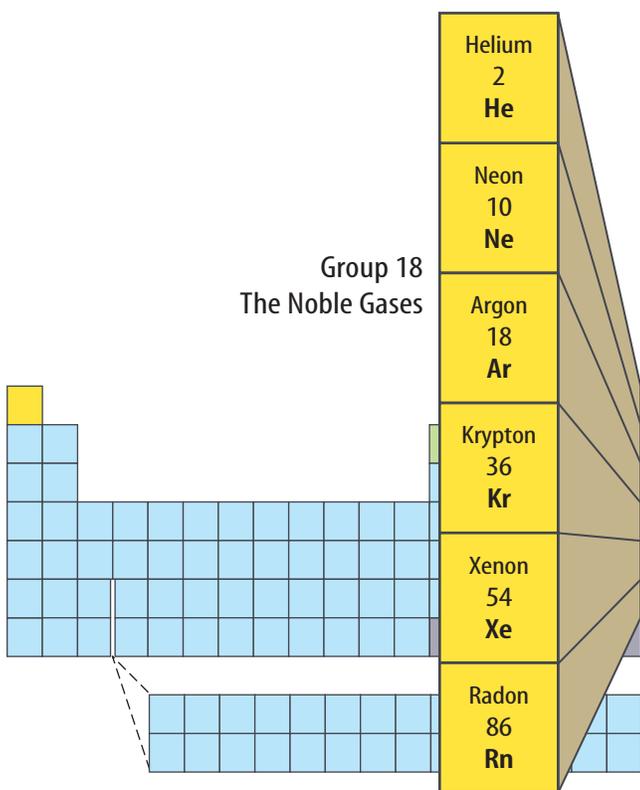
The halogen fluorine is the most reactive of the halogens in combining with other elements. Chlorine is less reactive than fluorine, and bromine is less reactive than chlorine. Iodine is the least reactive of the four nonmetals.

Figure 11 shows some uses of halogens.

Reading Check *What do halogens form with the alkali metals?*

Group 18—The Noble Gases The Group 18 elements are called the **noble gases**. This is because they rarely combine with other elements and are found only as uncombined elements in nature. Their reactivity is very low.

Helium is less dense than air, so it’s great for all kinds of balloons, from party balloons to blimps that carry television cameras high above sporting events. Helium balloons, such as the one in **Figure 12**, lift instruments into the upper atmosphere to measure atmospheric conditions. Even though hydrogen is lighter than helium, helium is preferred for these purposes because helium will not burn.



Uses for the Noble Gases The “neon” lights you see in advertising signs, like the one in **Figure 12**, can contain any of the noble gases, not just neon. Electricity is passed through the glass tubes that make up the sign. These tubes contain the noble gas, and the electricity causes the gas to glow. Each noble gas produces a unique color. Helium glows yellow, neon glows red-orange, and argon produces a bluish-violet color.

Argon, the most abundant of the noble gases on Earth, was first found in 1894. Krypton is used with nitrogen in ordinary lightbulbs because these gases keep the glowing filament from burning out. When a mixture of argon, krypton, and xenon is used, a bulb can last longer than bulbs that do not contain this mixture. Krypton lights are used to illuminate landing strips at airports, and xenon is used in strobe lights and was once used in photographic flash cubes.

At the bottom of the group is radon, a radioactive gas produced naturally as uranium decays in rocks and soil. If radon seeps into a home, the gas can be harmful because it continues to emit radiation. When people breathe the gas over a period of time, it can cause lung cancer.



Figure 12 Noble gases are used in many applications. Scientists use helium balloons to measure atmospheric conditions.



Each noble gas glows a different color when an electric current is passed through it.

Reading Check Why are noble gases used in lights?

section 2 review

Summary

Groups 1 and 2

- Groups 1 and 2 elements are always combined with other elements.
- The elements in Groups 1 and 2 are all metals except for hydrogen.
- Alkaline earth metals are not as active as the alkali metals.

Groups 13–18

- With Groups 13–18, a single group can contain metals, nonmetals, and metalloids.
- Nitrogen and phosphorus are required by living things.
- The halogen group will form salts with alkali metals.

Self Check

1. **Compare and contrast** the elements in Group 1 and the elements in Group 17.
2. **Describe** two uses for a member of each representative group.
3. **Identify** the group of elements that does not readily combine with other elements.
4. **Think Critically** Francium is a rare radioactive alkali metal at the bottom of Group 1. Its properties have not been studied carefully. Would you predict that francium would combine with water more or less readily than cesium?

Applying Skills

5. **Predict** how readily astatine would form a salt compared to the other elements in Group 17. Is there a trend for reactivity in this group?

Transition Elements

as you read

What You'll Learn

- **Identify** properties of some transition elements.
- **Distinguish** lanthanides from actinides.

Why It's Important

Transition elements provide the materials for many things including electricity in your home and steel for construction.

Review Vocabulary

mass number: the sum of neutrons and protons in the nucleus of an atom

New Vocabulary

- catalyst
- actinide
- lanthanide
- synthetic element

The Metals in the Middle

Groups 3–12 are called the transition elements and all of them are metals. Across any period from Group 3 through 12, the properties of the elements change less noticeably than they do across a period of representative elements.

Most transition elements are found combined with other elements in ores. A few transition elements such as gold and silver are found as pure elements.

The Iron Triad Three elements in period 4—iron, cobalt, and nickel—have such similar properties that they are known as the iron triad. These elements, among others, have magnetic properties. Industrial magnets are made from an alloy of nickel, cobalt, and aluminum. Nickel is used in batteries along with cadmium. Iron is a necessary part of hemoglobin, the substance that transports oxygen in the blood.

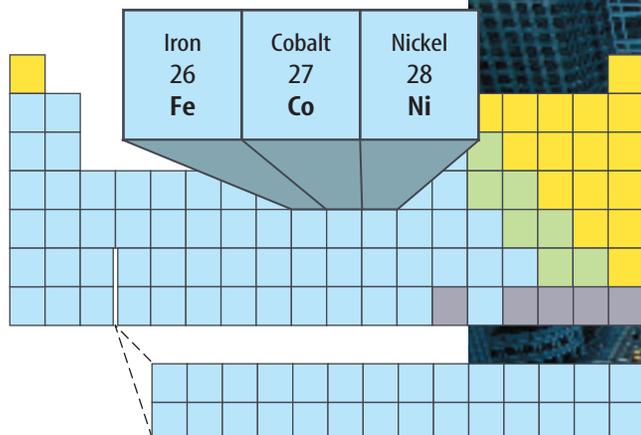
Iron also is mixed with other metals and with carbon to create a variety of steels with different properties. Structures such as bridges and skyscrapers, shown in **Figure 13**, depend upon steel for their strength.

 **Reading Check** Which metals make up the iron triad?

Figure 13 These buildings and bridges have steel in their structure.

Explain why you think steel is used in their construction.

The Iron Triad



Uses of Transition Elements Most transition metals have higher melting points than the representative elements. The filaments of lightbulbs, like the one in **Figure 14**, are made of tungsten, element 74. Tungsten has the highest melting point of any metal (3,410°C) and will not melt when a current passes through it.

Mercury, which has the lowest melting point of any metal (-39°C), is used in thermometers and in barometers. Mercury is the only metal that is a liquid at room temperatures. Like many of the heavy metals, mercury is poisonous to living beings. Therefore, mercury must be handled with care.

Chromium's name comes from the Greek word for color, *chroma*, and the element lives up to its name. Two substances containing chromium are shown in **Figure 15**. Many other transition elements combine to form substances with equally brilliant colors.

Ruthenium, rhodium, palladium, osmium, iridium, and platinum are sometimes called the platinum group because they have similar properties. They do not combine easily with other elements. As a result, they can be used as catalysts. A **catalyst** is a substance that can make something happen faster but is not changed itself. Other transition elements, such as nickel, zinc, and cobalt, can be used as catalysts. As catalysts, the transition elements are used to produce electronic and consumer goods, plastics, and medicines.



Figure 14 The transition metal tungsten is used in lightbulbs because of its high melting point.

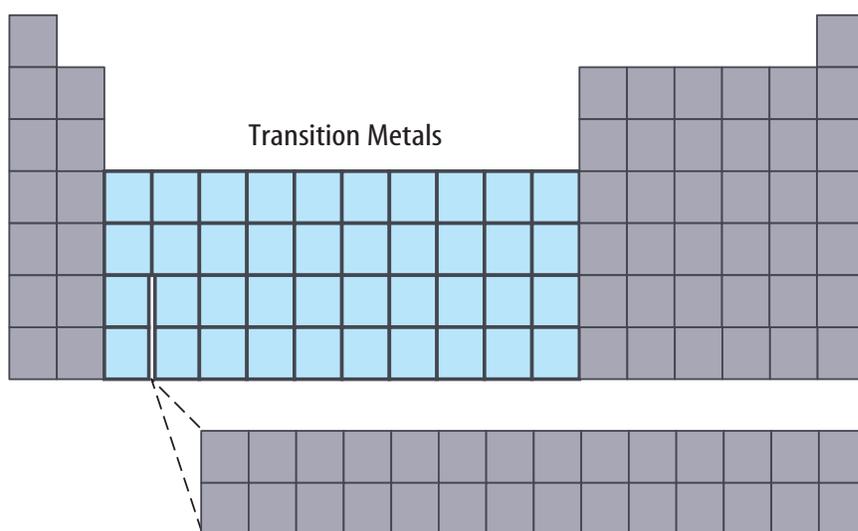


Figure 15 Transition metals are used in a variety of products.





Bright Lights Yttrium oxide (Y_2O_3) and europium oxide (Eu_2O_3) are used in color television screens to give a bright, natural color red. This blend of lanthanide elements will give off a red light when it's hit with a beam of electrons. Other compounds are used to make the additional colors required for a natural-looking picture.

Inner Transition Elements

There are two series of inner transition elements. The first series, from cerium to lutetium, is called the **lanthanides**. The lanthanides also are called the rare earths because at one time they were thought to be scarce. The lanthanides are usually found combined with oxygen in Earth's crust. The second series of elements, from thorium to lawrencium, is called the **actinides**.

Reading Check *What other name is used to refer to the lanthanides?*

The Lanthanides The lanthanides are soft metals that can be cut with a knife. The elements are so similar that they are hard to separate when they occur in the same ore, which they often do. Despite the name rare earth, the lanthanides are not as rare as originally thought. Earth's crust contains more cerium than lead. Cerium makes up 50 percent of an alloy called misch (MIHSH) metal. Flints in lighters, like the one in **Figure 16**, are made from misch metal. The other ingredients in flint are lanthanum, neodymium, and iron.

The Actinides All the actinides are radioactive. The nuclei of atoms of radioactive elements are unstable and decay to form other elements. Thorium, protactinium, and uranium are the only actinides that now are found naturally on Earth. Uranium is found in Earth's crust because its half-life is long—4.5 billion years. All other actinides are synthetic elements. **Synthetic elements** are made in laboratories and nuclear reactors. **Figure 17** shows how synthetic elements are made. The synthetic elements have many uses. Plutonium is used as a fuel in nuclear power plants. Americium is used in some home smoke detectors. Californium-252 is used to kill cancer cells.

Reading Check *What property do all actinides share?*

Figure 16 The flint in this lighter is called misch metal, which is about 50% cerium, 25% lanthanum, 15% neodymium, and 10% other rare earth metals and iron.



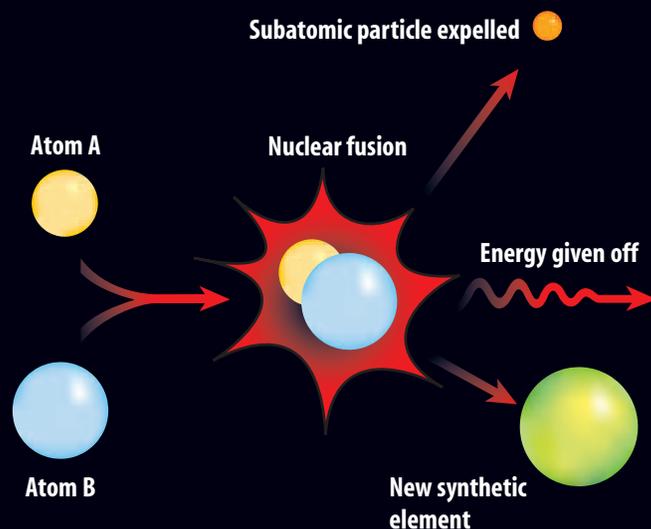
Lanthanide Series

Actinide Series

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

Figure 17

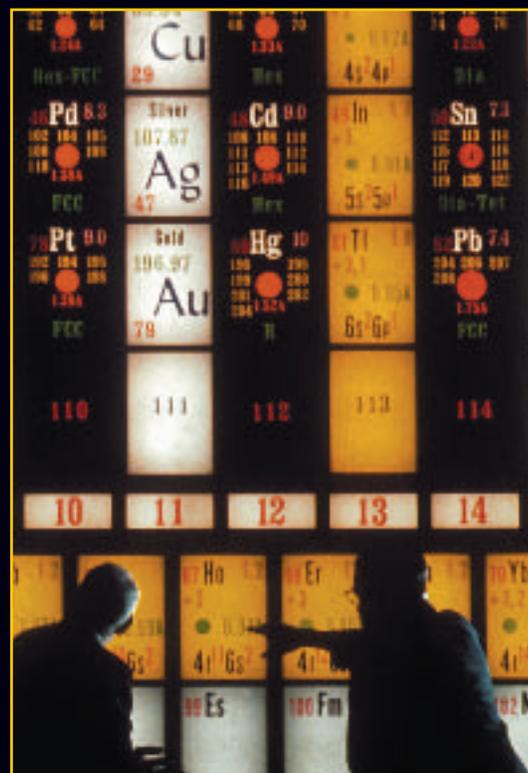
No element heavier than uranium, with 92 protons and 146 neutrons, is typically found in nature. But by using a device called a particle accelerator, scientists can make synthetic elements with atomic numbers greater than that of uranium. Within the accelerator, atomic nuclei are made to collide at high speeds in the hope that some will fuse together to form new, heavier elements. These “heavy” synthetic elements are radioactive isotopes, some of which are so unstable that they survive only a fraction of a second before emitting radioactive particles and decaying into other, lighter elements.



▲ Inside the airless vacuum chamber of a particle accelerator, such as this one in Hesse, Germany, streams of atoms move at incredibly high speeds.

► Recently, the IUPAC (International Union of Pure and Applied Chemistry) General Assembly confirmed the official name and symbol of element 110. Element 110 was previously known as Ununnilium and its symbol was Uun. The new name is darmstadtium and its symbol is Ds. Element 111 is expected to receive its official name and symbol in the near future.

▲ When atoms collide in an accelerator, their nuclei may undergo a fusion reaction to form a new—and often short-lived—synthetic element. Energy and one or more subatomic particles typically are given off in the process.



Topic: Health Risks

Visit bookk.msscience.com for Web links to information about health risks due to mercury.

Activity Write a paragraph on how mercury can affect your health.



Dentistry and Dental Materials

Dentists have been using amalgam for over 150 years to fill cavities in decayed teeth. Amalgam, a mixture of silver, copper, tin, and mercury, is the familiar “silver filling.” Because amalgam contains mercury, some people are concerned that the use of this type of filling may unnecessarily expose a person to mercury vapor. Today dentists have alternatives to amalgam. New composites, resins, and porcelains are being used to repair decayed, broken, or missing teeth. These new materials are strong, chemically resistant to body fluids, and can be altered to have the natural color of the tooth. Some of the new resins also contain fluoride that will protect the tooth from further decay. Many of these new materials would be useless without the development of new bonding agents. The new “glues” or bonding agents adhere the new materials to the natural tooth. These bonding agents must be strong and chemically resistant to body fluids.



Reading Check

Why are these new dental materials desirable for repairing teeth?

Orthodontists are using new nickel and titanium alloys for the wires on braces. These wires have shape memory. The wires undergo a special heat treatment process to lock in their shapes. If the wires are forced out of their heat-treated shape, the wires will try to return to their original shape. Orthodontists have found these wires useful in straightening crooked teeth. How do you think these wires help to straighten crooked teeth?

section 3 review

Summary

Transition Elements

- Groups 3–12, which are transition elements, are all metals.
- Their properties change less than the representative elements.
- The elements in the iron triad are iron, cobalt, and nickel.

Inner Transition Elements

- The lanthanide series contains elements from cerium to lutetium.
- The lanthanides also are known as the rare earth elements.
- The actinide series contains elements from thorium to lawrencium.

Self Check

1. **State** how the elements in the iron triad differ from other transition metals.
2. **Explain** the major difference between the lanthanides and actinides.
3. **Explain** how mercury is used.
4. **Describe** how synthetic elements are made.
5. **Think Critically** Iridium and cadmium are both transition elements. Predict which element is toxic and which element is more likely to be a catalyst. Explain.

Applying Skills

6. **Form Hypotheses** How does the appearance of a burned-out lightbulb compare to a new lightbulb? What could explain the difference?

Metals and Nonmetals

Real-World Question

Metals on asteroids appear attractive for mining to space programs because the metals are essential for space travel. An asteroid could be processed to provide very pure iron and nickel. Valuable by-products would include cobalt, platinum, and gold. How can miners determine if an element is a metal or a nonmetal?

Goals

- **Describe** the appearance of metals and nonmetals.
- **Evaluate** the malleability or brittleness of metals and nonmetals
- **Observe** chemical reactions of metals and nonmetals with an acid and a base.

Materials (per group of 2–3 students)

10 test tubes with rack	
10-mL graduated cylinder	marking pencil
forceps or tweezers	25 g carbon
small hammer or mallet	25 g silicon
dropper bottle of 0.5M HCl	25 g tin
dropper bottle of 0.1M CuCl ₂	25 g sulfur
test-tube brush	25 g iron

Safety Precautions



Procedure

1. Copy data table into your Science Journal. Fill in data table as you complete the lab.
2. Describe in as much detail as possible the appearance of the sample, including color, luster, and state of matter.
3. Use the hammer or mallet to determine malleability or brittleness.
4. Label 5 test tubes #1–5. Place a 1-g sample of each element in separate test tubes. Add 5 mL of HCl to each tube. If bubbles form, this indicates a chemical reaction.
5. Repeat step 4, substituting HCl with CuCl₂. Do not discard the solutions immediately. Continue to observe for five minutes. Some of the changes may be slow. A chemical reaction is indicated by a change in appearance of the element.

Analyze Your Data

1. **Analyze Results** What characteristics distinguish metals from nonmetals?
2. **List** which elements you discovered to be metals.
3. **Describe** a metalloid. Are any of the elements tested a metalloid? If so, name them.

Metal and Nonmetal Data

Element	Appearance	Malleable or Brittle	Reaction wth HCl	Reaction with CuCl ₂
carbon				
silicon				
tin	Do not write in this book.			
sulfur				
iron				

Conclude and Apply

1. **Explain** how the future might increase or decrease the need for selected elements.
2. **Infer** why discovering and mining metals on asteroids might be an important find.

Health Risks from Heavy Metals



Goals

- **Organize** and synthesize information on a chemical or heavy metal thought to cause health problems in the area where you live.
- **Communicate** your findings to others in your class.

Data Source



Visit bookk.msscience.com/internet_lab for more information about health risks from heavy metals, hints on health risks, and data from other students.

Real-World Question

Many heavy metals are found naturally on the planet. People and animals are exposed to these metals every day. One way to reduce the exposure is to know as much as possible about the effects of chemicals on you and the environment. Do heavy metals and other chemicals pose a threat to the health of humans? Could health problems be caused by exposure to heavy metals such as lead, or a radioactive chemical element, such as radon? Is the incidence of these problems higher in one area than another?

Make a Plan

1. Read general information concerning heavy metals and other potentially hazardous chemicals.
2. Use the sites listed at the link to the left to research possible health problems in your area caused by exposure to chemicals or heavy metals. Do you see a pattern in the type of health risks that you found in your research?
3. Check the link to the left to see what others have learned.

Health Risk Data Table

Location	Chemical or Heavy Metal	How People Come in Contact with Chemical	Potential Health Problem	Who Is Affected

Do not write in this book.

▶ Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. **Research information** that can help you find out about health risks in your area.
3. **Organize** your information in a data table like the one shown.
4. **Write** a report in your Science Journal using the results of your research on heavy metals.
5. Post your data in the table provided at the link below.

▶ Analyze Your Data

1. **Evaluate** Did all your sources agree on the health risk of the chemical or heavy metal?
2. **Analyze** all your sources for possible bias. Are some sources more reliable than others?
3. **Explain** how the health risk differs for adults and children.
4. **Identify** the sources of the heavy metals in your area. Are the heavy metals still being deposited in your area?

▶ Conclude and Apply

1. **Analyze Results** Were the same substances found to be health risks in other parts of the country? From the data at the link below, try to predict what chemicals or heavy metals are health risks in different parts of the country.
2. **Determine** what information you think is the most important for the public to be aware of.
3. **Explain** what could be done to decrease the risk of the health problems you identified.

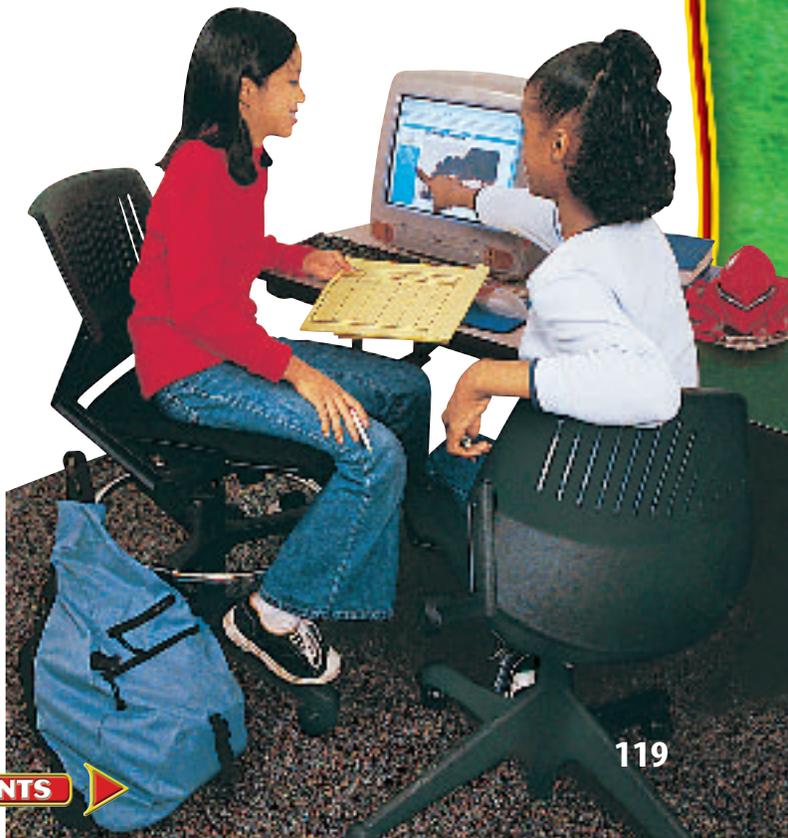
Communicating Your Data

Find this lab using the link below. **Post** your data in the table provided. **Compare** your data to those of other students.

Analyze and look for patterns in the data.

Scienceonline

bookk.msscience.com/internet_lab



Anansi Tries to Steal All the Wisdom in the World

A folktale, adapted by Matt Evans



The following African folktale about a spider named Anansi (or Anancy) is from the Ashanti people in Western Africa.

Anansi the spider knew that he was not wise... “I know... if I can get all of the wisdom in the village and put it in a hollow gourd... I would be the wisest of all!” So he set out to find a suitable gourd and then began his journey to collect the village’s wisdom... He looked around and spotted a tall, tall tree. “Ah,” he said to himself, “if I could hide my wisdom high in that tree, I would never have to worry about someone stealing it from me!”... He first took a cloth band and tied it around his waist. Then he tied the heavy gourd to the front of his belly where it would be safe. As he began to climb, however, the gourd full of wisdom kept getting in the way...

Soon Anansi’s youngest son walked by... “But Father,” said the son, “wouldn’t it be much easier if you tied the gourd behind you instead of in front?”... Anansi moved the gourd so that it was behind him and proceeded up the tree with no problems at all. When he had reached the top, he cried out, “I walked all over and collected so much wisdom I am the wisest person ever, but still my baby son is wiser than me. Take back your wisdom!” He lifted the gourd high over his head and spilled its contents into the wind. The wisdom blew far and wide and settled across the land. And this is how wisdom came to the world.

Understanding Literature

Folktales The African folktale you have just read is called an animal-trickster tale. Trickster tales come from Africa, the Caribbean, and Latin American countries. Trickster tales portray a wily and cunning animal or human who at times bewilders the more powerful and at other times becomes a victim of his or her own schemes. Describe other kinds of folktales, such as fairy tales and tall tales

Respond to the Reading

1. Is Anansi a clever spider?
2. Why did Anansi scatter the wisdom he had collected?
3. **Linking Science and Writing** Write a folktale featuring an animal as a trickster.



Elements are classified in relation to one another in a periodic table. They also are classified in groups of elements that share similar characteristics. Thus, there is a group of elements known as the alkali metals, another called the halogens, and so on. This way of classifying elements is similar to the way in which folktales are classified. Trickster tales have similar characteristics such as a character that has certain traits, like cleverness, wit, cunning, and an ability to survive.

Reviewing Main Ideas

Section 1

Introduction to the Periodic Table

1. When organized according to atomic number in a table, elements with similar properties occupy the same column and are called a group or family.
2. On the periodic table, the properties of the elements change gradually across a horizontal row called a period.
3. The periodic table can be divided into representative elements and transition elements.

Section 2

Representative Elements

1. The groups on the periodic table are known also by other names. For instance, Group 17 is known as halogens.
2. Atoms of elements in Groups 1 and 2 readily combine with atoms of other elements.

3. Each element in Group 2 combines less readily than its neighbor in Group 1. Each alkaline earth metal is denser and has a higher melting point than the alkali metal in its period.
4. Sodium, potassium, magnesium, and calcium have important biological roles.

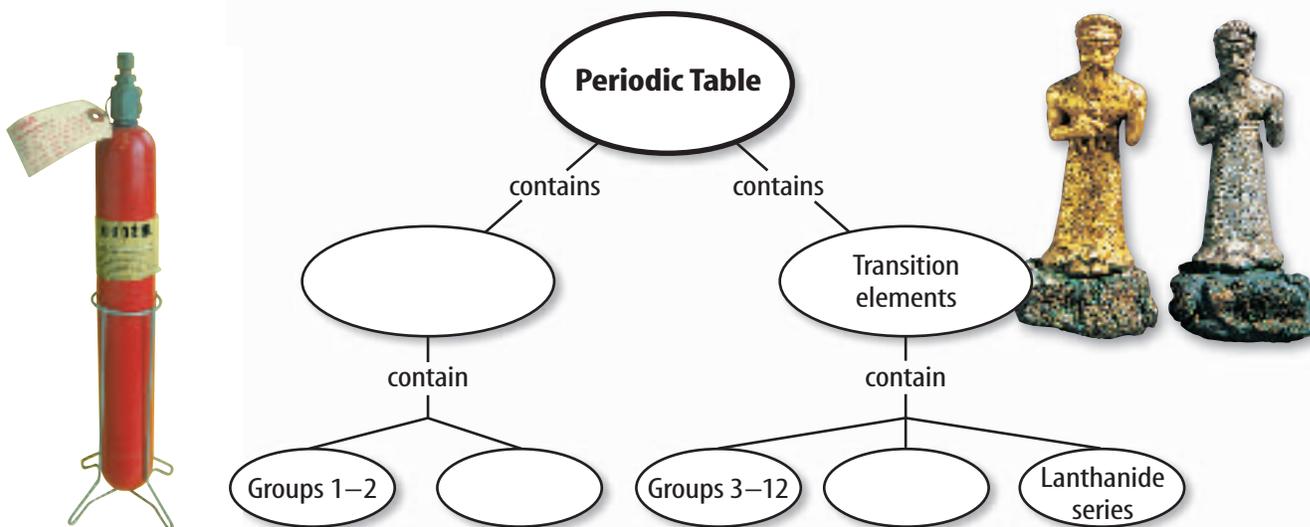
Section 3

Transition Elements

1. The metals in the iron triad are found in a variety of places. Iron is found in blood and in the structure of skyscrapers.
2. Copper, silver, and gold are fairly unreactive, malleable elements.
3. The lanthanides are naturally occurring elements with similar properties.
4. The actinides are radioactive elements. All actinides except thorium, proactinium, and uranium are synthetic.

Visualizing Main Ideas

Copy and complete the following concept map on the periodic table.



Using Vocabulary

actinides p. 114	metalloid p. 102
alkali metals p. 105	noble gases p. 110
alkaline earth metals p. 106	nonmetal p. 102
catalyst p. 113	period p. 99
group p. 99	representative element p. 99
halogens p. 110	semiconductor p. 107
lanthanides p. 114	synthetic elements p. 114
metal p. 102	transition elements p. 99

Answer the following questions using complete sentences.

- What is the difference between a group and a period?
 - What is the connection between a metalloid and a semiconductor?
 - What is a catalyst?
 - Arrange the terms *nonmetal*, *metal*, and *metalloid* according to increasing heat and electrical conductivity.
 - How is a metalloid like a metal? How is it different from a metal?
 - What are synthetic elements?
 - How are transition elements alike?
 - Why are some gases considered to be noble?
- Which element is NOT a part of the iron triad?
 - nickel
 - copper
 - cobalt
 - iron
 - Which element is located in Group 6, period 4?
 - tungsten
 - chromium
 - titanium
 - hafnium
 - Which element below is NOT a transition element?
 - gold
 - calcium
 - silver
 - copper
 - Several groups contain only metals. Which group contains only nonmetals?
 - Group 1
 - Group 12
 - Group 2
 - Group 18
 - Which of the following elements is likely to be contained in a substance with a brilliant yellow color?
 - chromium
 - carbon
 - iron
 - tin
 - Which halogen is radioactive?
 - astatine
 - chlorine
 - bromine
 - iodine
 - Which of the following describes the element tellurium?
 - alkali metal
 - transition metal
 - metalloid
 - lanthanide
 - A brittle, non-conducting, solid might belong to which of the following groups?
 - alkali metals
 - alkaline earth metals
 - actinide series
 - oxygen group



Checking Concepts

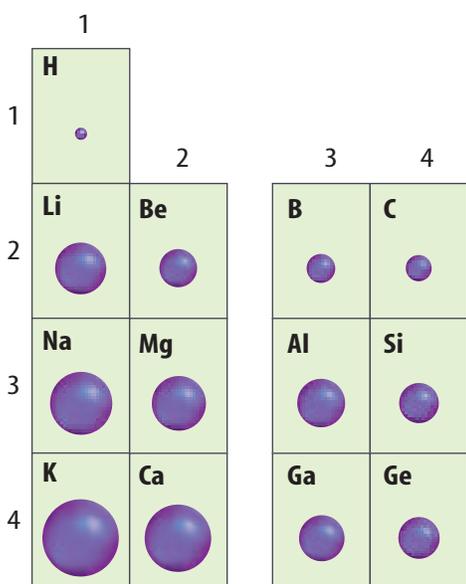
Choose the word or phrase that best answers the question.

- Which of the following groups from the periodic table combines most readily with other elements to form compounds?
 - transition metals
 - alkaline earth metals
 - alkali metals
 - iron triad

Thinking Critically

- 18. **Explain** why it is important that mercury be kept out of streams and waterways.
- 19. **Determine** If you were going to try to get the noble gas argon to combine with another element, would fluorine be a good choice for the other element? Explain.

Use the figure below to answer question 20.



- 20. **Interpret Data** The periodic table shows trends across the rows and down the columns. In this portion of the periodic table, the relative size of the atom is represented by a ball. What trend can you see in this part of the table for relative size?
- 21. **Evaluate** It is theorized that some of the actinides beyond uranium were once present in Earth's crust. If this theory is true, how would their half-lives compare with the half-life of uranium, which is 4.5 billion years?
- 22. **Recognize Cause and Effect** Why do photographers work in low light when they work with materials containing selenium?

- 23. **Predict** How would life on Earth be different if the atmosphere were 80 percent oxygen and 20 percent nitrogen instead of the other way around?
- 24. **Compare and contrast** Na and Mg, which are in the same period, with F and Cl, which are in the same group.

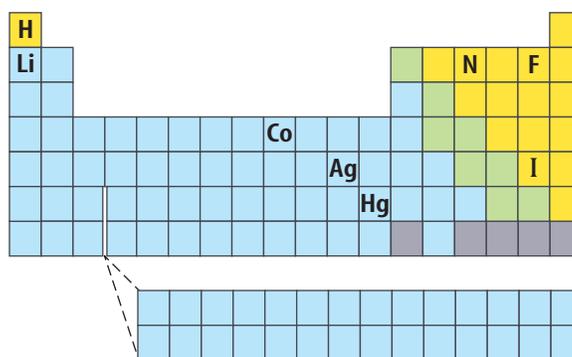
Performance Activities

- 25. **Ask Questions** Research the contribution that Henry G. J. Moseley made to the development of the modern periodic table. Research the background and work of this scientist. Write your findings in the form of an interview.

Applying Math

- 26. **Elements at Room Temperature** Make a bar graph of the representative elements that shows how many of the elements are solids, liquids, and gases at room temperature.
- 27. **Calculate** Using the information that you collected in question 26, calculate the percentage of solids, liquids, and gases within the representative elements.

Use the figure below to answer question 28.



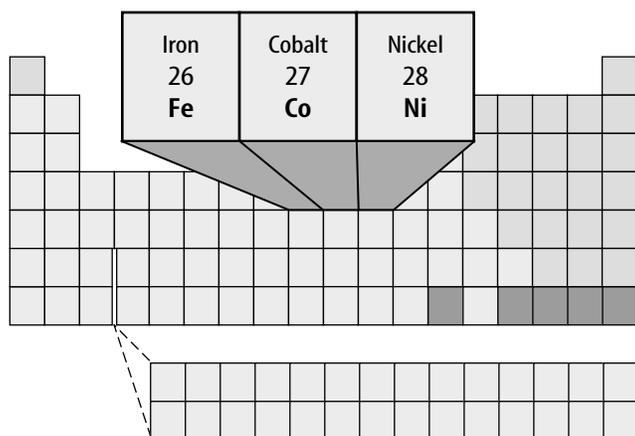
- 28. **Element Details** For each element shown, give the element's period and group number; whether the element is a metal or a nonmetal; and whether it is a solid, liquid, or gas at room temperature.

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- Which statement about the periodic table is TRUE?
 - Elements all occur naturally on Earth.
 - Elements occur in the order in which they were discovered.
 - Elements with similar properties occupy the same group.
 - Elements are arranged in the order Mendeleev chose.
- Which of these is NOT a property of metals?
 - malleability
 - luster
 - ductility
 - poor conductor of heat and electricity

Use the illustration below to answer questions 3 and 4.



- What name is given to these three elements which are used in processes that create steel and other metal mixtures?
 - lanthanides
 - the coin metals
 - actinides
 - the iron triad

Test-Taking Tip

The Best Answer Read all choices before answering the questions.

- To which category do these elements belong?
 - nonmetals
 - transition elements
 - noble gases
 - representative metals
- Which member of the boron family is used to make soft-drink cans, baseball bats, and siding for homes?
 - aluminum
 - boron
 - indium
 - gallium

Use the table below to answer questions 6 and 7.

H																				He	
Li	Be																			F	Ne
Na	Mg																			Cl	Ar
K	Ca																			Br	Kr
Rb	Sr																			I	Xe
Cs	Ba																			At	Rn
Fr	Ra																				

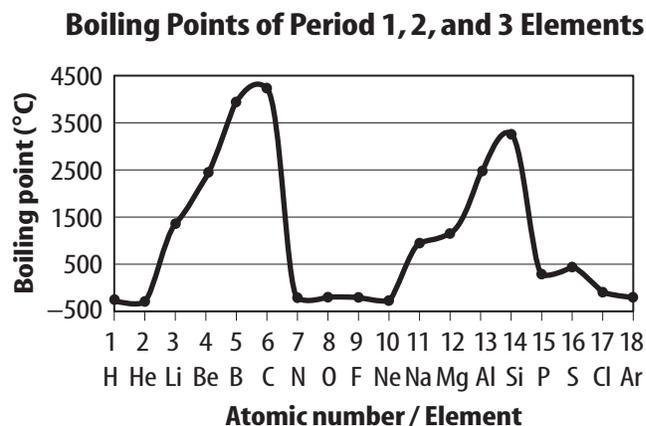
- Halogens are highly reactive nonmetals. Which group combines most readily with them?
 - Group 1, alkali metals
 - Group 2, alkaline earth metals
 - Group 17, halogens
 - Group 18, noble gases
- Which alkali metal element is most reactive?
 - Li
 - Na
 - K
 - Cs
- Many elements that are essential for life, including nitrogen, oxygen, and carbon, are part of what classification?
 - nonmetals
 - metals
 - metalloids
 - noble gases

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- Based on the information found in the periodic table, compare and contrast properties of the elements gold and silver.
- Why don't the element symbols always match the name? Give two examples and describe the origin of each symbol.

Use the graph below to answer questions 11 and 12.



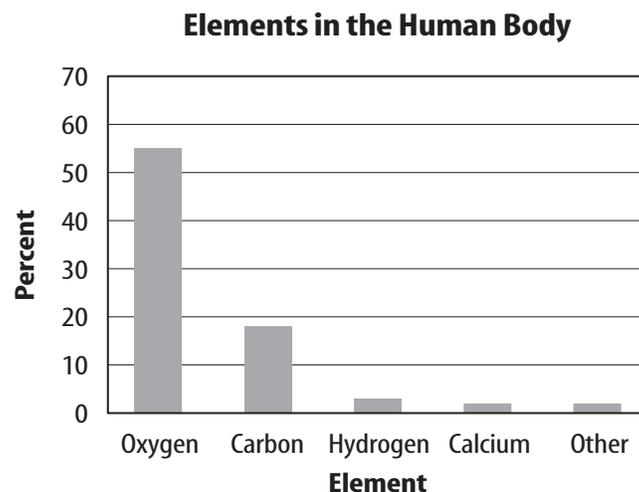
- The data shows that boiling point is a periodic property. Explain what the term *periodic property* means.
- Describe patterns evident in this data.
- Describe the mixture used by dentists for the past 150 years to fill cavities in decayed teeth. Why do many dentists today use other materials to repair teeth?
- Compare and contrast the periodic table that Mendeleev developed to the periodic table that Mosley organized.
- Choose a representative element group and list the elements in that group. Then list three to four uses for those elements.

Part 3 Open Ended

Record your answers on a sheet of paper.

- What role does nitrogen play in the human body? Explain the importance of bacteria in the soil which change the form in which nitrogen naturally occurs.
- Much of the wiring in houses is made from copper. What properties of copper make it ideal for this purpose?
- Why do some homeowners check for the presence of the noble gas radon in their homes?

Use the graph below to answer questions 19 and 20.



- The graph above shows elements present in the greatest amounts in the human body. Use information from the periodic table to create a chart which shows properties of each element, including its symbol, atomic number, the group to which it belongs, and whether it is a metal, non-metal, or metalloid.
- One element shown here is an alkaline earth metal. Compare the properties of the elements in this family to those of the elements found in Group 1.