A building as a Piece of Art!

Would you believe that this strange-looking building is an art museum? It is! It’s the Guggenheim Museum in Bilbao, Spain. The building is made of limestone blocks, glass, and the element titanium. Titanium was chosen because it is strong, lightweight, and very resistant to corrosion and rust. In fact, the half-millimeter-thick fish-scale titanium panels covering most of the building are guaranteed to last 100 years! In this chapter, you will learn about some other elements on the periodic table and their properties.
PLACEMENT PATTERN

In this activity, you will determine the pattern behind a new seating chart your teacher has created.

Procedure

1. In your ScienceLog, draw a seating chart for the classroom arrangement given to you by your teacher. Write the name of each of your classmates in the correct place on the chart.

2. Write information about yourself, such as your name, date of birth, hair color, and height, in the space that represents you on the chart.

3. Starting with the people around you, gather the same information about them. Write each person’s information in the proper space on the seating chart.

Analysis

4. In your ScienceLog, identify a pattern to the information you gathered that might explain the order of the people in the seating chart. If you cannot find a pattern, collect more information and look again.

5. Test your pattern by gathering information from a person you did not talk to before.

6. If the new information does not support your pattern, reanalyze your data and collect more information to determine another pattern.
Imagine you go to a new grocery store to buy a box of cereal. You are surprised by what you find. None of the aisles are labeled, and there is no pattern to the products on the shelves! You think it might take you days to find your cereal.

Some scientists probably felt a similar frustration before 1869. By that time, more than 60 elements had been discovered and described. However, it was not until 1869 that the elements were organized in any special way.

Discovering a Pattern

In the 1860s, a Russian chemist named Dmitri Mendeleev began looking for patterns among the properties of the elements. He wrote the names and properties of the elements on pieces of paper. He included density, appearance, atomic mass, melting point, and information about the compounds formed from the element. He then arranged and rearranged the pieces of paper, as shown in Figure 1. After much thought and work, he determined that there was a repeating pattern to the properties of the elements when the elements were arranged in order of increasing atomic mass.

The Properties of Elements Are Periodic

Mendeleev saw that the properties of the elements were periodic, meaning they had a regular, repeating pattern. Many things that are familiar to you are periodic. For example, the days of the week are periodic because they repeat in the same order every 7 days.

When the elements were arranged in order of increasing atomic mass, similar chemical and physical properties were observed in every eighth element. Mendeleev’s arrangement of the elements came to be known as a periodic table because the properties of the elements change in a periodic way.
Predicting Properties of Missing Elements  Look at the section of Mendeleev’s periodic table shown in Figure 2. Notice the question marks. Mendeleev recognized that there were elements missing and boldly predicted that elements yet to be discovered would fill the gaps. He also predicted the properties of the missing elements by using the pattern of properties in the periodic table. When one of the missing elements, gallium, was discovered a few years later, its properties matched Mendeleev’s predictions very well. Since that time, all of the missing elements on Mendeleev’s periodic table have been discovered. In the chart below, you can see Mendeleev’s predictions for another missing element—germanium—and the actual properties of that element.

### Properties of Germanium

<table>
<thead>
<tr>
<th></th>
<th>Mendeleev’s predictions</th>
<th>Actual properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic mass</td>
<td>72</td>
<td>72.6</td>
</tr>
<tr>
<td>Density</td>
<td>5.5 g/cm³</td>
<td>5.3 g/cm³</td>
</tr>
<tr>
<td>Appearance</td>
<td>dark gray metal</td>
<td>gray metal</td>
</tr>
<tr>
<td>Melting point</td>
<td>high melting point</td>
<td>937°C</td>
</tr>
</tbody>
</table>

Changing the Arrangement

Mendeleev noticed that a few elements in the table were not in the correct place according to their properties. He thought that the calculated atomic masses were incorrect and that more accurate atomic masses would eventually be determined. However, new measurements of the atomic masses showed that the masses were in fact correct.

The mystery was solved in 1914 by a British scientist named Henry Moseley (MOHZ lee). From the results of his experiments, Moseley was able to determine the number of protons—the atomic number—in an atom. When he rearranged the elements by atomic number, every element fell into its proper place in an improved periodic table.

Since 1914, more elements have been discovered. Each discovery has supported the periodic law, considered to be the basis of the periodic table. The periodic law states that the chemical and physical properties of elements are periodic functions of their atomic numbers. The modern version of the periodic table is shown on the following pages.
### Periodic Table of the Elements

Each square on the table includes an element’s name, chemical symbol, atomic number, and atomic mass.

<table>
<thead>
<tr>
<th>Period</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
<th>Group 7</th>
<th>Group 8</th>
<th>Group 9</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>H</td>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td>Hydrogen</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Li</td>
<td>Be</td>
<td>Sc</td>
<td>Ti</td>
<td>V</td>
<td>Cr</td>
<td>Mn</td>
<td>Fe</td>
<td>Co</td>
</tr>
<tr>
<td></td>
<td>Lithium</td>
<td>Beryllium</td>
<td>Scandium</td>
<td>Titanium</td>
<td>Vanadium</td>
<td>Chromium</td>
<td>Manganese</td>
<td>Iron</td>
<td>Cobalt</td>
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<tr>
<td></td>
<td>6.9</td>
<td>9.0</td>
<td>45.0</td>
<td>47.9</td>
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<td>58.9</td>
<td>58.9</td>
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<tr>
<td>3</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sodium</td>
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<td>Sc</td>
<td>Ti</td>
<td>V</td>
<td>Cr</td>
<td>Mn</td>
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</tr>
<tr>
<td>5</td>
<td>Rb</td>
<td>Sr</td>
<td>Y</td>
<td>Zr</td>
<td>Nb</td>
<td>Mo</td>
<td>Tc</td>
<td>Ru</td>
<td>Rh</td>
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<tr>
<td></td>
<td>Rubidium</td>
<td>Strontium</td>
<td>Yttrium</td>
<td>Zirconium</td>
<td>Niobium</td>
<td>Molybdenum</td>
<td>Technetium</td>
<td>Ruthenium</td>
<td>Rhodium</td>
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<td>91.2</td>
<td>92.9</td>
<td>95.9</td>
<td>97.9</td>
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<td>102.9</td>
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<td></td>
</tr>
<tr>
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<td>La</td>
<td>Hf</td>
<td>Ta</td>
<td>W</td>
<td>Re</td>
<td>Os</td>
<td>Ir</td>
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<td>Lanthanum</td>
<td>Hafnium</td>
<td>Tantalum</td>
<td>Tungsten</td>
<td>Rhenium</td>
<td>Osmium</td>
<td>Iridium</td>
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<td>Fr</td>
<td>Ra</td>
<td>Ac</td>
<td>Db</td>
<td>Sg</td>
<td>Bh</td>
<td>Hs</td>
<td>Mt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Francium</td>
<td>Radium</td>
<td>Actinium</td>
<td>Dubnium</td>
<td>Seaborgium</td>
<td>Bohrium</td>
<td>Hassium</td>
<td>Meitnerium</td>
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<td>223.0</td>
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<td>263.1</td>
<td>262.1</td>
<td>265.0</td>
<td>266.0</td>
<td></td>
</tr>
</tbody>
</table>

#### Background
- **Metals**
- **Metalloids**
- **Nonmetals**

#### Chemical symbol
- **Solid**
- **Liquid**
- **Gas**

---

The color of the chemical symbol indicates the physical state at room temperature. Carbon is a solid.

The background color indicates the type of element. Carbon is a nonmetal.

These elements are placed below the table to allow the table to be narrower.

---

**Chapter 12**

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<table>
<thead>
<tr>
<th>Group 13</th>
<th>Group 14</th>
<th>Group 15</th>
<th>Group 16</th>
<th>Group 17</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5</strong> B</td>
<td><strong>6</strong> C</td>
<td><strong>7</strong> N</td>
<td><strong>8</strong> O</td>
<td><strong>9</strong> F</td>
</tr>
<tr>
<td>Boron 10.8</td>
<td>Carbon 12.0</td>
<td>Nitrogen 14.0</td>
<td>Oxygen 16.0</td>
<td>Fluorine 19.0</td>
</tr>
<tr>
<td><strong>13</strong> Al</td>
<td><strong>14</strong> Si</td>
<td><strong>15</strong> P</td>
<td><strong>16</strong> S</td>
<td><strong>17</strong> Cl</td>
</tr>
<tr>
<td>Aluminum 27.0</td>
<td>Silicon 28.1</td>
<td>Phosphorus 31.0</td>
<td>Sulfur 32.1</td>
<td>Chlorine 35.5</td>
</tr>
<tr>
<td><strong>28</strong> Ni</td>
<td><strong>29</strong> Cu</td>
<td><strong>30</strong> Zn</td>
<td><strong>31</strong> Ga</td>
<td><strong>32</strong> Ge</td>
</tr>
<tr>
<td><strong>33</strong> As</td>
<td><strong>34</strong> Se</td>
<td><strong>35</strong> Br</td>
<td><strong>36</strong> Kr</td>
<td></td>
</tr>
<tr>
<td>Nickel 58.7</td>
<td>Copper 63.5</td>
<td>Zinc 65.4</td>
<td>Gallium 69.7</td>
<td>Germanium 72.6</td>
</tr>
<tr>
<td><strong>46</strong> Pd</td>
<td><strong>47</strong> Ag</td>
<td><strong>48</strong> Cd</td>
<td><strong>49</strong> In</td>
<td><strong>50</strong> Sn</td>
</tr>
<tr>
<td><strong>51</strong> Sb</td>
<td><strong>52</strong> Te</td>
<td><strong>53</strong> I</td>
<td><strong>54</strong> Xe</td>
<td></td>
</tr>
<tr>
<td>Palladium 106.4</td>
<td>Silver 107.9</td>
<td>Cadmium 112.4</td>
<td>Indium 114.8</td>
<td>Tin 118.7</td>
</tr>
<tr>
<td><strong>78</strong> Pt</td>
<td><strong>79</strong> Au</td>
<td><strong>80</strong> Hg</td>
<td><strong>81</strong> Tl</td>
<td><strong>82</strong> Pb</td>
</tr>
<tr>
<td><strong>83</strong> Bi</td>
<td><strong>84</strong> Po</td>
<td><strong>85</strong> At</td>
<td><strong>86</strong> Rn</td>
<td></td>
</tr>
<tr>
<td><strong>110</strong> Uun</td>
<td><strong>111</strong> Uuu</td>
<td><strong>112</strong> Uub</td>
<td><strong>113</strong> Uub</td>
<td></td>
</tr>
<tr>
<td>Ununninilium (271)</td>
<td>Unununinilium (272)</td>
<td>Ununinilium (277)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This zigzag line reminds you where the metals, nonmetals, and metalloids are.

The names and symbols of elements 110–112 are temporary. They are based on the atomic number of the element. The official name and symbol will be approved by an international committee of scientists.

A number in parentheses is the mass number of the most stable isotope of that element.

TOPIC: Periodic Table
GO TO: go.hrw.com
KEYWORD: HNO Periodic

Visit the HRW Web site to see the most recent version of the periodic table.
Finding Your Way Around the Periodic Table

At first glance, you might think studying the periodic table is like trying to explore a thick jungle without a guide—it would be easy to get lost! However, the table itself contains a lot of information that will help you along the way.

Classes of Elements  Elements are classified as metals, nonmetals, and metalloids, according to their properties. The number of electrons in the outer energy level of an atom also helps determine which category an element belongs in. The zigzag line on the periodic table can help you recognize which elements are metals, which are nonmetals, and which are metalloids.

Metals

Most elements are metals. Metals are found to the left of the zigzag line on the periodic table. Atoms of most metals have few electrons in their outer energy level, as shown at right.

Most metals are solid at room temperature. Mercury, however, is a liquid. Some additional information on properties shared by most metals is shown below.

- **Metals**
  - Most metals are good conductors of thermal energy. This iron griddle conducts thermal energy from a stovetop to cook your favorite foods.
  - Most metals are malleable, meaning that they can be flattened with a hammer without shattering. Aluminum is flattened into sheets to make cans and foil.
  - Most metals are ductile, which means that they can be drawn into thin wires. All metals are good conductors of electric current. The wires in the electrical devices in your home are made from the metal copper.
  - Metals tend to be shiny. You can see a reflection in a mirror because light reflects off the shiny surface of a thin layer of silver behind the glass.
Nonmetals are found to the right of the zigzag line on the periodic table. Atoms of most nonmetals have an almost complete set of electrons in their outer level, as shown at right. (Atoms of one group of nonmetals, the noble gases, have a complete set of electrons, with most having eight electrons in their outer energy level.)

More than half of the nonmetals are gases at room temperature. The properties of nonmetals are the opposite of the properties of metals, as shown below.

**Nonmetals**

- Nonmetals are **not malleable or ductile**. In fact, solid nonmetals, like carbon (shown here in the graphite of the pencil lead), are brittle and will break or shatter when hit with a hammer.
- Nonmetals are **not shiny**. In fact, solid nonmetals, like carbon, are brittle and will break or shatter when hit with a hammer.

**Metalloids**

Metalloids, also called semiconductors, are the elements that border the zigzag line on the periodic table. Atoms of metalloids have about a half-complete set of electrons in their outer energy level, as shown at right.

Metalloids have some properties of metals and some properties of nonmetals, as shown below.

- **Tellurium is shiny, but it is also brittle and is easily smashed into a powder.**
- **Boron is almost as hard as diamond, but it is also very brittle.** At high temperatures, boron is a good conductor of electric current.

---

**QuickLab**

**Conduction Connection**

1. Fill a **plastic-foam cup** with **hot water**.
2. Stand a piece of **copper wire** and a **graphite lead** from a mechanical pencil in the water.
3. After 1 minute, touch the top of each object. Record your observations.
4. Which material conducted thermal energy the best? Why?
Each Element Is Identified by a Chemical Symbol  Each square on the periodic table contains information about an element, including its atomic number, atomic mass, name, and chemical symbol. An international committee of scientists is responsible for approving the names and chemical symbols of the elements. The names of the elements come from many sources. For example, some elements are named after important scientists (mendelevium, einsteinium), and others are named for geographical regions (germanium, californium).

The chemical symbol for each element usually consists of one or two letters. The first letter in the symbol is always capitalized, and the second letter, if there is one, is always written in lowercase. The chart below lists the patterns that the chemical symbols follow, and the Activity will help you investigate two of those patterns further.

<table>
<thead>
<tr>
<th>Pattern of chemical symbols</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>first letter of the name</td>
<td>S—sulfur</td>
</tr>
<tr>
<td>first two letters of the name</td>
<td>Ca—calcium</td>
</tr>
<tr>
<td>first letter and third or later letter of the name</td>
<td>Mg—magnesium</td>
</tr>
<tr>
<td>letter(s) of a word other than the English name</td>
<td>Pb—lead (from the Latin <em>plumbum</em>, meaning &quot;lead&quot;)</td>
</tr>
<tr>
<td>first letter of root words that stand for the atomic number (used for elements whose official names have not yet been chosen)</td>
<td>Uun—ununnilium (uhn uhn NIL ee uhm) (for atomic number 110)</td>
</tr>
</tbody>
</table>

Activity

Draw a line down a sheet of paper to divide it into two columns. Look at the elements with atomic numbers 1 through 10 on the periodic table. Write all the chemical symbols and names that follow one pattern in one column on your paper and all chemical symbols and names that follow a second pattern in the second column. Write a sentence describing each pattern you found.

Writing the Chemical Symbols

One Set of Symbols

Look at the periodic table shown here. How is it the same as the periodic table you saw earlier? How is it different? Explain why it is important for scientific communication that the chemical symbols used are the same around the world.
Rows Are Called Periods Each horizontal row of elements (from left to right) on the periodic table is called a period. For example, the row from lithium (Li) to neon (Ne) is Period 2. A row is called a period because the properties of elements in a row follow a repeating, or periodic, pattern as you move across each period. The physical and chemical properties of elements, such as conductivity and the number of electrons in the outer level of atoms, change gradually from those of a metal to those of a nonmetal in each period, as shown in Figure 3.

Columns Are Called Groups Each column of elements (from top to bottom) on the periodic table is called a group. Elements in the same group often have similar chemical and physical properties. For this reason, sometimes a group is also called a family. You will learn more about each group in the next section.

The Periodic Table

1. Compare a period and a group on the periodic table.
2. How are the elements arranged in the modern periodic table?
3. Comparing Concepts Compare metals, nonmetals, and metalloids in terms of their electrical conductivity.
Grouping the Elements

You probably know a family with several members that look a lot alike. Or you may have a friend whose little brother or sister acts just like your friend. Members of a family often—but not always—have a similar appearance or behavior. Likewise, the elements in a family or group in the periodic table often—but not always—share similar properties. The properties are similar because the atoms of the elements have the same number of electrons in their outer energy level.

Groups 1 and 2: Very Reactive Metals

The most reactive metals are the elements in Groups 1 and 2. What makes an element reactive? The answer has to do with electrons in the outer energy level of atoms. 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 reactive and combine to form compounds. Elements whose atoms need to take, give, or share only one or two electrons to have a filled outer level tend to be very reactive.

The elements in Groups 1 and 2 are so reactive that they are only found combined with other elements in nature. To study the elements separately, the naturally occurring compounds must first be broken apart through chemical changes.

Group 1: Alkali Metals

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.

Alkali (AL kuh LIE) metals are soft enough to be cut with a knife, as shown in Figure 4. The densities of the alkali metals are so low that lithium, sodium, and potassium are actually less dense than water.

Figure 4 Metals so soft that they can be cut with a knife? Welcome to the alkali metals.
Alkali metals are the most reactive of the metals. This is because their atoms can easily give away the single electron in their outer level. For example, alkali metals react violently with water, as shown in Figure 5. Alkali metals are usually stored in oil to prevent them from reacting with water and oxygen in the atmosphere.

The compounds formed from alkali metals have many uses. Sodium chloride (table salt) can be used to add flavor to your food. Sodium hydroxide can be used to unclog your drains. Potassium bromide is one of several potassium compounds used in photography.

**Figure 5** As alkali metals react with water, they form hydrogen gas.

**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:** Silver-colored; more dense than alkali metals

Alkaline-earth metals are not as reactive as alkali metals because it is more difficult for atoms to give away two electrons than to give away only one when joining with other atoms.

The alkaline-earth metal magnesium is often mixed with other metals to make low-density materials used in airplanes. Compounds of alkaline-earth metals also have many uses. For example, compounds of calcium are found in cement, plaster, chalk, and even you, as shown in Figure 6.

**Figure 6** Smile! Calcium, an alkaline-earth metal, is an important component of a compound that makes your bones and teeth healthy.
Groups 3–12: Transition Metals

Groups 3–12 do not have individual names. Instead, these groups are described together under the name *transition metals*.

**Group contains:** Metals  
**Electrons in the outer level:** 1 or 2  
**Reactivity:** Less reactive than alkaline-earth metals  
**Other shared properties:** Shiny; good conductors of thermal energy and electric current; higher densities and melting points (except for mercury) than elements in Groups 1 and 2

The atoms of transition metals do not give away their electrons as easily as atoms of the Group 1 and Group 2 metals do, making transition metals less reactive than the alkali metals and the alkaline-earth metals. The properties of the transition metals vary widely, as shown in Figure 7.

![Figure 7 Transition metals have a wide range of physical and chemical properties.](image)

**Mercury** is used in thermometers because, unlike the other transition metals, it is in the liquid state at room temperature.

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

**Self-Check**

Why are alkali metals more reactive than alkaline-earth metals? *(See page 724 to check your answer.)*
Lanthanides and Actinides Some transition metals from Periods 6 and 7 are placed at the bottom of the periodic table to keep the table from being too wide. The properties of the elements in each row tend to be very similar.

Elements in the first row are called lanthanides because they follow the transition metal lanthanum. The lanthanides are shiny, reactive metals. Some of these elements are used to make different types of steel. An important use of a compound of one lanthanide element is shown in Figure 8.

Elements in the second row are called actinides because they follow the transition metal actinium. All atoms of actinides are radioactive, which means they are unstable. The atoms of a radioactive element can change into atoms of a different element. Elements listed after plutonium, element 94, do not occur in nature but are instead produced in laboratories. You might have one of these elements in your home. Very small amounts of americium (Am uhr ISH ee uhm), element 95, are used in some smoke detectors.

Figure 8 Seeing red? The color red appears on a computer monitor because of a compound formed from europium that coats the back of the screen.

REVIEW

1. What are two properties of the alkali metals?
2. What causes the properties of elements in a group to be similar?
3. Applying Concepts Why are neither the alkali metals nor the alkaline-earth metals found uncombined in nature?
Groups 13–16: Groups with Metalloids

Moving from Group 13 across to Group 16, the elements shift from metals to nonmetals. Along the way, you find the metalloids. These elements have some properties of metals and some properties of nonmetals.

Group 13: Boron Group

- **Group contains:** One metalloid and four metals
- **Electrons in the outer level:** 3
- **Reactivity:** Reactive
- **Other shared properties:** Solid 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, it was considered a precious metal because the process used to produce pure aluminum was very expensive. In fact, aluminum was even more valuable than gold, as shown in Figure 9.

Today, the process is not as difficult or expensive. Aluminum is now an important metal used in making lightweight automobile parts and aircraft, as well as foil, cans, and wires.

**Figure 9** During the 1850s and 1860s, Emperor Napoleon III of France used aluminum dinnerware because aluminum was more valuable than gold!

Group 14: Carbon Group

- **Group contains:** One nonmetal, two metalloids, and two metals
- **Electrons in the outer level:** 4
- **Reactivity:** Varies among the elements
- **Other shared properties:** Solid at room temperature

The metalloids silicon and germanium are used to make computer chips. The metal tin is useful because it is not very reactive. A tin can is really made of steel coated with tin. The tin is less reactive than the steel, and it keeps the steel from rusting.
The nonmetal carbon can be found uncombined in nature, as shown in Figure 10. Carbon forms a wide variety of compounds. Some of these compounds, including proteins, fats, and carbohydrates, are essential to life on Earth.

Group 15: Nitrogen Group

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>7</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
</tr>
<tr>
<td>15</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Phosphorus</td>
</tr>
<tr>
<td>33</td>
<td>As</td>
</tr>
<tr>
<td></td>
<td>Arsenic</td>
</tr>
<tr>
<td>51</td>
<td>Sb</td>
</tr>
<tr>
<td></td>
<td>Antimony</td>
</tr>
<tr>
<td>83</td>
<td>Bi</td>
</tr>
<tr>
<td></td>
<td>Bismuth</td>
</tr>
</tbody>
</table>

**Group contains:** Two nonmetals, two metalloids, and one metal  
**Electrons in the outer level:** 5  
**Reactivity:** Varies among the elements  
**Other shared properties:** All but nitrogen are solid at room temperature.

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

Although nitrogen is unreactive, phosphorus is extremely reactive, as shown in Figure 11. In fact, phosphorus is only found combined with other elements in nature.

Group 16: Oxygen Group

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>8</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Oxygen</td>
</tr>
<tr>
<td>16</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>Sulfur</td>
</tr>
<tr>
<td>34</td>
<td>Se</td>
</tr>
<tr>
<td></td>
<td>Selenium</td>
</tr>
<tr>
<td>52</td>
<td>Te</td>
</tr>
<tr>
<td></td>
<td>Tellurium</td>
</tr>
<tr>
<td>84</td>
<td>Po</td>
</tr>
<tr>
<td></td>
<td>Polonium</td>
</tr>
</tbody>
</table>

**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 percent of air. Oxygen is necessary for substances to burn, such as the chemicals on the match in Figure 11. Sulfur, another common member of Group 16, can be found as a yellow solid in nature. The principal use of sulfur is to make sulfuric acid, the most widely used compound in the chemical industry.
Groups 17 and 18: Nonmetals Only

The elements in Groups 17 and 18 are nonmetals. The elements in Group 17 are the most reactive nonmetals, but the elements in Group 18 are the least reactive nonmetals. In fact, the elements in Group 18 normally won’t react at all with other elements.

Group 17: Halogens

Halogens 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.

Although the chemical properties of the halogens are similar, the physical properties are quite different, as shown in Figure 12.

Both chlorine and iodine are used as disinfectants. Chlorine is used to treat water, while iodine mixed with alcohol is used in hospitals.

Group 18: Noble Gases

Noble gases are unreactive nonmetals. Because the atoms of the elements in this group have a complete set of electrons in their outer level, they do not need to lose or gain any electrons. Therefore, they do not react with other elements under normal conditions.

All of the noble gases are found in Earth’s atmosphere in small amounts. Argon, the most abundant noble gas in the atmosphere, makes up almost 1 percent of the atmosphere.
The nonreactivity of the noble gases makes them useful. Ordinary light bulbs last longer when filled with argon than they would if filled with a reactive gas. Because argon is unreactive, it does not react with the metal filament in the light bulb even when the filament gets hot. The low density of helium causes blimps and weather balloons to float, and its nonreactivity makes helium safer to use than hydrogen. One popular use of noble gases that does not rely on their nonreactivity is shown in Figure 13.

**Hydrogen Stands Apart**

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 placed above Group 1 in the periodic table because atoms of the alkali metals also have only one electron in their outer level. Atoms of hydrogen, like atoms of alkali metals, can give away one electron when joining with other atoms. However, hydrogen’s physical properties are more like the properties of nonmetals than of metals. As you can see, hydrogen really is in a group of its own.

Hydrogen is the most abundant element in the universe. Hydrogen’s reactive nature makes it useful as a fuel in rockets, as shown in Figure 14.

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**REVIEW**

1. In which group are the unreactive nonmetals found?
2. What are two properties of the halogens?
3. **Making Predictions** In the future, a new halogen may be synthesized. Predict its atomic number and properties.
4. **Comparing Concepts** Compare the element hydrogen with the alkali metal sodium.
Chapter Highlights

SECTION 1

Vocabulary
periodic (p. 302)
periodic law (p. 303)
period (p. 309)
group (p. 309)

Section Notes
• Mendeleev developed the first periodic table. He arranged elements in order of increasing atomic mass. The properties of elements repeated in an orderly pattern, allowing Mendeleev to predict properties for elements that had not yet been discovered.

• Moseley rearranged the elements in order of increasing atomic number.

• The periodic law states that the chemical and physical properties of elements are periodic functions of their atomic numbers.

• Elements in the periodic table are divided into metals, metalloids, and nonmetals.

• Each element has a chemical symbol that is recognized around the world.

• A horizontal row of elements is called a period. The elements gradually change from metallic to nonmetallic from left to right across each period.

• A vertical column of elements is called a group or family. Elements in a group usually have similar properties.

Labs
Create a Periodic Table (p. 678)

Skills Check

Visual Understanding

PERIODIC TABLE OF THE ELEMENTS Scientists rely on the periodic table as a resource for a large amount of information. Review the periodic table on pages 304–305. Pay close attention to the labels and the key; they will help you understand the information presented in the table.

CLASSES OF ELEMENTS Identifying an element as a metal, nonmetal, or metalloid gives you a better idea of the properties of that element. Review the figures on pages 306–307 to understand how to use the zigzag line on the periodic table to identify the classes of elements and to review the properties of elements in each category.
Vocabulary
alkali metals (p. 310)
alkaline-earth metals (p. 311)
halogens (p. 316)
noble gases (p. 316)

Section Notes
• The alkali metals (Group 1) are the most reactive metals. Atoms of the alkali metals have one electron in their outer level.
• The alkaline-earth metals (Group 2) are less reactive than the alkali metals. Atoms of the alkaline-earth metals have two electrons in their outer level.
• The transition metals (Groups 3–12) include most of the well-known metals as well as the lanthanides and actinides located below the periodic table.
• Groups 13–16 contain the metalloids along with some metals and nonmetals. The atoms of the elements in each of these groups have the same number of electrons in their outer level.
• The halogens (Group 17) are very reactive nonmetals. Atoms of the halogens have seven electrons in their outer level.
• The noble gases (Group 18) are unreactive nonmetals. Atoms of the noble gases have a complete set of electrons in their outer level.
• Hydrogen is set off by itself because its properties do not match the properties of any one group.
Chapter Review

USING VOCABULARY

Complete the following sentences by choosing the appropriate term from each pair of terms listed below.

1. Elements in the same vertical column in the periodic table belong to the same ___? (group or period)

2. Elements in the same horizontal row in the periodic table belong to the same ___? (group or period)

3. The most reactive metals are __?__ (alkali metals or alkaline-earth metals)

4. Elements that are unreactive are called __?__ (noble gases or halogens)

UNDERSTANDING CONCEPTS

Multiple Choice

5. An element that is a very reactive gas is most likely a member of the
   a. noble gases.  
   b. alkali metals. 
   c. halogens. 
   d. actinides.

6. Which statement 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 under water.
   d. Alkali metals are unreactive.

7. Which statement about the periodic table is false?
   a. There are more metals than nonmetals.
   b. The metalloids are located in Groups 13 through 16.
   c. The elements at the far left of the table are nonmetals.
   d. Elements are arranged by increasing atomic number.

8. One property of most nonmetals is that they are
   a. shiny.
   b. poor conductors of electric current.
   c. flattened when hit with a hammer.
   d. solids at room temperature.

9. Which is a true statement about elements?
   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.

10. Which is NOT found on the periodic table?
    a. the atomic number of each element
    b. the symbol of each element
    c. the density of each element
    d. the atomic mass of each element

Short Answer

11. Why was Mendeleev’s periodic table useful?

12. How is Moseley’s basis for arranging the elements different from Mendeleev’s?

13. How is the periodic table like a calendar?

14. Describe the location of metals, metalloids, and nonmetals on the periodic table.
15. Use the following terms to create a concept map: periodic table, elements, groups, periods, metals, nonmetals, metalloids.

16. When an element with 115 protons in its nucleus is synthesized, will it be a metal, a nonmetal, or a metalloid? Explain.

17. Look at Mendeleev’s periodic table in Figure 2. Why was Mendeleev not able to make any predictions about the noble gas elements?

18. Your classmate offers to give you a piece of sodium he found while hiking. What is your response? Explain.

19. Determine the identity of each element described below:
   a. This metal is very reactive, has properties similar to magnesium, and is in the same period as bromine.
   b. This nonmetal is in the same group as lead.
   c. This metal is the most reactive metal in its period and cannot be found uncombined in nature. Each atom of the element contains 19 protons.

20. The chart below shows the percentages of elements in the Earth’s crust.

Excluding the “Other” category, what percentage of the Earth’s crust is
   a. alkali metals?
   b. alkaline-earth metals?

21. 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.

Take a minute to review your answers to the Pre-Reading Questions found at the bottom of page 300. Have your answers changed? If necessary, revise your answers based on what you have learned since you began this chapter.