

# Periodic Table

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Jean Brainard, Ph.D.

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# CHAPTER 1

# Periodic Table

## CHAPTER OUTLINE

- 1.1 How Elements Are Organized
- 1.2 Classes of Elements
- 1.3 Groups of Elements
- 1.4 References



Imagine going to the library and finding all the books in big messy piles like the one above. It could take a very long time to find the book you wanted. You might give up without even trying. Of course, in most libraries, books are arranged in an orderly way, like the books shown below. For example, novels, like those pictured here, are arranged in alphabetical order by author's last name. Not only can you quickly find the book you want, you can also scan the books nearby to find others by the same author. It's clear that grouping books in an organized way is very useful.



The same is true of chemical elements. For many years, scientists looked for a good way to organize them. This became increasingly important as more and more elements were discovered. In this chapter, you'll read how elements were first organized and how they are organized today. You'll see why an orderly arrangement of elements, like the books in a library, is also very useful.

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# 1.1 How Elements Are Organized

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## Lesson Objectives

- Describe Mendeleev's periodic table of the elements.
- Give an overview of the modern periodic table of the elements.

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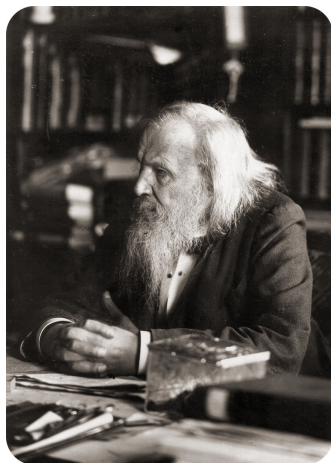
## Vocabulary

- group
- period
- periodic table

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## Introduction

Scientists first started looking for a way to organize the elements in the 1700s. They were trying to find a method to group together elements with similar properties. No one could come up with a good solution. It wasn't until the 1860s that a successful method was devised. It was developed by a Russian chemist named Dmitri Mendeleev. He is pictured in **Figure 1.1**. You can learn more about him and his work at this URL: <http://videos.howstuffworks.com/science-channel/27862-100-greatest-discoveries-the-periodic-table-video.htm>.



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**FIGURE 1.1**

Dmitri Mendeleev developed the first periodic table of the elements in 1869.

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## Mendeleev's Periodic Table of the Elements

Mendeleev was a teacher as well as a chemist. He was writing a chemistry textbook and needed a way to organize the elements so it would be easier for students to learn about them. He made a set of cards of the elements, similar to a deck of playing cards, with one element per card. On the card, he wrote the element's name, atomic mass, and known properties. He arranged and rearranged the cards in many different ways, looking for a pattern. He finally found it when he placed the elements in order by atomic mass.

### A Repeating Pattern

You can see how Mendeleev organized the elements in **Figure 1.2**. From left to right across each row, elements are arranged by increasing atomic mass. Mendeleev discovered that if he placed eight elements in each row and then continued on to the next row, the columns of the table would contain elements with similar properties. He called the columns **groups**. They are sometimes called families, because elements within a group are similar but not identical to one another, like people in a family.

Reihen	Gruppe I. — R <sup>0</sup>	Gruppe II. — R <sup>0</sup>	Gruppe III. — R <sup>0</sup> <sup>3</sup>	Gruppe IV. RH <sup>4</sup> R <sup>0</sup> <sup>2</sup>	Gruppe V. RH <sup>5</sup> R <sup>0</sup> <sup>3</sup>	Gruppe VI. RH <sup>6</sup> R <sup>0</sup> <sup>3</sup>	Gruppe VII. RH R <sup>0</sup> <sup>7</sup>	Gruppe VIII. — R <sup>0</sup> <sup>4</sup>
1	II=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=60, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	So=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

**FIGURE 1.2**

Mendeleev's table of the elements organizes the elements by atomic mass. The table has a repeating pattern.

Mendeleev's table of the elements is called a **periodic table** because of its repeating pattern. Anything that keeps repeating is referred to as periodic. Other examples of things that are periodic include the monthly phases of the moon and the daily cycle of night and day. The term **period** refers to the interval between repetitions. In a periodic table, the periods are the rows of the table. In Mendeleev's table, each period contains eight elements, and then the pattern repeats in the next row.

## Predicting Missing Elements

Did you notice the blanks in Mendeleev's table (**Figure 1.2**)? They are spaces that Mendeleev left for elements that had not yet been discovered when he created his table. He predicted that these missing elements would eventually be discovered. Based on their position in the table, he could even predict their properties. For example, he predicted a missing element in row 5 of his group 3. He said it would have an atomic mass of about 68 and be a soft metal like other group 3 elements. Scientists searched for the missing element. They found it a few years later and named it gallium. Scientists searched for the other missing elements. Eventually, all of them were found.

An important measure of a good model is its ability to make accurate predictions. This makes it a useful model. Clearly, Mendeleev's periodic table was a useful model. It helped scientists discover new elements and make sense of those that were already known.

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## The Modern Periodic Table of the Elements

A periodic table is still used today to classify the elements. **Figure 1.3** shows the modern periodic table. You can see an interactive version at this URL: <http://www.ptable.com/>.

### Basis of the Modern Periodic Table

In the modern periodic table, elements are organized by atomic number. The atomic number is the number of protons in an atom of an element. This number is unique for each element, so it seems like an obvious way to organize the elements. (Mendeleev used atomic mass instead of atomic number because protons had not yet been discovered when he made his table.) In the modern table, atomic number increases from left to right across each period. It also increases from top to bottom within each group. How is this like Mendeleev's table?

### Reading the Table

Besides atomic number, the periodic table includes each element's chemical symbol and class. Some tables include other information as well.

- The chemical symbol consists of one or two letters that come from the chemical's name in English or another language. The first letter is always written in upper case. The second letter, if there is one, is always written in lower case. For example, the symbol for lead is Pb. It comes from the Latin word *plumbum*, which means "lead." Find lead in **Figure 1.3**. What is its atomic number? You can access videos about lead and other elements in the modern periodic table at this URL: <http://www.periodicvideos.com/index.htm>.
- The classes of elements are metals, metalloids, and nonmetals. They are color-coded in the table. Blue stands for metals, orange for metalloids, and green for nonmetals. You can read about each of these three classes of elements later in the chapter, in the lesson "Classes of Elements."

### Periods

Rows of the modern table are called periods, as they are in Mendeleev's table. From left to right across a period, each element has one more proton than the element before it. In each period, elements change from metals on the left side of the table, to metalloids, and then to nonmetals on the right. **Figure 1.4** shows this for period 4.

Some periods in the modern periodic table are longer than others. For example, period 1 contains only two elements. Periods 6 and 7, in contrast, are so long that some of their elements are placed below the main part of the table. They



The periodic table is organized into groups and periods. The groups are labeled at the top: 1A, 2A, 3A, 4A, 5A, 6A, 7A, and 8A. The periods are numbered 1 through 7. The table is color-coded into three main regions: METALS (blue), METALLOIDS (orange), and NONMETALS (green). The lanthanides and actinides are shown as separate rows below the main table.

1 1A																	18 8A							
1 H 1.00794 HYDROGEN																	2 He 4.0026 HELIUM							
3 Li 6.941 LITHIUM	4 Be 9.0122 BERYLLIUM	METALS										METALLOIDS			NONMETALS				5 B 10.811 BORON	6 C 12.011 CARBON	7 N 14.0064 NITROGEN	8 O 15.999 OXYGEN	9 F 18.998 FLUORINE	10 Ne 20.180 NEON
11 Na 22.990 SODIUM	12 Mg 24.305 MAGNESIUM	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al 26.982 ALUMINUM	14 Si 28.086 SILICON	15 P 30.974 PHOSPHORUS	16 S 32.06 SULFUR	17 Cl 35.45 CHLORINE	18 Ar 39.948 ARGON							
19 K 39.098 POTASSIUM	20 Ca 40.078 CALCIUM	21 Sc 44.956 SCANDIUM	22 Ti 47.88 TITANIUM	23 V 50.942 VANADIUM	24 Cr 51.996 CHROMIUM	25 Mn 54.938 MANGANESE	26 Fe 55.845 IRON	27 Co 58.933 COBALT	28 Ni 58.693 NICKEL	29 Cu 63.546 COPPER	30 Zn 65.38 ZINC	31 Ga 69.723 GALLIUM	32 Ge 72.63 GERMANIUM	33 As 74.922 ARSENIC	34 Se 78.96 SELENIUM	35 Br 79.904 BROMINE	36 Kr 83.80 KRYPTON							
37 Rb 85.468 RUBIDIUM	38 Sr 87.62 STRONTIUM	39 Y 88.906 YTTORIUM	40 Zr 91.224 ZIRCONIUM	41 Nb 92.906 NIOBIUM	42 Mo 95.94 MOLYBDENUM	43 Tc 98.906 TECHNETIUM	44 Ru 101.07 RHODIUM	45 Rh 102.905 RHODIUM	46 Pd 106.42 PALLADIUM	47 Ag 107.868 SILVER	48 Cd 112.411 CADMIUM	49 In 114.818 INDIUM	50 Sn 118.710 TIN	51 Sb 121.760 ANTIMONY	52 Te 127.603 TELLURIUM	53 I 126.905 IODINE	54 Xe 131.29 XENON							
55 Cs 132.905 CESIUM	56 Ba 137.327 BARIUM	57-71 La-Lu LANTHANIDES	72 Hf 178.49 HAFNIUM	73 Ta 180.95 TANTALUM	74 W 183.84 TUNGSTEN	75 Re 186.207 RHENIUM	76 Os 190.233 OSMIUM	77 Ir 192.222 IRIDIUM	78 Pt 195.084 PLATINUM	79 Au 196.967 GOLD	80 Hg 200.59 MERCURY	81 Tl 204.384 THALLIUM	82 Pb 207.2 LEAD	83 Bi 208.980 BISMUTH	84 Po 209 POLONIUM	85 At 210 ASTATINE	86 Rn 222 RADON							
87 Fr 223 FRANCIUM	88 Ra 226 RADIUM	89-103 Ac-Lr ACTINIDES	104 Rf 261 RUTHERFORDIUM	105 Db 262 DUBNIUM	106 Sg 263 SEABORGIUM	107 Bh 264 BOHRIUM	108 Hs 265 HASSIUM	109 Mt 266 MEITNERIUM	110 Ds 271 DARMSTADTIUM	111 Rg 272 ROSGENIUM	112 Cn 285 COPIERNICIUM	113 Uut 288 UNUNTRIUM	114 Uuq 289 UNUNQUADIUM	115 Uup 288 UNUNPENTIUM	116 Uuh 289 UNUNHEXIUM	117 Uus 294 UNUNSEPTIUM	118 Uuo 294 UNUNOCTIUM							
LANTHANIDES		57 La 138.905 LANTHANUM	58 Ce 140.12 CELIUM	59 Pr 140.908 PRASEODYMIUM	60 Nd 144.242 NEODYMIUM	61 Pm 144.913 PROMETHIUM	62 Sm 150.362 SAMARIUM	63 Eu 151.964 EUROPIUM	64 Gd 157.253 GADOLINIUM	65 Tb 158.925 TERBIUM	66 Dy 162.505 DYSPROSIUM	67 Ho 164.930 HOLMIUM	68 Er 167.259 ERBIUM	69 Tm 168.934 THULIUM	70 Yb 173.043 Ytterbium	71 Lu 174.967 LUTETIUM								
ACTINIDES		89 Ac 227 ACTINIUM	90 Th 232 THORIUM	91 Pa 231 Protactinium	92 U 238 URANIUM	93 Np 237 NEPTUNIUM	94 Pu 244 PLUTONIUM	95 Am 243 AMERICIUM	96 Cm 247 CURIUM	97 Bk 247 BERKELIUM	98 Cf 251 CALIFORNIUM	99 Es 252 EINSTEINIUM	100 Fm 257 FERMIUM	101 Md 258 Mendelevium	102 No 259 Nobelium	103 Lr 262 Lawrencium								

FIGURE 1.3

The modern periodic table of the elements is a lot like Mendeleev's table. But the modern table is based on atomic number instead of atomic mass. It also has more than 110 elements. Mendeleev's table only had about 65 elements.

are the elements starting with lanthanum (La) in period 6 and actinium (Ac) in period 7. Some elements in period 7 have not yet been named. They are represented by temporary symbols, such as Uub.

## Groups

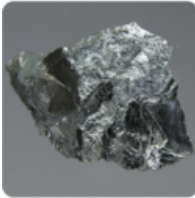
Columns of the modern table are called groups, as they are in Mendeleev's table. However, the modern table has many more groups — 18 to be exact. Elements in the same group have similar properties. For example, all elements in group 18 are colorless, odorless gases. You can read about the different groups of elements in this chapter's lesson on "Groups of Elements."

## Lesson Summary

- Mendeleev developed the first periodic table of the elements in 1869. He organized the elements by increasing atomic mass. He used his table to predict unknown elements. These were later discovered.
- The modern periodic table is based on atomic number. Elements in each period go from metals on the left to

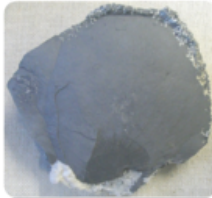
19 K 39.098 POTASSIUM	20 Ca 40.078 CALCIUM	21 Sc 44.956 SCANDIUM	22 Ti 47.867 TITANIUM	23 V 50.942 VANADIUM	24 Cr 51.996 CHROMIUM	25 Mn 54.938 MANGANESE	26 Fe 55.845 IRON	27 Co 58.933 COBALT	28 Ni 58.693 NICKEL	29 Cu 63.546 COPPER	30 Zn 65.392 ZINC	31 Ga 69.723 GALLIUM	32 Ge 72.630 GERMANIUM	33 As 74.922 ARSENIC	34 Se 78.96 SELENIUM	35 Br 79.904 BROMINE	36 Kr 83.801 KRYPTON
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**24**  
**Cr**  
51.996  
CHROMIUM

Chromium (Cr) is a shiny, silver-colored metal. It is added to steel to make it harder.



**33**  
**As**  
74.922  
ARSENIC

Arsenic (As) is a poisonous metalloid. It is used in very small amounts in cell phones and other electronic products.



**36**  
**Kr**  
83.801  
KRYPTON

Krypton (Kr) is a gaseous nonmetal. It is used in fluorescent lights.

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**FIGURE 1.4**

Like other periods, period 4 changes from metals on the left to metalloids and then nonmetals on the right.

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metalloids and then nonmetals on the right. Within groups, elements have similar properties.

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## Lesson Review Questions

### Recall

1. How did Mendeleev organize the elements?
2. How does the modern periodic table differ from Mendeleev's table?
3. What is a period in the periodic table?
4. What is a group in the periodic table?

### Apply Concepts

5. An unknown element has an atomic number of 44. Identify the element's symbol and the symbols of two other elements that have similar properties.

### Think Critically

6. Mendeleev's table and the modern periodic table organize the elements based on different information, yet most elements are in the same order in both tables. Explain why.

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## Points to Consider

Elements are classified as metals, metalloids, or nonmetals.



- Do you know some examples of metals?
- How do you think metals might differ from the other two classes of elements?

## 1.2 Classes of Elements

### Lesson Objectives

- Identify properties of metals.
- List properties of nonmetals.
- Describe metalloids.
- Relate valence electrons to reactivity of elements by class.

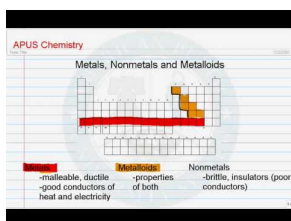
### Vocabulary

- metal
- metalloid
- nonmetal
- valence electron

### Introduction

Elements in different groups are lumped together in one of three classes, depending on their properties. The classes are metals, nonmetals, and metalloids. Knowing the class of an element lets you predict many of its properties. The video at the URL below is a good introduction to the classes.

<http://www.youtube.com/watch?v=ZuQmionhkGU> (2:04)



#### MEDIA

Click image to the left for more content.

### Metals

**Metals** are elements that are good conductors of electricity. They are the largest of the three classes of elements. In fact, most elements are metals. Look back at the modern periodic table (**Figure 1.3**) in this chapter's lesson "How Elements Are Organized." Find the metals in the table. They are all the elements that are color-coded blue. Examples include sodium (Na), silver (Ag), and zinc (Zn).



Most metals are shiny. That's because they reflect a lot of light. This tray is made mainly of the metal silver (Ag).



Most metals are ductile. This means they can be pulled into long thin shapes, like these wires made of the metal copper (Cu).



Most metals are malleable. This means they can be formed into thin sheets without breaking, like this foil made of the metal aluminum (Al).

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**FIGURE 1.5**

The three properties described here characterize most metals.

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Metals have relatively high melting points, so almost all are solids at room temperature. The only exception is mercury (Hg), which is a liquid. Most metals are also good conductors of heat. That's why they are used for cooking pots and stovetops. Metals have other characteristic properties as well. Most are shiny, ductile, and malleable. These properties are illustrated in **Figure 1.5**. You can dig deeper into the properties of metals at this URL: [http://www.bc.co.uk/schools/gcsebitesize/science/add\\_gateway/periodictable/metalsrev1.shtml](http://www.bc.co.uk/schools/gcsebitesize/science/add_gateway/periodictable/metalsrev1.shtml).

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## Nonmetals

**Nonmetals** are elements that do not conduct electricity. They are the second largest class of elements. Find the nonmetals in **Figure 1.3**. They are all the elements on the right side of the table that are color-coded green. Examples of nonmetals include helium (He), carbon (C), and oxygen (O).

Nonmetals generally have properties that are the opposite of those of metals. They also tend to vary more in their properties than metals do. For example, nonmetals have relatively low boiling points, so many of them are gases at room temperature. But several nonmetals are solids, including carbon and phosphorus (P). One nonmetal, bromine (Br), is a liquid at room temperature.

Generally, nonmetals are also poor conductors of heat. In fact, they may be used for insulation. For example, the down filling in a down jacket is mostly air, which consists mainly of nitrogen (N) and oxygen (O). These nonmetal gases are poor conductors of heat, so they keep body heat in and cold air out. Solid nonmetals are dull rather than shiny. They are also brittle rather than ductile or malleable. You can see examples of solid nonmetals in **Figure 1.6**. You can learn more about specific nonmetals with the interactive table at this URL: <http://library.thinkquest.org/3659/pertable/nonmetal.html>.



These yellow piles of powder are sulfur (S), a nonmetal. Sulfur in rocks has been ground up to produce a powder. The powder has been heaped on a dock for shipment.



The "lead" in this pencil is actually graphite, a form of the nonmetal carbon (C). Graphite is brittle. It breaks easily if you put too much pressure on it.



These match heads are coated with the nonmetal phosphorus (P). Phosphorus is not malleable. If you tried to pound it flat, it would crumble into a powder.

### FIGURE 1.6

Unlike metals, solid nonmetals are dull and brittle.

## Metalloids

Metalloids are elements that fall between metals and nonmetals in the periodic table. Just seven elements are metalloids, so they are the smallest class of elements. In **Figure 1.3**, they are color-coded orange. Examples of metalloids include boron (B), silicon (Si), and germanium (Ge).

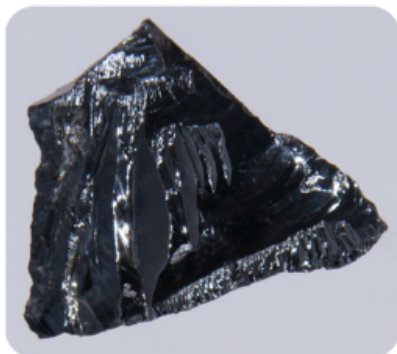
**Metalloids** have some properties of metals and some properties of nonmetals. For example, many metalloids can conduct electricity but only at certain temperatures. These metalloids are called semiconductors. Silicon is an example. It is used in computer chips. It is also the most common metalloid on Earth. It is shiny like a metal but brittle like a nonmetal. You see a sample of silicon in **Figure 1.7**. The figure also shows other examples of metalloids. You can learn more about the properties of metalloids at this URL: <http://library.thinkquest.org/3659/pertable/metalloid.html>.

## Classes of Elements and Electrons

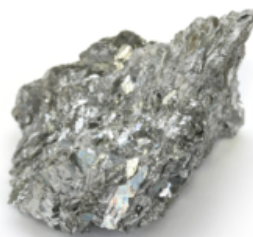
From left to right across the periodic table, each element has one more proton than the element to its left. Because atoms are always electrically neutral, for each added proton, one electron is also added. Electrons are added first to the lowest energy level possible until that level is full. Only then are electrons added to the next higher energy level.

### Electrons by Class

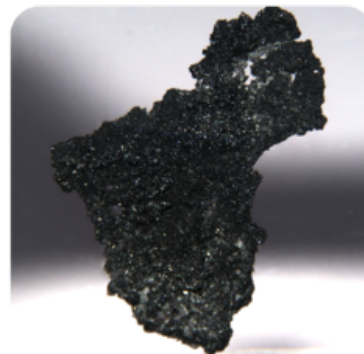
The increase in electrons across the periodic table explains why elements go from metals to metalloids and then to nonmetals from left to right across the table. Look at period 2 in **Figure 1.8** as an example. Lithium (Li) is a metal, boron (B) a metalloid, and fluorine (F) and neon (Ne) are nonmetals. The inner energy level is full for all four elements. This level has just one orbital and can hold a maximum of two electrons. The outer energy level is a different story. This level has four orbitals and can hold a maximum of eight electrons. Lithium has just one electron in this level, boron has three, fluorine has seven, and neon has eight.



Silicon (Si) is a metal that can conduct electricity but not as well as a metal. It is shiny but brittle. It chips easily, like glass.



Antimony (Sb) is a metalloid that is shiny like a metal but brittle like a nonmetal.



Boron (B) is a metalloid that is somewhat shiny. It also conducts electricity like a metal. However, it is brittle like a nonmetal.

**FIGURE 1.7**

Metalloids share properties with both metals and nonmetals.

## Valence Electrons and Reactivity

The electrons in the outer energy level of an atom are called **valence electrons**. It is valence electrons that are potentially involved in chemical reactions. The number of valence electrons determines an element's reactivity, or how likely the element is to react with other elements. The number of valence electrons also determines whether the element can conduct electric current. That's because electric current is the flow of electrons. **Table 1.1** shows how these properties vary in elements from each class.

- Metals such as lithium have an outer energy level that is almost empty. They "want" to give up their few valence electrons so they will have a full outer energy level. As a result, metals are very reactive and good conductors of electricity.
- Metalloids such as boron have an outer energy level that is about half full. These elements need to gain or lose too many electrons for a full outer energy level to come about easily. As a result, these elements are not very reactive. They may be able to conduct electricity but not very well.
- Some nonmetals, such as bromine, have an outer energy level that is almost full. They "want" to gain electrons so they will have a full outer energy level. As a result, these nonmetals are very reactive. Because they only accept electrons and do not give them up, they do not conduct electricity.
- Other nonmetals, such as neon, have a completely full outer energy level. Their electrons are already in the most stable arrangement possible. They are unreactive and do not conduct electricity.

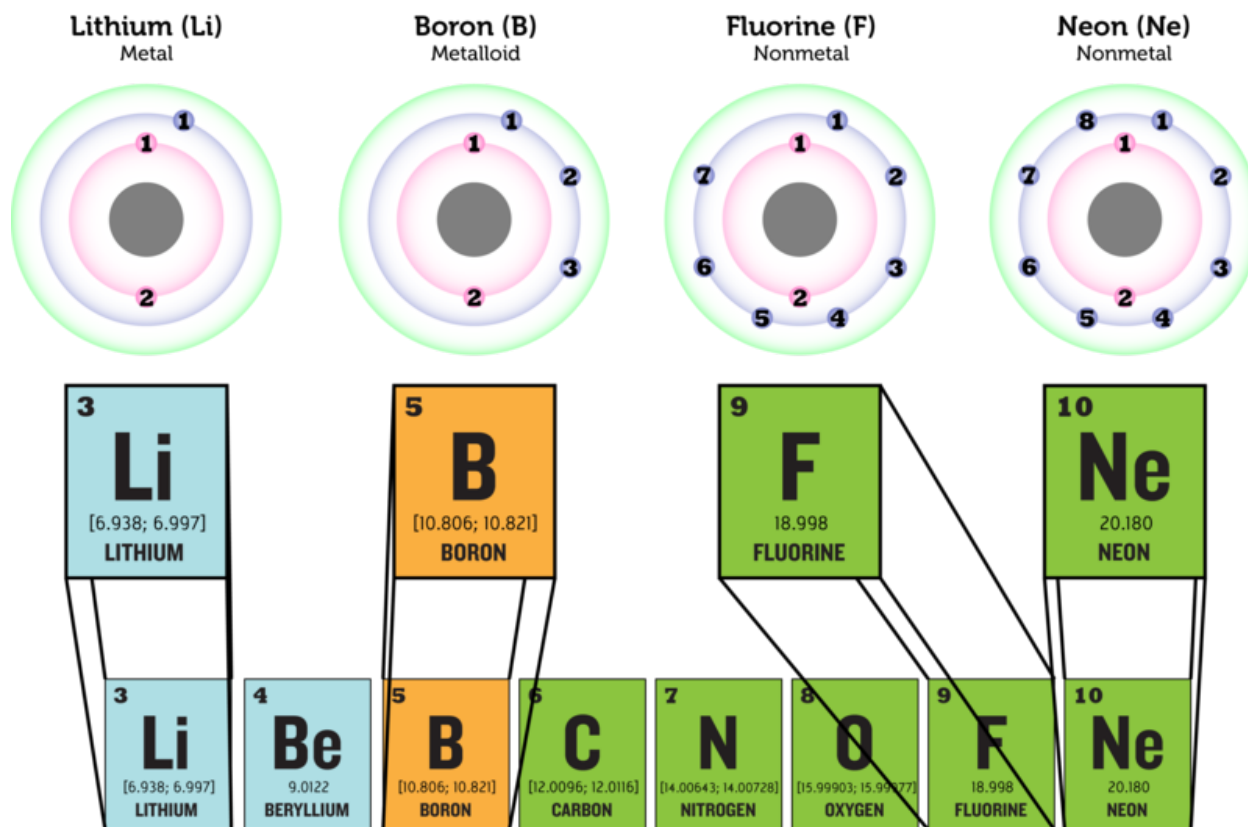


FIGURE 1.8

The number of electrons increases from left to right across each period in the periodic table. In period 2, lithium (Li) has the fewest electrons and neon (Ne) has the most. How do the numbers of electrons in their outer energy levels compare?

**TABLE 1.1:** These examples show the relative reactivity of elements in the three classes.

Element  
Lithium



Description

Lithium (Li) is a highly reactive metal. It has just one electron in its outer energy level. Lithium reacts explosively with water (see picture). It can react with moisture on skin and cause serious burns.



**TABLE 1.1:** (continued)

Element  
Boron



Description

Boron (B) is a metalloid. It has three valence electrons and is less reactive than lithium. Boron compounds dissolved in water form boric acid. Dilute boric acid is weak enough to use as eye wash.

Bromine



Bromine (Br) is an extremely reactive nonmetal. This picture shows it reacting with aluminum foil in a test tube. The aluminum starts burning within a couple of minutes of the bromine contacting it.

Neon



Neon (Ne) is a nonmetal gas with a completely filled outer energy level. This makes it unreactive, so it doesn't combine with other elements. Neon is used for lighted signs like this one. You can learn why neon gives off light at this link: <http://www.scientificamerican.com/article.cfm?id=how-do-neon-lights-work>

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## Lesson Summary

- Metals are elements that are good conductors of electricity. They are the largest class of elements. Many metals are shiny, ductile, and malleable. They are also good conductors of heat. Almost all metals are solids at room temperature.
- Nonmetals are elements that do not conduct electricity. They are the second largest class of elements. Nonmetals are also poor conductors of heat. The majority of nonmetals are gases. Solid nonmetals are dull and brittle.
- Metalloids are elements that have properties of both metals and nonmetals. Some can conduct electricity but only at certain temperatures. They may be shiny but brittle. All metalloids are solids at room temperature.
- Atoms of elements in different classes vary in their number of valence electrons. This explains their differences in reactivity and conductivity.

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## Lesson Review Questions

### Recall

1. What are metals? Name one example.
2. Define nonmetal, and give an example.
3. State one way that metalloids may be like metals and one way they may be like nonmetals.
4. What are valence electrons?

### Apply Concepts

1. A mystery element is a dull, gray solid. It is very reactive with other elements. Classify the mystery element as a metal, nonmetal, or metalloid. Explain your answer.

### Think Critically

1. Create a Venn diagram for metals, metalloids, and nonmetals. The diagram should show which properties are different and which, if any, are shared among the three groups of elements.
2. Relate number of valence electrons to reactivity of classes of elements.

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## Points to Consider

The number of valence electrons increases from left to right across each period of the periodic table. By the end of the period, the outer energy level is full. Moving on to the next period of the table, electrons are added to the next higher energy level. This happens in each row of the periodic table.

- How do you think the number of valence electrons compares in elements within the same column (group) of the periodic table?
- How might this be reflected in the properties of elements within a group?

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## 1.3 Groups of Elements

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### Lesson Objectives

- Identify hydrogen and alkali metals.
- Describe alkaline Earth metals.
- List properties of transition metals.
- Identify groups containing metalloids.
- Give properties of halogens.
- Describe noble gases.

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### Vocabulary

- alkali metal
- alkaline Earth metal
- halogen
- noble gas
- transition metal

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### Introduction

Elements in the same column, or group, of the periodic table have the same number of valence electrons in their outer energy level. This gives them many similar properties. The rest of this chapter describes properties of the different groups of elements. You can watch a video about the groups at this link: <http://www.khanacademy.org/video/groups-of-the-periodic-table?playlist=Chemistry>.

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### Group 1: Hydrogen and Alkali Metals

All the elements in group 1 have just one valence electron, so they are highly reactive. Group 1 is shown in **Figure 1.9**. At the top of this group is hydrogen (H), which is a very reactive, gaseous nonmetal. It is the most common element in the universe.

All the other elements in group 1 are **alkali metals**. They are the most reactive of all metals, and along with the elements in group 17, the most reactive elements. Because alkali metals are so reactive, they are only found in nature combined with other elements. The alkali metals are soft. Most are soft enough to cut with a knife. They are also low in density. Some of them even float on water. All are solids at room temperature. You can see a video demonstrating the reactivity of alkali metals with water at this URL: <http://www.youtube.com/watch?v=m55kgyApYrY> (3:17).




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**MEDIA**

Click image to the left for more content.

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## Sodium (Group 1)



1	H 1.00784-1.00811 HYDROGEN
3	Li (6.938; 6.997) LITHIUM
11	Na 22.990 SODIUM
19	K 39.098 POTASSIUM
37	Rb 85.468 RUBIDIUM
55	Cs 132.905 CESIUM
87	Fr 223.020 FRANCIUM

Sodium (Na) is an alkali metal. It is so reactive that it doesn't occur alone in nature. It is commonly found combined with chlorine (Cl) as sodium chloride (NaCl), which is table salt.

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**FIGURE 1.9**

In group 1 of the periodic table, all the elements except hydrogen (H) are alkali metals.

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## Group 2: Alkaline Earth Metals

The **alkaline Earth metals** include all the elements in group 2 (see **Figure 1.10**). These metals have just two valence electrons, so they are very reactive, although not quite as reactive as the alkali metals. In nature, they are always found combined with other elements. Alkaline Earth metals are silvery grey in color. They are harder and denser than the alkali metals. All are solids at room temperature.

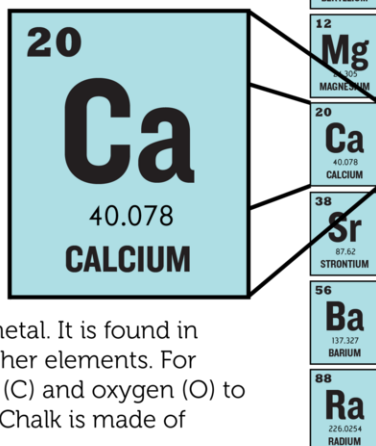
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## Groups 3-12: Transition Metals

Groups 3–12 of the periodic table contain **transition metals** (see **Figure 1.11**). Transition metals have more valence electrons and are less reactive than metals in the first two metal groups. The transition metals are shiny. Many are silver colored. They tend to be very hard, with high melting and boiling points. All except mercury (Hg) are solids at room temperature.

Transition metals include the elements that are placed below the periodic table. Those that follow lanthanum (La) are called lanthanides. They are all shiny, relatively reactive metals. Those that follow Actinium (Ac) are called actinides. They are all radioactive metals. This means they are unstable. They break down into different, more stable elements. You can read more about radioactive elements in the chapter *Nuclear Chemistry*. Many of the actinides do not occur in nature but are made in laboratories.

## Calcium (Group 2)



Calcium (Ca) is an alkaline Earth metal. It is found in nature only in compounds with other elements. For example, it combines with carbon (C) and oxygen (O) to form calcium carbonate (CaCO<sub>3</sub>). Chalk is made of calcium carbonate.

FIGURE 1.10

The alkaline Earth metals make up group 2 of the periodic table.

## Groups 3-12: Transition Metals

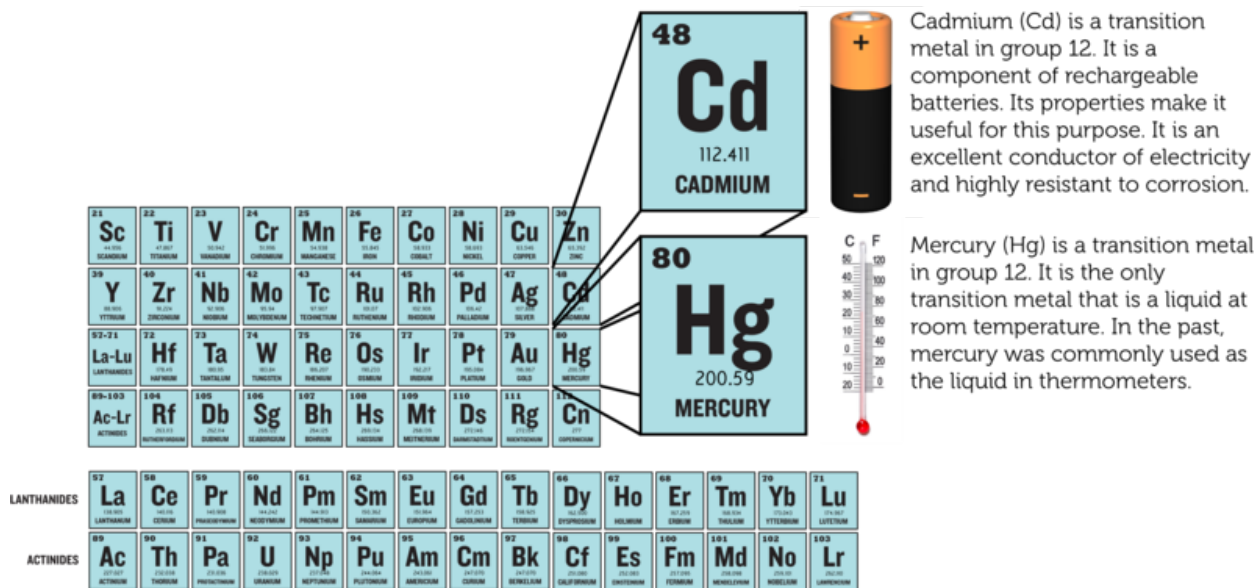


FIGURE 1.11

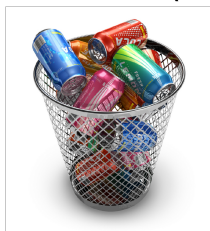
All the elements in groups 3–12 are transition metals.

## Groups 13-16: Groups Containing Metalloids

Groups 13–16 each contain one or more metalloids. These groups are shown in **Figure 1.12**.

## Groups 13-16: Metalloids

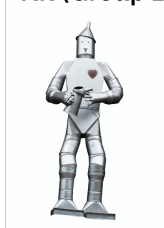
### Aluminum (Group 13)



**13**  
**Al**  
26.982  
ALUMINUM

Aluminum (Al) is a shiny, low-density metal in group 13. It is durable, ductile, and malleable. Aluminum's properties make it a good choice for objects such as beverage cans, lawn furniture, and siding on homes.

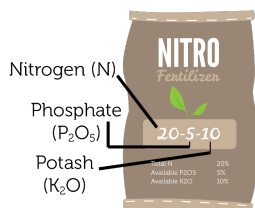
### Tin (Group 14)



**50**  
**Sn**  
114.818  
TIN

Tin (Sn) is a shiny, silver-colored metal in Group 14. The tin man in *The Wizard of Oz* was afraid of "rusting," but tin doesn't really rust (only iron rusts). In fact, tin is not very reactive with oxygen at all. That's one reason why it is used in food cans and for roofs.

### Nitrogen (Group 15)



**7**  
**N**  
[14.00643; 14.00728]  
NITROGEN

Nitrogen (N) is a gaseous nonmetal in group 15. It makes up 78% of Earth's atmosphere. Plants need nitrogen but are unable to use gaseous nitrogen in the air. Fertilizers supply nitrogen in a form plants can use.

### Selenium (Group 16)



**34**  
**Se**  
78.963  
SELENIUM

Selenium (Se) is a solid nonmetal in group 16. People need small amounts of selenium for good health. Nuts and fish are good food sources of selenium.

<b>5</b> <b>B</b> [10.806; 10.821] BORON	<b>6</b> <b>C</b> [12.0096; 12.0116] CARBON	<b>7</b> <b>N</b> [14.00643; 14.00728] NITROGEN	<b>8</b> <b>O</b> [15.99903; 15.99977] OXYGEN
<b>13</b> <b>Al</b> 26.982 ALUMINUM	<b>14</b> <b>Si</b> [28.084; 28.086] SILICON	<b>15</b> <b>P</b> 30.974 PHOSPHORUS	<b>16</b> <b>S</b> [32.059; 32.076] SULFUR
<b>31</b> <b>Ga</b> 69.723 GALLIUM	<b>32</b> <b>Ge</b> 69.723 GERMANIUM	<b>33</b> <b>As</b> 74.922 ARSENIC	<b>34</b> <b>Se</b> 78.963 SELENIUM
<b>49</b> <b>In</b> 114.818 INDIUM	<b>50</b> <b>Sn</b> 114.818 TIN	<b>51</b> <b>Sb</b> 121.760 ANTIMONY	<b>52</b> <b>Te</b> 127.603 TELLURIUM
<b>81</b> <b>Tl</b> [204.382; 204.385] THALLIUM	<b>82</b> <b>Pb</b> 204.383 LEAD	<b>83</b> <b>Bi</b> 208.980 BISMUTH	<b>84</b> <b>Po</b> 208.982 POLONIUM

FIGURE 1.12

These groups each contain one or more metalloids.

- Group 13 is called the boron group. The only metalloid in this group is boron (B). The other four elements are metals. All group 13 elements have three valence electrons and are fairly reactive. All are solids at room temperature.
- Group 14 is called the carbon group. Carbon (C) is a nonmetal. The next two elements are metalloids, and the final two are metals. All the elements in the carbon group have four valence electrons. They are not very reactive. All are solids at room temperature.
- Group 15 is called the nitrogen group. The first two elements in this group are nonmetals. These are followed by two metalloids and one metal. All the elements in the nitrogen group have five valence electrons, but they vary in their reactivity. Nitrogen (N) is not reactive at all. Phosphorus (P), in contrast, is quite reactive. In fact, it is found naturally only in combination with other substances. Nitrogen is a gas at room temperature. The other group 15 elements are solids.



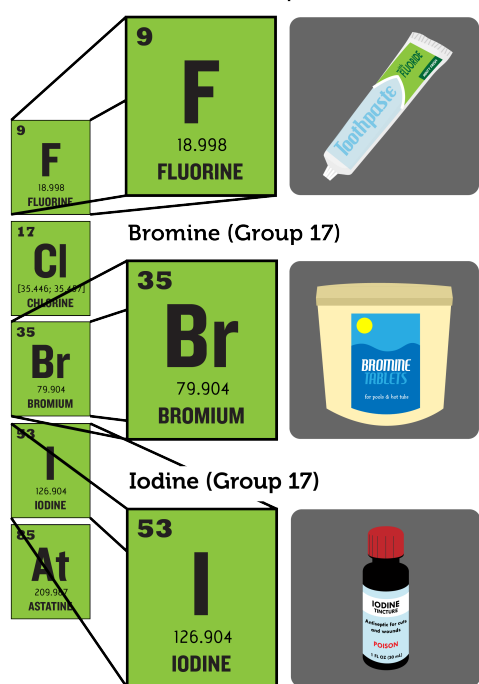
- Group 16 is called the oxygen group. The first three elements in this group are nonmetals. They are followed by one metalloid and one metal. All the elements in the oxygen group have six valence electrons, and all are reactive. Oxygen (O), for example, readily reacts with metals to form compounds such as rust. Oxygen is a gas at room temperature. The other four elements in group 16 are solids.

## Group 17: Halogens

Elements in group 17 are called **halogens** (see **Figure 1.13**). They are highly reactive nonmetals with seven valence electrons. The halogens react violently with alkali metals, which have one valence electron. The two elements combine to form a salt. For example, the halogen chlorine (Cl) and the alkali metal sodium (Na) react to form table salt, or sodium chloride (NaCl). The halogen group includes gases, liquids, and solids. For example, chlorine is a gas at room temperature, bromine (Br) is a liquid, and iodine (I) is a solid. You can watch a video demonstrating the reactivity of halogens at this URL: [http://www.youtube.com/watch?v=mY7o28-l\\_WU&feature=related](http://www.youtube.com/watch?v=mY7o28-l_WU&feature=related).

### Group 17: Halogens

**Fluorine (Group 17)**



Fluorine (F) is a gaseous halogen. Evidence shows that fluorine helps prevent tooth decay. That's why it is added to toothpaste in the form of sodium fluoride. You can learn how it protects teeth at: [http://www.animated-teeth.com/tooth\\_decay/t4\\_tooth\\_decay\\_fluoride.htm](http://www.animated-teeth.com/tooth_decay/t4_tooth_decay_fluoride.htm)

**Bromine (Group 17)**

Bromine (Br) is the only liquid halogen. In tablet form, bromine is used to purify water in swimming pools and hot tubs. It reacts with bacteria and other germs and renders them harmless.

**Iodine (Group 17)**

Iodine (I) is a solid halogen. It is added to alcohol and used as an antiseptic. It reacts with germs on cuts and wounds. Small amounts of iodine are also needed for good health. In the U.S., iodine is added to table salt to prevent iodine deficiencies. Does the salt you use contain iodine?

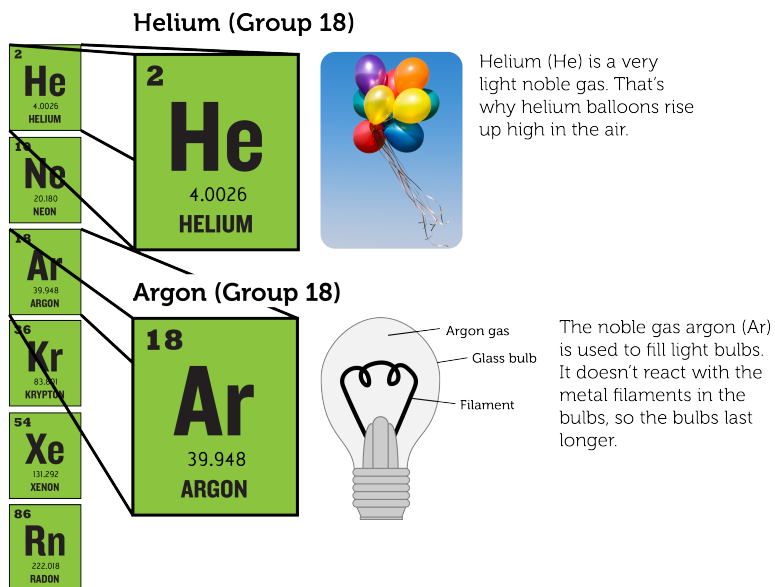
**FIGURE 1.13**

Group 17 consists of the nonmetals called halogens.

## Group 18: Noble Gases

Group 18 elements are nonmetals called **noble gases** (see **Figure 1.14**). They are all colorless, odorless gases. Their outer energy level is also full, so they are the least reactive elements. In nature, they seldom combine with other substances. For a short video about the noble gases and their properties, go to this URL: <http://www.youtube.com/watch?v=QLrofyj6a2s> (1:17).

## Group 18: Noble Gases



**FIGURE 1.14**

Noble gases include helium and argon.

## Lesson Summary

- Group 1 of the periodic table consists of hydrogen and the alkali metals. Hydrogen is a very reactive nonmetal. The alkali metals are the most reactive metals.
- Group 2 consists of the alkaline Earth metals. They are very reactive but less so than the alkali metals.
- Groups 3–12 contain transition metals. They are less reactive than metals in groups 1 and 2.
- Groups 13–16 each contain at least one metalloid. They also contain metals and/or nonmetals. Elements in these groups vary in reactivity and other properties.
- Group 17 contains halogens. They are highly reactive nonmetals.
- Group 18 consists of noble gases. They are unreactive and rarely combine with other elements.

## Lesson Review Questions

### Recall

1. What are alkali metals? What is one example?
2. Identify an alkaline Earth metal. How reactive is it?
3. Which element is the only transition metal that is a liquid at room temperature?
4. In which groups of the periodic table would you find metalloids?
5. State why halogens are highly reactive.
6. Describe noble gases.

### Apply Concepts

7. Assume you have a sample of an unknown element. At room temperature, it is a soft solid. You cut a small piece from the sample with a knife and drop the piece into a container of water. It bursts into flames. Which group of the periodic table does the unknown element belong in?

### Think Critically

8. Both hydrogen (H) and helium (He) are gaseous nonmetals. Why are they placed on opposite sides of the periodic table?

---

### Points to Consider

Reactive elements combine easily with other elements. This explains why they usually exist in nature in compounds rather than in pure form.

- How do you think elements join together to form compounds?
- Do you think this might vary from one group of elements to another?

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