12

The Periodic Table

The Big Idea

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

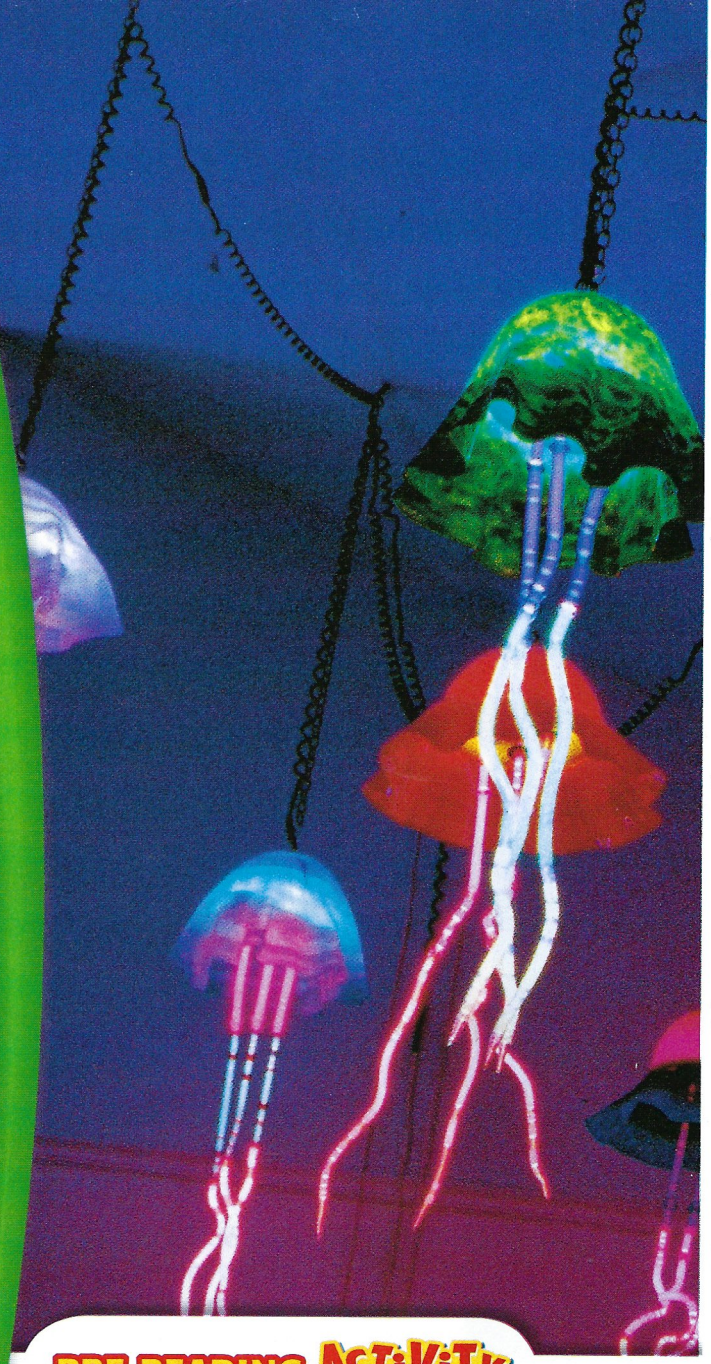
SECTION

1 Arranging the Elements. 336

2 Grouping the Elements 344

About the PHOTO

You already know or have heard about elements on the periodic table, such as oxygen, carbon, and neon. Neon gas was discovered in 1898. In 1902, a French engineer, chemist, and inventor named Georges Claude made the first neon lamp. In 1910, Claude made the first neon sign, and in 1923, he introduced neon signs to the United States. Now, artists such as Eric Ehlenberger use glass and neon to create interesting works of art, such as these neon jellyfish.

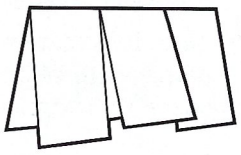


PRE-READING ACTIVITY

FOLDNOTES

Three-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Three-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the three-panel flip chart with "Metal," "Nonmetal," and "Metalloid." As you read the chapter, write information you learn about each category under the appropriate flap.



SECTION 1

Arranging the Elements

Suppose you went to the video store and all the videos were mixed together. How could you tell the comedies from the action movies? If the videos were not arranged in a pattern, you wouldn't know what kind of movie you had chosen!

Scientists in the early 1860s had a similar problem. At that time, scientists knew some of the properties of more than 60 elements. However, no one had organized the elements according to these properties. Organizing the elements according to their properties would help scientists understand how elements interact with each other.

What You Will Learn

- Describe how Mendeleev arranged elements in the first periodic table.
- Explain how elements are arranged in the modern periodic table.
- Compare metals, nonmetals, and metalloids based on their properties and on their location in the periodic table.
- Describe the difference between a period and a group.

Vocabulary

periodic
periodic law
period
group

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the difference between periods and groups.

Discovering a Pattern

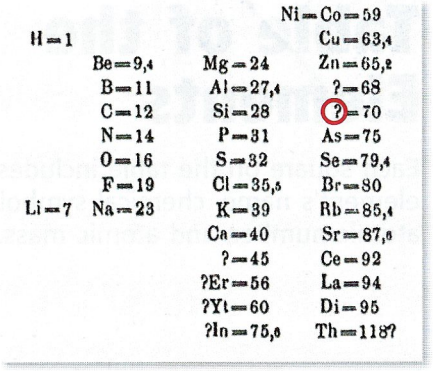
Dmitri Mendeleev (duh MEE tree MEN duh LAY uhf), a Russian chemist, discovered a pattern to the elements in 1869. First, he wrote the names and properties of the elements on cards. Then, he arranged his cards, as shown in **Figure 1,** by different properties, such as density, appearance, and melting point. After much thought, he arranged the elements in order of increasing atomic mass. When he did so, a pattern appeared.

Reading Check **How had Mendeleev arranged elements when he noticed a pattern?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *By playing "chemical solitaire" on long train rides, Mendeleev organized the elements according to their properties.*

Table 1 Properties of Germanium		
	Mendeleev's predictions (1869)	**Actual properties**
Atomic mass	70	72.6
Density*	5.5 g/cm^3	5.3 g/cm^3
Appearance	dark gray metal	gray metal
Melting point*	high melting point	937°C

* at room temperature and pressure



			Ni=Co=59
H=1			Cu=63,4
	Be=9,4	Mg=24	Zn=65,2
	B=11	Al=27,4	?=68
	C=12	Si=28	?=70
	N=14	P=31	As=75
	O=16	S=32	Se=79,4
	F=19	Cl=35,5	Br=80
Li=7	Na=23	K=39	Rb=85,4
		Ca=40	Sr=87,6
		?=45	Ce=92
		?Er=56	La=94
		?Yt=60	Di=95
		?In=75,6	Th=118?

Figure 2 *Mendeleev used question marks to mark some elements that he thought would be found later.*

Periodic Properties of the Elements

Mendeleev saw that when the elements were arranged in order of increasing atomic mass, those that had similar properties occurred in a repeating pattern. That is, the pattern was periodic. **Periodic** means "happening at regular intervals." The days of the week are periodic. They repeat in the same order every 7 days. Similarly, Mendeleev found that the elements' properties followed a pattern that repeated every seven elements. His table became known as the *periodic table of the elements*.

periodic describes something that occurs or repeats at regular intervals

periodic law the law that states that the repeating chemical and physical properties of elements change periodically with the atomic numbers of the elements

Predicting Properties of Missing Elements

Figure 2 shows part of Mendeleev's first try at arranging the elements. The question marks show gaps in the pattern. Mendeleev predicted that elements yet to be found would fill these gaps. He used the pattern he found to predict their properties. **Table 1** compares his predictions for one missing element—germanium—with its actual properties. By 1886, all of the gaps had been filled. His predictions were right.

Changing the Arrangement

A few elements' properties did not fit the pattern in Mendeleev's table. Mendeleev thought that more-accurate atomic masses would fix these flaws in his table. But new atomic mass measurements showed that the masses he had used were correct. In 1914, Henry Moseley (MOHZ lee), a British scientist, determined the number of protons—the atomic number—in an atom. All elements fit the pattern in Mendeleev's periodic table when they were arranged by atomic number.

Look at the periodic table on the next two pages. All of the more than 30 elements discovered since 1914 follow the periodic law. The **periodic law** states that the repeating chemical and physical properties of elements change periodically with the elements' atomic numbers.

Reading Check **What property is used to arrange elements in the periodic table?**

CONNECTION TO Language Arts

WRITING SKILL **Hidden Help** You may be asked to memorize some of the chemical symbols. A story or poem that uses the symbols might be helpful. In your **science journal,** write a short story, poem, or just a few sentences in which the words correspond to and bring to mind the chemical symbols of the first 20 elements.

Periodic Table of the Elements

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

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

6	Atomic number
C	Chemical symbol
Carbon	Element name
12.0	Atomic mass

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

Background
- Metals
- Metalloids
- Nonmetals

Chemical symbol
- Solid
- Liquid
- Gas

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Period 1	1 H Hydrogen 1.0								
Period 2	3 Li Lithium 6.9	4 Be Beryllium 9.0							
Period 3	11 Na Sodium 23.0	12 Mg Magnesium 24.3							
Period 4	19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.8	27 Co Cobalt 58.9
Period 5	37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9
Period 6	55 Cs Cesium 132.9	56 Ba Barium 137.3	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2
Period 7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)

A row of elements is called a *period*.

A column of elements is called a *group* or *family*.

Values in parentheses are the mass numbers of those radioactive elements' most stable or most common isotopes.

Lanthanides	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4
Actinides	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)

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

Topic: **Periodic Table**
Go To: **go.hrw.com**
Keyword: **HN0 PERIODIC**
Visit the HRW Web site for updates on the periodic table.

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

Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
								2 **He** Helium 4.0
			5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
			13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulfur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
110 **Ds** Darmstadtium (281)	111 **Uuu** Unununium (272)	112 **Uub** Ununbium (285)	113 **Uut** Ununtrium (284)	114 **Uuq** Ununquadium (289)	115 **Uup** Ununpentium (288)			

The discovery of elements 113, 114, and 115 has been reported but not confirmed.

The names and three-letter symbols of elements are temporary. They are based on the atomic numbers of the elements. Official names and symbols will be approved by an international committee of scientists.

63 **Eu** Europium 152.0	64 **Gd** Gadolinium 157.2	65 **Tb** Terbium 158.9	66 **Dy** Dysprosium 162.5	67 **Ho** Holmium 164.9	68 **Er** Erbium 167.3	69 **Tm** Thulium 168.9	70 **Yb** Ytterbium 173.0	71 **Lu** Lutetium 175.0
95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

The Periodic Table and Classes of Elements

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

Elements are classified as metals, nonmetals, and metalloids, according to their properties. The number of electrons in the outer energy level of an atom is one characteristic that 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.

Quick Lab

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 min, touch the top of each object. Record your observations.
4. Which material conducted thermal energy the best? Why?

Metals

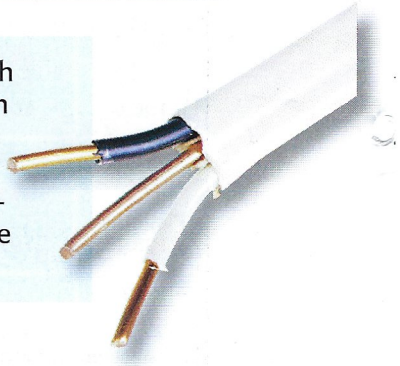
Most elements are metals. Metals are found to the left of the zigzag line on the periodic table. Atoms of most metals have few electrons in their outer energy level. Most metals are solid at room temperature. Mercury, however, is a liquid at room temperature. Some additional information on properties shared by most metals is shown in **Figure 3.**

Reading Check **What are four properties shared by most metals?**

Figure 3 **Properties of Metals**

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.

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 of copper.



Most metals are **malleable,** which means that they can be flattened with a hammer and will not shatter. Aluminum is flattened into sheets to make cans and foil.

Most metals are **good conductors of thermal energy.** This iron griddle conducts thermal energy from a stove top to cook your favorite foods.

Figure 4 **Properties of Nonmetals**

Nonmetals are **not malleable or ductile.** In fact, solid nonmetals, such as carbon in the graphite of the pencil lead, are brittle and will break or shatter when hit with a hammer.

Sulfur, like most nonmetals, is **not shiny.**

Nonmetals are **poor conductors of thermal energy and electric current.** If the gap in a spark plug is too wide, the nonmetals nitrogen and oxygen in the air will stop the spark and a car's engine will not run.

Nonmetals

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. Atoms of the elements in Group 18, the noble gases, have a complete set of electrons. More than half of the nonmetals are gases at room temperature. Many properties of nonmetals are the opposite of the properties of metals, as shown in **Figure 4.**

Metalloids

Metalloids, also called *semiconductors,* are the elements that border the zigzag line on the periodic table. Atoms of metalloids have about half of a complete set of electrons in their outer energy level. Metalloids have some properties of metals and some properties of nonmetals, as shown in **Figure 5.**

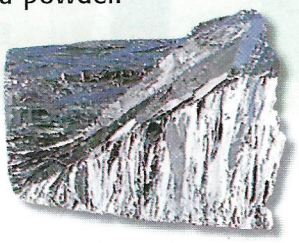
MATH PRACTICE

Percentages

Elements are classified as metals, nonmetals, and metalloids. Use the periodic table to determine the percentage of elements in each of the three categories.

Figure 5 **Properties of Metalloids**

Tellurium is **shiny,** but it is **brittle** and can easily be smashed into a powder.



Boron is almost as **hard** as diamond, but it is also **very brittle.** At high temperatures, it is a **good conductor of electric current.**

Decoding the Periodic Table

The periodic table may seem to be in code. In a way, it is. But the colors and symbols will help you decode the table.

Each Element Is Identified by a Chemical Symbol

Each square on the periodic table includes an element's name, chemical symbol, atomic number, and atomic mass. The names of the elements come from many sources. Some elements, such as mendelevium, are named after scientists. Others, such as californium, are named after places. Some element names vary by country. But the chemical symbols are the same worldwide. For most elements, the chemical symbol has one or two letters. The first letter is always capitalized. Any other letter is always lowercase. The newest elements have temporary three-letter symbols.

Rows Are Called *Periods*

Each horizontal row of elements (from left to right) on the periodic table is called a **period.** Look at Period 4 in **Figure 6.** The physical and chemical properties of elements in a row follow a repeating, or periodic, pattern as you move across the period. Properties such as conductivity and reactivity change gradually from left to right in each period.

Columns Are Called *Groups*

Each vertical 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, a group is also called a *family*.

Reading Check Why is a group sometimes called a family?

SCHOOL to HOME

Patterns of Symbols

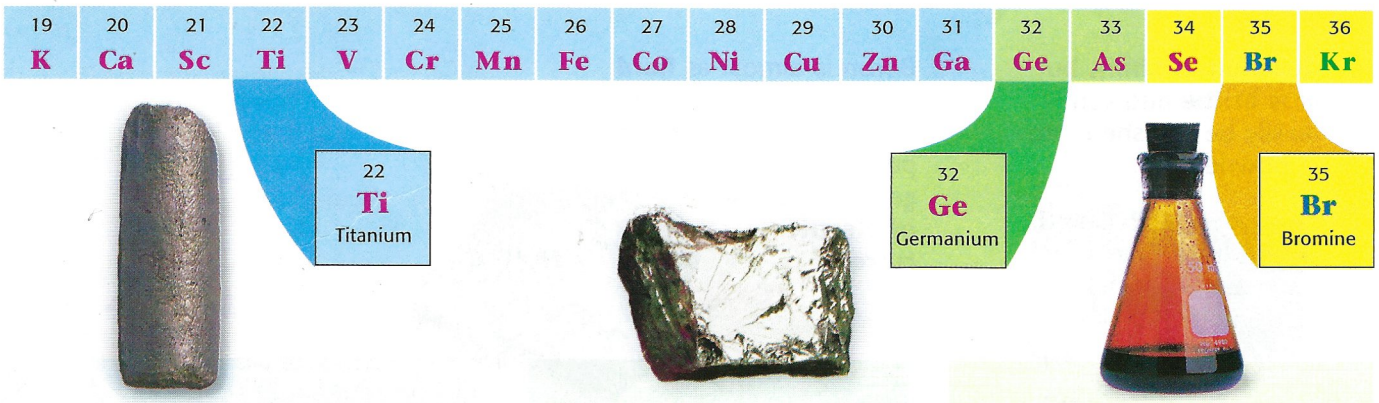
Divide a sheet of paper into four columns. Look at the elements whose atomic numbers are 1 to 20 on the periodic table. With a parent, find patterns that describe the relationship between the chemical symbols and names of elements. In each column, write all of the chemical symbols and names that follow a single pattern. At the top of each column, write a sentence describing the pattern.

ACTIVITY

period in chemistry, a horizontal row of elements in the periodic table

group a vertical column of elements in the periodic table; elements in a group share chemical properties

Figure 6 *As you move from left to right across a row, the elements become less metallic.*



Elements at the left end of a period, such as **titanium,** are very metallic.

Elements farther to the right, such as **germanium,** are less metallic.

Elements at the far-right end of a period, such as **bromine,** are nonmetallic.

SECTION Review

Summary

- Mendeleev developed the first periodic table by listing the elements in order of increasing atomic mass. He used his table to predict that elements with certain properties would be discovered later.
- Properties of elements repeat in a regular, or periodic, pattern.
- Moseley rearranged the elements in order of increasing atomic number.
- The periodic law states that the repeating chemical and physical properties of elements relate to and depend on elements' atomic numbers.
- Elements in the periodic table are classified as metals, nonmetals, and metalloids.
- Each element has a chemical symbol.
- A horizontal row of elements is called a *period*.
- Physical and chemical properties of elements change across each period.
- A vertical column of elements is called a *group* or *family*.
- Elements in a group usually have similar properties.

Using Key Terms

1. In your own words, write a definition for the term *periodic*.

Understanding Key Ideas

2. Which of the following elements should be the best conductor of electric current?
   - **a.** germanium
   - **b.** sulfur
   - **c.** aluminum
   - **d.** helium
3. Compare a period and a group on the periodic table.
4. What property did Mendeleev use to position the elements on the periodic table?
5. State the periodic law.

Critical Thinking

6. **Identifying Relationships** An atom that has 117 protons in its nucleus has not yet been made. Once this atom is made, to which group will element 117 belong? Explain your answer.
7. **Applying Concepts** Are the properties of sodium, Na, more like the properties of lithium, Li, or magnesium, Mg? Explain your answer.

Interpreting Graphics

8. The image below shows part of a periodic table. Compare the image below with the similar part of the periodic table in your book.

1	1 H 1.0079 水素			
2	3 Li 6.941 リチウム	4 Be 9.01218 ベリリウム		
3	11 Na 22.98977 ナトリウム	12 Mg 24.305 マグネシウム		
4	19 K	20 Ca	21 Sc	22 Ti

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