Section 2

Organizing the Elements

Reading Preview

Key Concepts

- How did Mendeleev discover the pattern that led to the periodic table?
- What data about elements are found in the periodic table?
- How is the organization of the periodic table useful for predicting the properties of elements?

Key Terms

- atomic mass
- periodic table
- chemical symbol
- period
- group

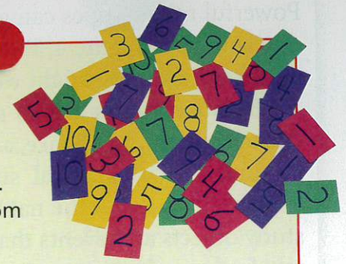
Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

Patterns in the Elements

Question	Answer
What pattern of elements did Mendeleev discover?	Patterns appeared when . . .

Lab zone Discover Activity



Which Is Easier?

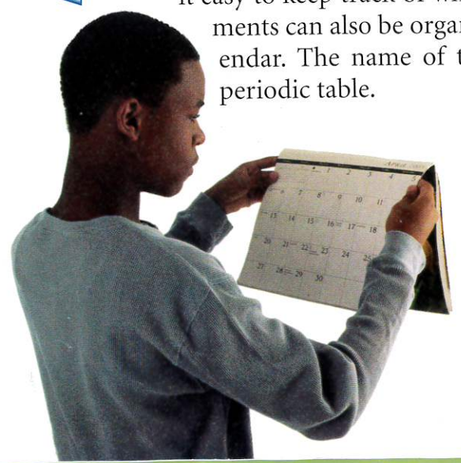
1. Make 4 sets of 10 paper squares, using a different color for each set. Number the squares in each set from 1 through 10.
2. Place all of the squares on a flat surface, numbered side up. Don't arrange them in order.
3. Ask your partner to name a square by color and number. Have your partner time how long it takes you to find this square.
4. Repeat Step 3 twice, choosing different squares each time. Calculate the average value of the three times.
5. Rearrange the squares into four rows, one for each color. Order the squares in each row from 1 to 10.
6. Repeat Step 3 three times. Calculate an average time.
7. Trade places with your partner and repeat Steps 2 through 6.

Think It Over

Inferring Which average time was shorter, the one produced in Step 4 or Step 6? Why do you think the times were different?

You wake up, jump out of bed, and start to get dressed for school. Then you ask yourself a question: Is there school today? To find out, you check the calendar. There's no school today because it's Saturday.

The calendar arranges the days of the month into horizontal periods called weeks and vertical groups called days of the week. This arrangement follows a repeating pattern that makes it easy to keep track of which day it is. The chemical elements can also be organized into something like a calendar. The name of the "chemists' calendar" is the periodic table.



◀ A calendar organizes the days of the week into a useful, repeating pattern.

Patterns in the Elements

By 1869, a total of 63 elements had been discovered. These elements had a wide variety of properties. A few were gases. Two were liquids. Most were solid metals. Some reacted explosively as they formed compounds. Others reacted more slowly. Scientists wondered if the properties of elements followed any sort of pattern. A Russian scientist, Dmitri Mendeleev (men duh LAY ef), discovered a set of patterns that applied to all the elements.

Mendeleev's Work Mendeleev knew that some elements have similar chemical and physical properties. For example, both fluorine and chlorine are gases that irritate the lungs and form similar compounds. Silver and copper, shown in Figure 5, are both shiny metals that tarnish if exposed to air. Mendeleev thought these similarities were important clues to a hidden pattern.

To try to find that pattern, Mendeleev wrote each element's melting point (M.P.), density, and color on individual cards. He also included the element's atomic mass and the number of chemical bonds it could form. The **atomic mass** of an element is the average mass of all the isotopes of that element. Mendeleev tried various arrangements of cards. **He noticed that a pattern of properties appeared when he arranged the elements in order of increasing atomic mass.**

Mendeleev's Periodic Table Mendeleev found that the properties of elements repeated. After fluorine (F), for instance, the next heaviest element he knew was sodium (Na). (Neon had not yet been discovered.) Sodium reacted with water the same way that lithium (Li) and potassium (K) did. So he placed the cards for these elements into a group. He did the same with other similar elements.

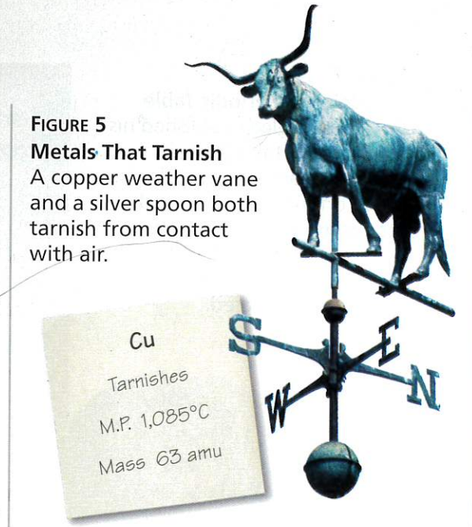


FIGURE 5
Metals That Tarnish
A copper weather vane and a silver spoon both tarnish from contact with air.

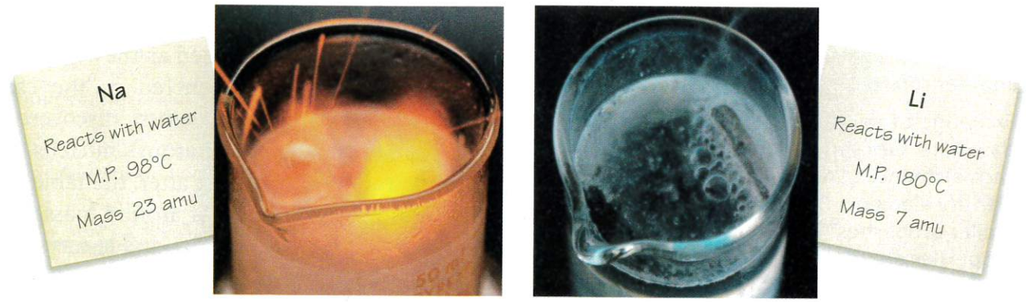
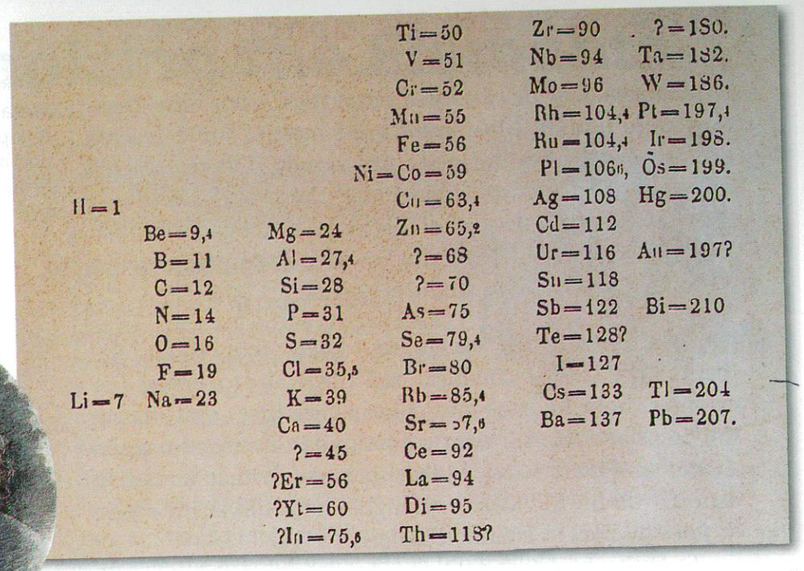


FIGURE 6
Metals That React With Water
Lithium and sodium both react with water. **Interpreting Photographs** *Which metal reacts more vigorously with water?*



			Ti=50	Zr=90	?=180.	
			V=51	Nb=94	Ta=182.	
			Cr=52	Mo=96	W=186.	
			Mn=55	Rh=104,4	Pt=197,4	
			Fe=56	Ru=104,4	Ir=198.	
			Ni=Co=59	Pl=106,	Os=199.	
H=1			Cu=63,4	Ag=108	Hg=200.	
	Be=9,4	Mg=24	Zn=65,2	Cd=112		
	B=11	Al=27,4	?=68	Ur=116	Au=197?	
	C=12	Si=28	?=70	Sn=118		
	N=14	P=31	As=75	Sb=122	Bi=210	
	O=16	S=32	Se=79,4	Te=128?		
	F=19	Cl=35,5	Br=80	I=127		
Li=7	Na=23	K=39	Rb=85,4	Cs=133	Tl=204	
		Ca=40	Sr=87,6	Ba=137	Pb=207.	
		?=45	Ce=92			
		?Er=56	La=94			
		?Yt=60	Di=95			
		?In=75,6	Th=118?			

FIGURE 7
Mendeleev's Periodic Table
When Mendeleev published his first periodic table, he left question marks in some places. Based on the properties and atomic masses of surrounding elements, he predicted that new elements with specific properties would be discovered.

Predicting New Elements Mendeleev found that arranging the known elements strictly by increasing atomic mass did not always group similar elements together. So, he moved a few of his element cards into groups where the elements did have similar properties. After arranging all 63 elements, three blank spaces were left. Mendeleev predicted that the blank spaces would be filled by elements that had not yet been discovered. He even predicted the properties of those new elements.

In 1869, Mendeleev published the first periodic table. It looked something like the one shown in Figure 7. Within 16 years, chemists discovered the three missing elements—scandium, gallium, and germanium. Their properties are close to those that Mendeleev had predicted.

The Modern Periodic Table In the **periodic table** used today, the properties of the elements repeat in each period—or row—of the table. (The word *periodic* means "in a regular, repeated pattern.") The periodic table has changed a little since Mendeleev's time. New elements were added as they were discovered. Also, an important change occurred in the early 1900s. In 1913, Henry Moseley, a British scientist, discovered a way to measure the positive charge on an atom's nucleus—in other words, the atomic number. Not long after, the table was rearranged in order of atomic number, not atomic mass. As a result, a few of the elements shifted position, and some of the patterns of properties became more regular. An up-to-date version of the table appears on pages 84 and 85.

Lab zone Skills Activity

Classifying

Choose any ten elements and assign them letters from *A* to *J*. On an index card for each element, write the letter for the element and list some of its properties. You may list properties that you learn about in this chapter or properties presented in another reference source.

Exchange cards with a classmate. Can you identify each element? Can you identify elements that have similar properties? Which properties are most helpful in identifying elements?

Finding Data on Elements

The periodic table has one square for each element. **In this book, each square includes the element's atomic number, chemical symbol, name, and atomic mass.**

Atomic Number Look at the periodic table on the next two pages and find the square for iron. That square is reproduced below in Figure 8. The first entry in the square is the number 26, the atomic number of iron. From Section 1, you know that the atomic number tells you that every iron atom has 26 protons in its nucleus. Because it has 26 protons, an iron atom also has 26 electrons.

Chemical Symbols and Names Just below the atomic number are the letters Fe—the **chemical symbol** for iron. Most chemical symbols contain either one or two letters. Often, an element's symbol is an abbreviation of the element's name in English. For example, zinc's symbol is Zn, the symbol for calcium is Ca, and the symbol for silicon is Si. Other elements, especially those that were known in ancient times, have symbols that are abbreviations of their Latin names. For example, the Latin name of sodium is *natrium*, so its symbol is Na. The Latin name of potassium is *kalium*, so its symbol is K. The symbol Au for gold stands for *aurum*. Fe for iron stands for *ferrum*, and Pb for lead stands for *plumbum*.

Average Atomic Mass The last number in the square is the average atomic mass. For iron, this value is 55.847 amu. The atomic mass is an average because most elements consist of a mixture of isotopes. For example, iron is a mixture of four isotopes. About 92 percent of iron atoms are iron-56 (having 30 neutrons). The rest are a mixture of iron-54, iron-57, and iron-58. The average atomic mass of iron is determined from the combined percentages of all its isotopes.

Reading Checkpoint **Why is the atomic mass of an element an average?**

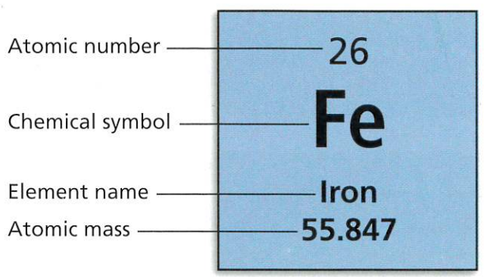


FIGURE 8
Iron
Bok choy is a green, leafy vegetable used in Asian cooking. It is rich in iron.
Interpreting Diagrams *What does atomic number 26 in the square tell you about iron?*

FIGURE 9

Periodic Table of the Elements

The periodic table includes over 100 elements. Many of the properties of an element can be predicted by its position in the table.

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Key

C	Solid
Br	Liquid
H	Gas
Tc	Not found in nature

Symbol
One- or two-letter symbols identify most elements. Some periodic tables also list the names of the elements.

Period

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.0079																	2 He Helium 4.0026
2	3 Li Lithium 6.941	4 Be Beryllium 9.0122											5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.179
3	11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.098	20 Ca Calcium 40.08	21 Sc Scandium 44.956	22 Ti Titanium 47.90	23 V Vanadium 50.941	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.933	28 Ni Nickel 58.71	29 Cu Copper 63.546	30 Zn *Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.59	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
5	37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.22	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.4	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.69	51 Sb Antimony 121.75	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.30
6	55 Cs Cesium 132.91	56 Ba Barium 137.33	71 Lu Lutetium 174.97	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.85	75 Re Rhenium 186.21	76 Os Osmium 190.2	77 Ir Iridium 192.22	78 Pt Platinum 195.09	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.37	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	103 Lr Lawrencium (262)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (264)	108 Hs Hassium (265)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (269)	111 *Uuu Unununium (272)	112 *Uub Ununbium (277)		114 *Uuq Ununquadium				

To make the table easier to read, the lanthanides and the actinides are printed below the rest of the elements. Follow the blue shading to see how they fit in the table.

Lanthanides

57	58	59	60	61	62
La Lanthanum 138.91	Ce Cerium 140.12	Pr Praseodymium 140.91	Nd Neodymium 144.24	Pm Promethium (145)	Sm Samarium 150.4

Actinides

89	90	91	92	93	94
Ac Actinium (227)	Th Thorium 232.04	Pa Protactinium 231.04	U Uranium 238.03	Np Neptunium (237)	Pu Plutonium (244)

Key

- Metal
- Metalloid
- Nonmetal
- Properties not established

Atomic Number
The atomic number is the number of protons in an atom's nucleus.

Atomic Mass
Atomic mass is the average mass of an element's atoms. Atomic masses in parentheses are those of the most stable isotope.

Many periodic tables include a zigzag line that separates the metals from the nonmetals.

*Name not officially assigned

63	64	65	66	67	68	69	70
Eu Europium 151.96	Gd Gadolinium 157.25	Tb Terbium 158.93	Dy Dysprosium 162.50	Ho Holmium 164.93	Er Erbium 167.26	Tm Thulium 168.93	Yb Ytterbium 173.04

95	96	97	98	99	100	101	102
Am Americium (243)	Cm Curium (247)	Bk Berkelium (247)	Cf Californium (251)	Es Einsteinium (252)	Fm Fermium (257)	Md Mendelevium (258)	No Nobelium (259)

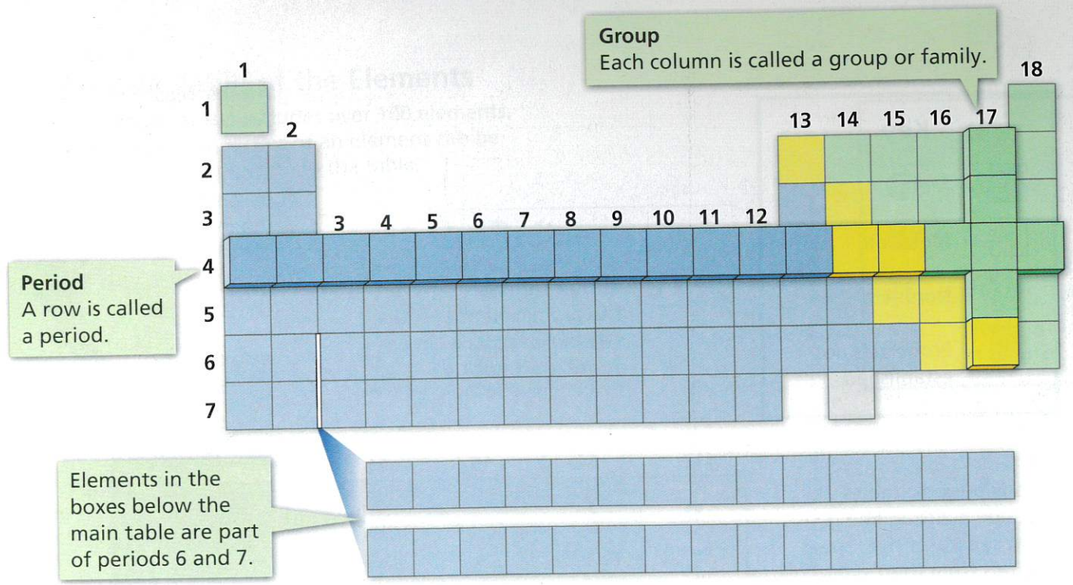

FIGURE 10
Periods and Groups
The 18 columns of the periodic table reflect a repeating pattern of properties that generally occur across a period. **Interpreting Tables** *How many periods are in the periodic table?*

Organization of the Periodic Table

Remember that the periodic table is arranged by atomic number. Look over the entire table, starting at the top left with hydrogen (H), which has atomic number 1. Follow the atomic numbers as they increase from left to right, and read across each row.

The properties of an element can be predicted from its location in the periodic table. As you look at elements across a row, the elements' properties change in a predictable way. This predictability is the reason that the periodic table is so useful to chemists.

Periods The table is arranged in horizontal rows called **periods.** A period contains a series of different elements, just as a week on a calendar has a series of seven days. As you move across a period from left to right, properties of the elements change according to a pattern.

As an example, look at the fourth period of the periodic table in Figure 10. The elements on the left of this period are highly reactive metals, such as potassium (K) and calcium (Ca). Elements in the center of the period are relatively unreactive metals, such as nickel (Ni) and copper (Cu). Elements to the right of these include metalloids such as arsenic (As) and the nonmetals selenium (Se) and bromine (Br). The last element in a period is always a very unreactive gas. In this period, that element is krypton (Kr).

Groups The modern periodic table has 7 periods, which form 18 vertical columns. The elements in a column are called a **group.** Groups are also known as families. The groups are numbered, from Group 1 on the left of the table to Group 18 on the right. Group 17 is highlighted in Figure 10. Most groups are named for the first element in the column. Group 14, for example, is the carbon family. Group 15 is the nitrogen family.

Because the pattern of properties of elements repeats in each new period, the elements in each group have similar characteristics. The elements in Group 1 are all metals that react violently with water, while the metals in Group 2 all react with water slowly or not at all. Group 17 elements react violently with elements from Group 1. Group 18 elements rarely react at all.

Reading Checkpoint **How many groups are in the modern periodic table?**

FIGURE 11
Group 13 Element
This sample of gallium metal is an element in Group 13.

Section 2 Assessment

Target Reading Skill **Asking Questions** Use your graphic organizer about the section headings to help you answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** In what order did Mendeleev arrange the elements in the first periodic table?
   b. **Explaining** What pattern did Mendeleev discover when he arranged the elements?
   c. **Comparing and Contrasting** Describe two differences between Mendeleev's periodic table and the modern periodic table.
2. a. **Identifying** List three kinds of information about an element that can be found in a square of the periodic table.
   b. **Interpreting Tables** What element has 47 protons in its nucleus?
   c. **Making Generalizations** Why aren't the atomic masses of most elements whole numbers?
3. a. **Describing** What does an element's location in the periodic table tell you about that element?
   b. **Predicting** Use the periodic table to name two elements that you would expect to have properties very much like those of calcium.

Writing in Science

Advertisement Write an advertisement that you could use to sell copies of Mendeleev's periodic table to chemists in 1869. Be sure to emphasize the benefits of the table to the chemical profession. Remember, the chemists have never seen such a table.