

Organizing the Elements

Reading Preview

Key Concepts

- How did Mendeleev discover the pattern that led to the periodic table?
- What information about elements does the periodic table provide?
- How are elements created?

Key Terms

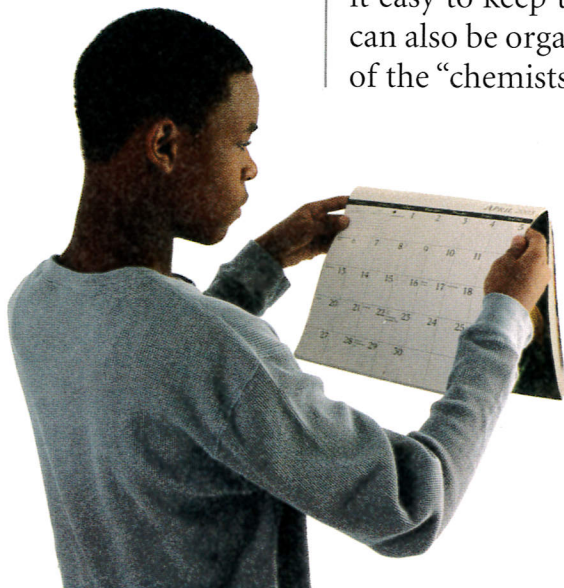
- atomic mass • periodic table
- period • group
- chemical symbol
- plasma • nuclear fusion

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 . . .



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

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.

FIGURE 11
Metals That Tarnish
A copper weather vane and a silver spoon both tarnish from contact with air.



Cu

Tarnishes

M.P. 1,085°C

Mass 63 amu



Ag

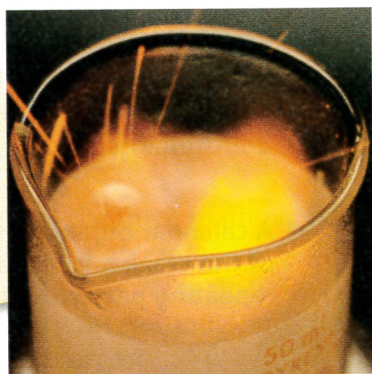
Tarnishes

M.P. 962°C

Mass 108 amu

FIGURE 12
Metals That React With Water
Lithium and sodium both react with water. **Interpreting Photographs**
Which metal reacts more vigorously with water?

Na
Reacts with water
M.P. 98°C
Mass 23 amu



Li
Reacts with water
M.P. 180°C
Mass 7 amu

Patterns in the Elements

By 1869, a total of 63 elements had been discovered. 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 11, are both shiny metals that tarnish if exposed to air. Mendeleev thought these similarities were important clues to a hidden pattern.

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** is the average mass of all the isotopes of an 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.) But 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.



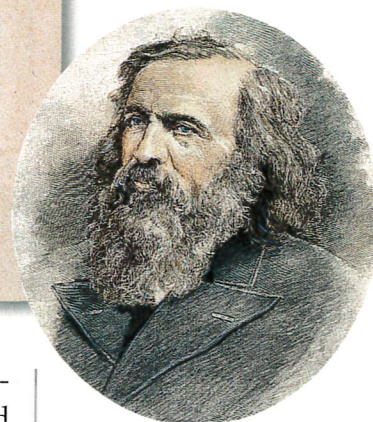
**Reading
Checkpoint**

What properties do silver and copper share?

FIGURE 13

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.



			Ti=50	Zr=90	?=150.
			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=106,4	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	Su=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?		

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 13. 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 the next two pages.

FIGURE 14
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

	1								9
1	H Hydrogen 1.0079								
2	Li Lithium 6.941	Be Beryllium 9.0122							
3	Na Sodium 22.990	Mg Magnesium 24.305							
4	K Potassium 39.098	Ca Calcium 40.08	Sc Scandium 44.956	Ti Titanium 47.90	V Vanadium 50.941	Cr Chromium 51.996	Mn Manganese 54.938	Fe Iron 55.847	Co Cobalt 58.933
5	Rb Rubidium 85.468	Sr Strontium 87.62	Y Yttrium 88.906	Zr Zirconium 91.22	Nb Niobium 92.906	Mo Molybdenum 95.94	Tc Technetium (98)	Ru Ruthenium 101.07	Rh Rhodium 102.91
6	Cs Cesium 132.91	Ba Barium 137.33	Lu Lutetium 174.97	Hf Hafnium 178.49	Ta Tantalum 180.95	W Tungsten 183.85	Re Rhenium 186.21	Os Osmium 190.2	Ir Iridium 192.22
7	Fr Francium (223)	Ra Radium (226)	Lr Lawrencium (262)	Rf Rutherfordium (261)	Db Dubnium (262)	Sg Seaborgium (263)	Bh Bohrium (264)	Hs Hassium (265)	Mt Meitnerium (268)

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

Group

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

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

- Metal
- Metalloid
- Nonmetal
- Properties not established

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

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

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

									18 2 He Helium 4.0026
			13 5 B Boron 10.81	14 6 C Carbon 12.011	15 7 N Nitrogen 14.007	16 8 O Oxygen 15.999	17 9 F Fluorine 18.998		10 10 Ne Neon 20.179
			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
9 27 Co Cobalt 58.933	10 28 Ni Nickel 58.71	11 29 Cu Copper 63.546	12 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
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
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)
109 Mt Meitnerium (268)	110 Ds Darmstadtium (269)	111 *Uuu Unununium (272)	112 *Uub Ununbium (277)		114 *Uuq Ununquadium				

*Name not officially assigned

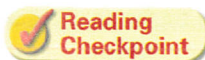
63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04
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95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)
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Reading an Element's Square 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. Other periodic tables may include more information, and some may include less. Look again at the large periodic table shown earlier in this section and find the square for iron. That square is reproduced below in Figure 16. The first entry in the square is the number 26, the atomic number for iron. Recall 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.

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.



Why is the atomic mass of an element an average?

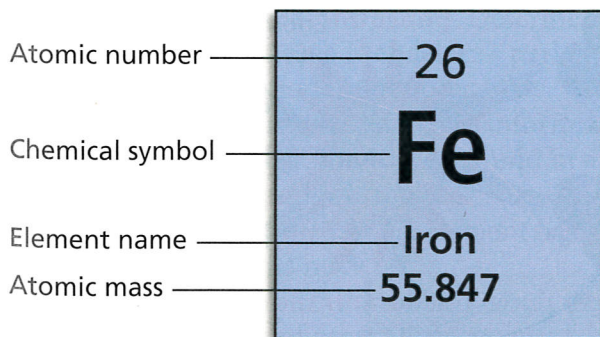


FIGURE 16

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?

How Elements Form in Stars

You have learned that elements are the simplest substances from which other forms of matter are made. Do you wonder where the elements come from? The answer might surprise you: stars! By studying the sun and other stars, scientists have formed hypotheses about the origins of matter on Earth.

Matter in the Sun Like many other stars, the sun is made mostly of one element—hydrogen. This hydrogen exists at tremendously high pressures and at temperatures as hot as 15 million degrees Celsius. At these extremes, matter does not exist as solid, liquid, or gas. Instead, it is **plasma**, a state of matter that consists of a gas-like mixture of free electrons and nuclei of atoms that have been stripped of electrons.

Remember that atomic nuclei contain protons, which are positively charged. So the atoms that are stripped of their electrons in a plasma are positively charged nuclei. Usually positive charges repel one another. But in stars, the pressure is so high that nuclei are squeezed close together and collide.

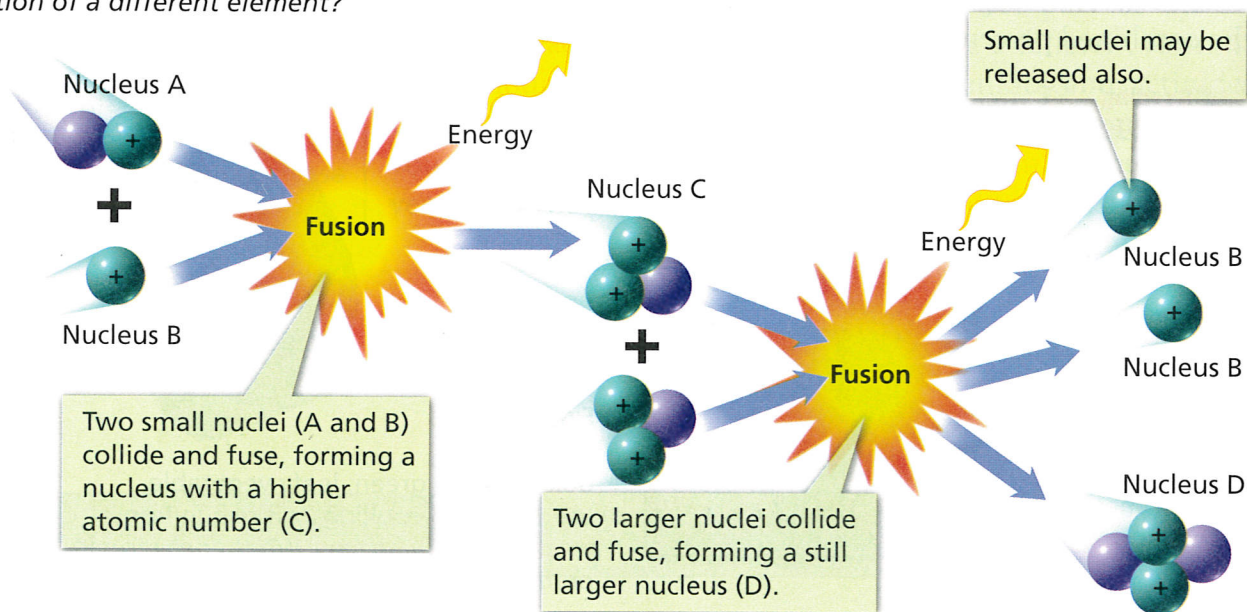
New Elements from Fusion When colliding nuclei have enough energy, they can join together, as shown in Figure 17. **Nuclear fusion** is a process in which two atomic nuclei combine, forming a larger nucleus and releasing huge amounts of energy. **Nuclear fusion, which occurs in stars on a huge scale, combines smaller nuclei into larger nuclei, creating heavier elements.** In the sun, different isotopes of hydrogen fuse, producing nuclei of helium. The energy produced in this reaction is the most important source of energy in the sun.

FIGURE 17

Nuclear Fusion

During nuclear fusion, two atomic nuclei collide and fuse.

Applying Concepts How can nuclear fusion result in the production of a different element?



As helium builds up in the sun's core, other fusion reactions occur. Over time, these fusion reactions form nuclei of slightly heavier elements, such as carbon, nitrogen, and oxygen. Stars the size of the sun do not contain enough energy to produce elements heavier than oxygen. But larger stars do. These stars are hot enough to produce elements such as magnesium and silicon. In more massive stars, fusion continues until the core is almost all iron.

How, then, are the elements that are heavier than iron produced? In the final hours of the most massive stars, scientists have observed an event called a supernova. The star explodes, producing temperatures up to 1 billion degrees Celsius. A supernova provides enough energy to create the heaviest elements. These elements are blown off into space as the star burns out.

Most astronomers agree that the matter in the sun and its planets originally came from a gigantic supernova that occurred billions of years ago. If so, this means that the matter all around you was created in a star, and all matter on Earth is a form of stardust.



FIGURE 18
Supernova
The Crab Nebula is the supernova of a massive star first observed on Earth in A.D. 1054 by Chinese astronomers.
Making Generalizations What elements may have formed in this supernova that would not have formed in a smaller star?



Where are elements heavier than iron produced?

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

- Reviewing** In what order did Mendeleev arrange the elements in the first periodic table?
 - Explaining** What pattern did Mendeleev discover when he arranged the elements?
 - Comparing and Contrasting** Describe two differences between Mendeleev's periodic table and the modern periodic table.
- Identifying** List three kinds of information about an element that can be found in a square of the periodic table.
 - Interpreting Tables** What element has 47 protons in its nucleus?
 - Making Generalizations** Why aren't the atomic masses of most elements whole numbers?
- Identifying** What is the process that produces elements in stars?
 - Explaining** How are the elements carbon, nitrogen, and oxygen produced in stars like the sun?
 - Developing Hypotheses** Earth has abundant amounts of iron, but also has many elements heavier than iron. Form a hypothesis to explain the presence of these heavier elements.

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 that the chemists have never seen such a table.