

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 . . .



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.

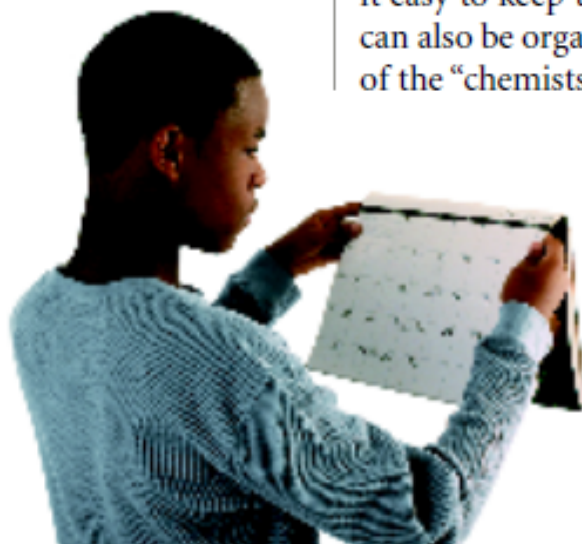


Think It Over

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.

FIGURE 11

Metals That Tarnish

A copper weather vane and a silver spoon both tarnish from contact with air.

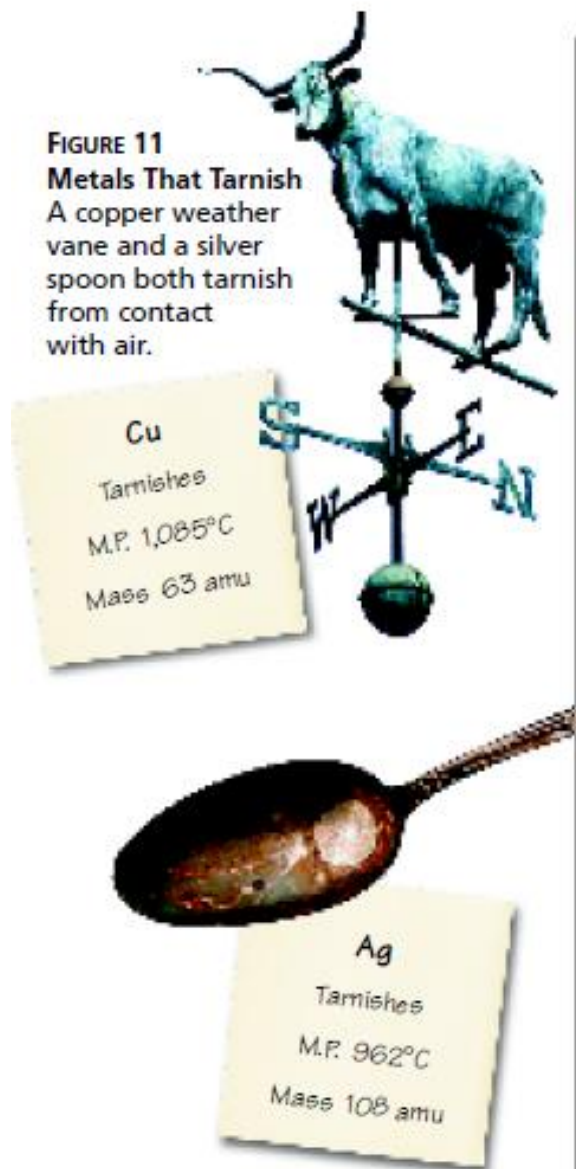


FIGURE 12

Metals That React With Water

Lithium and sodium both react with water. **Interpreting Photographs** Which metal reacts more vigorously with water?



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 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	1	2	3	4	5	6	7	8	9
1	1 H Hydrogen 1.0079								
2	3 Li Lithium 6.941	4 Be Beryllium 9.0122							
3	11 Na Sodium 22.990	12 Mg Magnesium 24.305							
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
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
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
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)

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.

			13	14	15	16	17	18
			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	2 He Helium 4.0026
			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	10 Ne Neon 20.179
10	11	12						
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
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
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)
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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Lab zone Skills Activity

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?

The properties of an element can be predicted from its location in the periodic table. This predictability is the reason that the periodic table is so useful to chemists. Knowing how the table is organized can make the table useful to you, too.

Remember that the periodic table is arranged by atomic number. Look over the entire table in Figure 14 on the previous two pages, starting at the upper left with hydrogen (H). Notice that the atomic numbers increase from left to right.

Periods The table is organized in horizontal rows called **periods**. A period contains a series of different elements, just as a week on a calendar has a series of different days. From left to right, the properties of the elements change in a pattern. For example, elements on the left side of the table are highly reactive metals. Less reactive metals are in the middle of the table. Next come the metalloids, followed by the nonmetals on the right. This pattern is repeated in each period.

Groups As a result of the repeating pattern of properties, the elements of the modern periodic table fall into 18 vertical columns, or **groups**. These groups—sometimes known as families—consist of elements with similar characteristics. For example, The elements in Group 1 are metals that react violently with water, while the elements in Group 2 react with water slowly or not at all. Group 17 elements react violently with elements from Group 1, but Group 18 elements rarely react at all.

The elements known as the lanthanides and the actinides are part of Periods 6 and 7. But these elements are usually printed below the others, and they are not part of the 18 groups already described. Figure 15 shows a different form of the periodic table. It includes the lanthanides and actinides where they would fit, according to their atomic numbers. If you wanted to show more than an element's symbol, this version of the periodic table would be hard to fit in a book!

An Expanded Periodic Table

If the lanthanides and actinides were placed within the body of the periodic table, they would increase the number of groups to 32.

1	H																	He														
2	Li	Be											B	C	N	O	F	Ne														
3	Na	Mg											Al	Si	P	S	Cl	Ar														
4	K	Ca											Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
5	Rb	Sr											Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe				
6	Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Uuu	Uub	Uuc					

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.



Reading
Checkpoint

Why is the atomic mass of an element an average?

Atomic number	26
Chemical symbol	Fe
Element name	Iron
Atomic mass	55.847



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?