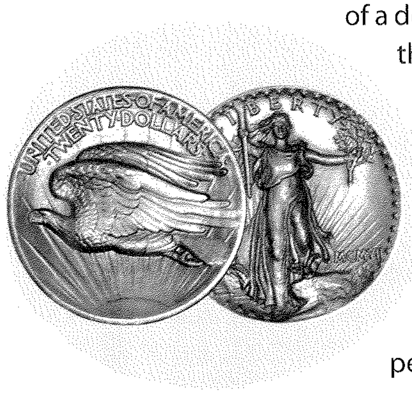
6.2 Classifying the Elements

Connecting to Your World

The sculptor Augustus Saint-Gaudens designed this gold coin at the request of Theodore Roosevelt. President Roosevelt wanted coins minted in the United States to be as beautiful as ancient Greek coins, which he admired. The coin is an example of a double eagle. The name derives from the fact that the coin was worth twice as much as $10 coins called eagles. A coin may contain a lot of information in a small space—its value, the year it was minted, and its country of origin. Each square in a periodic table also contains a lot of information. In this section, you will learn what types of information are usually listed in a periodic table.



Guide for Reading

Key Concepts

- What type of information can be displayed in a periodic table?
- How can elements be classified based on their electron configurations?

Vocabulary

alkali metals
alkaline earth metals
halogens
noble gases
representative elements
transition metal
inner transition metal

Reading Strategy

Relating Text and Visuals
As you read, look carefully at Figure 6.9. After you read the section, explain what you can tell about an element from the color assigned to its square and the color assigned to its symbol.

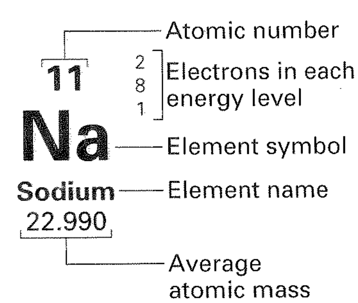
Squares in the Periodic Table

The periodic table displays the symbols and names of the elements, along with information about the structure of their atoms. Figure 6.8 shows one square from the detailed periodic table of the elements in Figure 6.9 on page 162. In the center of the square is the symbol for sodium (Na). The atomic number for sodium (11) is above the symbol. The element name and average atomic mass are below the symbol. There is also a vertical column with the numbers 2, 8, and 1, which are the number of electrons in each occupied energy level of a sodium atom.

The symbol for sodium is printed in black because sodium is a solid at room temperature. In Figure 6.9, the symbols for gases are in red. The symbols for the two elements that are liquids at room temperature, mercury and bromine, are in blue. The symbols for some elements in Figure 6.9 are printed in green. These elements are not found in nature. In Chapter 25, you will learn how scientists produce these elements.

The background colors in the squares are used to distinguish groups of elements. For example, two shades of gold are used for the metals in Groups 1A and 2A. The Group 1A elements are called **alkali metals,** and the Group 2A elements are called **alkaline earth metals.** The name alkali comes from the Arabic *al aqali*, meaning "the ashes." Wood ashes are rich in compounds of the alkali metals sodium and potassium. Some groups of nonmetals also have special names. The nonmetals of Group 7A are called **halogens.** The name halogen comes from the combination of the Greek word *hals*, meaning salt, and the Latin word *genesis*, meaning "to be born." There is a general class of compounds called salts, which include the compound called table salt. Chlorine, bromine and iodine, the most common halogens, can be prepared from their salts.

Figure 6.8 This is the element square for sodium from the periodic table in Figure 6.9. **Interpreting Diagrams** ***What does the data in the square tell you about the structure of sodium atoms?***



Periodic Table of the Elements

Representative Elements

- Alkali Metals
- Alkaline Earth Metals
- Other Metals
- Metalloids
- Nonmetals
- Noble Gases

Transition Elements

- Transition Metals
- Inner transition metals

C	Solid
Br	Liquid
He	Gas
Tc	Not found in nature

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B
1 H Hydrogen 1.0079 (1)								
3 Li Lithium 6.941 (2 1)	4 Be Beryllium 9.0122 (2 2)							
11 Na Sodium 22.990 (2 8 1)	12 Mg Magnesium 24.305 (2 8 2)							
19 K Potassium 39.098 (2 8 8 1)	20 Ca Calcium 40.08 (2 8 8 2)	21 Sc Scandium 44.956 (2 8 9 2)	22 Ti Titanium 47.90 (2 8 10 2)	23 V Vanadium 50.941 (2 8 11 2)	24 Cr Chromium 51.996 (2 8 13 1)	25 Mn Manganese 54.938 (2 8 13 2)	26 Fe Iron 55.847 (2 8 14 2)	27 Co Cobalt 58.933 (2 8 15 2)
37 Rb Rubidium 85.468 (2 8 18 8 1)	38 Sr Strontium 87.62 (2 8 18 8 2)	39 Y Yttrium 88.906 (2 8 18 9 2)	40 Zr Zirconium 91.22 (2 8 18 10 2)	41 Nb Niobium 92.906 (2 8 18 12 1)	42 Mo Molybdenum 95.94 (2 8 18 13 1)	43 Tc Technetium (98) (2 8 18 14 1)	44 Ru Ruthenium 101.07 (2 8 18 15 1)	45 Rh Rhodium 102.91 (2 8 18 16 1)
55 Cs Cesium 132.91 (2 8 18 18 8 1)	56 Ba Barium 137.33 (2 8 18 18 8 2)	71 Lu Lutetium 174.97 (2 8 18 32 9 2)	72 Hf Hafnium 178.49 (2 8 18 32 10 2)	73 Ta Tantalum 180.95 (2 8 18 32 11 2)	74 W Tungsten 183.85 (2 8 18 32 12 2)	75 Re Rhenium 186.21 (2 8 18 32 13 2)	76 Os Osmium 190.2 (2 8 18 32 14 2)	77 Ir Iridium 192.22 (2 8 18 32 15 2)
87 Fr Francium (223) (2 8 18 32 18 8 1)	88 Ra Radium (226) (2 8 18 32 18 8 2)	103 Lr Lawrencium (262 (2 8 18 32 32 9 2)	104 Rf Rutherfordium (261) (2 8 18 32 32 10 2)	105 Db Dubnium (262) (2 8 18 32 32 11 2)	106 Sg Seaborgium (263) (2 8 18 32 32 12 2)	107 Bh Bohrium (264) (2 8 18 32 32 13 2)	108 Hs Hassium (265) (2 8 18 32 32 14 2)	109 Mt Meitnerium (268) (2 8 18 32 32 15 2)

Elements 104–114 are the transactinide elements.

Lanthanide Series

57 La Lanthanum 138.91 (2 8 18 18 9 2)	58 Ce Cerium 140.12 (2 8 18 20 8 2)	59 Pr Praseodymium 140.91 (2 8 18 21 8 2)	60 Nd Neodymium 144.24 (2 8 18 22 8 2)	61 Pm Promethium (145) (2 8 18 23 8 2)	62 Sm Samarium 150.4 (2 8 18 24 8 2)

Actinide Series

89 Ac Actinium (227) (2 8 18 32 18 9 2)	90 Th Thorium 232.04 (2 8 18 32 18 10 2)	91 Pa Protactinium 231.04 (2 8 18 32 20 9 2)	92 U Uranium 238.03 (2 8 18 32 21 9 2)	93 Np Neptunium (237) (2 8 18 32 22 9 2)	94 Pu Plutonium (244) (2 8 18 32 24 8 2)

Figure 6.9 In this periodic table, the colors of the boxes are used to classify representative elements and transition elements.

Key:

14	Atomic number
2 8 4	Electrons in each energy level
Si	Element symbol
Silicon	Element name
* 28.086	Average atomic mass

*The atomic masses in parentheses are the mass numbers of the longest-lived isotope of elements for which a standard atomic mass cannot be defined.

10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
								2 He Helium 4.0026 (2)
			5 B Boron 10.81 (2 3)	6 C Carbon 12.011 (2 4)	7 N Nitrogen 14.007 (2 5)	8 O Oxygen 15.999 (2 6)	9 F Fluorine 18.998 (2 7)	10 Ne Neon 20.179 (2 8)
			13 Al Aluminum 26.982 (2 8 3)	14 Si Silicon 28.086 (2 8 4)	15 P Phosphorus 30.974 (2 8 5)	16 S Sulfur 32.06 (2 8 6)	17 Cl Chlorine 35.453 (2 8 7)	18 Ar Argon 39.948 (2 8 8)
28 Ni Nickel 58.71 (2 8 16 2)	29 Cu Copper 63.546 (2 8 18 1)	30 Zn Zinc 65.38 (2 8 18 2)	31 Ga Gallium 69.72 (2 8 18 3)	32 Ge Germanium 72.59 (2 8 18 4)	33 As Arsenic 74.922 (2 8 18 5)	34 Se Selenium 78.96 (2 8 18 6)	35 Br Bromine 79.904 (2 8 18 7)	36 Kr Krypton 83.80 (2 8 18 8)
46 Pd Palladium 106.4 (2 8 18 18)	47 Ag Silver 107.87 (2 8 18 18 1)	48 Cd Cadmium 112.41 (2 8 18 18 2)	49 In Indium 114.82 (2 8 18 18 3)	50 Sn Tin 118.69 (2 8 18 18 4)	51 Sb Antimony 121.75 (2 8 18 18 5)	52 Te Tellurium 127.60 (2 8 18 18 6)	53 I Iodine 126.90 (2 8 18 18 7)	54 Xe Xenon 131.30 (2 8 18 18 8)
78 Pt Platinum 195.09 (2 8 18 32 17 1)	79 Au Gold 196.97 (2 8 18 32 18 1)	80 Hg Mercury 200.59 (2 8 18 32 18 2)	81 Tl Thallium 204.37 (2 8 18 32 18 3)	82 Pb Lead 207.2 (2 8 18 32 18 4)	83 Bi Bismuth 208.98 (2 8 18 32 18 5)	84 Po Polonium (209) (2 8 18 32 18 6)	85 At Astatine (210) (2 8 18 32 18 7)	86 Rn Radon (222) (2 8 18 32 18 8)
110 Ds Darmstadtium (269) (2 8 18 32 32 17 1)	111 Rg Roentgenium (272) (2 8 18 32 32 18 1)	112 *Uub Ununbium (277) (2 8 18 32 32 18 2)		114 *Uuq Ununquadium				

*Name not officially assigned.

63 Eu Europium 151.96 (2 8 18 25 8 2)	64 Gd Gadolinium 157.25 (2 8 18 25 9 2)	65 Tb Terbium 158.93 (2 8 18 27 8 2)	66 Dy Dysprosium 162.50 (2 8 18 28 8 2)	67 Ho Holmium 164.93 (2 8 18 29 8 2)	68 Er Erbium 167.26 (2 8 18 30 8 2)	69 Tm Thulium 168.93 (2 8 18 31 8 2)	70 Yb Ytterbium 173.04 (2 8 18 32 8 2)
95 Am Americium (243) (2 8 18 32 25 8 2)	96 Cm Curium (247) (2 8 18 32 25 9 2)	97 Bk Berkelium (247) (2 8 18 32 27 8 2)	98 Cf Californium (251) (2 8 18 32 28 8 2)	99 Es Einsteinium (252) (2 8 18 32 29 8 2)	100 Fm Fermium (257) (2 8 18 32 30 8 2)	101 Md Mendelevium (258) (2 8 18 32 31 8 2)	102 No Nobelium (259) (2 8 18 32 32 8 2)

Figure 6.10 This blimp contains helium, one of the noble gases. **Applying Concepts** ***What does the ability of a helium-filled blimp to rise in air tell you about the density of helium?***

Electron Configurations in Groups

Electrons play a key role in determining the properties of elements. So there should be a connection between an element's electron configuration and its location in the periodic table. **Elements can be sorted into noble gases, representative elements, transition metals, or inner transition metals based on their electron configurations.** You may want to refer to Figure 6.9 as you read about these classes of elements.

The Noble Gases The blimp in Figure 6.10 is filled with helium. Helium is an example of a noble gas. The **noble gases** are the elements in Group 8A of the periodic table. These nonmetals are sometimes called the inert gases because they rarely take part in a reaction. The electron configurations for the first four noble gases in Group 8A are listed below.

Helium (He)	$1s^2$
Neon (Ne)	$1s^22s^22p^6$
Argon (Ar)	$1s^22s^22p^63s^23p^6$
Krypton (Kr)	$1s^22s^22p^63s^23p^63d^{10}4s^24p^6$

Look at the description of the highest occupied energy level for each element, which is highlighted in yellow. The *s* and *p* sublevels are completely filled with electrons. Chapter 7 will explain how this arrangement of electrons is related to the relative inactivity of the noble gases.

The Representative Elements Figure 6.11 shows the portion of the periodic table containing Groups 1A through 7A. Elements in these groups are often referred to as **representative elements** because they display a wide range of physical and chemical properties. Some are metals, some are nonmetals, and some are metalloids. Most of them are solids, but a few are gases at room temperature, and one, bromine, is a liquid.

In atoms of representative elements, the *s* and *p* sublevels of the highest occupied energy level are not filled. Look at the electron configurations for lithium, sodium, and potassium. In atoms of these Group 1A elements, there is only one electron in the highest occupied energy level. The electron is in an *s* sublevel.

Lithium (Li)	$1s^22s^1$
Sodium (Na)	$1s^22s^22p^63s^1$
Potassium (K)	$1s^22s^22p^63s^23p^64s^1$

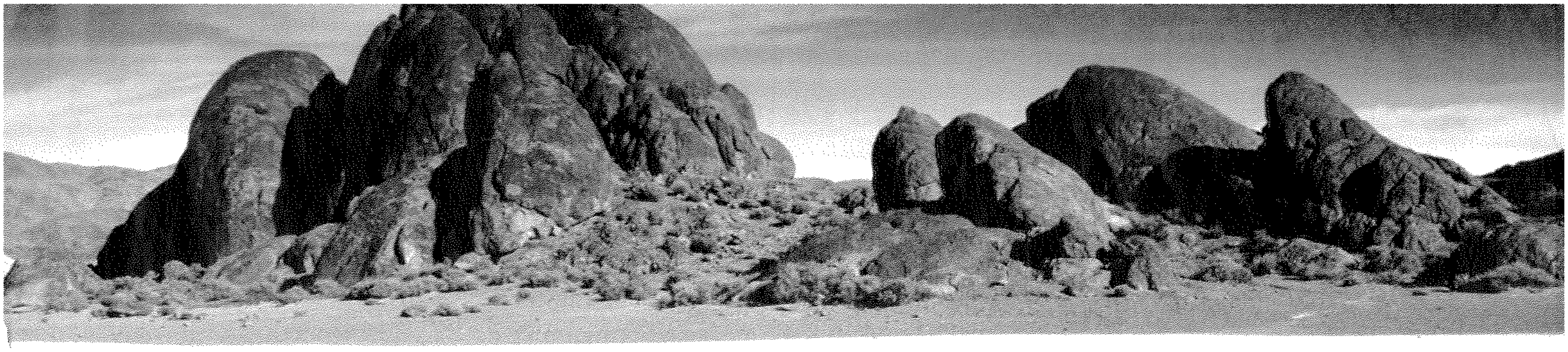
In atoms of carbon, silicon, and germanium, in Group 4A, there are four electrons in the highest occupied energy level.

Carbon (C)	$1s^22s^22p^2$
Silicon (Si)	$1s^22s^22p^63s^23p^2$
Germanium (Ge)	$1s^22s^22p^63s^23p^63d^{10}4s^24p^2$

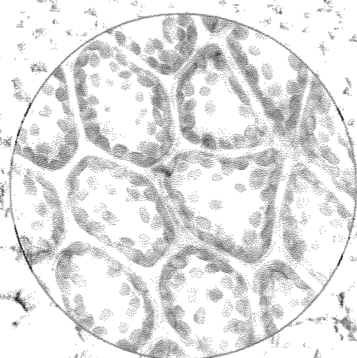
For any representative element, its group number equals the number of electrons in the highest occupied energy level.

Checkpoint ***Why are noble gases sometimes referred to as inert gases?***

Go Online
NSTA SCILINKS
For: Links on Chemical Families
Visit: www.SciLinks.org
Web Code: cdn-1062



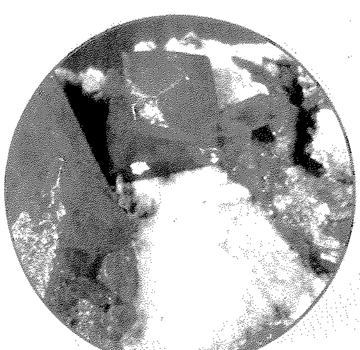
Magnesium This magnified view of a leaf shows the green structures where light energy is changed into chemical energy. The compound chlorophyll, which contains magnesium, absorbs the light.



Sodium When salt lakes evaporate, they form salt pans like this one in Death Valley, California. The main salt in a salt pan is sodium chloride.

1A	2A	3A	4A	5A	6A	7A
1 H Hydrogen 1.0079						
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
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
19 K Potassium 39.098	20 Ca Calcium 40.08	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
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	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
55 Cs Cesium 132.91	56 Ba Barium 137.33	81 Tl Thallium 204.37	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)
87 Fr Francium (223)	88 Ra Radium (226)					

Figure 6.11 Some of the representative elements exist in nature as elements. Others are found only in compounds.



Arsenic This bright red ore is a major source of arsenic in Earth's crust. It contains a compound of arsenic and sulfur.

Sulfur These scientists are sampling gases being released from a volcano through a vent called a fumarole. The yellow substance is sulfur.

Transition Elements

In the periodic table, the B groups separate the A groups on the left side of the table from the A groups on the right side. Elements in the B groups, which provide a connection between the two sets of representative elements, are referred to as transition elements. There are two types of transition elements—transition metals and inner transition metals. They are classified based on their electron configurations.

The transition metals are the Group B elements that are usually displayed in the main body of a periodic table. Copper, silver, gold, and iron are transition metals. In atoms of a **transition metal,** the highest occupied *s* sublevel and a nearby *d* sublevel contain electrons. These elements are characterized by the presence of electrons in *d* orbitals.

The inner transition metals appear below the main body of the periodic table. In atoms of an **inner transition metal,** the highest occupied *s* sublevel and a nearby *f* sublevel generally contain electrons. The inner transition metals are characterized by *f* orbitals that contain electrons. Before scientists knew much about inner transition metals, people began to refer to them as rare-earth elements. This name is misleading because some inner transition metals are more abundant than other elements.

Blocks of Elements If you consider both the electron configurations and the positions of the elements in the periodic table, another pattern emerges. In Figure 6.12, the periodic table is divided into sections, or blocks, that correspond to the highest occupied sublevels. The *s* block contains the elements in Groups 1A and 2A and the noble gas helium. The *p* block contains the elements in Groups 3A, 4A, 5A, 6A, 7A, and 8A, with the exception of helium. The transition metals belong to the *d* block, and the inner transition metals belong to the *f* block.

You can use Figure 6.12 to help determine electron configurations of elements. Each period on the periodic table corresponds to a principal energy level. Say an element is located in period 3. You know that the *s* and *p* sublevels in energy levels 1 and 2 are filled with electrons. You read across period 3 from left to right to complete the configuration. For transition elements, electrons are added to a *d* sublevel with a principal energy level that is one less than the period number. For the inner transition metals, the principal energy level of the *f* sublevel is two less than the period number. This procedure gives the correct electron configurations for most atoms.

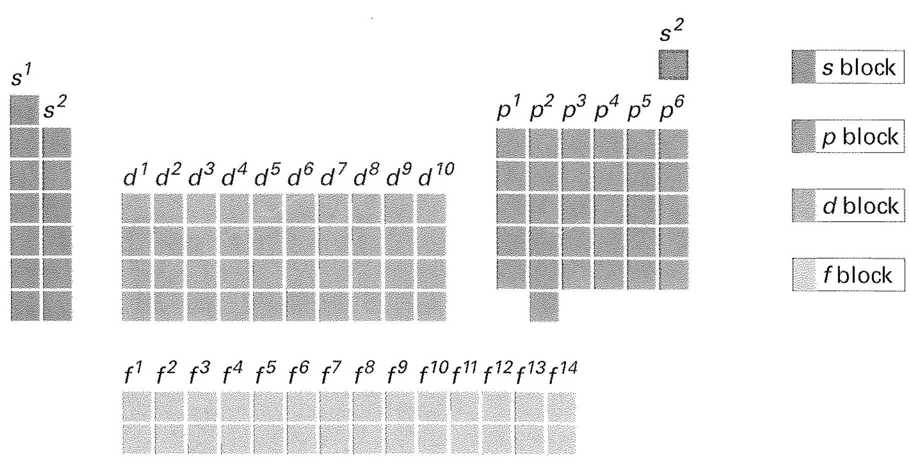


Figure 6.12 This diagram classifies elements into blocks according to sublevels that are filled or filling with electrons.
Interpreting Diagrams ***In the highest occupied energy level of a halogen atom, how many electrons are in the p sublevel?***

CONCEPTUAL PROBLEM 6.1

Using Energy Sublevels to Write Electron Configurations

Nitrogen is an element that organisms need to remain healthy. However, most organisms cannot obtain nitrogen directly from air. A few organisms can convert elemental nitrogen into a form that can be absorbed by plant and animal cells. These include bacteria that live in lumps called *nodules* on the roots of legumes. The photograph shows the nodules on a bean plant. Use Figure 6.12 to write the electron configuration for nitrogen (N), which has atomic number 7.

1 Analyze ***Identify the relevant concepts.***

For all elements, the atomic number is equal to the total number of electrons. For a representative element, the highest occupied energy level is the same as the number of the period in which the element is located. From the group in which the element is located, you can tell how many electrons are in this energy level.

2 Solve ***Apply concepts to this situation.***

Nitrogen is located in the second period of the periodic table and in the third group of the p block. Nitrogen has seven electrons. Based on Figure 6.12, the configuration for the two electrons in the first energy level is $1s^2$. The configuration for the five electrons in the second energy level is $2s^2 2p^3$.

Practice Problems

8. Use Figure 6.9 and Figure 6.12 to write the electron configurations of the following elements.
a. carbon **b.** strontium **c.** vanadium
(*Hint:* Remember that the principal energy level number for elements in the d block is always one less than the period number.)

9. List the symbols for all the elements whose electron configurations end as follows. Each n represents an energy level.
a. ns^2np^1
b. ns^2np^5
c. $ns^2np^6nd^2(n+1)s^2$

6.2 Section Assessment

10. **Key Concept** What information can be included in a periodic table?

11. **Key Concept** Into what four classes can elements be sorted based on their electron configurations?

12. Why do the elements potassium and sodium have similar chemical properties?

13. Classify each element as a representative element, transition metal, or noble gas.
a. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$
b. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$
c. $1s^2 2s^2 2p^6 3s^2 3p^2$

14. Which of the following elements are transition metals: Cu, Sr, Cd, Au, Al, Ge, Co?

15. How many electrons are in the highest occupied energy level of a Group 5A element?

Elements Handbook

Noble Gases Look at the atomic properties of noble gases on page R36. Use what you know about the structure of atoms to explain why the color produced in a gas discharge tube is different for each gas.

Interactive Textbook

Assessment 6.2 Test yourself on the concepts in Section 6.2.

with ChemASAP