The Periodic Table

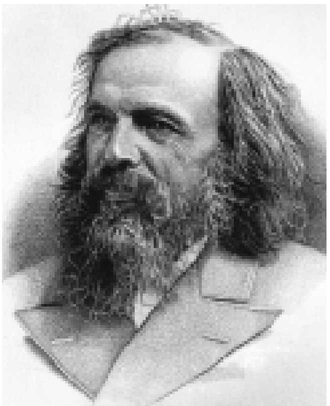


Figure 2.31 Dmitri Ivanovich Mendeleev was born in Siberia, the youngest of 17 children.

By the 1850s, chemists had identified a total of 58 elements, and nobody knew how many more there might be. Chemists attempted to create a classification system that would organize their observations. The various "family" systems were useful for some elements, but most family relationships were not obvious. What else could a classification system be based on?

By the 1860s several scientists were trying to sort the known elements according to atomic mass. **Atomic mass** is the average mass of an atom of an element. According to Dalton's atomic theory, each element had its own kind of atom with a specific atomic mass, different from the atomic mass of any other elements. One scientist created a system that was so accurate it is still used today. He was a Russian chemist named Dmitri Mendeleev (1834–1907).

Mendeleev Builds a Table

Mendeleev made a card for each known element. On each card, he put data similar to the data you see in Figure 2.32.

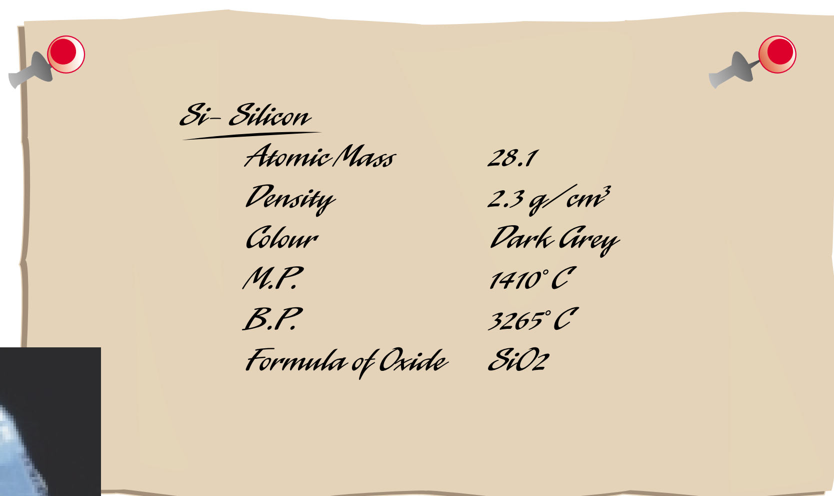


Figure 2.32 The card above shows modern values for silicon, rather than the ones Mendeleev actually used. His values were surprisingly close to modern ones. The atomic mass measurement indicates that silicon is 28.1 times heavier than hydrogen. You can observe other properties of silicon in Figure 2.33.

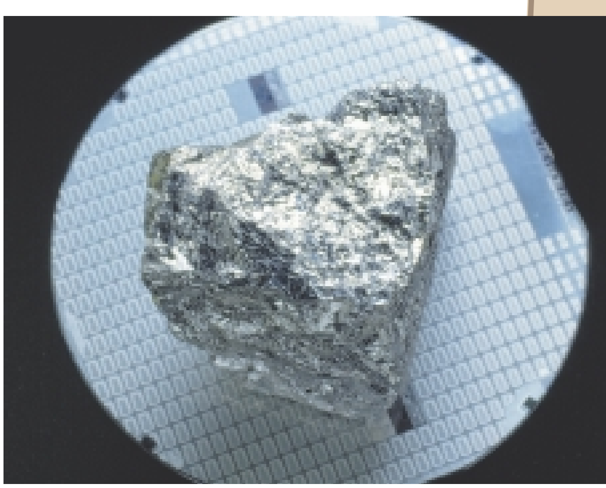


Figure 2.33 The element silicon is melted and formed into a crystal. The crystal is then sliced into thin wafers to produce electronic devices such as these microprocessor chips.

Mendeleev pinned all the cards to the wall, in order of increasing atomic mass. He "played cards" for several months, arranging the elements in vertical columns and horizontal rows. In the next activity, you will model Mendeleev's method.

Find Out ACTIVITY

Chemical Solitaire

In this activity, you will arrange element cards in groups according to their atomic mass and other properties.

Materials

sheet of property cards for fictional elements (provided by your teacher)

scissors

Procedure ✷ Analyzing and Interpreting

1. Cut the sheet into separate cards.
2. Line up the cards in order of increasing atomic mass.
3. Examine the cards to look for properties that are similar enough to justify placing certain elements above or below each other in a family. Find an arrangement that also keeps the cards in order by atomic mass.
4. Compare your arrangement with that of other students. Are there any refinements you can make to your arrangement? If so, record your new arrangement.

What Did You Find Out?

1. Which cards probably represent metallic elements? Which probably represent non-metallic elements? Give reasons for your opinions.
2. Which elements are solids? Which are liquids? Which are gases? Explain how you know.
3. Which of your arrangements do you think is the best? Why?

Extensions

4. How long did it take you to classify these elements? Mendeleev had to classify 63 elements. How long do you think it took him?
5. Where do you think Mendeleev got the data he wrote on his cards? (Hint: Do you think he performed all the experiments himself to get the data?)

Putting the Elements in Order

When Mendeleev arranged the elements in order of increasing atomic mass, he found that the properties of the elements repeated at definite, or periodic, intervals. The eighth element in his arrangement (sodium) had properties similar to the first (lithium), and the fifteenth element (potassium) had properties similar to the eighth. Therefore the first, eighth, and fifteenth elements made up a chemical family. The pattern Mendeleev discovered became known as the periodic table.

Mendeleev left gaps in his table, blank spaces predicting the existence of elements not yet found or even suspected by other chemists. He even predicted properties of these unknown elements, which spurred on other scientists to prove or disprove his predictions.

How did Mendeleev's table make it possible for him to predict the properties of other, still undiscovered, elements? Mendeleev noted which families had spaces. He inferred that the missing elements would have properties similar to those of other members of the family. Two examples, gallium and germanium, are famous for having been discovered shortly after Mendeleev predicted their existence and physical properties (see Figure 2.34). The discovery of gallium and germanium was a remarkable example of experimental evidence confirming a scientific prediction.

Figure 2.34 The melting point of gallium is so low that it will melt in a person's hand.

Mendeleev had noticed a periodic relationship between increasing atomic mass and chemical properties of elements. His work provided a logical organization for a huge amount of data about the elements, but no one could explain why the elements showed their amazing periodicity.

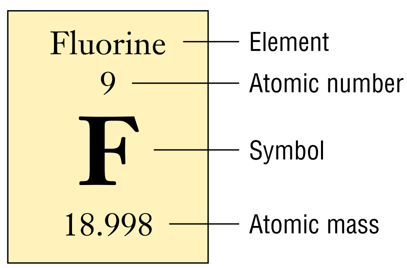
By about 1915, chemists and physicists had developed models of atomic structure, and it became clear that atomic structure was the key to explaining the periodicity of chemical properties. The periodic table was therefore reorganized with a focus on atomic structure rather than just atomic mass. The changes were surprisingly few. The resulting modern periodic table is based on a special number for each element, called its atomic number.

The **atomic number** is the number of protons an element has in its nucleus. For example, the atomic number of fluorine is nine, indicating that there are nine protons in the nucleus. The atomic number of oxygen is eight, so it has eight protons in the nucleus. Since all atoms are neutral, their positive and negative charges must be balanced. In other words, atoms contain an equal number of electrons and protons. How many electrons must be in a fluorine atom? How many electrons must be in an oxygen atom?

Did You Know?

The number of protons in an atom determines what element it is. For example, all atoms that contain three protons in the nucleus are atoms of lithium.

The atomic mass, atomic number, and symbol for an element are sometimes represented in a periodic table like this:



Math CONNECT

Calculate the number of neutrons in the following elements. The approximate mass number is given for each in parentheses: carbon (19), neon (20), sodium (23), and magnesium (24).

Mass Number

Chemists use another number, called the **mass number**, to give the total number of protons and neutrons in an atom.

$$\begin{array}{rl} & \text{number of protons} \\ + & \text{number of neutrons} \\ \hline = & \text{mass number} \end{array}$$

If you know the atomic number and mass number, you can calculate the number of neutrons by subtracting:

$$\begin{array}{rl} & \text{mass number} \\ - & \text{atomic number} \\ \hline = & \text{number of neutrons} \end{array}$$

The mass number of fluorine is 19. If you subtract its atomic number of nine, you can conclude that an atom of fluorine must contain ten neutrons.

INVESTIGATION 2-D

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- ✹ Analyzing and Interpreting
- Communication and Teamwork

Meet the Modern Periodic Table

Part 1

Every Element Has Its Own Number

Think About It

The periodic table below is simplified. It shows the general shape of the table and includes symbols for the elements, arranged in order of their atomic number. It also indicates which elements are gases, which are liquids, and which are solids at room temperature.

Notice the "staircase" on the right-hand side. The metals are found to the left of the staircase. The non-metals are found to the right (except for hydrogen). The metalloids are on either side of the staircase.

Legend: gas = red; liquids = blue; solids = black
- metals (white)
- metalloids (blue shading)
- non-metals (tan shading)

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

A simplified view of part of the modern periodic table

What to Do

1. An element's position in the periodic table is determined by its atomic number. The numbering system begins with hydrogen (H), atomic number 1, in the upper left-hand corner and moves from left to right. The numbers skip any blank space in between, so helium (He) has atomic number 2. The numbers then jump back to the left again, so lithium (Li), atomic number 3, is next.

   Make a copy of this simplified periodic table and record these atomic numbers on it.

2. Infer and record the atomic numbers for beryllium (Be) and boron (B). Do the same for the rest of this horizontal row, from carbon (C) to neon (Ne).

Analyze

1. Which element in each pair below has the larger atomic number? Explain how you know.
   - **(a)** carbon (C) or silicon (Si)
   - **(b)** silicon (Si) or phosphorus (P)
   - **(c)** beryllium (Be) or sodium (Na)

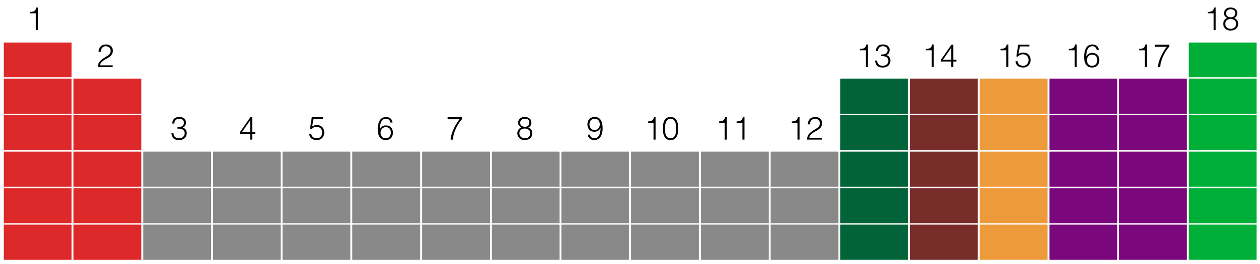
CONTINUED ▶

Part 2

Every Element Is Part of a Group

Think About It

Chemists call each vertical column in the periodic table a group. Chemical families are located in the same group.



How groups appear in the periodic table

What to Do

Combine information from the simplified periodic table in Part 1 and the diagram above to answer the following questions.

1. There are 18 groups in the periodic table, as you can see by counting across the top of the diagram. Locate the elements in the second group in your simplified periodic table.
2. Record the symbols for these elements in a vertical list. Which element in the list has the largest atomic number?
3. Which element would you expect to have the greatest atomic mass? Why?

Analyze

1. List the symbols, and as many names as you can, of the other elements that are found in the same group as the elements below.
   (a) aluminum (Al)
   (b) potassium (K)
   (c) lead (Pb)
2. Locate the elements copper (Cu), silver (Ag), and gold (Au) on your simplified periodic table. Are they in the same group? Is this what you expected?
3. List these chemical families in your notebook: alkali metals, alkaline earth metals, noble gases, and halogens. Which group number is each family? (Refer to pages 121–125 if you need help.)

Part 3

Every Element Is Part of a Period

Think About It

The horizontal rows of the periodic table are called **periods**. There are seven periods, although these simplified diagrams show only six. You probably noticed the empty spaces in the middle of Periods 1, 2, and 3. There is a reason for these spaces. For example, even though helium has an atomic number 2, it does not belong next to hydrogen. Helium belongs in the group having similar chemical properties — the noble gases. Mendeleev and other scientists of his time were aware of these gaps. However, the explanation for the gaps did not come until much later when scientists began to explore the inner structure of the atom.

How periods appear in the periodic table

What to Do

Combine information from the simplified periodic table in Part 1 and the diagram above to answer the following questions.

1. Record the symbols of the elements in Period 2 so they are stretched out horizontally across a page. Place the symbols of the elements in Period 3 directly beneath them, as they appear in the table.

2. Most of the elements are solids at room temperature. In your simplified periodic table, elements that are liquids at room temperature are in blue. Circle all of the liquids on your periodic table. Do any of them appear in Period 2 or Period 3?

3. Elements that are gases at room temperature are in red. Mark all of these on your periodic table with a highlighter. You will find gases in both Period 2 and Period 3. For each gas in Period 2, is there a corresponding gas underneath it (in the same group) in Period 3? Period 4? Period 5?

Pause & Reflect

Can survival depend on a knowledge of the elements? Primo Levi was born in Italy and trained as a chemist. During World War II he was arrested and sent to a concentration camp. Levi attributes his survival to his passion for chemistry. He wrote a book called *The Periodic Table* in which chemical elements are metaphors for human experience. In the chapter called "Carbon," Levi observes how all living things are united as he follows a carbon atom through rocks, leaves, milk, blood, and muscle. He uses the element hydrogen to explain the explosive nature of his life as a teenager. Levi states, "Chemistry is the art of separating, weighing, and distinguishing. These are also useful exercises for people to perform and use when trying to give body to their own imagination." What do you think Levi means in this quotation? Is there some way you could use the properties of an element as a metaphor?

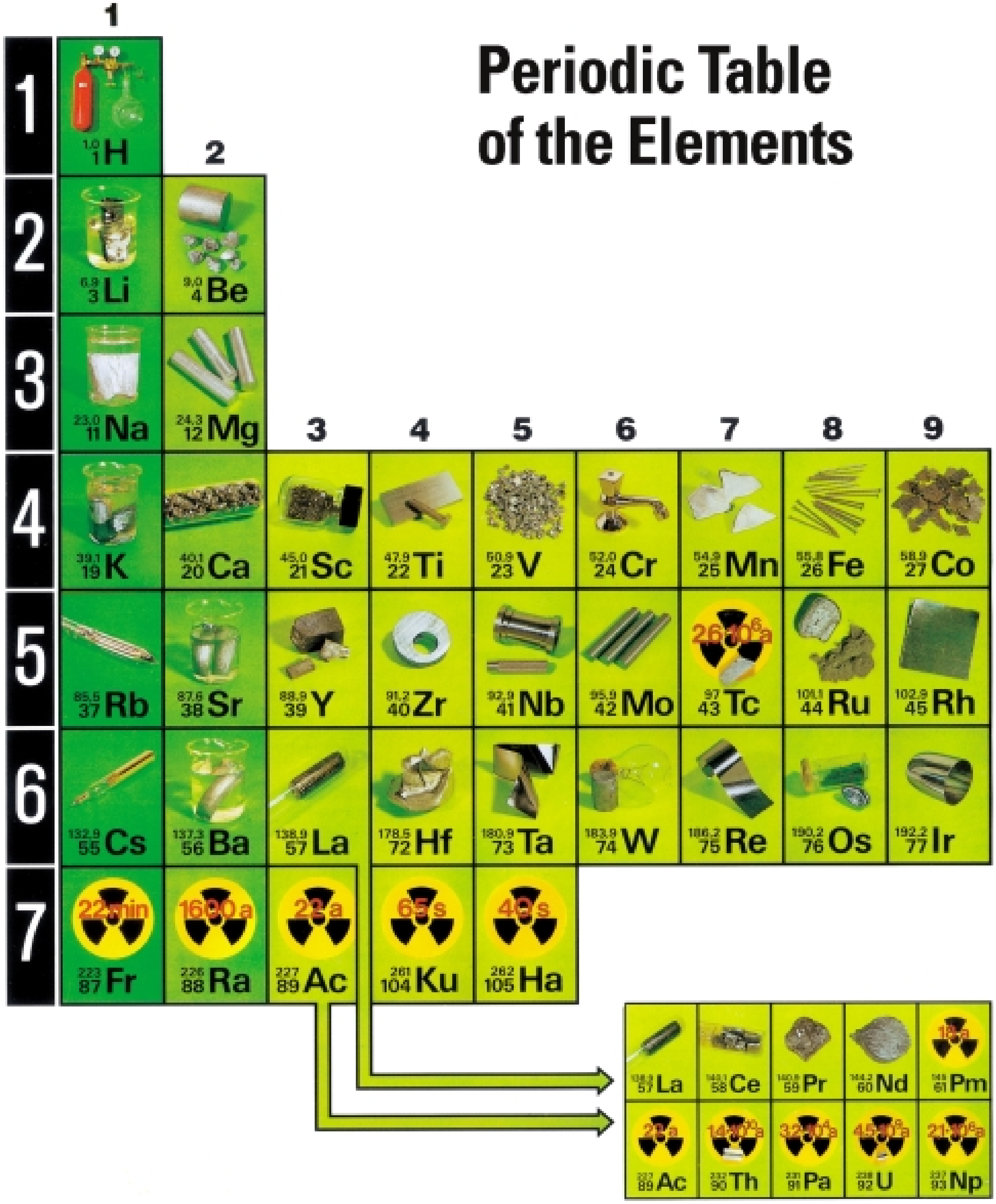
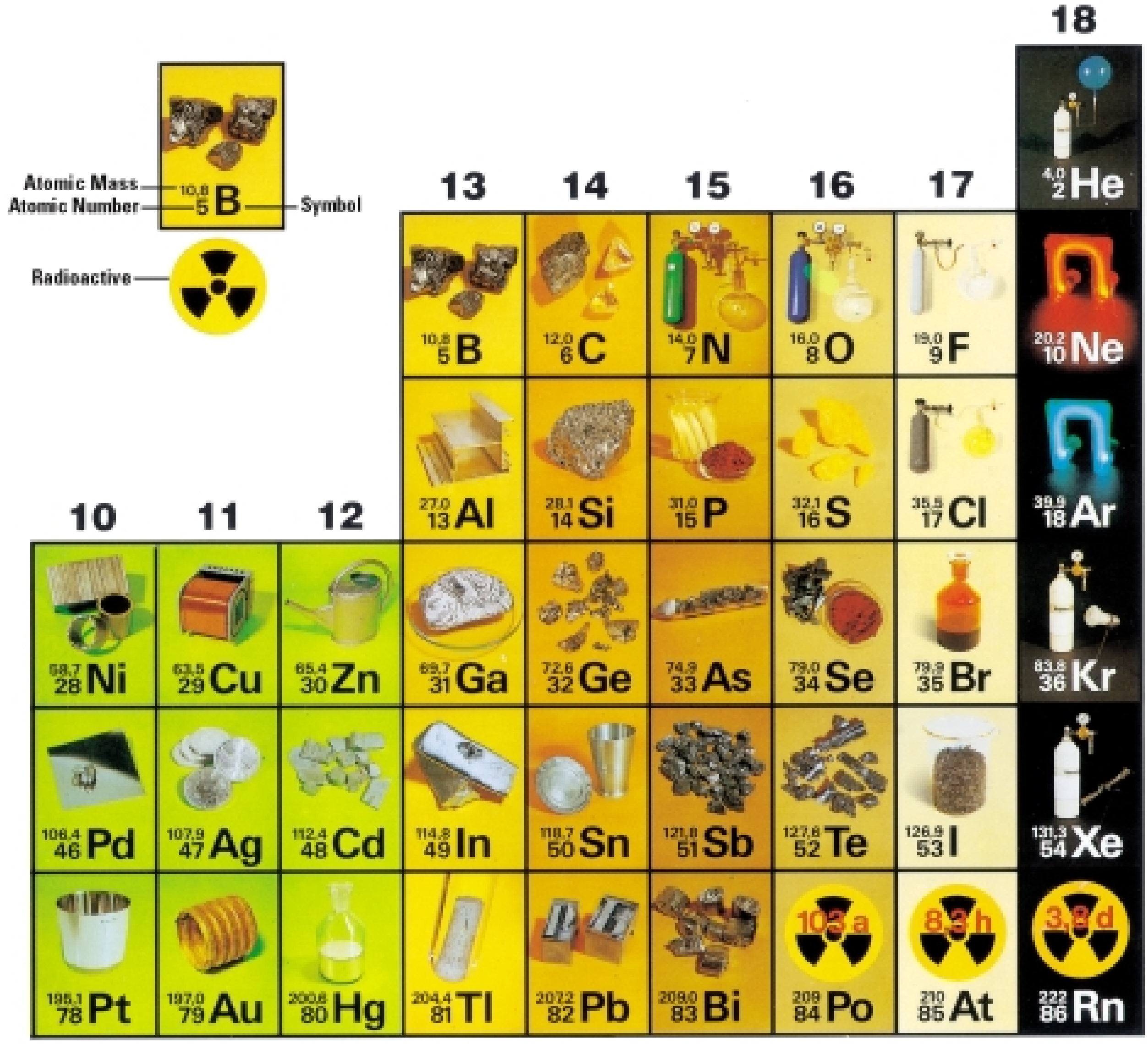


Figure 2.35 Pictorial Periodic Table
The periodic table shown here illustrates samples of the elements and common uses. It differs somewhat from the up-to-date table that you will find in Appendix B.



Atomic Mass
Atomic Number
Symbol
10.8 5 B
Radioactive
13
14
15
16
17
18
10
11
12
4.0 2 He
10.8 5 B
12.0 6 C
14.0 7 N
16.0 8 O
19.0 9 F
20.2 10 Ne
27.0 13 Al
28.1 14 Si
31.0 15 P
32.1 16 S
35.5 17 Cl
39.9 18 Ar
58.7 28 Ni
63.5 29 Cu
65.4 30 Zn
69.7 31 Ga
72.6 32 Ge
74.9 33 As
79.0 34 Se
79.9 35 Br
83.8 36 Kr
106.4 46 Pd
107.9 47 Ag
112.4 48 Cd
114.8 49 In
118.7 50 Sn
121.8 51 Sb
127.6 52 Te
126.9 53 I
131.3 54 Xe
195.1 78 Pt
197.0 79 Au
200.6 80 Hg
204.4 81 Tl
207.2 82 Pb
209.0 83 Bi
209 84 Po
210 85 At
222 86 Rn
8.3 h
3.8 d

62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr

Find Out ACTIVITY

Infer and Identify

How can you tell which element is which? The physical and chemical properties of a substance will give you clues. Can you solve the mysteries? Appendix C may be helpful once you have filled in all of the chart except for the element's name.

Safety Precautions

Identify safety precautions and discuss with your teacher.

Materials

elements and testing apparatus, as identified by your teacher

Procedure

Performing and Recording
Communication and Teamwork

1. Make an observation chart.
2. Select an element. Discuss general observations of the element with your group. Record your observations on the chart.
3. As a group discuss and decide on the chemical and physical properties for which you could safely test the element. Get approval for your tests and safety precautions from your teacher.
4. Conduct the tests. Record your results on your chart. Discuss any new questions, problems, or ideas that arise from the test results. Try to come to a consensus with your group on the identity of the element. Return the element to its proper location.
5. Repeat steps 2–4 for each of the elements.

What Did You Find Out?

Analyzing and Interpreting

1. Which two elements were the easiest to identify? Why?
2. Which properties were the hardest to determine?
3. Some of the elements were metals. Make a hypothesis about what characteristics a substance must have to be considered a metal.
4. Why do you suppose your teacher did not give you a sample of mercury, bromine, or plutonium?

Extension

5. Find photographs in Figure 2.35, the Pictorial Periodic Table of each of the elements you tested. Compare the illustration with the sample you used. What questions do you have about each element? Choose one of your questions and research the answer. Share your answer with the class.

Figure 2.36 A radioactive form of iodine can be used to produce an image of the thyroid gland.

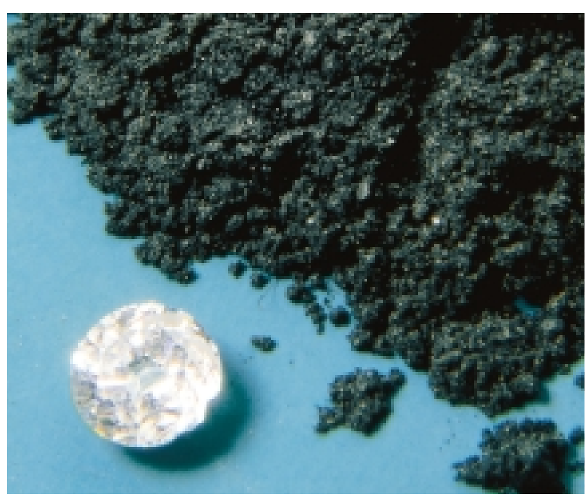


Figure 2.37 Carbon occurs naturally in different forms, such as graphite and diamonds. In which ways are the physical properties of graphite and diamonds different?

Figure 2.38 Sodium has a silvery lustre, typical of many metals. It is shiniest where it has just been cut. If you have smelled chlorine bleach, then you are familiar with the gas chlorine. Together, sodium and chlorine form salt.

STRETCH Your Mind

Only nine new natural elements were discovered in the twentieth century. However, scientists extended the periodic table by creating synthetic elements in nuclear reactors and particle accelerators. A particle accelerator is a machine used to move nuclear particles at very high speeds. When new elements are created in the accelerator, they last only for a short time — sometimes just a fraction of a second. Why don't they last longer?

TOPIC 5 Review

1. Why is the table called a "periodic" table?
2. How many groups of elements are in the modern periodic table of elements? Why are the elements grouped into rows and columns?
3. List the first 18 elements of the periodic table. State two properties of each element.
4. **Apply** For what purposes might modern scientists use the periodic table?
5. **Thinking Critically** Are the physical properties of the compound sodium chloride (table salt) an average of the properties of the elements it contains? (See Figure 2.38 above.) Explain.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

What would you like to know about elements and their properties? Create a KWL chart about six different elements. List what you know, then list what you wonder about each element. Search for answers at the web site above. Go to the web site above, and click on Web Links to find out where to go next. Then list what you have learned on your chart.