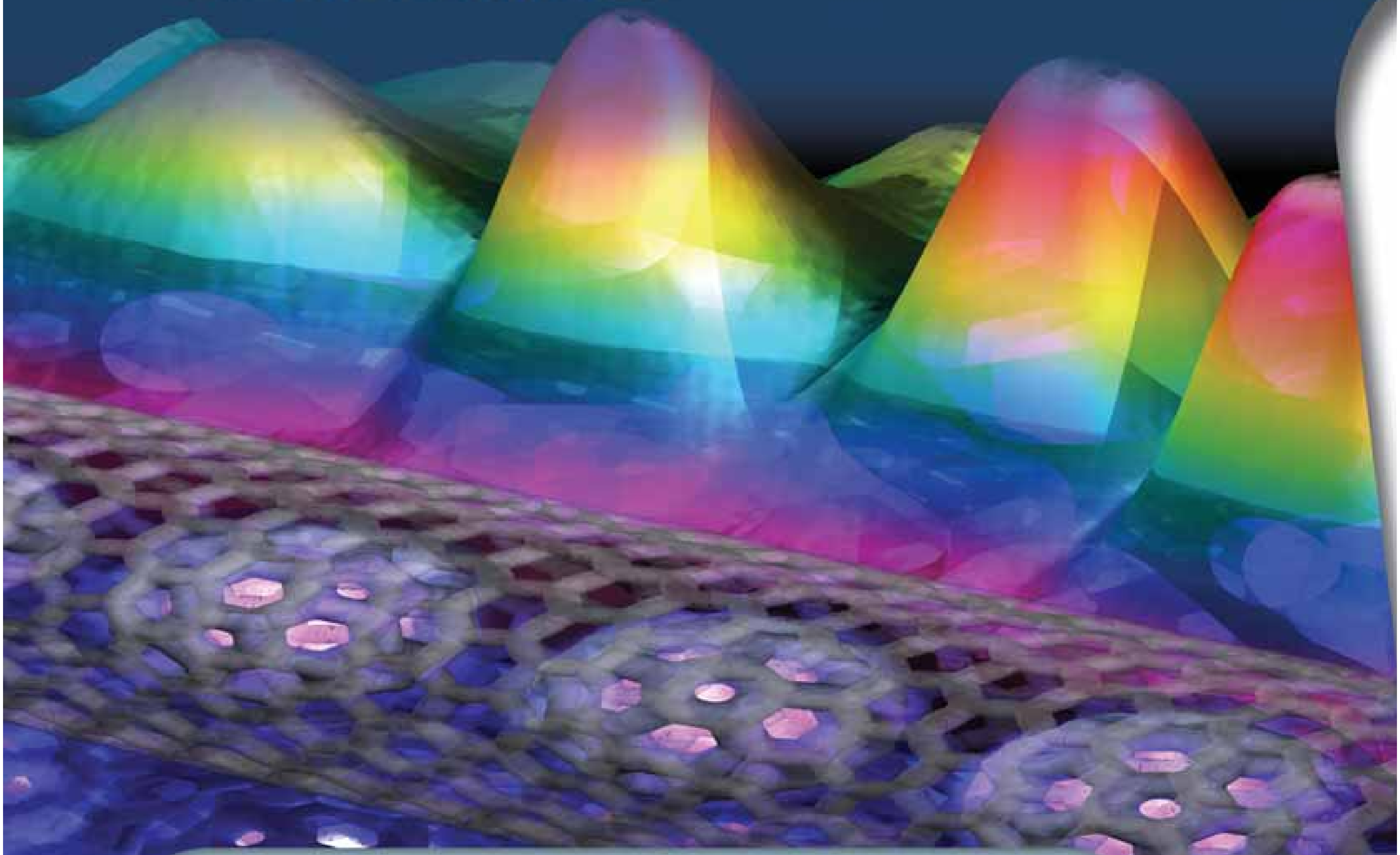
Chapter 2

Elements are the building blocks of matter.



This computer model represents a carbon nanotube, a microscopic hollow tube made of carbon atoms. The nanotube is one-billionth the diameter of a human hair, but is stronger than a steel thread of the same size and can conduct electricity and heat.

Today, we are on the edge of a revolution in our ability to create new products like the nanotube that have amazing and useful properties. These products include self-cleaning cotton, plastic computer chips, and computer displays woven into cloth. The revolution is taking place because we now understand many of the properties of elements, the building blocks of matter. We can use this knowledge to put individual atoms together in precisely planned and completely new ways.

What You Will Learn

In this chapter, you will
- **distinguish** between metals, non-metals, and metalloids
- **explain** the organization of the periodic table
- **predict** the properties of a family of elements in the periodic table
- **compare** the characteristics and atomic structures of elements

Why It Is Important

All types of matter are made out of elements or combinations of elements. Knowledge of the elements is the starting point to understanding such things as how your body functions, how plastics are made, and how to build antibiotics.

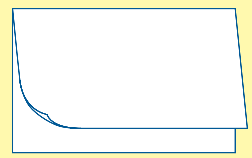
Skills You Will Use

In this chapter, you will
- **compare** the properties of various elements
- **classify** elements according to their position on the periodic table
- **draw** Bohr model diagrams
- **work** co-operatively in activities

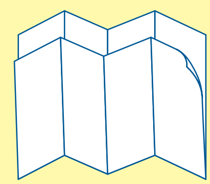
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 2.

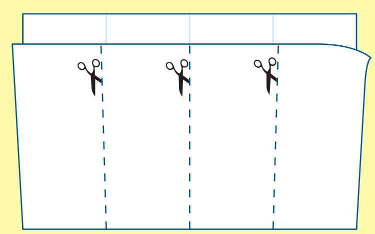
STEP 1 **Fold** a sheet of paper in half as shown. Make the back edge about 3 cm longer than the front edge. (Hint: from the tip of your index finger to your first knuckle is about 2.5 cm.)



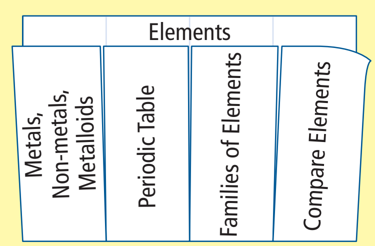
STEP 2 **Turn** the paper so the fold is to the bottom. Then, **fold** it into fourths.



STEP 3 **Unfold** and **cut** only the top layer along the three fold lines to make four tabs.



STEP 4 **Label** the Foldable as shown.



Organize As you read this chapter, use your Foldable to organize and record your notes on the elements.

2.1 Elements

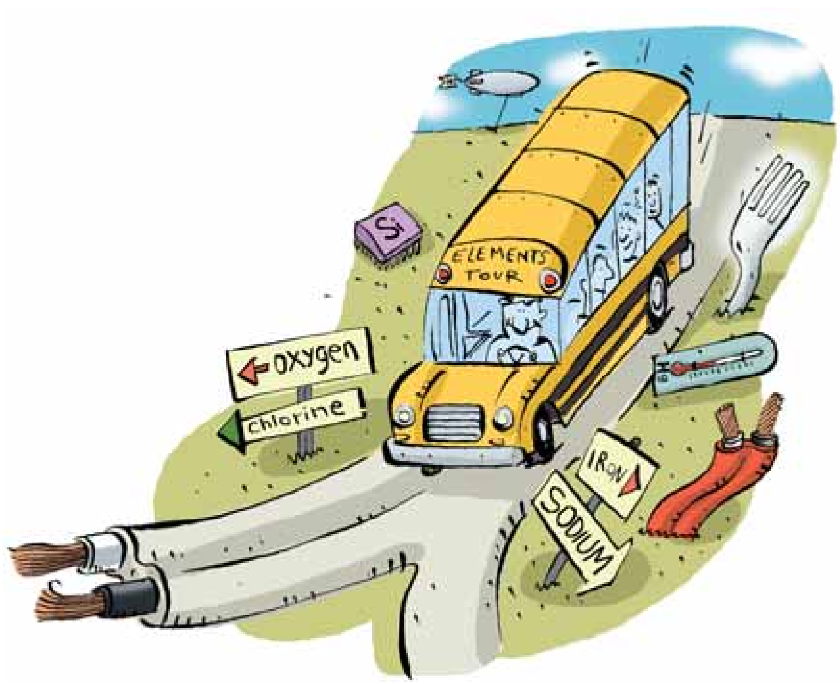
There are about 92 pure substances called elements that occur naturally. Each element is made of only one kind of atom. All other forms of matter are made from combinations of elements. Each element is represented by a one- or two-letter symbol. Common elements include hydrogen (H), iron (Fe), oxygen (O), sodium (Na), chlorine (Cl), mercury (Hg), silver (Ag), and silicon (Si).

Words to Know

chemical symbol
metal
non-metal

Did You Know?

Marie Curie (1867–1934) and her husband, Pierre, discovered the element radium. She named the element polonium after her home country, Poland. The element curium, discovered in 1944, was named in her honour. Marie Curie was the first scientist to be awarded two Nobel prizes.



Our Earth, the Sun, and everything else in our solar system, along with all the stars and galaxies beyond, contain an amazing variety of matter. You may recall that an element is a pure substance that cannot be broken down or separated into simpler substances. The reason an element cannot be broken down further is that it is already very simple: each element is made of only one kind of atom. In other words, all atoms of an element have the same number of protons.

Elements can be found in your pencils, your coins, and your portable music player. All electronic devices, like the portable headphones in Figure 2.1 on the next page, are made of a variety of elements. The gold on the tips of the wires helps improve the transmission of the electric signal from the music player to the headphones. The copper wire carries the signal. The plastic that insulates this wire is made mainly of the elements carbon and hydrogen. The magnets that help to convert the electric signal to sound are made of three different elements: iron, boron, and neodymium.

2-1A Meet the Elements

Find Out ACTIVITY

In this activity, you will examine a variety of elements. You will observe their colour, state, crystallinity, electrical conductivity, and magnetic properties. Record these properties in a table of elements similar to this one.

Name	Symbol	Colour	State	Crystallinity	Conducts Electricity?	Magnetic?
Gold	Au	Yellow	Solid	Non-crystalline	Yes	No

Safety

- If an element is in a sealed container, do not open the container. Some elements are too poisonous or reactive to handle.

Materials

- selection of elements
- conductivity tester
- magnet
- hand lens

What to Do

1. Your teacher will give you a variety of elements to examine.
2. For each element, record its name, chemical symbol, and as many properties as you can observe.
3. Clean up and put away the equipment you have used. Wash your hands thoroughly.

What Did You Find Out?

1. What do the elements that conduct electricity have in common?
2. What do the elements that do not conduct electricity have in common?
3. If you were asked to put all the elements you examined into two groups according to properties they had in common, how would you do it? Explain your method.

Chemical Symbols

There are more than 115 different elements. The elements have different names in different languages, so chemists all over the world use a set of international symbols for them. The **chemical symbol** for each element consists of one or two letters. If the symbol is only one letter, that letter is capitalized. If it is two letters, the first letter is capitalized, and the second letter is not capitalized.

The elements listed in Table 2.1 on the next page are grouped as solids, liquids, and gases at room temperature (25°C). The descriptions of the ancient names may help you remember the symbols. Most of these names are derived from Greek words. Other sources of some symbols are given in the table.

Figure 2.1 Headphones are made of many elements, such as copper (Cu), gold (Au), and carbon (C).

Table 2.1 Thirty-five Common Elements

Name of Element	Symbol	Origin of Element's Symbol
Gases at room temperature		
hydrogen	H	*Hydros genes* = water forming
helium	He	*Helios* = sun
neon	Ne	*Neon* = new
nitrogen	N	*Nitron* = saltpetre (an explosive)
oxygen	O	*Oxys genes* = acid forming
fluorine	F	*Fluere* = Latin for flowing
chlorine	Cl	*Chloros* from *khloros* = pale green
Liquids at room temperature		
bromine	Br	*Bromos* = smelly
mercury	Hg	*Hydrargyrum* = Latin for liquid silver
Solids at room temperature		
lithium	Li	*Lithos* = stone
sodium	Na	*Natrium* = Latin for sodium
potassium	K	*Kalium* = Latin for potash
rubidium	Rb	*Rubidus* = Latin for red
cesium	Cs	*Caesius* = Latin for bluish-grey
beryllium	Be	*Beryllos* = emerald
magnesium	Mg	*Magnesia alba* = a place in Greece
calcium	Ca	*Calx* = Latin for limestone
strontium	Sr	*Strontian* = a village in Scotland
barium	Ba	*Barys* = heavy
titanium	Ti	*Titans* = gods from Greek mythology
chromium	Cr	*Chroma* = colour
manganese	Mn	*Magnesia negra* = Latin for black magnesium
iron	Fe	*Ferrum* = Latin for iron
cobalt	Co	*Cobald* from *kobold* = German for goblin
nickel	Ni	*kupfer Nickel* = German for devil's copper
copper	Cu	*Cuprum* = Latin for Cyprian
zinc	Zn	*Zink* = German for zinc
silver	Ag	*Argentum* = Latin for silver
gold	Au	*Aurum* = Latin for gold
tin	Sn	*Stannum* = Latin for tin
lead	Pb	*Plumbum* = Latin for lead
carbon	C	*Carbo* = Latin for coal
phosphorus	P	*Phosphoros* = bringer of light
sulphur	S	*Sulphurium* = Latin for sulphur
iodine	I	*Iodes* = violet

Word Connect

The Latin *plumbum*, meaning lead, has given us the word "plumber." The ancient Romans used lead extensively in their water systems because it was soft and did not rust. Unfortunately, the pipes released small amounts of lead into the water, causing widespread lead poisoning.

A Tour of Some Common Elements

Recall from Chapter 1 that physical properties include characteristics such as state and colour. **Chemical properties** describe a substance's ability to react chemically with other substances to form new products. Reactivity is a chemical property. The elements below – four metals and four non-metals – have a variety of physical and chemical properties. **Metals** are typically hard, shiny, malleable, ductile, and good conductors of heat and electricity. **Non-metals** tend not to have these properties and are usually gases or brittle solids at room temperature. Metals and non-metals vary in their reactivity.

Suggested Activity

Conduct an Investigation 2-1B on page 48

Hydrogen (H)

Hydrogen is a colourless, odourless, tasteless, and highly flammable gas. It is also the lightest element. Our Sun and other stars are mostly made of hydrogen in its plasma state. Hydrogen makes up over 90 percent of the atoms in the universe and is highly reactive. Most hydrogen on Earth is found combined with oxygen as water. Hydrogen is used in producing ammonia for fertilizers and for treating fossil fuels. Since it is lighter than air, hydrogen can be used to inflate weather balloons and to lift airships. Automobiles are now being made that can run on hydrogen gas instead of gasoline. The only by-product is pure water.

Did You Know?

Most of your body's mass is made of oxygen (65 percent), carbon (18 percent), hydrogen (10 percent), nitrogen (3 percent), and calcium (2 percent). Other elements found in your body include phosphorus, sulphur, and chlorine.

Iron (Fe)

Iron is a very strong metal, especially when mixed with carbon to make steel. Large concrete structures such as buildings and swimming pools have long iron bars embedded in the concrete to give it strength (Figure 2.2).

Like all metals, iron is ductile. It can be heated and then drawn into wire as thin as the threads in steel wool. But iron has a weakness as a structural material: it can rust when exposed to water and oxygen. Steel ships are painted on the outside to help prevent rust.

Figure 2.2 Iron's strength makes it useful in construction.

Oxygen (O)

Oxygen is a non-metal. It is the gaseous element we breathe to stay alive. Our cells combine oxygen with sugar to release energy. Only about 21 percent of the atmosphere is oxygen, but this is enough to maintain life. Virtually all the oxygen in our atmosphere was put there by plants over the past 3 billion years. Plants produce oxygen as a by-product of photosynthesis.

Oxygen is a major component of water, which covers three-quarters of Earth's surface. Most rocks, which make up Earth's outer crust, are made of oxygen combined with other elements such as silicon, iron, and aluminum. Oxygen can react with most other elements (Figure 2.3).

Figure 2.3 Oxygen is very reactive. Under the right conditions, it can cause steel wool to burn.

Sodium (Na)

Sodium is a metal, but it is an unusual one. Your knife and fork, high-tension power lines, automobile frames—all are made of metals. Sodium looks metallic, but it cannot be used for any of these purposes because it is too soft. In fact, as shown in Figure 2.4, it can be cut with a knife.

A pot made of sodium metal could not be used to boil water. Why not? Recall that water boils at 100°C. Sodium melts at only 98°C, so the sodium pot would melt before the water boiled. Sodium cannot even be used to *hold* water. Water poured into a sodium pot would react violently, releasing a large amount of hydrogen and heat. It could even cause an explosion (Figure 2.5). Sodium and water also react together to form a toxic chemical used in drain cleaner.

Figure 2.4 Sodium is shiny and metallic but unusually soft.

Figure 2.5 Sodium metal reacts with water on contact.

Figure 2.6 Chlorine

Chlorine (Cl)

Chlorine is a pale yellow-green gas (Figure 2.6). Chlorine is added to water in swimming pools and to some water supplies to kill bacteria. It is safe in pools, but in high concentrations it is deadly. Yet chlorine combines with sodium to form table salt. It is an amazing thing that two highly toxic elements, sodium and chlorine, can combine to make something that is essential to most life forms.

Figure 2.7 The switch turns on when the mercury flows over both wire leads, making an electrical connection. When the tube tilts, the connection is broken, and the switch turns off.

Mercury (Hg)

Mercury is unique among metals: it is a liquid at room temperature. This property makes it an ideal component of "sparkless switches," needed in places where explosive gases are used, such as welding shops. Like all metals, mercury is an excellent conductor of electricity. Sealed inside a glass container, the mercury flows into a position so that it connects two metal contacts with no chance of a spark getting out (Figure 2.7). Although mercury has this unusual property, it is not fundamentally different from other metals. All metals become liquid at some temperature.

Mercury is a poison. Mercury vapour—a gas that forms over liquid mercury—is especially toxic.

Silver (Ag)

Silver may be one of the main reasons that British Columbia was originally settled. In the 1800s, a large deposit of a mineral called galena was discovered on the shore of Kootenay Lake. Galena is an important ore of lead and silver. When people learned there could be silver in the area, the news set off a "silver rush" of prospectors, miners, and settlers into the region. Several British Columbia communities, such as Kaslo, Nelson, and Slocan, were established because of the silver rush.

Figure 2.8 Silver's properties make it useful for jewellery, cutlery, and coins.

Silver is a white metallic element with many useful properties (Figure 2.8). It can be polished, moulded, and stretched and is both malleable and ductile. Besides being a precious metal that is used extensively in jewellery and silverware, silver is better than any other metal at conducting heat and electricity. Computer keyboards usually use silver contacts to ensure electrical conduction with even the lightest and fastest keystrokes. Silver also beats all the other metals when it comes to reflectivity and thermal conductivity. Musical instruments such as flutes even have better quality of tone when made of silver.

Explore More

The element gold is soft, durable, and an excellent conductor of electricity. These properties make it useful for joining contact points in electronic components. Find out more about the many uses of gold at **www.bcscience9.ca.**

Silicon (Si)

Silicon is the second most common element in Earth's crust (after oxygen). It is brittle, grey, and has a metallic lustre, although it is not a metal (Figure 2.9). Silicon is widely used in industry as a semiconductor. A *semiconductor* is a poor conductor of electricity at low temperatures, but a good conductor at high temperatures. Silicon is also used in manufacturing computer chips and hardware and is combined with aluminum to make the frames of automobiles. When it combines with oxygen, silicon can form quartz and opal. Silicon also helps structure the external coverings of some sea creatures, such as the spines of the sea urchin.

Figure 2.9 A micrograph of the surface of silicon

Reading Check

1. List three properties of sodium that are different from the properties of iron.
2. What are some properties of iron that make it a good material for construction?
3. What is mercury's unique property?
4. List two ways in which chlorine is beneficial to humans.
5. What are three useful properties of silver?

Suggested Activity

Think About It 2-1C on page 49

2-1B Generating and Burning Hydrogen Gas

SkillCheck

- Observing
- Predicting
- Measuring
- Working co-operatively

Safety

- Wear safety goggles and protective clothing.
- Handle chemicals safely.
- Wash your hands thoroughly after doing this investigation.

Materials

- medium-diameter test tube
- large-diameter test tube (to fit over medium test tube)
- test tube rack
- candle
- matches
- wooden splints
- dilute hydrochloric acid solution (HCl)
- zinc metal (mossy)
- test tube holder
- chemical waste container

In this activity, you will generate hydrogen gas by combining a reactive metal with an acid. You will safely burn the hydrogen in a procedure called the "pop" test. Work with one or two partners.

Question

How can a burning wooden splint be used to test for the presence of hydrogen gas?

Procedure

1. Place the medium test tube in the test tube rack. Make sure the large test tube will fit over the medium test tube. Set the large test tube aside.
2. Set up a candle and light it. Have several wooden splints nearby.
3. Carefully pour hydrochloric acid (HCl) into the medium test tube until the test tube is no more than $\frac{1}{3}$ full. Be careful not to spill. If any acid does spill, ask your teacher for the best way to clean it up.
4. Place one or two pieces of zinc metal in the hydrochloric acid. The reaction will begin slowly. Look for bubbles forming on the surface of the zinc. These bubbles are hydrogen gas. Note any colour changes that occur on the surface of the zinc.
5. Using a test tube holder, hold the large test tube upside down over the mouth of the medium test tube to collect the hydrogen gas. The gas is invisible, but you will probably have collected enough in about 30 s.

6. Lift the large test tube away from the generating equipment. Keep it upside down so you do not lose any gas.

Inquiry Focus

7. Light a wooden splint and bring the flame near the base of the large test tube until the hydrogen gas ignites. Be prepared for a "pop" sound and do not drop the test tube! Observe.
8. Repeat the gas collection and ignition a few more times. Because oxygen is needed for burning to occur, blow into the large test tube a few times before refilling it with hydrogen. This will help produce a good "pop."
9. When you are finished, pour the contents of the medium test tube into the chemical waste container provided by your teacher.
10. Clean up and put away the equipment you have used.

Analyze

1. How does the appearance of the zinc metal change as it reacts with the acid?
2. Predict what might happen to the zinc if it were left in the acid for a long time.

Conclude and Apply

1. Describe the appearance of zinc metal when it is reacting with hydrochloric acid.
2. Describe what happens during a positive test for hydrogen gas.

2-1C Essential Elements

Think About It

Each element has a history. Some elements have been known since ancient times, whereas others have only been discovered recently. In this activity, you will research an element and present your findings.

What to Do

1. Choose an element. Research some or all of the following information: when and where the element was discovered; its appearance; its physical and chemical properties; important compounds it is found in; its importance to life; whether it is rare or common; and its commercial value, if any. Be sure to cite your sources. You can begin your search at **www.bcscience9.ca**.
2. Demonstrate that you know your element. You could write an advertisement for it, create a commercial for it, make a poster describing it, lead a discussion on it, or use some other presentation, approved by your teacher.
3. Share your information with other students.

Wild, Weird, Wonderful

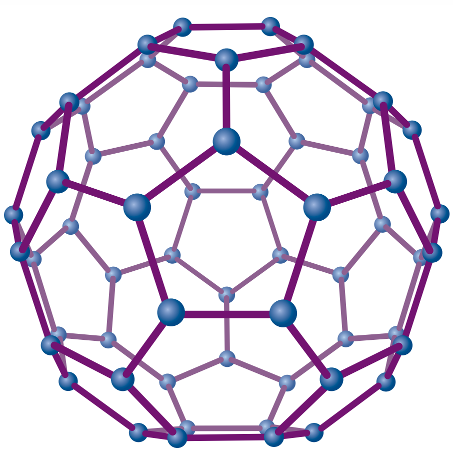
www Science

The Carbon Connection

Carbon has many forms. The black core of your pencil is one form of carbon called graphite. But the diamond in a drill bit or an engagement ring is pure carbon, too. Why are their properties so different? Although both graphite and diamond are made of carbon, their atoms are arranged differently. The different arrangement of atoms give each of these forms of carbon very different properties.

Graphite is used for pencils because it is soft and makes a dark mark on paper. Graphite is also the black pigment used in photocopiers, ink-jet printers, and paints. In fact, you are looking at graphite right now—it was used to print all the black letters on this page. When graphite is subjected to extreme heat and pressure, the arrangement of carbon atoms changes, and it turns into diamond. Diamond is transparent and extremely hard—so hard that the only thing that can scratch a diamond is another diamond.

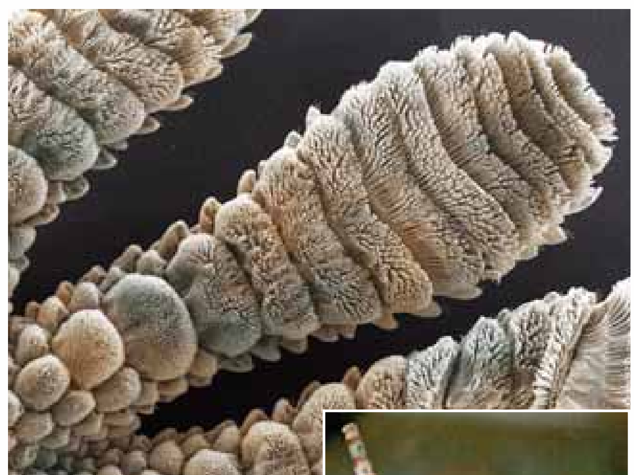
Recently, a new form of carbon was found that is soft and slippery like talcum powder and can be used as a lubricant. Sixty carbon atoms bond together in the same shape as a soccer ball, which also has 60 points, or vertices. The new form of carbon is called buckminsterfullerene, after the American architect and engineer R. Buckminster Fuller, who built structures of this shape. It is informally known as buckyball.



Carbon atoms in buckminsterfullerene

Researchers are now working on yet another form of carbon: nanotubes. Nanotechnology is the science and technology of very small things, such as objects built one atom at a time. Carbon nanotubes several millimetres long have already been made in the laboratory. Now they are beginning to be used as adhesives. Imagine an adhesive patch a few centimetres square that could support the weight of a person yet be easily peeled off again.

Inspired by observations of the gecko, the tiny lizard in the photo, researchers are creating adhesives with just this kind of ability. The gecko can run up windows and across ceilings thanks to millions of microscopic hairs on its footpads, as shown in the micrograph. An adhesive with nanofibres that mimic these hairs is expected to have 200 times the sticking power of the real thing.



Researchers are studying gecko footpads to develop adhesive patches.

Check Your Understanding

Checking Concepts

1. (a) What is an element?
(b) Approximately how many elements are there?

2. Why are chemical symbols for the elements used?

3. Use Table 2.1 on page 44 to help you answer the following:
(a) List the symbols of the four gases whose element symbols have only one letter.
(b) List the names of both elements that are liquids at room temperature.
(c) Write the symbols of any four solids whose symbols have only one letter.
(d) List the names of any four solids whose symbols have two letters.

4. In table 2.1, which four elements were named after places?

5. Give the name and symbol for the element based on each of the following ancient meanings in Table 2.1 on page 44:
(a) goblin
(b) smelly
(c) violet
(d) emerald
(e) flowing
(f) new
(g) pale green
(h) liquid silver
(i) red
(j) bluish-grey
(k) bringer of light

6. Which is the lightest element?

7. Which element is a better conductor of electricity: silver or gold?

8. What elements are used to make steel?

9. What percentage of our atmosphere is composed of oxygen?

10. What is the source of the oxygen in our atmosphere?

11. Explain why sodium metal would not be a good material for drinking glasses.

12. Why is the element chlorine used in swimming pools?

13. Which element makes up over 90 percent of the atoms in the universe?

14. Which element does silicon combine with to make quartz?

Understanding Key Ideas

15. Compare the rate of reaction of sodium in water to that of iron in water.

16. Mercury and sodium are both metals. List the ways they are:
(a) similar
(b) different

17. Mercury is the only metal to exist as a liquid at room temperature.
(a) Does this mean it is fundamentally different from all other metals? Explain your answer.
(b) Describe one practical use of the element mercury.
(c) Why would it be unsafe to open a jar of liquid mercury and smell the air above it, even if none spilled out?

18. Give three examples of elements that are in substances or objects that you use.

Pause and Reflect

Each element has a set of unique properties. How is each element different in terms of the number of its protons?