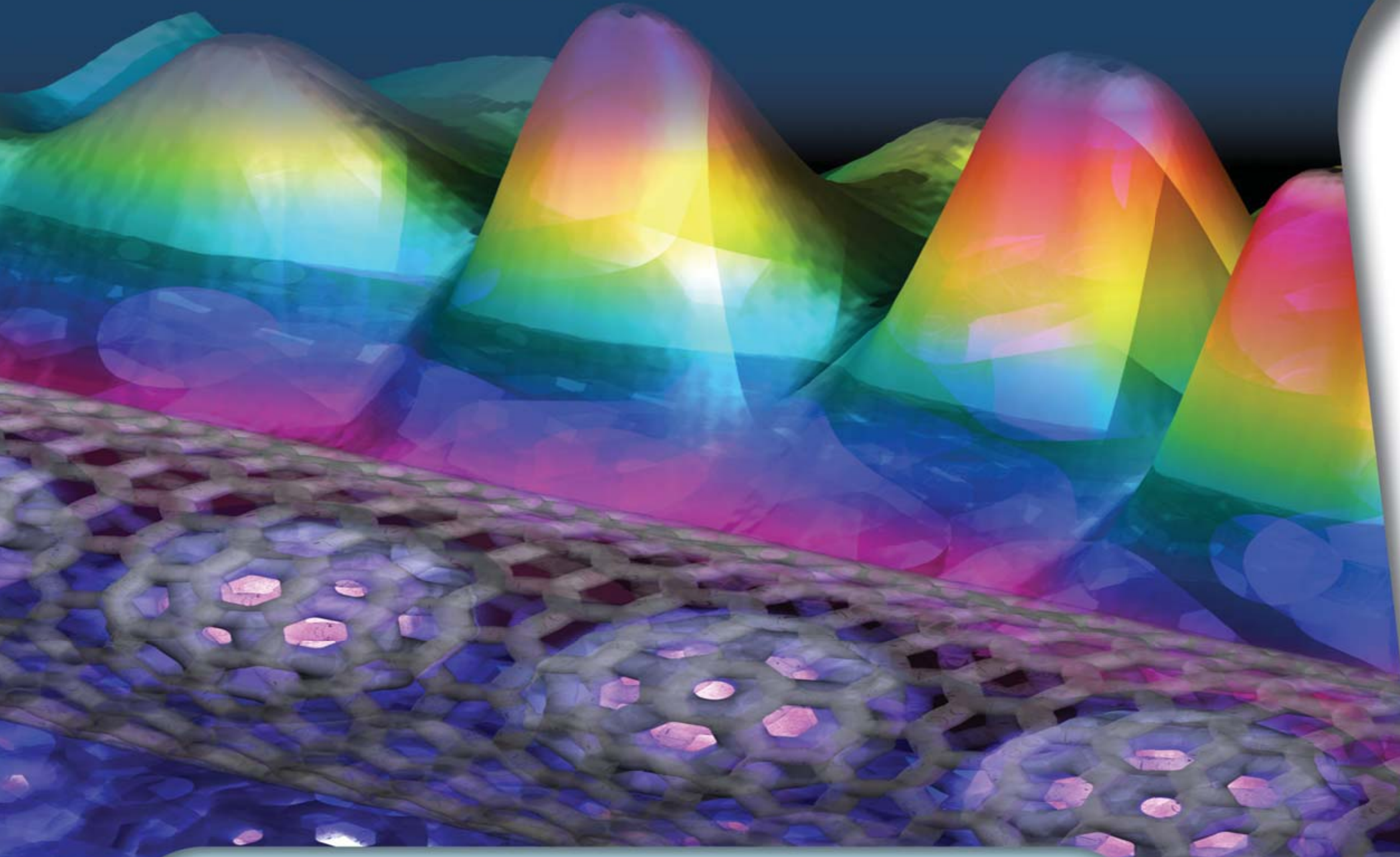
Chapter 2

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 100 thousand times thinner than 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.

FOLDABLES™
Reading & Study Skills

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

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

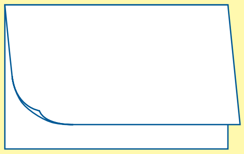
Why It Is Important

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.

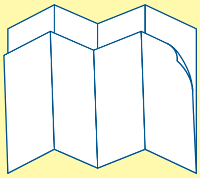
Skills You Will Use

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

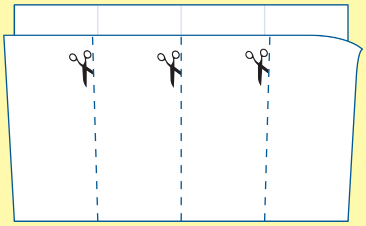
STEP 1 **Fold** a sheet of paper in half as shown. Make the back edge about 3 cm longer than the front edge. (Hint: from the tip of your index finger to your first knuckle is about 2.5 cm.)



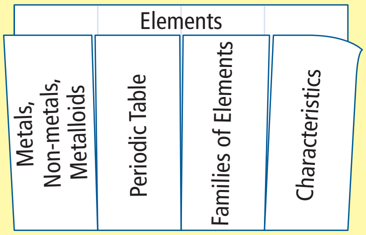
STEP 2 **Turn** the paper so the fold is to the bottom. Then, **fold** it into fourths.



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

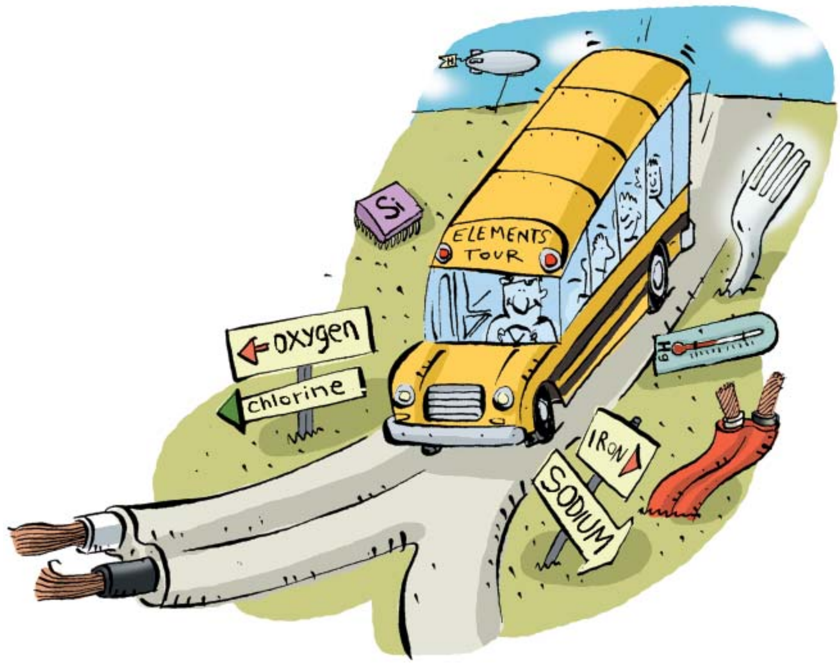
There are about 92 pure substances called elements that occur naturally. Each element is made of only one kind of atom. All other forms of matter are made from combinations of elements. Each element is represented by a one- or two-letter symbol. Common elements include hydrogen (H), iron (Fe), oxygen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

Key Terms

chemical symbol
metal
non-metal

Did You Know?

Marie Curie (1867–1934) and her husband, Pierre, discovered the elements radium and polonium. She named 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.

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, lustre, electrical conductivity, and magnetic properties. Record these properties in a table of elements similar to this one.

Name	Symbol	Colour	State	Lustre	Conducts Electricity?	Magnetic?
Gold	Au	Yellow	Solid	Metallic	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

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. Around 92 of these occur in nature, while the remainder are synthetic elements that have been observed in laboratories. 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	***H**ydros genes* = water forming
helium	He	***He**lios* = sun
neon	Ne	***Ne**on* = new
nitrogen	N	***N**itron* = saltpetre (an explosive)
oxygen	O	***O**xys genes* = acid forming
fluorine	F	***F**luere* = Latin for flowing
chlorine	Cl	***Cl**oros* from *khloros* = pale green
Liquids at room temperature		
bromine	Br	***Br**omos* = smelly
mercury	Hg	***H**ydrar**g**yrum* = Latin for liquid silver
Solids at room temperature		
lithium	Li	***Li**thos* = stone
sodium	Na	***Na**trium* = Latin for sodium
potassium	K	***K**alium* = Latin for potash
rubidium	Rb	***R**u**b**idus* = Latin for red
cesium	Cs	***C**ae**s**ius* = Latin for bluish-grey
beryllium	Be	***Be**ryllos* = emerald
magnesium	Mg	***M**a**g**nesia alba* = a place in Greece
calcium	Ca	***Ca**lx* = Latin for limestone
strontium	Sr	***S**t**r**ontian* = a village in Scotland
barium	Ba	***Ba**rys* = heavy
titanium	Ti	***Ti**tans* = gods from Greek mythology
chromium	Cr	***C**h**r**oma* = colour
manganese	Mn	***M**ag**n**esia negra* = Latin for black magnesium
iron	Fe	***Fe**rrum* = Latin for iron
cobalt	Co	***Co**bald* from *kobold* = German for goblin
nickel	Ni	*kupfer **Ni**ckel* = German for devil's copper
copper	Cu	***Cu**prum* = Latin for Cyprian
zinc	Zn	***Z**i**n**k* = German for zinc
silver	Ag	***Ag**entum* = Latin for silver
gold	Au	***Au**rum* = Latin for gold
tin	Sn	***S**ta**n**num* = Latin for tin
lead	Pb	***P**lum**b**um* = Latin for lead
carbon	C	***C**arbo* = Latin for coal
phosphorus	P	***P**hosphoros* = bringer of light
sulphur	S	***S**ulphurium* = Latin for sulphur
iodine	I	***I**odes* = 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 44

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).

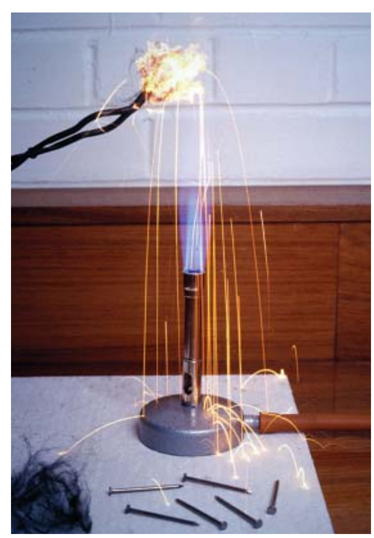


Figure 2.3 Oxygen is very reactive. Under the right conditions, it can cause steel wool to burn.

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)


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.discoveringscience.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.

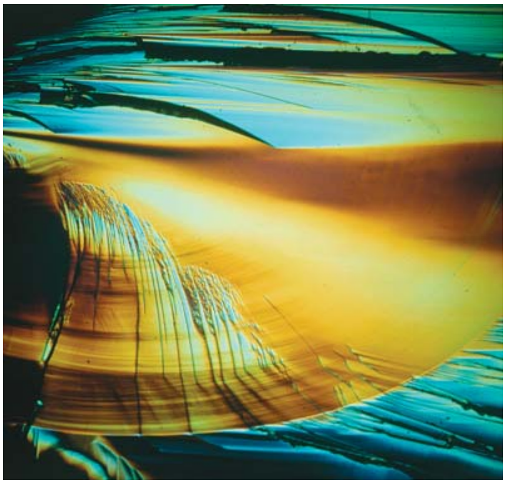


Figure 2.9 A micrograph of the surface of silicon

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 45

2-1B Generating and Burning Hydrogen Gas

SkillCheck

- Observing
- Predicting
- Measuring
- Working co-operatively

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?

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

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 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 or use a stopper 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 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 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.discoveringscience9.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

Getting Metal from Stone

Aluminum and copper are used to make many products we use in our daily lives. However, these metals and other common elements have not always been easy to obtain. Scientists have developed different processes to efficiently extract elements from the compounds and ores in which they are found in nature.

Aluminum is the most abundant metal in Earth's crust, but it hasn't always been readily available for our use. Because aluminum is a very reactive metal, it is never found as a pure element in nature. It is combined with other elements as a compound in aluminum ore. Ore is rock that contains desired chemicals that must be extracted. Bauxite, a red clay, is the most common aluminum ore. Before scientists discovered methods for extracting aluminum, people used bauxite in cooking pots. The aluminum oxide contained in the bauxite made the pots strong and rust-resistant.

Bauxite mining

In the 19th century, scientists developed a process for collecting pure aluminum from aluminum oxide. They also invented a process for extracting aluminum oxide from bauxite. Aluminum was once a very expensive metal because it was so rare. Today, because of the development of efficient extraction methods, aluminum is more affordable.

Copper products

Copper is another valuable metal that must be extracted from ore. Copper ores usually contain only small amounts of the element, often in the form of copper oxide or copper sulphide compounds. The traditional method of extracting copper from copper sulphide is called thermal decomposition. Copper sulphide is heated to produce copper and sulphur dioxide. The reaction is quick, but it uses a lot of energy. The sulphur dioxide that is produced also contributes to pollution. Scientists have developed a method for extracting copper from ore using bacteria. The bacteria survive by using the energy stored in the bond between sulphur and copper. By breaking this bond to gain energy, these bacteria separate the copper from the ore. The process, called bioleaching, is cleaner and more energy-efficient than the traditional method of extraction.

Bauxite mining and traditional methods of copper extraction cause air and water pollution and destruction of wildlife habitat. Today, copper and aluminum can be recycled to reduce these negative effects. Scientists have developed extraction methods for recovering valuable metals from old electronics, such as cell phones, DVD players, VCRs, and walkmans.

Electronic waste

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 40 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 two 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 40:
   (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?

2.2 The Periodic Table and Chemical Properties

The periodic table organizes the elements according to their properties. Elements are listed in rows by increasing order of atomic number. Rows are arranged in such a way that elements with similar properties line up in vertical columns. Rows are called periods, and columns are called families or groups. Each element in the table is recorded using its name, symbol, atomic number, and atomic mass. Two families of metals are the alkali metals and the alkaline earth metals. Two families of non-metals are the halogens and the noble gases.

Key Terms

alkali metals
alkaline earth metals
atomic mass
atomic number
chemical family
halogens
metalloid
noble gases
period
periodic table
transition metals

In the 19th century, chemists began looking for a way to organize their observations of the elements. Could elements having similar properties be grouped together? What sort of properties could be used? In 1867, a Russian chemist and teacher, Dmitri Mendeleev (Figure 2.10), wrote down the name of every known element on a separate card, like the one shown in Figure 2.11. He also wrote down properties he thought were important, such as density, colour, melting point, and boiling point. Then he sorted and re-sorted the cards into rows and columns until he found a pattern.

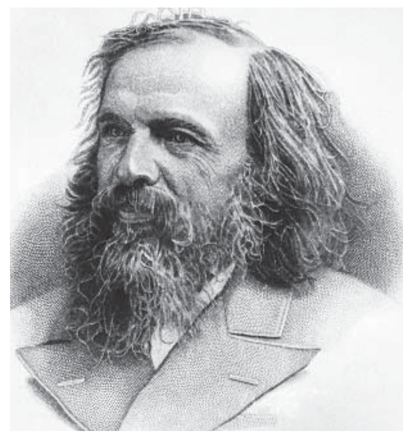


Figure 2.10 Dmitri Mendeleev was a teacher and chemist born in Russia.

Many scientists were trying to organize the elements into a table, but Mendeleev's special insight was that there needed to be holes in the table—places left for elements that had yet to be discovered. From the placement of the holes and the properties of the surrounding elements, Mendeleev was able to predict the properties of elements that were later discovered.

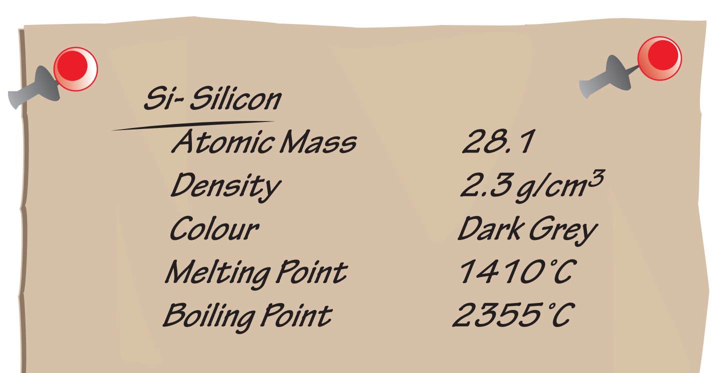


Figure 2.11 Mendeleev wrote down the known properties of each element on a card like this.

Did You Know?

Harriet Brooks (1876–1933) was a Canadian researcher who worked with Ernest Rutherford. She was one of the early scientists who found that a gas being released from the element radium was in fact a new element: radon.

The Periodic Table

We still use Mendeleev's table today, but we call it the periodic table. The **periodic table** is a chart that organizes the elements according to their physical and chemical properties. There are many versions of the periodic table, each of which includes different sets of information. Most versions include each element's name, symbol, atomic number, and atomic mass (Figure 2.12).

- The **atomic number** equals the number of protons in the nucleus of each atom of an element. It is always a whole number. The atomic number also represents the mass of the protons measured in atomic mass units (amu).
- The atomic number for any atom also equals the number of electrons surrounding the nucleus of each atom of an element. All atoms are neutral in charge, so the number of positive charges (protons) equals the number of negative charges (electrons).
- Atomic numbers increase one by one through the periodic table.
- **Atomic mass** is the average mass of the atoms of an element. It is written as a decimal number and is also measured in amu.
- Mass number is the number of protons and neutrons in an atom of an element. It can be approximated by rounding off the atomic mass. The number of neutrons in an atom can be calculated from the mass number and the atomic number:
  number of neutrons = mass number – atomic number
- Atomic mass and mass number tend to increase along with atomic number. There are some exceptions, such as between cobalt and nickel.

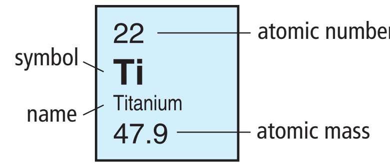


Figure 2.12 Each element has its own box in the periodic table.

Suggested Activity

Think About It 2-2B on page 54

Did You Know?

There are different forms, or *isotopes*, of an element that contain the same number of protons but have differing numbers of neutrons. Isotopes of an element have the same atomic number but different mass numbers. Mass number represents the mass of atoms of a particular isotope. Since atomic mass is an average mass from all isotopes, it can give only an average number of neutrons found in the atoms of an element.

2-2A Understanding the Periodic Table — Think About It

The composition of an atom can be represented using just two numbers, the atomic number and the mass number. In this activity, you will use the relationship between atomic number and mass number to determine the number of each type of subatomic particle in an atom.

What to Do

1. Copy the table below.
2. Use the periodic table on the next page to find the atomic number, atomic mass, element name, and/or symbol. Round off the atomic mass to estimate the mass number. Use your knowledge of the relationships between atomic number, mass number, and the number of protons, neutrons, and electrons to complete the table.

Element Name	Symbol	Atomic Number	Mass Number	# protons	# neutrons	# electrons
	K	19	39			
		18			22	
	Ra		226			
					61	47
			201	80		
hydrogen			1			

Periodic Table of the Elements

metal | metalloid | non-metal

Atomic Number → 22; Symbol → Ti; Name → Titanium; Atomic Mass → 47.9

O natural | Db synthetic

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.0																	2 He Helium 4.0
2	3 Li Lithium 6.9	4 Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
3	11 Na Sodium 23.0	12 Mg Magnesium 24.3											13 Al Aluminum 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulphur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
4	19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.8	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
5	37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
6	55 Cs Cesium 132.9	56 Ba Barium 137.3	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (272)	112 Uub* Ununbium (285)	113 Uut* Ununtrium (284)	114 Uuq* Ununquadium (289)	115 Uup* Ununpentium (288)	116 Uuh* Ununhexium (292)		118 Uuo* Ununoctium (294)

* Temporary names

58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	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)	103 Lr Lawrencium (262)

Based on mass of C-12 at 12.00.

Any value in parentheses is the mass of the most stable or best known isotope for elements that do not occur naturally.

Figure 2.13 The periodic table of the elements

Metals, Non-metals, and Metalloids

Mendeleev arranged the elements according to their properties, which created some interesting patterns. For example, the elements form three groups: metals, non-metals, and metalloids. Notice in Table 2.2 below that **metalloids** are elements that share some properties with metals and some properties with non-metals.

Table 2.2 Properties of Metals, Non-metals, and Metalloids

	State at Room Temperature	Appearance	Conductivity	Malleability and Ductility
Metals	• solid except for mercury (a liquid)	• shiny lustre	• good conductors of heat and electricity	• malleable • ductile
Non-metals	• some gases • some solids • only bromine is a liquid	• not very shiny	• poor conductors of heat and electricity	• brittle • not ductile
Metalloids	• solids	• can be shiny or dull	• may conduct electricity • poor conductors of heat	• brittle • not ductile

A shortened form of the periodic table that includes the metals, non-metals, and metalloids is shown in Figure 2.14 below.

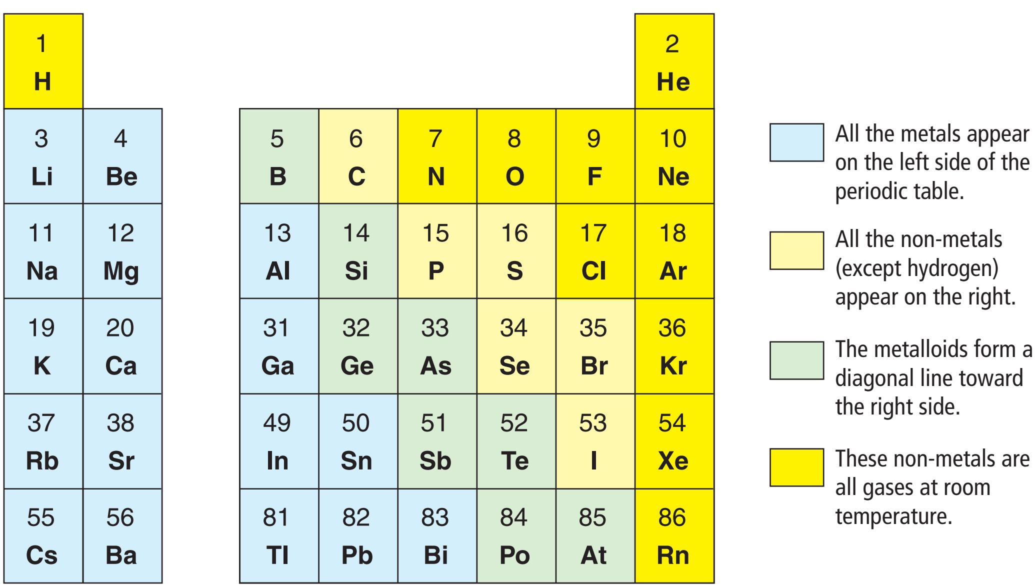


Figure 2.14 The metals, non-metals, and metalloids as they appear in the periodic table

Did You Know?

Why is hydrogen, a gaseous non-metal, grouped with the metals on the left side of the periodic table? Some periodic tables place hydrogen separate from the rest of the table, as in Figure 2.13, or on both sides of the periodic table—both on the far left and beside helium on the right. This is because hydrogen has two "personalities." It reacts like a metal in some situations, and like a non-metal in others.

Periods and Families

Each horizontal row in the periodic table is called a **period**. The periods are numbered from one to seven. For example, hydrogen and helium are in the first period. Lithium is the first of eight elements in the second period.

Chemical families or groups are arranged in vertical columns in the periodic table. Elements in the same **chemical family** have similar physical and chemical properties. The families are in numbered columns 1 to 18 of the table. Four well-known groups are the alkali metals, the alkaline earth metals, the halogens, and the noble gases (Figure 2.15).

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 +Ac	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub						

halogens

noble gases

alkali metals

alkaline earth metals

transition metals

Figure 2.15 Elements can be classified according to their characteristics.

Alkali metals (Column 1 excluding hydrogen) Li, Na, K, Rb, Cs, Fr

All the **alkali metals** are highly reactive (Figure 2.16), and reactivity increases as you go down the group. Alkali metals react with both oxygen and water and combine readily with non-metallic elements. They have low melting points, all of which are below 200°C. The alkali metals are soft and can be cut with a knife. Cesium is softer and more reactive than lithium.

Figure 2.16 Alkali metals are soft and highly reactive.

Figure 2.17 Calcium (A) and magnesium (B) are alkaline earth metals.

Alkaline earth metals (Column 2) Be, Mg, Ca, Sr, Ba, Ra

Alkaline earth metals (Figure 2.17) are less reactive than the alkali metals but will burn in air if heated. They produce bright flames and are used in fireworks. For example, the classic red colour of fireworks is caused by strontium. Alkaline earth metals will also react with water but not as vigorously as alkali metals do. Calcium reacts more quickly than magnesium.

Halogens (Column 17) F, Cl, Br, I, At

The **halogens** are non-metals and are highly reactive (Figure 2.18). Only fluorine and chlorine are gases at room temperature. Bromine is a liquid and iodine is a solid. Fluorine is the most reactive, and iodine is the least. Astatine is incredibly rare. No one has ever collected enough to determine its physical properties.

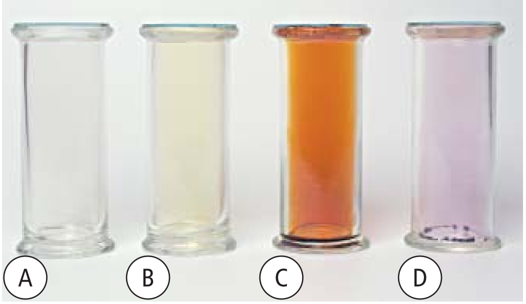


Figure 2.18 The halogens: fluorine (A), chlorine (B), bromine (C), iodine (D)

Noble gases (Column 18) He, Ne, Ar, Kr, Xe, Rn

The **noble gases** are the most stable and unreactive elements in the periodic table. At room temperature, they are colourless, odourless gases. Some of the gases, such as argon and neon, are used in light fixtures (Figure 2.19). Some, such as neon, glow in distinctive colours. You may know that helium is lighter than air, and that is why helium balloons quickly float out of reach when released.

Figure 2.19 The noble gases are stable and unreactive. Argon is used inside the tubes of this energy-efficient fluorescent light bulb.

Transition Metals

Transition metals are a set of metallic elements that are found at the centre of the periodic table. Like other metals, they are malleable, ductile, and good conductors of heat and electricity. They are grouped together because the arrangement of their electrons is very complex and it differs from that of other metals. This means they have a wide range of chemical and physical properties. Three of the transition metals—iron, cobalt, and nickel—are the only known elements that are magnetic. Transition metals cannot be called a "chemical family" because they are spread out over ten columns of the periodic table (columns 3-12). However, some similarities do exist within each column. For example, copper, silver, and gold are all very resistant to corrosion.

Reading Check

1. List two pieces of information besides an element's name and symbol that are recorded on a typical periodic table.
2. State how many protons are present in each of the following atoms: (a) silicon, (b) chromium, and (c) iodine.
3. List the following elements by atomic mass from lightest to heaviest: zinc, calcium, cobalt, nickel, carbon. Write the atomic mass beside each one.
4. Explain why hydrogen's position on the periodic table is unusual.
5. Where on the periodic table do you find the (a) metals, (b) non-metals, and (c) metalloids?

Explore More

Discovered in 1944, the element americium is used in a common household device that saves many lives every year. Find out more about this device and americium. Begin your research at **www.discoveringscience9.ca**.

2-2B The Modern Periodic Table

In this activity, you will use a simplified periodic table to discover the patterns of properties of elements.

The table below shows the general shape of a simplified periodic table. Elements are represented with symbols and are arranged in order of their atomic number. Also shown are gases, liquids, and solids at room temperature. Note that the colours of the blocks in the table indicate which elements are metals, non-metals, and metalloids.

gas = red
liquids = blue
solids = black

metals
metalloids
non-metals

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

At first glance, it seems that the periodic table takes up unnecessary space. Would it not make more sense just to arrange the elements by increasing atomic number in a simple square grid?

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

Listing elements in a grid

While a square grid may take up less space, chemists would not find such an arrangement very useful. The modern periodic table reflects an arrangement that puts similar elements close together. To understand why the periodic table is constructed the way it is and how to properly read it, you must know how chemists group elements according to their characteristics.

Groups in the periodic table

Chemists have identified families of elements that share similar properties. These families are grouped together in the periodic table in vertical columns. By creating such groups, chemists are better able to predict what properties elements will have. The groups and organization of the periodic table allowed them to correctly predict the characteristics of elements before they were even discovered.

The atomic number of an element helps determine its position in the periodic table. The numbering starts with the lowest atomic number 1 (hydrogen, H) and moves from left to right. The gaps in the table are skipped over, so the next element, with atomic number 2 (helium, He), goes in the top right corner. The next element, atomic number 3 (lithium, Li), starts at the left again underneath hydrogen.

What to Do

1. Make a copy of the simplified periodic table. Add the atomic numbers for hydrogen, helium, and lithium to your periodic table.
2. Using the previously described pattern, fill in the atomic numbers for the elements from carbon (C) to neon (Ne). It is not necessary to fill in numbers for the whole table.
3. 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)
4. There are 18 groups in the periodic table. Locate the elements in column 2 in your simplified periodic table. Record the symbols for these elements in a vertical list.
   (a) Which element in the list has the largest atomic number?
   (b) Which element would you expect to have the greatest atomic mass? Why?
5. List the symbols (and names wherever possible) of the other elements that are found in the same group as the elements below.
   (a) aluminum (Al)
   (b) potassium (K)
   (c) lead (Pb)
6. Locate the elements copper (Cu), silver (Ag), and gold (Au) on your simplified periodic table.
   (a) Are they in the same column?
   (b) Is this what you expected? Explain.
   (c) How do these elements differ from elements in column 1 or 2?
7. Review and compare the periodic table and grid methods of listing the elements. Explain why the periodic table is more useful to chemists than the grid.

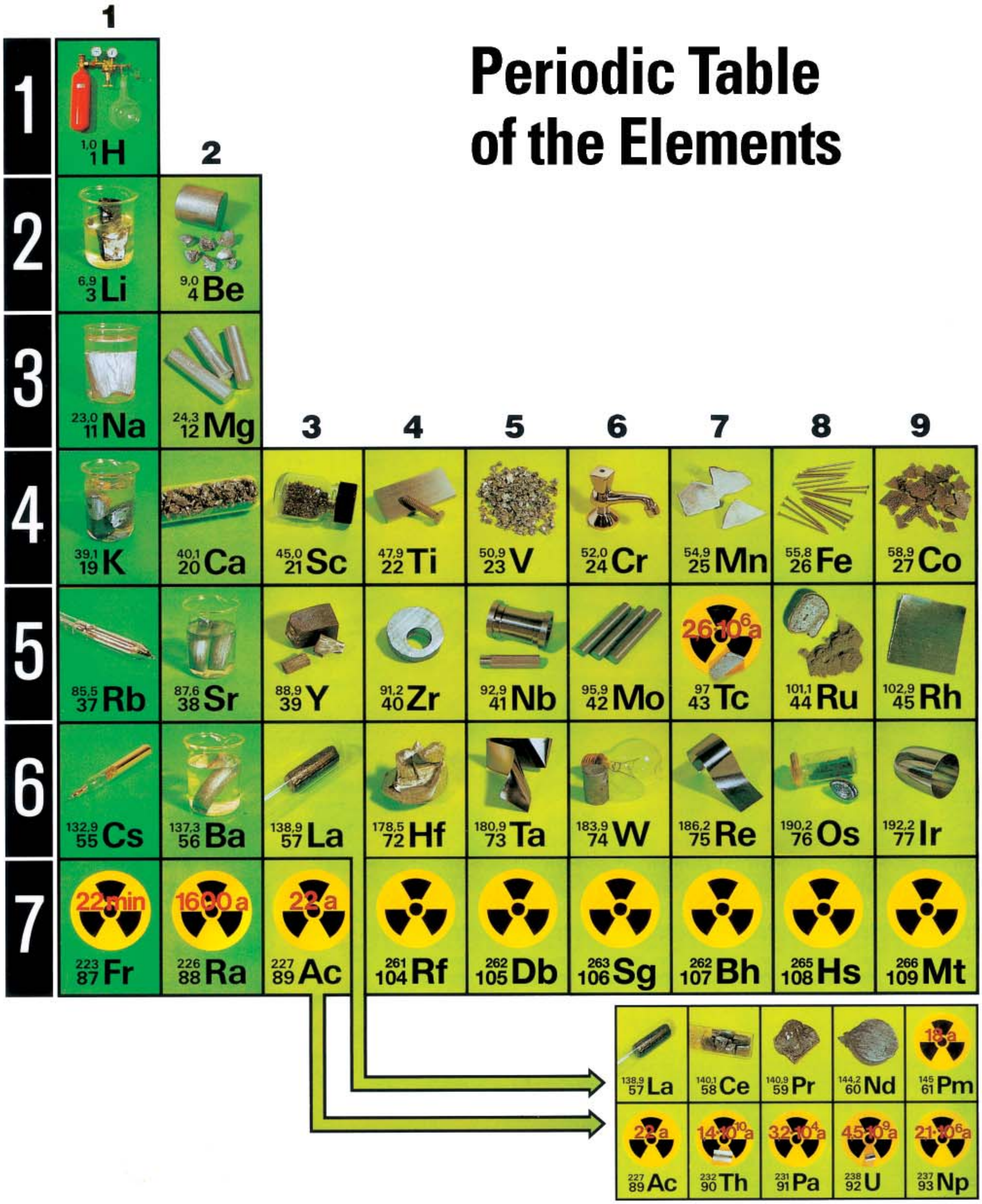
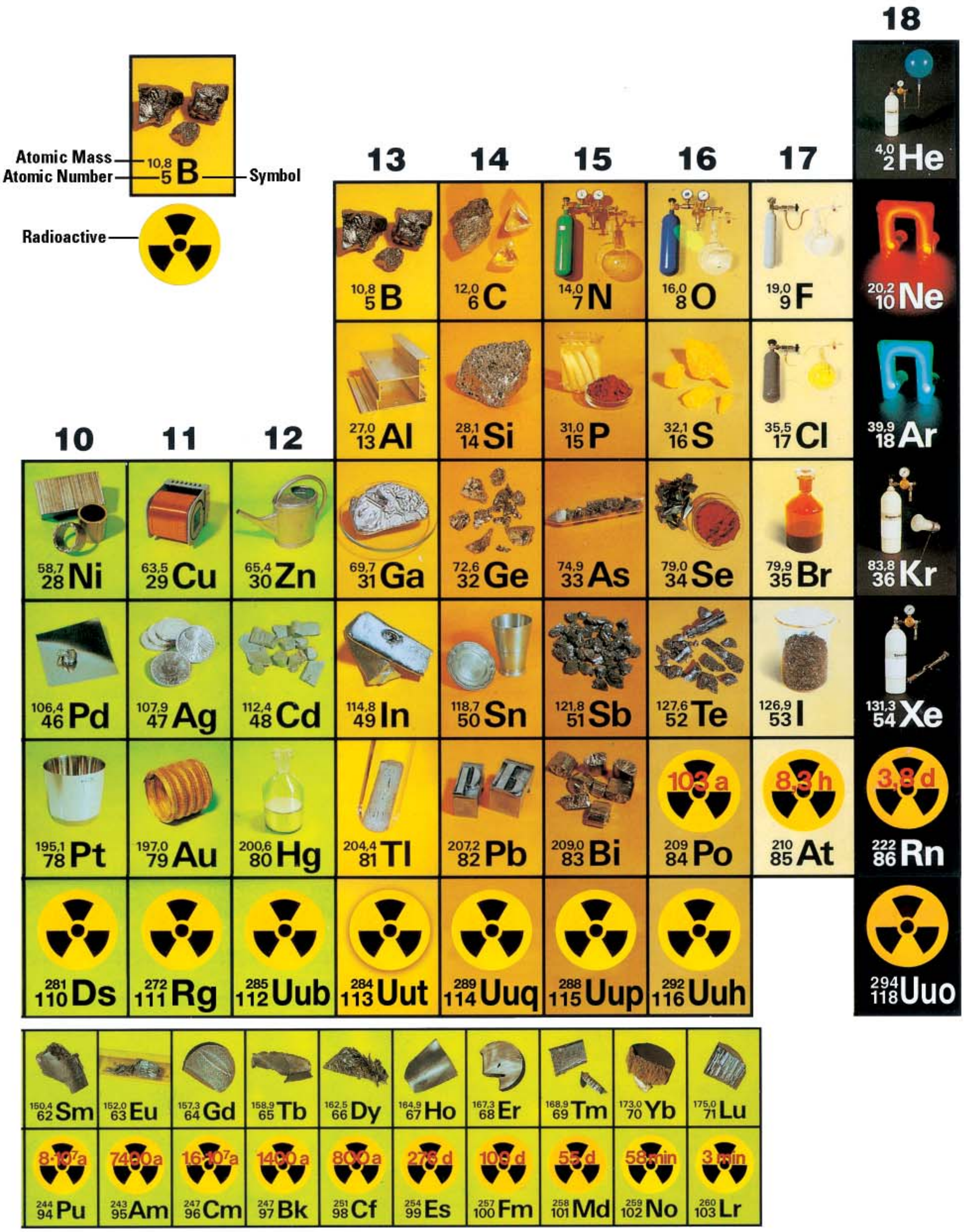


Figure 2.20 The periodic table shown here illustrates samples of the elements and common uses.



Atomic Mass
Atomic Number
Symbol
Radioactive
10,8 5 B
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
103 a
209 84 Po
8,3 h
210 85 At
3,8 d
222 86 Rn
281 110 Ds
272 111 Rg
285 112 Uub
284 113 Uut
289 114 Uuq
288 115 Uup
292 116 Uuh
294 118 Uuo
150,4 62 Sm
152,0 63 Eu
157,3 64 Gd
158,9 65 Tb
162,5 66 Dy
164,9 67 Ho
167,3 68 Er
168,9 69 Tm
173,0 70 Yb
175,0 71 Lu
$8 \cdot 10^7$a
7400a
$16 \cdot 10^7$a
1400 a
800a
276 d
100 d
55 d
58 min
3 min
244 94 Pu
243 95 Am
247 96 Cm
247 97 Bk
251 98 Cf
254 99 Es
257 100 Fm
258 101 Md
259 102 No
260 103 Lr

Wild, Weird, Wonderful

www Science

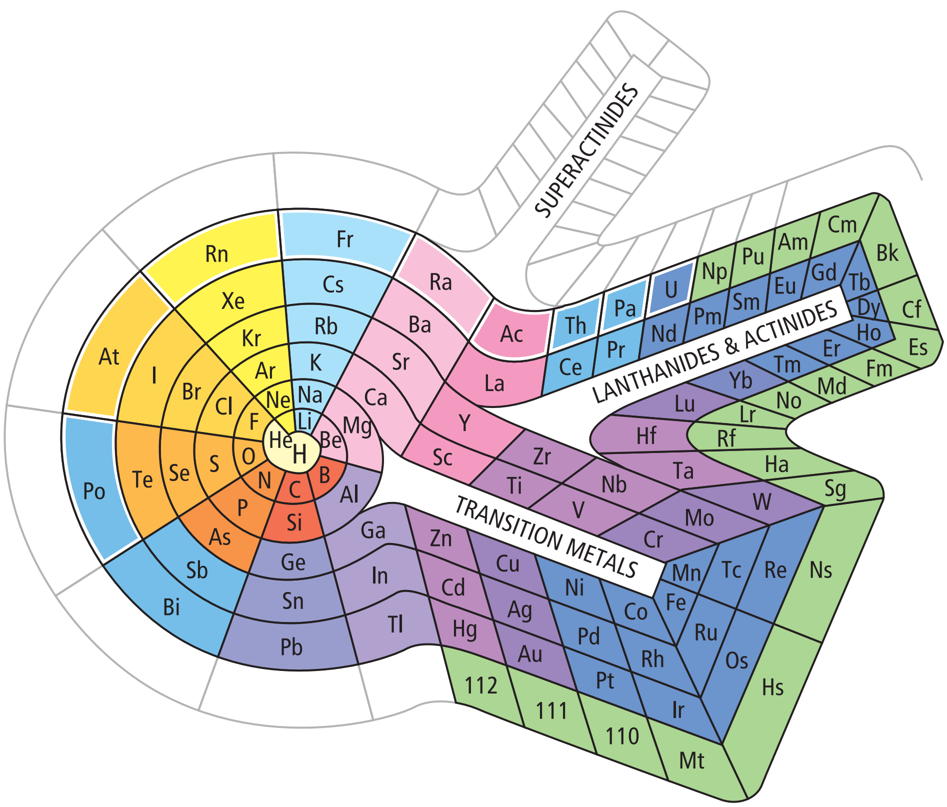
Peculiar Periodic Tables

You might not recognize the chart on this page as a periodic table, but it is. Look closely and you will see the symbols for all the elements. The colours identify the chemical families.

The periodic table that you have been using is the most common version, but it is not the only one. If you search the Internet for alternative periodic tables, you will find diamond-shaped tables, triangle-shaped ones, other spirals, and even 3-D tables. Designers of new periodic tables are looking for ways to improve the table to make it easier to see all the relationships among the elements.

The designer of this table wanted to emphasize the periods, so it has two periods of 8 elements, then two of 18 elements, then two of 32, and so on. The "arms" that stick out from the spiral are the lanthanides and actinides. These are the elements that you will find in those two rows down below the standard period table. In this spiral, they are connected with all the other elements.

Like Mendeleev's original periodic table, this table has an "empty" place for new elements. The design predicts that new elements will fit into the arm labelled "superactinides" that branches off between radium (Ra) and actinium (Ac). Not all scientists agree. Some think that new elements will be found between thorium (Th) and protactinium (Pa). Watch for discoveries of new elements to see who is right.



Dr. Theodor Benfey's spiral periodic table

Check Your Understanding

Checking Concepts

1. What is the periodic table?
2. What information does the atomic number of an element reveal about the structure of the atoms of that element?
3. In the periodic table used today, are the elements listed in order of atomic number or atomic mass?
4. Use the periodic table on page 50 to find the atomic number for each of the following elements.
   (a) helium
   (b) oxygen
   (c) iron
   (d) gold
   (e) uranium
   (f) mendelevium
5. Which has more protons, an atom of sodium or an atom of potassium?
6. What does atomic mass measure?
7. The unit for atomic mass is the amu. What does each letter stand for?
8. What is the pattern in which atomic mass changes through the periodic table?
9. In the periodic table on page 50, find the atomic mass for each of the following elements:
   (a) lithium
   (b) silicon
   (c) iron
   (d) copper
   (e) mercury
10. Which has more mass, an atom of gold or an atom of lead?
11. An element has 15 protons and a mass number of 31. What element is being represented? How many electrons and neutrons does this atom of the element have?
12. An atom of an element with atomic number 37 has 48 neutrons. What is the mass number of this atom? How many electrons are surrounding the nucleus?
13. What is the difference between atomic number and atomic mass?
14. Why might hydrogen be considered a unique element?
15. How are transition metals similar to other metals?
16. Why are alkali metals rarely found in pure form?
17. The elements in the periodic table may be classified as one of three types. What are the names of these types?
18. (a) List the names of four families in the periodic table.
    (b) Which are families of metals?
    (c) Which are families of non-metals?
19. From the periodic table on page 50, list five elements that are metalloids.
20. What are the horizontal rows in the periodic table called?
21. What are the vertical columns in the periodic table called?

Understanding Key Ideas

22. Which family of metals contains elements that are soft enough to cut with a knife?
23. Which family of metals is used in fireworks?
24. Which chemical family contains elements that at room temperature are solids, liquids, and gases?
25. List two properties of the elements in the noble gas family.
26. Explain the difference between mass number and atomic mass.

Pause and Reflect

In this section, you have learned how to make predictions about particular elements based on each element's position in the periodic table. This means it is possible to predict the properties of elements that have not yet been observed. For example, francium is so rare that there have never been enough atoms in one place for anyone to actually observe it. Still, you can predict several of its properties. What do you think would be some properties of francium, element number 87?

2.3 The Periodic Table and Atomic Theory

In a Bohr-Rutherford diagram, electrons are arranged in shells in a specific pattern around the nucleus. The electrons in the outermost electron shell are called valence electrons. The number of valence electrons in an atom determines many of its chemical and physical properties. The atoms of all alkali metals have one valance electron; an atom of each alkaline earth metal has two valence electrons; and an atom of each halogen has seven valence electrons. Noble gas atoms have filled valence shells, which makes them chemically stable. All noble gas elements have eight valence electrons except helium, which is stable with two valence electrons.

Key Terms

Bohr-Rutherford diagram
electron shells
energy levels

The periodic table is full of patterns. For example, non-metals appear on the right. This is no accident. Patterns occur as a result of regular changes in the structure of the atoms of these elements. Elements with similar properties line up in columns because all those elements are similar in the arrangement of their electrons.

One way to show the arrangement of electrons in an atom is with a Bohr-Rutherford diagram. A **Bohr-Rutherford diagram** shows how many electrons are in each electron shell surrounding the nucleus (Figure 2.21). This type of diagram is named after Niels Bohr (Figure 2.22) and Ernest Rutherford, whose models of the atom you studied in section 1.3. The regions surrounding the nucleus of an atom are sometimes called **energy levels** or **electron shells**. The shell nearest the nucleus can hold 0, 1, or 2 electrons. The next two shells outward can each hold up to 8 electrons. Any remaining electrons will fill the fourth shell, to a maximum of 18. This pattern of 2, 8, 8, and 18 applies to all atoms, although not all atoms have that many electrons.

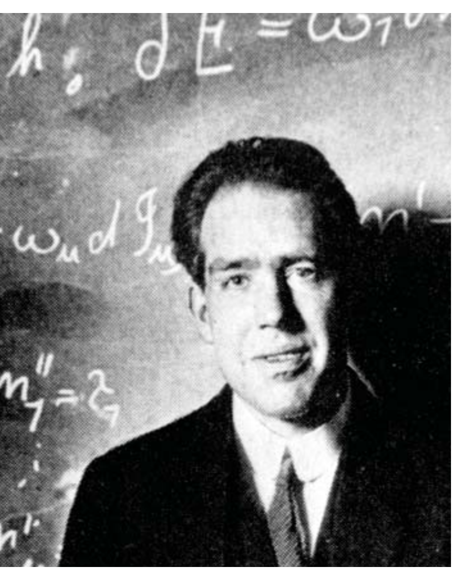


Figure 2.22 Niels Bohr

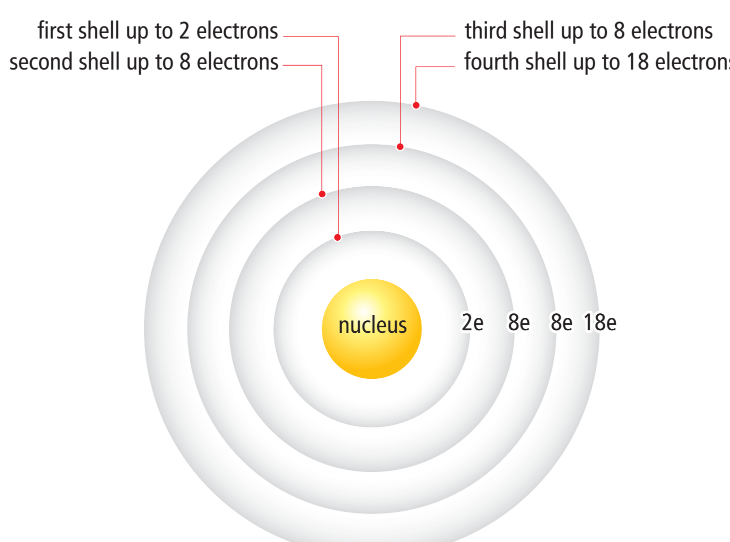
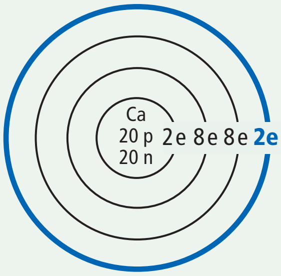


Figure 2.21 A Bohr-Rutherford diagram showing electron shells

2-3A Looking for Patterns in Atoms

Think About It

The number of electrons in an atom is always equal to the number of protons. The protons are in the nucleus, while the electrons surround the nucleus in energy levels or shells. In this activity, you will compare the electron arrangements in various atoms.



The arrangement of electrons in a calcium atom

Material

- coloured pencils or felt pens

What to Do

1. Your teacher will assign you several atoms to sketch using Bohr-Rutherford diagrams. Use a periodic table to look up the atomic number and symbol of each atom. Record this number in the centre of the paper to represent the protons in the atom, as shown in the diagram.
2. Calculate the number of neutrons in the atom by subtracting the atomic number from the mass number. Record this number in the centre of the paper to represent the neutrons in the atom, as shown in the diagram.
3. Starting with the shell nearest the nucleus, fill all of the shells with the appropriate number of electrons. Remember that the maximum number of electrons in the first shell is two, in the second and third shells is eight, and in the fourth shell is eighteen.
4. Highlight the number of electrons in the outermost energy level.
5. Compare your atoms with those of others in the class. Look for similarities between atoms of the same family.
6. Arrange all the sketches on the wall just as they appear in the periodic table.

What Did You Find Out?

1. What is the pattern in the arrangement of electrons as you move down a family?
2. What is the pattern in the arrangement of electrons as you move across a period from left to right?

Bohr-Rutherford Model Diagrams

A Bohr-Rutherford diagram usually contains the element symbol, the number of protons in the atom, the number of neutrons in the atom, and a way to show where the electrons are. Figure 2.23 shows how you could draw a Bohr-Rutherford diagram for the element potassium (atomic number 19).

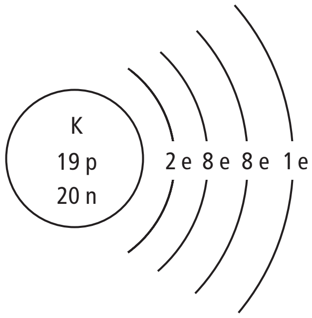


Figure 2.23 This diagram represents an atom of potassium using a Bohr-Rutherford diagram.

Did You Know?

Alchemists could not turn lead into gold, but in 1980, Nobel Prize winning physicist Glen Seaborg did just that. He used nuclear reactions to make microscopic amounts, and the cost was much greater than mining for gold. His remarkable achievement added to our understanding of how atoms work.

Valence Electrons and Chemical Families

Figure 2.24 below shows how the electrons are arranged in each atom of the first 18 elements. Notice that the first electron shell is filled (2 electrons) before the second electron shell is filled. Likewise, the second electron shell is filled (8 electrons) before the third shell. The third shell is filled (8 electrons) before the fourth shell, which can hold up to 18 electrons.

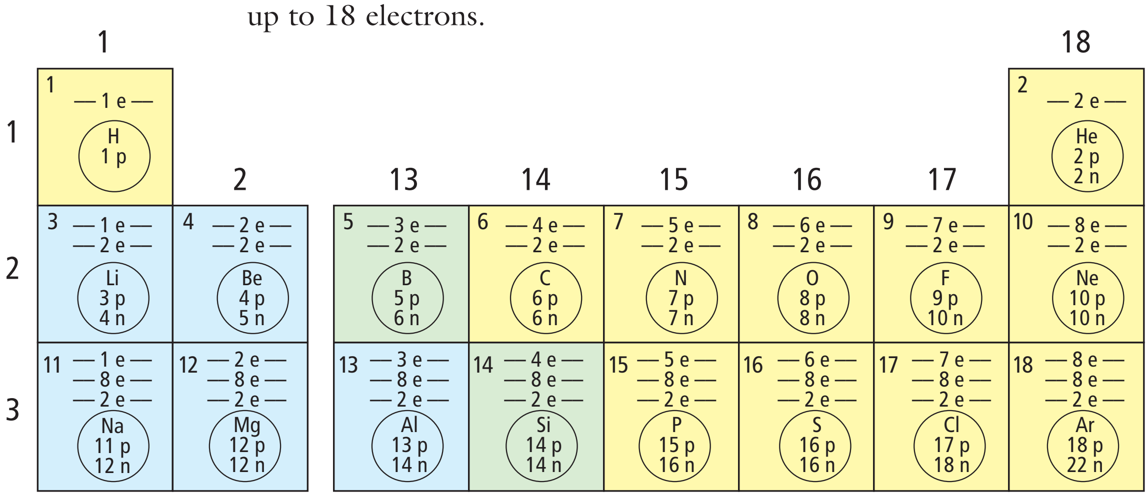


Figure 2.24 Electron arrangements in the first 18 elements

Did You Know?

Look closely at hydrogen, atomic number 1. It has one electron in its outer shell—the same electron configuration as all of the metals in column 1. But hydrogen also has the same electron configuration as the elements in column 7. All of the halogens are one electron away from having a full electron shell. Since the first electron shell can hold only two electrons, hydrogen is also one electron away from having a full electron shell. This is the reason for hydrogen's special position in the periodic table.

The electrons in the outermost shell (those farthest from the nucleus) have the strongest influence on the properties of an atom. These electrons in the outermost shell are called valence electrons. The shell that contains the outermost electrons is called the valence shell.

You will notice several striking patterns in Figure 2.24.

- Most elements in the same family have the same number of valence electrons. For example, halogens have seven valence electrons. Noble gases have full valence shells. With the exception of helium, noble gases have eight valence electrons.
- The period number indicates the number of shells that have electrons.
- Elements in the same period have valence electrons in the same shell.

Noble Gas Stability

The noble gases (He, Ne, Ar, Kr, Xe, Rn) are normally unreactive, which means the atoms do not form new substances with other atoms. Why? Because their atoms have filled valence shells—the maximum number of electrons in their outermost shells. That makes them stable. For two atoms to join together to make a new substance, atoms must gain, lose, or share electrons. But atoms with filled valence shells will not easily trade or share electrons. They have what we call noble gas stability.

Atoms from other families often try to achieve a kind of stability similar to the noble gases. To do this, they will gain or lose electrons. For example, metals, which usually have one, two, or three valence electrons, will often lose them all. When metals lose their valance electrons, their remaining electrons will have the same arrangement as the noble gas in their row in the periodic table.

What about non-metals? They gain one, two, or three extra electrons in order to achieve noble gas stability. They will gain or share exactly enough electrons to achieve the same electron arrangement as the noble gas in their row in the periodic table.

How Elements React

You have already learned that elements in the same group share both chemical and physical properties. Their shared properties are due to their electron configuration, specifically the number of electrons in the outermost shell.

The alkali metals, which have one electron in their outermost energy level, and the halogens, which have seven electrons in their outermost energy level, are highly reactive. The alkaline earth metals, with two electrons in their outermost shell, are slightly less reactive. The noble gases, with eight electrons in their outermost energy level, are not normally reactive at all.

The most reactive of the groups are the ones that are one electron away from having a complete outer electron shell. Similarly, the least reactive group has a full outer electron shell. This is because an element reacts to fill its outer electron shell. Noble gases do not normally react, as their outer shell is already full. An element that has seven electrons in its outer shell will react readily with an element that has one electron in its outer shell so that both atoms have full outer electron shells. A full valence shell gives an atom stability.

Suggested Activity

Conduct an Investigation 2-3B on page 64

Reading Check

1. How many electrons can there be in each of the first three shells surrounding an atom?
2. Draw a simple Bohr-Rutherford diagram for the following elements: (a) hydrogen, (b) lithium, (c) sodium, and (d) chlorine.
3. List the number of electrons in the outermost shell in atoms from each family: (a) alkali metals, (b) alkaline earth metals, (c) halogens, and (d) noble gases.
4. How does electron configuration relate to reactivity?

Explore More

Atomic radius is an estimate of the distance from the atom's nucleus to its "edge." The larger the radius, the larger the atom. But having more electrons does not always mean a larger atom. As usual with the periodic table, there is a pattern. Find out more about this and other periodic trends of the elements at **www.discoveringscience9.ca**.

2-3B Flaming Metal Ions

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Predicting
- Measuring
- Working co-operatively

Safety

- Handle chemicals safely.
- Be careful around open flames.
- Tie back long hair.
- Wash your hands thoroughly after doing this investigation.

Materials

- felt pen
- 9 small test tubes
- test tube rack
- wooden splints that have been soaked in a selection of solutions containing metal ions
- Bunsen burner
- diffraction-grating glasses

In this activity, you will heat several compounds in the flame of a Bunsen burner until the flame takes on a colour characteristic of the metal ion in the compound. The colours are related to the arrangement of electrons in each ion.

Question

How can you use a flame test to identify metal ions?

Procedure

1. Label the top of each test tube with the symbol of the metal ion that is in solution: Na, Ca, K, Li, Ba, Sr, Cu, Unknown 1, and Unknown 2.
2. Your teacher will set out a supply of wooden splints that have been soaked in solutions of metal ions. Take one splint per group for each metal ion, and place it in the appropriate test tube.
3. Light a Bunsen burner. Set it so that it has a blue flame. Have one person put on diffraction-grating glasses.
4. Place the wooden splints in the flame, one at a time, and note the colour of the metal ion.
5. Test the two unknown solutions. Both are metal ions from the seven you have tested. Try to identify them.
6. Clean up and put away your equipment.

Analyze

1. How did you identify the ions in your unknown solutions?
2. Which metal ions were difficult to distinguish?
3. Suggest how the diffraction-grating glasses can help in identifying metal ions using the flame test.

Conclude and Apply

1. Describe how the flame test enabled you to identify the unknown metal ions.

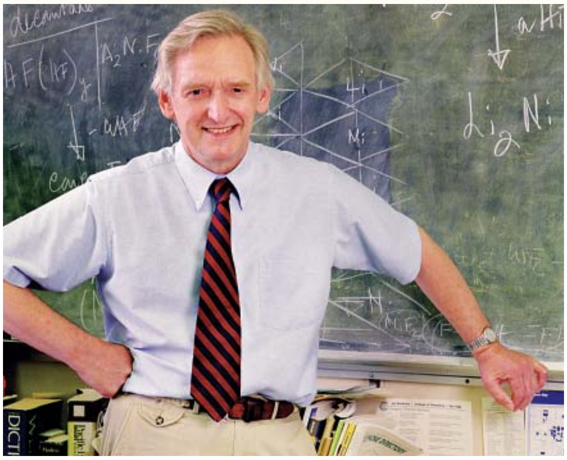
Science Watch

Compounds of the Noble Gases

Until 1962, chemists thought the noble gas elements were unreactive and unable to form a connection with any other kind of atom. This means they could not combine with other elements to form compounds. Then Neil Bartlett, a young British-born professor at the University of British Columbia, mixed a platinum–fluorine compound with the noble gas xenon. As Bartlett had imagined, the two materials reacted. They formed a new substance containing xenon.

Before long, news of Bartlett's discovery was heard around the world. Other scientists repeated his experiment and were also able to demonstrate that xenon could react chemically. Since xenon's new-found reactivity had broken the family mould, you might think that xenon would no longer be a part of the noble gas chemical family. However, xenon's place in the family was actually strengthened a short time later by the discovery of compounds involving other noble gases, including radon and argon. The noble gases were still a family. Science had simply found out something new about them.

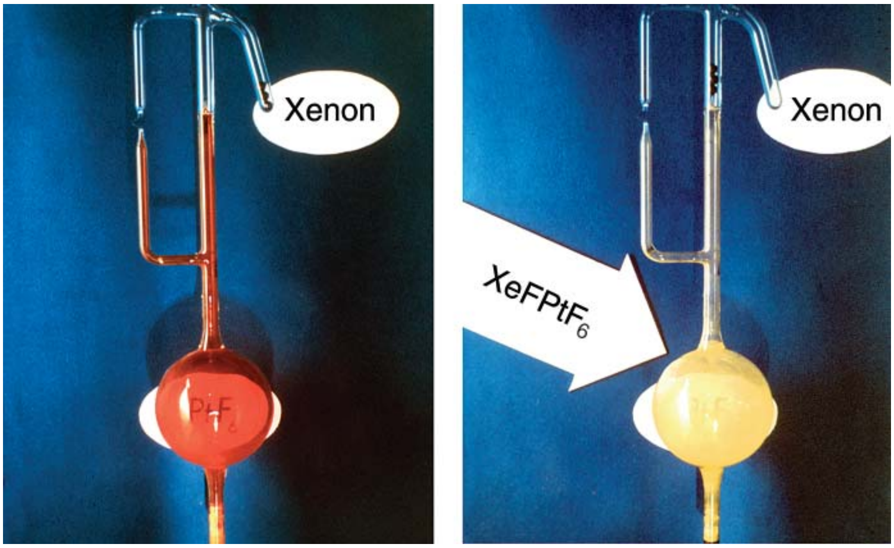
Compounds made from noble gases have proven extremely useful. They have been used in lasers and in the production of anti-tumour agents to fight cancer.



Neil Bartlett discovered that some noble gases could react chemically. After that, every chemistry book in the world had to be rewritten.

Questions

1. Before 1962, what property of noble gases led scientists to think that these elements could not form compounds?
2. What noble gas did Neil Bartlett use to form the first noble gas compound? What two other noble gases were later found to be able to form compounds?
3. Describe one way in which noble gas compounds have been used.



The yellow substance is the first noble gas compound discovered.

Wild, Weird, Wonderful

www Science

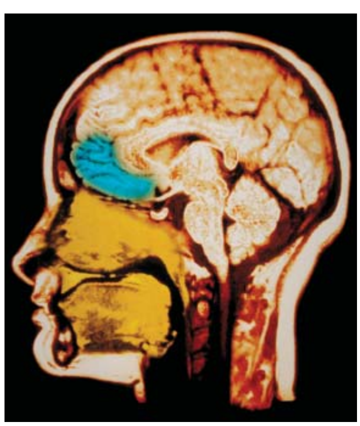
Helium—More Than Just Balloons

Helium has more uses than just inflating balloons.

Helium is a noble gas used in arc welding to prevent the metal reacting with the air.

Have you ever watched a helium balloon drift high into the sky and wondered what it would be like to soar along with it? Helium is an element that is lighter than air, which gives large balloons the ability to fly high and even to take passengers with them. The photograph shows a balloonist at a height of 2000 m being held aloft by 30 balloons. How did he get down? By breaking some of the balloons to release the helium. The helium eventually drifted into the upper atmosphere and floated off into space.

Only about 10 percent of the helium in the world is used to fill balloons. Its other uses are very down to Earth. About 20 percent is used as liquid helium to supercool magnets in magnetic resonance imaging (MRI) machines. MRI machines make images of the insides of our bodies like the one shown here. Another 20 percent of the world's helium is used in arc welding. Helium and other unreactive gases are released during the welding. This keeps the melting metal from reacting with the air.



An MRI image of a human head.

Helium is used in many other applications, including in deep sea breathing systems to reduce the risk of decompression sickness, and in nuclear reactor coolant systems, refrigeration systems, and lasers.

Where does all the helium come from? Helium is produced deep inside Earth by the radioactive decay of elements such as uranium and thorium. It is usually held inside rocks but can also become trapped with natural gas. There it builds up over millions of years. When the natural gas is extracted from wells, up to 8 percent of the gas can be helium. In the early days of natural gas drilling, the helium was just released into the air without being used.

Our consumption of helium is now so great that some scientists fear that Earth's helium resources could be used up in the next century. After that, the nearest sources may be the Moon or one of our neighbouring planets, such as Neptune.

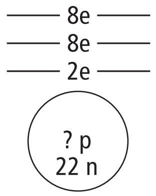
Check Your Understanding

Checking Concepts

1. On the periodic table on page 50, locate the metalloid with the lowest atomic number. What is its name and symbol?
2. Draw a Bohr-Rutherford diagram for atoms of each of the following elements:
   (a) carbon
   (b) fluorine
   (c) magnesium
   (d) sulphur
3. (a) What is an electron shell?
   (b) How many electrons can each of the three shells nearest the nucleus hold?
4. How many electrons are in each electron shell in an atom of argon?
5. Give an example of an element with
   (a) one electron in its outer shell.
   (b) five electrons in its outer shell.
   (c) seven electrons in its outer shell.
6. Is the electron arrangement in a sodium ion similar to neon or to argon?
7. What element has a full outer energy level that does not contain eight electrons?
8. What is similar about the electron arrangements of all the alkaline earth metals?
9. Describe the pattern in the way the electron arrangement changes going left to right across the third period.

Understanding Key Ideas

10. Why are the chemical and physical properties of sodium similar to those of lithium, but not those of calcium?
11. What feature of the electron arrangements in noble gases causes them to be chemically unreactive?
12. (a) How can a metal atom achieve noble gas stability?
    (b) How can a non-metal atom achieve noble gas stability?
13. Draw a Bohr-Rutherford diagram for each of the following atoms:
    (a) Ne
    (b) O
    (c) K
    (d) Be
    (e) Si
    (f) Al
    (g) P
    (h) Cl
14. Use the Bohr-Rutherford diagram below to answer the following questions. This diagram shows the number of electrons and neutrons, but not the number of protons.
    (a) What element does the diagram represent?
    (b) What is the atomic mass of this atom?
    (c) Is this element a metal or a non-metal? Explain.



Pause and Reflect

The hydrogen atom is considered unique because of its electron configuration. What is unique about it, and how does that affect the physical and chemical properties of hydrogen?

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated the periodic table as a means of organizing the elements according to their physical and chemical properties. Create your own summary of the key ideas of this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 8 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Characteristics of Some Common Elements
2. Information Given in the Periodic Table
3. Chemical Families
4. Bohr-Rutherford Diagrams
5. How Outer Electrons Relate to Chemical Families

Checking Concepts

1. What is an element?
2. List three common objects that contain one or more elements.
3. Write the names of the elements corresponding to the following symbols:
   (a) Ni
   (b) Na
   (c) K
   (d) Cu
4. Provide the chemical symbol for each of the following elements:
   (a) zinc
   (b) tungsten
   (c) iron
   (d) magnesium
   (e) calcium
5. Name two elements that are liquids at room temperature.
6. List four properties typical of metals.
7. Iron is a very strong metal.
   (a) What element(s) can be added to it to make it even stronger?
   (b) What is this new metal called?
8. List two ways in which mercury is different from silver.
9. What is the name of the chart that organizes the elements according to their physical and chemical properties?
10. What does the atomic mass of an element measure?
11. What is the relationship between the number of protons in an atom and its atomic number?
12. What is the relationship between atomic number, mass number, and number of neutrons?
13. What is a chemical family?
14. Name the chemical families in columns 1, 2, 17, and 18.
15. Compare the alkaline earth metals to the alkali metals according to their reactivity with water.
16. What is the most important chemical property of the noble gases?
17. What does a Bohr-Rutherford diagram represent?
18. Define each of these terms:
    (a) periodic table
    (b) energy level
19. List the number of electrons in the outermost electron shell in atoms of each of the following elements:
    (a) sodium
    (b) aluminum
    (c) oxygen
    (d) argon
20. (a) Which chemical family is composed of elements with filled outer electron shells?
    (b) How does having filled outer electron shells affect the reactivity of these elements?

Understanding Key Ideas

21. How is a physical property different from a chemical property?

22. Describe the pattern of the atomic numbers in the periodic table.

23. What is the atomic number of each of these elements?
(a) antimony
(b) arsenic
(c) manganese
(d) selenium

24. Use the periodic table to find the atomic mass of hydrogen, oxygen, nitrogen, and rhenium.
(a) Which of these elements has the heaviest atoms?
(b) Which has the lightest?

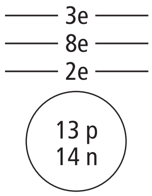
25. Locate the following elements in the periodic table: nickel, niobium, iridium, and germanium.
(a) Which are transition metals?
(b) Which has the greatest number of energy levels?
(c) Which is a metalloid?
(d) Which two are in period 4?
(e) Which is in column 10?

26. Locate the following elements in the periodic table: iron, americium, ruthenium, uranium.
(a) Which has the heaviest atoms?
(b) Which two are in column 8?

27. Explain why H is listed in the same column as the metals Li, Na, and K, even though H is a non-metal.

28. Draw Bohr-Rutherford diagrams for Be, Mg, and Ca.

29. Identify the following atoms:

(a)


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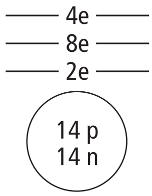

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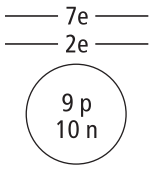

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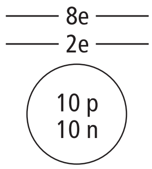

Pause and Reflect

In this chapter, you have investigated how elements are the building blocks of matter. The elements are organized into the periodic table. Why is the periodic table an important tool for anyone studying chemistry?