# TOPIC 4 Classifying Elements

**Figure 2.21** Marie Curie and her husband, Pierre, discovered the element radium. Marie invented the term "radioactivity." She was the first scientist to be awarded two Nobel prizes. The element curium, discovered in 1944, was named in her honour.

New elements are still being discovered. How are elements named and sorted? Do some elements have similar properties?

## Element Symbols

The explosion of chemical knowledge during the nineteenth century could have led to confusion. The names of the elements came from many different sources. The first chemist to report a new element had the right to name it. For example, the chemist Marie Curie discovered the element polonium and named it after the country of her birth, Poland. Uranium was named after the planet Uranus. Einsteinium was named after the physicist Albert Einstein. Since it would be very difficult and time consuming to write names like these over and over again, a system of **element symbols** was developed. The system provided symbols for all the known elements. It also showed how to create symbols for any new elements that might be discovered. For example, the element symbol for lithium is Li. The symbol for boron is B, and the symbol for magnesium is Mg. You can find more examples of modern element symbols along with ancient symbols in Figure 2.22.

Although every language has its own way of saying and spelling the names of the elements, the symbols that are used to represent the elements are the same throughout the world. The next Find Out Activity will help you understand how this international system works.

### *Computer* CONNECT

Find out how elements received their names. Research ten elements on the Internet or in the library. Use a spreadsheet program on a computer or a hand-drawn chart to create categories for the names given to the elements. A few possible categories are celestial names, geographical names, Latin names, and mineral names. Sort the elements into categories. Compare your categories and elements with those of your classmates.

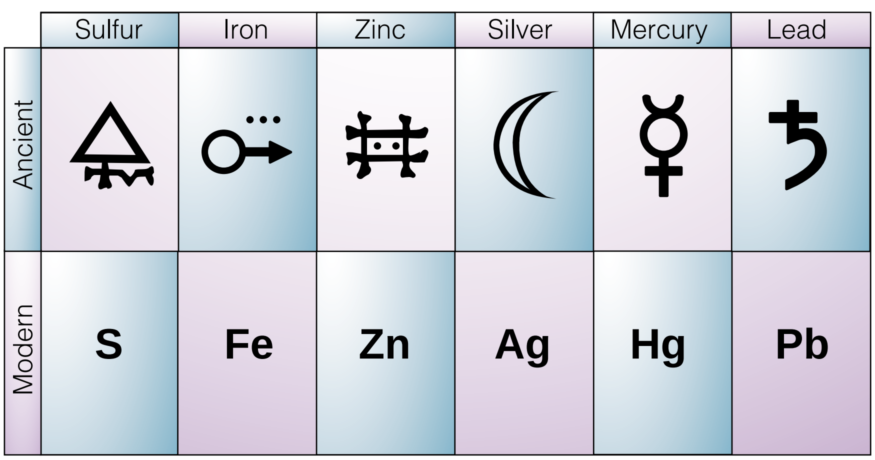


**Figure 2.22** Compare the ancient and modern symbols for these elements.

Find Out ACTIVITY

## Symbols for Elements

How are symbols for elements determined?

### Materials

Appendix C: Properties of Common Substances

your collection of element cards from Find Out Activity: Collect the Elements.

### Procedure • Analyzing and Interpreting

1. Kal's body mass is 50 kg. Most of it (48 kg) is made up of just four elements: hydrogen (H), oxygen (O), carbon (C), and nitrogen (N). The symbols for these elements are in the parentheses. Use Appendix C: Properties of Common Substances to name four other elements that have the first letter of their name as their symbol.
2. About 1 kg of calcium is distributed throughout Kal's bones, teeth, and blood.
   - **(a)** What element already has the symbol C?
   - **(b)** Refer to Appendix C. What is the symbol for calcium?
   - **(c)** Name four other elements that have the first two letters of their name as their symbol.
3. Several element names begin with "b."
   - **(a)** The element boron can be used to make silicon computer chips conduct more electricity. Boron's symbol is B. Infer likely symbols for barium, beryllium, bismuth, and bromine. Check your ideas in Appendix C.
   - **(b)** In 1947 chemists in Berkeley, California, manufactured a new element and named it berkelium. Reread your answer for 3(a), than infer a likely symbol for berkelium. Refer to Appendix C. What is the symbol for berkelium?
4. The seven metals known to the ancients were called by their Latin names for centuries: *argentum* for silver, *aurum* for gold, *cuprum* for copper, *ferrum* for iron, *hydragyrum* for mercury, *plumbum* for lead, and *stannum* for tin.
   - **(a)** Infer possible symbols for these metals. Use Appendix C to check your inferences.
   - **(b)** Infer which metal was probably used for water pipes in ancient times. Explain how its name helped you make your inference.
5. The hair-thin wire in a light bulb is made of an element with two official names. Most of the world knows it as tungsten, but it is called wolfram in its country of discovery. Refer to Appendix C. Which name was used to create this element's symbol?

### What Did You Find Out?

1. Add symbols on your element cards. Add to your collection any new elements you wish or any your teacher suggests.

Cool Tools

Bertram Brockhouse was born in 1918 in Lethbridge, Alberta. As a young boy he enjoyed fishing, dismantling radios, and reading popular electronics magazines. He spent many years researching the energy absorbed and released by atoms as they interact. In order to study the internal structure of atoms, he developed a neutron spectrometer. The neutron spectrometer used a beam of neutrons to show details of atoms thousands of times finer than had been revealed before. Bertram Brockhouse and an American, C.G. Shull, received the Nobel Prize in Chemistry in 1994 for their work. The neutron spectrometer is now used to investigate the internal structure of crystals, metals, gems, and rocks.

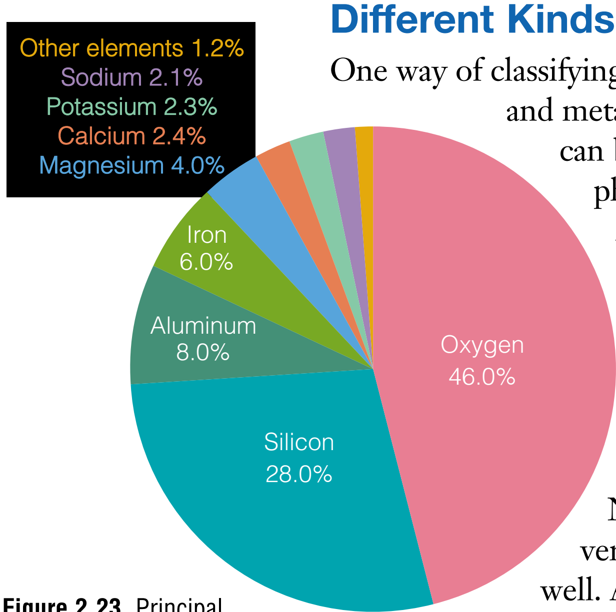


**Figure 2.23** Principal elements in Earth's crust as measured by mass.

**Figure 2.24** At room temperature mercury is a liquid.

## Different Kinds of Elements

One way of classifying elements is to sort them into metals, non-metals, and metalloids. Metals conduct electricity and heat. They can be hammered into sheets and stretched into wires — physical properties called *malleability* and *ductility*. Metals have a shiny appearance or lustre, and all of them, except mercury, are solids at room temperature.

Non-metals, such as oxygen and sulfur, differ from metals in several ways. At room temperature, some are gases, some are solids, and only one is a liquid. The non-metals that are solid are brittle. Non-metals cannot be stretched into wires, are not very shiny, and do not conduct electricity or heat very well. Among the principal elements in Earth's crust (see Figure 2.23), the only non-metal is oxygen. Even when it is cooled to its liquid state, oxygen does not conduct electricity, and solid oxygen is very brittle.

Some elements, such as silicon, have properties that lie "in between" metals and non-metals. These elements are called metalloids, and they can have properties of both metals and non-metals. Silicon is the only metalloid found among the principal elements in the crust. In its most common compound, it appears as silicon dioxide. Although silicon can be made to conduct electricity, its properties lie in between those of metals and non-metals.

Metalloids are few in number. Non-metals are more numerous, but metals are the most numerous of these three kinds of elements. Compare the properties of the three different kinds of elements listed in Table 2.3.

**Table 2.3** Properties of Metals, Non-Metals, and Metalloids

| | State at room temperature | Appearance | Conductivity | Malleability and ductility |
|---|---|---|---|---|
| Metals | • solids, except for mercury (a liquid) | • shiny lustre | • good conductors of heat and electricity | • malleable<br>• ductile |
| Non-metals | • some gases<br>• some solids<br>• only bromine is liquid | • not very shiny | • poor conductors of heat and electricity | • brittle<br>• not ductile |
| Metalloids | • solids | • can be shiny or dull | • may conduct electricity<br>• poor conductors of heat | • brittle<br>• not ductile |

### DidYouKnow?

Iron was one of the first elements put to use by humans thousands of years ago because it was easily extracted from iron ore by heat. The discovery and extraction of other elements occurred much more slowly. Over 112 elements are now known.

Find Out ACTIVITY

## Identifying Metals

**Teacher Demonstration**

Scientists use the light given off by elements to determine the composition of the planets and stars. The brilliant colours you will see in flame tests can reveal metals in the compounds or mixtures that contain them.

### Safety Precautions

Your teacher will demonstrate this activity.

### Materials

Bunsen burner, heat-resistant pad, Q-tips™ or Nichrome™ wire, aqueous solutions of barium chloride, calcium chloride, potassium chloride, sodium chloride

### Procedure ✶ Performing and Recording

1. Make a table like the one below to record the results of the tests. Give your table a title.

| Compound | Colour of flame |
|---|---|
| barium chloride | |

2. Put the Bunsen burner on the heat-resistant pad, light it, and adjust the air supply to produce a hot flame with a blue cone.

3. Dip one end of a Q-tip™ or Nichrome™ wire into one of the solutions, then hold the saturated tip so it is just touching the blue cone of the flame. You may need to hold the Q-tip™ or Nichrome™ wire in this position for as long as 30 s. Record the colour of the flame.

4. Repeat step 3 for the other solutions, and record the colours of the flames.

### What Did You Find Out? ✶ Analyzing and Interpreting

1. How do you know that the colour of the flame is due to the metals and not to something else in the solutions?

2. If you saw a fireworks display that was green, what metal might be present?

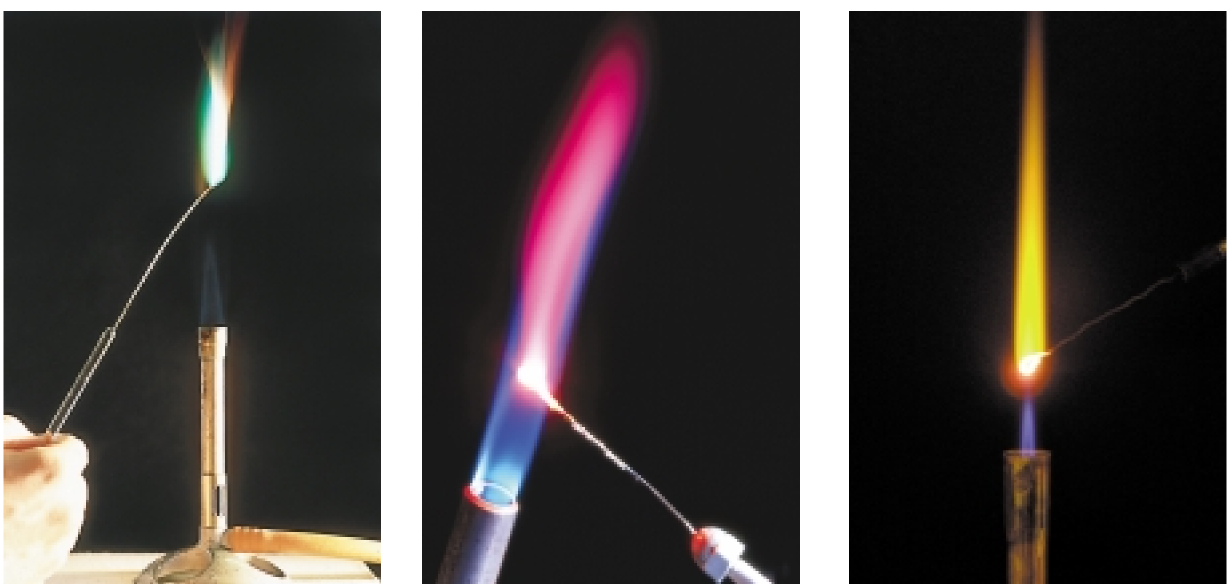

**Figure 2.25** Flame tests for three different elements are shown. Discuss these pictures as a class. Which elements burn with these colours?

**Figure 2.26** Stainless steel braces are made of carbon, nickel, and iron. Teeth will straighten due to the strength of the elements.

## Chemical Families

Elements are everywhere ... even in your mouth. Which elements can you see at work in Figure 2.26?

The metals used in the mouth need to be unreactive with mild acids and with gases that are inhaled and exhaled. Gold, silver, and copper can be mixed and will not react readily with oxygen. If you need a new tooth to be made and moulded to your mouth, it might be made of a combination of gold, silver, and copper.

The term **chemical family** is used to describe a group of related elements that have similar properties. Gold, silver, and copper were once used to make coins and are often referred to as coinage metals. In the next activity you will consider their chemical properties.

Find Out ACTIVITY

### A Chemical Family

The members of a chemical family are not identical, but they do have certain features in common. Scan the table below, and answer the questions that follow it.

| Property | Elements | | | | |
|---|---|---|---|---|---|
| | Aluminum (Al) | Copper (Cu) | Gold (Au) | Iron (Fe) | Silver (Ag) |
| effect of acid on cleaned, bare, pure metal | reacts with acid; hydrogen gas released | unreactive with most acids | unreactive with most acids | reacts with acid; hydrogen gas released | unreactive with most acids |
| compound formed with oxygen? | readily | not readily | not readily | readily | not readily |
| malleability | very malleable | very malleable | highly malleable | malleable | very malleable |
| electrical conductivity | very good | second best of all metals | excellent | good | best of all metals |

**Procedure** Analyzing and Interpreting

Use the word "pattern" in your answers to the following questions.

1. The coinage metals — copper, silver, and gold — are considered to be a chemical family. List three arguments to explain why.
2. **(a)** List arguments in favour of including aluminum in the family of coinage metals.
   **(b)** List arguments against including aluminum.
3. **(a)** List arguments in favour of including iron in the family of coinage metals.
   **(b)** List arguments against including iron.
4. Do you think aluminum belongs to the same chemical family as iron? List arguments for and against.

## Alkali Metals

Most metals are reactive. However, alkali metals are so reactive that many of them require special storage (see Figure 2.27). Why are they so reactive? There is a tendency for electrons to be found in pairs. Each alkali metal has an unpaired electron and tends to get rid of the electron by forming a compound. A list of alkali metals is provided below. You can see pictures of alkali metals in Figure 2.35, the Pictorial Periodic Table, on pages 132-133.

**Figure 2.27A** *(left)* Freshly cut sodium is bright and shiny, but only while stored in oil.

**Figure 2.27B** After a few minutes' exposure the surface of the sodium has dulled because the sodium atoms have reacted with oxygen from the air.

**Figure 2.27C** When a small lump of sodium is dropped into water, a vigorous reaction takes place.

| Alkali metals (very reactive) |
|---|
| lithium<br>Li |
| sodium<br>Na |
| potassium<br>K |
| rubidium<br>Rb |
| cesium<br>Cs |
| francium<br>Fr |

| Alkaline earth metals (fairly reactive) |
|---|
| beryllium<br>Be |
| magnesium<br>Mg |
| calcium<br>Ca |
| strontium<br>Sr |
| barium<br>Ba |
| radium<br>Ra |

## Alkaline Earth Metals

Another chemical family is the alkaline earth metals. Their name comes from early chemists who thought anything that was insoluble in water and unchanged by heat was one of the "earth" elements. The alkaline earth elements react fairly vigorously with some substances, but they are not as reactive as the alkali metals. For example, magnesium reacts with water but less vigorously than sodium does. A list of alkaline earth metals is provided above. You can see pictures of these metals in Figure 2.35, the Pictorial Periodic Table, on pages 132-133. You can investigate the reactivity of metals in the next investigation.

**Figure 2.28** When magnesium burns, it gives off intense white light and white smoke. Since magnesium burns in carbon dioxide, what kind of fire extinguisher can be used to put out a magnesium fire?

INQUIRY

INVESTIGATION 2-C

SKILLCHECK

Initiating and Planning

Performing and Recording

Analyzing and Interpreting

Communication and Teamwork

# Ready to React

Scientists have been able to arrange metals in order of activity. Metals high on the activity series table react readily. Metals lower on the table react less readily. A metal will replace any metal beneath it in the table during a reaction. This type of reaction is called a displacement reaction. Notice that copper, silver, and gold are at the bottom of the list. These elements are relatively inactive, so they often occur in Earth as veins of relatively pure elements. Most other metals are more active and occur as compounds.

## Question

How do you recover the solute from a solution using an active metal?

## Hypothesis

As a group, make a hypothesis about what will happen when aluminum foil is placed in a solution of copper (II) sulfate and hydrochloric acid. Refer to the Activity Series of Metals table to help you make the hypothesis.

**Activity Series of Metals**

| | |
|---|---|
| lithium | **Most active** |
| potassium | ↓ |
| barium | |
| calcium | |
| sodium | |
| magnesium | |
| aluminum | |
| zinc | |
| iron | |
| nickel | |
| tin | |
| lead | |
| (hydrogen) | |
| copper | |
| mercury | |
| silver | |
| gold | **Least active** |

### Apparatus

triple beam or electronic balance
mortar and pestle
scoopula
2 400 mL beakers
10 mL graduated cylinder
stirring rod
funnel
retort stand
ring clamp or burette

### Materials

copper (II) sulfate
water
hydrochloric acid (3 mol/L)
box of baking soda for spilled acid
aluminum foil
filter paper

### Safety Precautions

- Don't let the hydrochloric acid touch your skin. If you accidentally spill it on your skin, wash it off immediately with lots of cool water and inform your teacher.

### Day One

### Part 1

## Procedure

1. Make an observation chart to use for this investigation.
2. **Measure** about 2.5 g of copper (II) sulfate. Place the copper (II) sulfate in the mortar and grind until you have a fine powder.
3. Use the scoopula to scoop the powder into a 400 mL beaker.
4. Add 30 mL of water to the copper (II) sulfate in the beaker. Stir until the powder has dissolved. **Observe** and **record** your observations on the chart.

5. Add 5 mL of hydrochloric acid (3 mol/L) to the beaker. **Record** your observations. **CAUTION:** Handle the acid and anything that it touches with caution. Be sure to rinse out the graduated cylinder when you are done. Neutralize any spills with baking soda. Wipe up any spills immediately. Wash your hands after cleaning spills.

6. Cut a small piece of aluminum foil (4 cm × 4 cm). **Measure** the mass of the foil and **record**.

7. Roll the foil around the stirring rod. Place the foil in the beaker of copper (II) sulfate and acid. Gently submerge the foil in the solution with the stirring rod. **Observe** carefully. Touch the outside bottom of the beaker with your hand. **Record** your observations.

#### Part 2

### Procedure

1. **Measure** and **record** the mass of the filter paper.

2. Fold a piece of filter paper and place it in the funnel. Dampen the filter paper with water so it will stay in place.

3. Attach the funnel to a retort stand with a ring clamp or burette clamp. Place an empty beaker under the funnel.

4. Carefully pour the acidic solution through the filter paper. Do not let the solution pour over the sides of the filter paper. If particles remain in the beaker, add a small amount of water to rinse them into the filter paper.

5. Pour 20 mL of water through the residue on the filter paper to get rid of any excess acid.

6. Unfold the filter paper. Place the filter paper and residue in a safe place to dry. Rinse stirring rod, funnel, and beakers to remove acid.

#### Day Two

7. **Measure** the mass of the residue and filter paper. **Record**. Subtract the mass of the clean piece of filter paper. **Record**.

8. Place the residue in the container provided by your teacher.

### Analyze

1. What colour was the first copper (II) sulfate solution you made?
2. What happened to the solution when you added hydrochloric acid?
3. Was there a chemical or physical change in this experiment? Give reasons for your answers.
4. What substance was recovered in this investigation? How do you know?

### Conclude and Apply

5. Compare the mass of the original metal (aluminum) to the mass of the residue. What conclusion can you draw based on your evidence?
6. What would happen if you added more aluminum foil to the beaker after the reaction was complete?

### Extension

7. How could displacement reactions be used in mining metals? Research in the library or on the Internet. Present your answer in the form of a flowchart.

## The Noble Gases

Chemists find the noble gases interesting because they are so unreactive. As you will find out, unreactivity can be a very useful property.

Consider an ordinary light bulb. If the slightest leak allows air to get inside the glass covering, the filament will burn out in a bright flash of light and the bulb will go dark. Exposure to oxygen makes the tungsten filament burn. The filament burns because electrons of hot tungsten atoms are transferred to nearby oxygen atoms. If oxygen is excluded, however, tungsten cannot react. Modern light bulbs are usually filled with argon, an unreactive gas, to keep the tungsten filament from burning out. Argon is a noble gas.

**Figure 2.29** Each colour in this advertising sign is caused by a different noble gas. Argon produces the blue colour and helium produces yellow-white. Lighting designers can obtain more colours by adding other substances to the gas mixture. Why do different gases produce different colours?

Numerous laboratory experiments have confirmed that all noble gases are chemically "stable." Noble gases do not have any unpaired electrons. Therefore, noble gases are highly unlikely to take part in a chemical change. In fact, only the very largest noble gas atoms can be made to react chemically at all. Even when they do react, their compounds soon decompose, allowing the noble gas to separate into single atoms again.

A list of noble gases is provided on this page. Locate the noble gases in Figure 2.35, the Pictorial Periodic Table on pages 132–133.

**Word CONNECT**

Look up "argon" in a dictionary, and find out about the Greek word it comes from. Why is "argon" a good name for an unreactive gas?

| Noble Gases |
| --- |
| helium<br>He |
| neon<br>Ne |
| argon<br>Ar |
| krypton<br>Kr |
| xenon<br>Xe |
| radon<br>Rn |

**DidYouKnow?**

Before 1963, chemistry textbooks claimed that the noble gases were entirely inert — that is, they would never form chemical compounds. Then Canadian chemist Neil Bartlett startled the scientific world by preparing noble gas compounds in a laboratory at the University of British Columbia. The methods he used to rearrange the electrons were not exceptionally difficult, but the compounds proved to be unstable. The noble gas atoms are definitely more stable when uncombined.

## The Halogens

Halogens are naturally found in the form of compounds because halogen atoms react vigorously with almost every other element. Halogens, like alkali metals, have an unpaired electron. However, halogens have a tendency to gain an available electron when they form compounds. Even the least reactive halogens are extremely corrosive and harmful. There are many common uses for halogen compounds. For example, fluorine compounds are added to some toothpastes and some city water supplies. The compounds help prevent decay by making tooth enamel stronger and more resistant to decay. Read the list of halogens on the next page, then locate their pictures in figure 2.35, the Pictorial Periodic Table on pages 132–133.

| Halogens (very reactive) |
|---|
| fluorine F |
| chlorine Cl |
| bromine Br |
| iodine I |
| astatine At |

**Figure 2.30** At room temperature chlorine (*left*) is a gas, bromine (*centre*) is a liquid, and iodine (*right*) is a solid. Can you explain why?

**Word CONNECT**

Three of the halogens — chlorine (Cl), bromine (Br), and iodine (I) — derive their names from Greek words that describe one of their properties. Chlorine comes from *chloros*, describing the greenish-yellow colour of the gas. (You may also recall the word "chlorophyll" from your earlier science studies. What colour is chlorophyll?) *Iodeides* means violet-coloured, which describes the vapour of iodine. Look up "bromine" in a dictionary. Which Greek word is it derived from? What could you guess about bromine vapour?

## TOPIC 4 Review

**1.** In the eighteenth century, 18 elements were discovered. Their symbols are Co, Pt, Ni, H, N, Cl, Mn, O, Mo, Te, W, U, Zr, Ti, F, Sr, Be, and Cr.
   **(a)** List these symbols. Write one symbol on each line.
   **(b)** Use Appendix C to write the name for each element beside its symbol.

**2.** **(a)** Give an example of a metallic element.
   **(b)** Give an example of a non-metallic element.
   **(c)** Give an example of a metalloid element.

**3.** What are four physical properties used to compare metals, non-metals, and metalloids?

**4.** Describe the physical and chemical properties of the "coinage metals" that make them suitable for use in coins.

**5.** Briefly describe some uses of the noble gases mentioned in this Topic. What chemical properties do they have in common?

**Math CONNECT**

Consider the lists you made in question 1. What is the total number of elements in the list? How many of these elements are metals? (Hint: Consult Appendix C.) Express the number of metallic elements as a percentage of the total number of elements in the list.