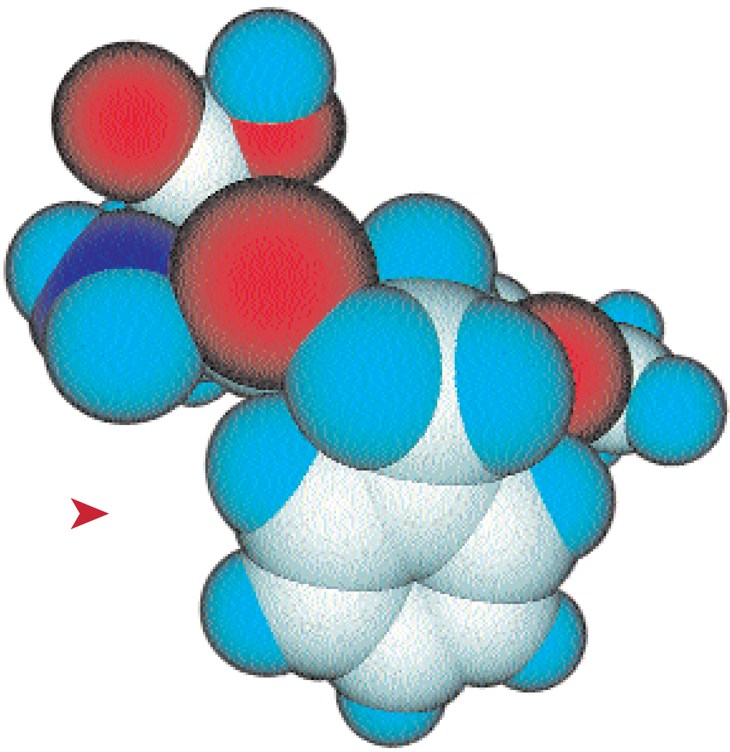
CHAPTER 2

Elements and Compounds

Getting Started

1 Douglas Cardinal is an architect who often creates models of structures to give shape to a concept. Architects use models not only to help them uncover design problems and solve them, but also to make the concepts much easier for other people to understand and visualize. Have you ever built a model? What did it teach you? Brainstorm a list of the possible uses of models.



2 In science, models are not just physical constructions. A model can be a diagram, a classification system, a mental picture, a theory. In fact, a model is any means of representing a thing or process. Models are made to help us visualize things we cannot see or things we find difficult to understand. What scientific models are you already familiar with?

Choose one and ask yourself what the model seeks to explain, and how complete that explanation is.

3 A Montreal woman is helped from her home during the 1998 ice storm. Emergency generators used to provide electricity spread carbon monoxide fumes through her apartment complex. Carbon monoxide is a poisonous gas that kills people every year.

How can the particle theory help us understand substances like carbon monoxide? The particle theory suggests that matters are made of basic building blocks, called elements. An element is composed of only one kind of atom. Atoms can be assembled in different ways. For example, carbon and oxygen atoms can be combined to form the gas you exhale with every breath (carbon dioxide) or the dangerous gas that affected this woman (carbon monoxide). What other combinations of atoms are you aware of, and how can they affect our daily lives?

Reflecting

Think about the questions in 1, 2, 3. What ideas do you already have? What other questions do you have about scientific models and elements and compounds? Think about your answers and questions as you read the chapter.

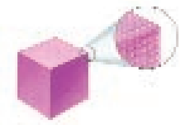
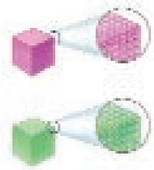
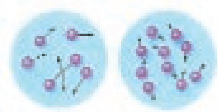
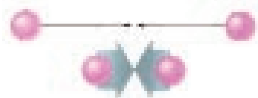
Try This: Finding Pure Substances

1. Pure substances are samples of matter that contain only one type of particle. In a small group, make a list of at least 20 pure substances that you know about. Include everyday substances such as water, copper, and gold. Also be sure to include substances you have used in the laboratory. Remember that pure substances can be solids, liquids, or gases, and their names can have one word or more than one word in them.
2. Scientists have found that chemical changes can split the particles in some pure substances into smaller particles. Other pure substances cannot be broken down. In your group, discuss your list of pure substances. Which ones do you think can be split?

Models of Matter: The Particle Theory

Observing and experimenting with matter has led scientists to theorize about what matter really is. Their working definition of matter is anything that takes up space and has mass. When we observe matter, we see that it behaves in countless ways and can be put to countless uses. But is matter one, definable thing? Over the centuries, scientists have created many models to explain what matter is, to explain what lies beyond what we can physically observe. One of the most enduring models of matter is the particle theory.

Table 1 **The Particle Theory of Matter**

Principle	Illustration
1. All matter is made up of tiny particles.	
2. All particles of one substance are the same. Different substances are made of different particles.	
3. The particles are always moving. The more energy the particles have, the faster they move.	
4. There are attractive forces between the particles. These forces are stronger when the particles are closer together.	

Building Blocks of Matter: The Particle Theory

More than 2000 years ago in Greece, a philosopher named Democritus suggested that matter was made up of tiny particles too small to be seen. He thought that if you kept cutting a substance into smaller and smaller pieces, you would eventually come to the smallest possible particles—the building blocks of matter. The basic principles of the particle theory are reviewed in **Table 1**.

Pure Substances and Mixtures

Using the particle theory, we can understand two categories of substances: pure substances and mixtures. A **pure substance** contains only one kind of particle. For example, a piece of aluminum foil contains only aluminum particles. Sugar is a pure substance. It contains only sugar particles. A scoop of sugar made from Canadian sugar beets contains exactly the same kind of particles as a scoop of sugar made from Australian sugar cane.

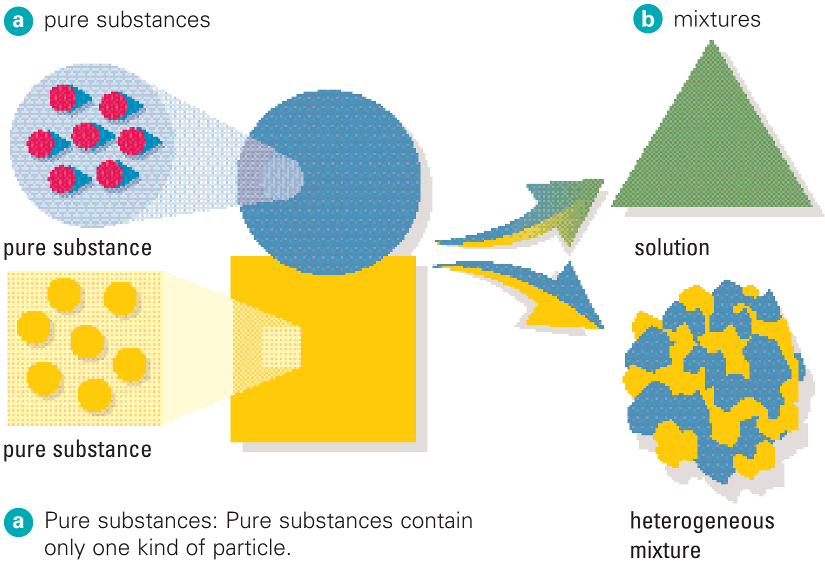
A **mixture** contains at least two different pure substances, or two different types of particles. When you drink a glass of milk or eat a cookie, you are consuming mixtures of different substances. Most common substances are mixtures. **Figure 1** shows the relationship between pure substances and mixtures.

Classifying Mixtures

Imagine you have a sample to identify that you think is a mixture. What type of mixture might it be? Perhaps your mixture is a solution, like sugar in water. If you add a small amount of sugar to water and stir, the sugar disappears as it dissolves. A **solution** may be made up of liquids, solids, or gases. Air is a solution of gases. Perfumes are solutions of alcohol and fragrances. Many alloys are solutions of solid metals.

The sample of matter may be a **heterogeneous mixture**, like pizza. When you make a pizza, tomato sauce, cheese, mushrooms, and pepperoni are mixed together or scattered on top of the crust. Each part can be easily seen. Garden soil, oil and vinegar, salad dressing, and garbage are all heterogeneous mixtures.

Figure 1



a Pure substances: Pure substances contain only one kind of particle.

b Mixtures: When two pure substances are mixed together, sometimes they mix smoothly and sometimes they mix unevenly. If the particles mix very well with one another—so well that you can see only one phase or visible part—the mixture is called a solution. You say that one substance dissolves in another. If the particles don't mix well with one another, you will see more than one phase. This type of mixture is called a heterogeneous mixture.

Elements and Compounds

Many properties of matter can be explained by using the particle theory. But what are these particles? Two hundred years ago, scientists like the one in **Figure 2** already knew of thousands of pure substances and were constantly discovering more. Scientists hoped that by breaking down these substances, they would discover the building blocks of matter—the particles that Democritus suggested couldn't be broken down any further. Once they knew all the building blocks, they believed they would be able to predict the properties of a pure substance from the properties of the "blocks" or "particles" of which it was made.

Figure 2

Using equipment like this, scientists of several centuries ago conducted experiments on matter.

As a result of these efforts, scientists now know of over 100 of these building blocks, which they call elements. **Elements** are pure substances that cannot be broken down into simpler substances. Water, which is formed from two of these elements (hydrogen and oxygen), is a compound. **Compounds** are pure substances that contain two or more different elements in a fixed proportion. They are formed when elements combine together in chemical reactions. For example, in water, there are always twice as many particles of hydrogen as particles of oxygen. **Table 2** shows how the classification of matter can be expanded to include elements and compounds.

Table 2 **Pure Substances and Mixtures**

Elements in substance	Type of substance	Description
element A alone	pure substance (element)	Only element A is visible.
elements A and B	pure substance (compound)	The compound may have completely different properties from each of the elements; the elements are chemically combined.
	mixture (solution)	The solution may look very similar to one of the elements, as particles of the other element are hidden within it.
	mixture (heterogeneous)	Particles of each element can be seen separately.

Atoms and Elements

How can we use the particle theory to understand elements and compounds? Once again, water provides a clue. At one time, people thought that water was made up of particles that could not be broken down further. We now know, however, that water can be broken down into hydrogen and oxygen and that, when we measure the volumes of the gases, we always get twice as much hydrogen as oxygen. One water particle is formed from the particles of two elements: two particles of hydrogen and one particle of oxygen as shown in **Figure 3**.

Scientists now call the particles in the particle theory **atoms**. Each element is made of only one kind of atom. Since there are more than 100 elements, there are more than 100 kinds of atoms.

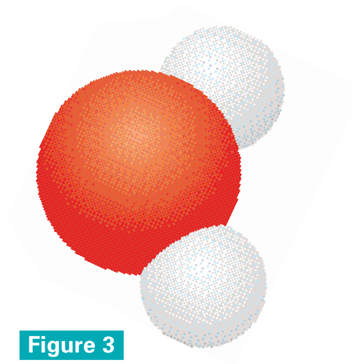
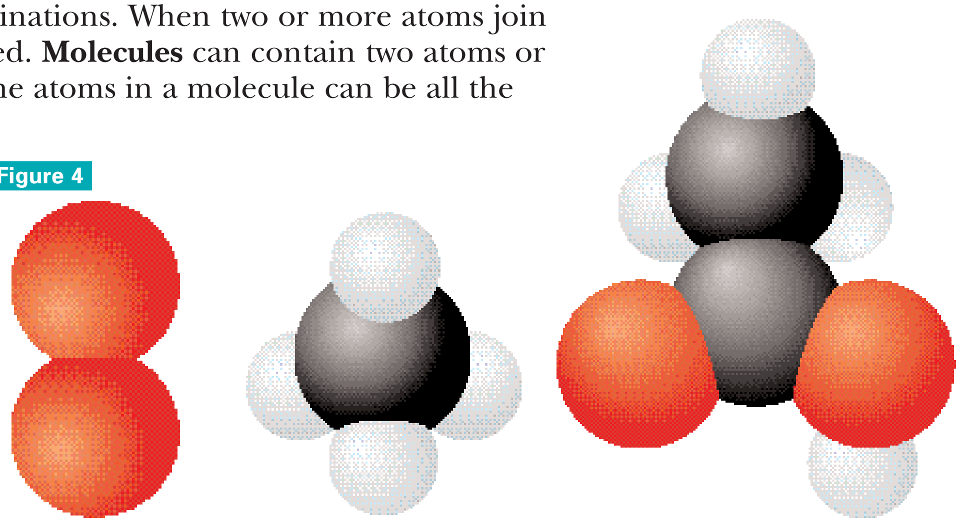


Figure 3
A model of a water molecule

Molecules

Atoms join together in combinations. When two or more atoms join together, a molecule is formed. **Molecules** can contain two atoms or many thousands of atoms. The atoms in a molecule can be all the same kind of atom. For example, in the element oxygen there are two oxygen atoms in each molecule. Molecules can also be made of two or more different kinds of atoms. For example, a compound called butane (a fuel) contains four carbon atoms and ten hydrogen atoms in each molecule.

Figure 4



(a) Atoms of the element oxygen join together in pairs, forming oxygen molecules.

(b) In the compound methane (the main component of natural gas), each molecule contains one carbon atom and four hydrogen atoms.

(c) In acetic acid (vinegar), each molecule has eight atoms: two carbon atoms, two oxygen atoms, and four hydrogen atoms.

Models of Molecules

Examine the models of molecules shown in **Figure 4**. The first shows a molecule that contains two atoms of oxygen. This is a molecule of the element oxygen. The other two show molecules of compounds.

Different Molecules from the Same Elements

In compounds, atoms of one element join together in a fixed ratio with atoms of other elements. For example, when hydrogen and oxygen combine in the ratio of 2:1, the compound they form is always water. What happens if hydrogen and oxygen combine in a different ratio? The result is a different compound with different properties. In nature, there is only one other compound that contains only hydrogen and oxygen: hydrogen peroxide. In hydrogen peroxide, hydrogen and oxygen atoms are in a 2:2 ratio, as shown in **Figure 5**.

The properties of water and hydrogen peroxide are very different. Water is everywhere on Earth, part of all living things. Hydrogen peroxide is a much more reactive compound. In **Figure 6** it is shown interacting with a drop of blood.

Other elements can also be combined in different ratios to produce different compounds. For example, acetic acid (vinegar) contains atoms of hydrogen, oxygen, and carbon. These same elements also combine to form many other compounds, including sugars and fats.

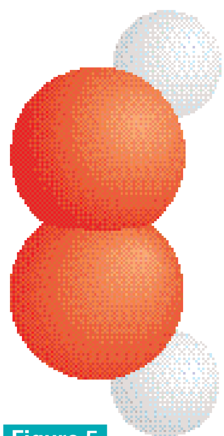


Figure 5
A hydrogen peroxide molecule has two hydrogen atoms and two oxygen atoms. Compare this with the model of water shown in Figure 3.

Figure 6
A hydrogen peroxide solution bubbles as blood is added. Hydrogen peroxide is used in antiseptics. It bubbles when it touches dirt and blood in cuts or scrapes. Water in a similar situation does not react.

Understanding Concepts

1. Use diagrams to explain the difference between
   (a) a pure substance and a mixture
   (b) a solution and a heterogeneous mixture
2. Create a summary chart for the concepts in this section: element, compound, atom, mixture, and molecule. Include the following headings: term, definition, example.
3. Give examples of two molecules that are made from the same types of atoms.
4. State whether each of the following pure substances is an element or a compound. Explain your reasoning.
   (a) A clear, colourless liquid that can be split into two gases with different properties.
   (b) A yellow solid that always has the same properties and cannot be broken down.
   (c) A colourless gas that burns to produce carbon dioxide and water.

Reflecting

5. Look back to the Try This activity in Getting Started. Are there any changes you would make in your answers?

Challenge

The particle theory is a model used to help explain matter. How would you use this model in the challenge you have chosen?

2.2 Investigation

SKILLS MENU
- ○ Questioning
- ● Hypothesizing
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ○ Communicating

Classifying Elements

When you go into a drugstore, you notice that products with similar properties are grouped together. Soaps and skin care products are in one section, vitamins and herbal products in another, and so on. In the same way, hardware stores often group nails, screws, and other fasteners together. You have already investigated the physical properties of pure substances, including some elements. Can we use these properties to classify elements—the basic building blocks of matter? In this investigation you will examine a number of elements and classify them on the basis of lustre, malleability, and other physical properties.

Materials

- safety goggles
- apron
- small pieces of paper or baking cups
- samples of some of the following elements: aluminum, chromium, iron, nickel, tin, cobalt, lead, copper, magnesium, silicon, zinc, carbon, sulfur, iodine
- magnet
- conductivity apparatus (flashlight bulb and holder, leads with alligator clamps, 1.5 V-battery)

Question

How may a selection of elements be grouped or classified?

Hypothesis

1 Look at the list of elements in the Materials list. Which elements would you group together, based on previous knowledge? Explain your grouping.

Procedure

2 Draw a data table in your notebook as shown in **Table 1**.

Table 1

Element	Properties					
	Colour	Lustre	Malleability	Density	Magnetism	Electrical Conductivity
?	?	?	?	?	?	?
?	?	?	?	?	?	?

3 Put on your apron and safety goggles.

4 Print the name of each element on a small piece of paper or baking cup. Obtain a sample of each element on the paper or in the cup labelled with its name. Throughout this activity, make sure not to mix the samples.

Your teacher will demonstrate properties of silicon and iodine. Students should not handle iodine, which is poisonous.

5 Examine each of the elements and note its colour and lustre (shininess). Your teacher may have scraped the surface of some samples to expose the element underneath.

(a) Record your observations.

6 Try to bend or break the samples. (Your teacher will demonstrate with some elements, including silicon and iodine.) You will recall that substances that can be bent or hammered into a sheet are described as malleable. Substances that shatter or crumble may be described as brittle.

(a) Record your observations.

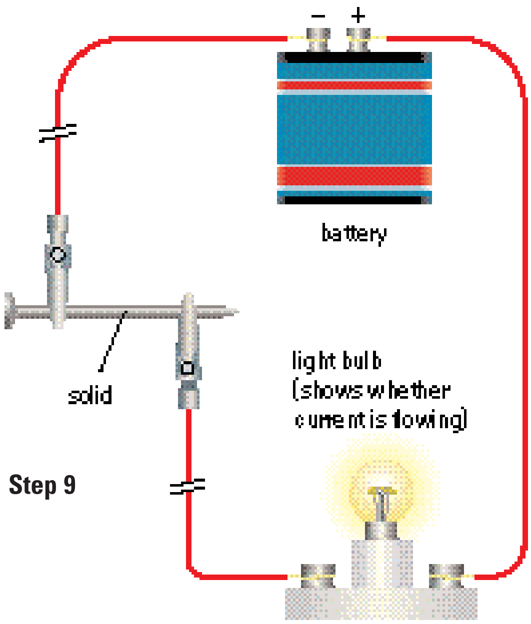
7 Which elements seem heavy or light for their size, compared with the other elements? (That is, how would you rate their densities?)

(a) Record your observations.

8 Use a magnet to determine which elements are magnetic and which are nonmagnetic.

(a) Record your observations.

9 Assemble the conductivity apparatus. Touch the electrical leads or alligator clamps to opposite ends of each sample of element. If the lamp glows, the element is a conductor. If the lamp does not glow, the element is an insulator.



Step 9

(a) Record your observations.

10 Return the samples of the elements to your teacher for recycling and further use. Put away any materials as directed by your teacher. Clean up your work station. Wash your hands.

Analysis and Communication

11 Based on your observations, can you classify elements according to different properties?

12 Write a summary supporting your view, providing evidence from your investigation. 7D

Making Connections

1. How do the properties of the following elements determine their use?
   - **(a)** Copper and aluminum are used in electrical wiring.
   - **(b)** Carbon rods are used in some batteries.
   - **(c)** Steel (iron) cans can be separated easily from aluminum cans.
2. You may have noticed that when you put a metal object against your skin, it feels cold. Why does this happen? What physical property of metals explains this observation? What uses does this property have?

Exploring

3. Research other ways of classifying elements. Use these new strategies to classify the elements you studied in this activity. Compare your new groupings with the previous ones.

Reflecting

4. Think of situations where it might be useful to classify elements.

Putting Metals to Work

You have investigated the classification of elements as metals and nonmetals based on their physical properties (**Figures 1** and **2**). Similar characteristics can be observed in their chemical behaviour. The physical and chemical properties of **metals** make them very useful substances in many applications. Because copper and aluminum conduct electricity well, they are used in wiring and electrical circuits. The lack of reactivity of gold and silver make them valuable in jewellery. The hardness and strength of metals make them useful in buildings and automobiles. Their ability to be shaped easily and conduct heat have made metals useful for centuries in cooking pots and utensils.

Figure 1
Metals are generally shiny and malleable solids that are good conductors of heat and electricity.

Figure 2
Nonmetals are generally dull, brittle, nonconducting solids or gases at room temperature.

Metals and Industry

People have used metals for tools and jewellery for thousands of years. More recently, many other uses have been found for different metals and mixtures of metals. For instance, platinum is a very unreactive metal that can be used in precision instruments. Uranium is a very dense metal that is used in nuclear power plants.

Many less dense, or "light" metals, also have useful applications. Sodium can be used in chemical reactions. Magnesium is a light, strong metal that can be used in automobile wheels and luggage, especially in cases designed for photographic equipment, which requires extra protection. Aluminum pots and pans are sometimes used in kitchens because of their light weight and good heat conductivity.

One group of metals is shown in **Table 1** and **Figure 3**. These elements are called **heavy metals** because they show the typical shininess and other physical properties of metals, as well as having very high density. Many of these elements are more than four times as dense as water.

Compounds of many heavy metals are essential in small amounts in healthy plants and animals. However, in larger quantities they can cause damage to living things. Heavy metal compounds may be absorbed directly from the air or water through leaves, roots, skin, lungs, or gills. Animals can also absorb them from the organisms they consume. In a

Figure 3
Heavy metals, such as gold, silver, nickel, and copper are used in coinage.

Table 1 **Heavy Metal Elements and Their Uses**

Metal	Selected Properties	Typical Uses
tungsten	very high melting point	light-bulb filaments
chromium	resists corrosion	chrome plating
iron	forms strong alloys	structural steel
copper	good conductor	electrical wire
nickel	resists corrosion	coinage
lead	resistant to acid, soft	batteries
zinc	forms protective coating	galvanized containers
tin	resists corrosion	coating for steel cans
mercury	conductor	home thermostat switches

Try This: How Much Metal?

Beverage cans can be made of aluminum or steel. Aluminum cans are lighter than steel cans because steel is mainly iron, a heavy metal. But which can uses more metal? You can get a rough idea by measuring the masses (in grams) of a steel can and an aluminum can that are similar in size. Look up the densities (in g/cm^3) and calculate the volume of metal (in cm^3) used in the manufacture of each type of can.

normal food chain, a predator eats many smaller animals over time and may accumulate poisonous levels of metal compounds in the liver or other organs. Generally, concentrations increase up a food chain from plants to herbivores to carnivores.

Lead is a heavy metal that can have damaging environmental effects. Lead poisoning can harm the nervous system and the brain. Until the 1960s, lead was often used in drain pipes, in paints, and even in gasoline. Unfortunately, young children sometimes ate flakes of paint and people of all ages were harmed by inhaling lead-containing dusts from automobile exhausts. Today, most drain pipes are made from plastic, and alternative paints and lead-free gasolines have been developed. Mercury, shown in **Figure 4**, is another heavy metal that can be dangerous.

Heavy metals in the environment today can come from many sources. Industries, mining operations, and power plants must take care not to carelessly release substances into the air or water.

Figure 4
Mercury metal is unusual because it is a liquid at room temperature. Discharge of mercury compounds into the environment from pulp mills and industrial plants is dangerous because mercury damages the nervous systems of fish and humans.

Did You Know?

Mercury was used in felt-making for top hats, so many hatters went mad with mercury poisoning, hence the expression: "Mad as a hatter."

Understanding Concepts

1. Make a chart listing the properties of metals and nonmetals.
2. **(a)** Why are some elements called heavy metals?
   (b) Give examples of three heavy metals and list their uses.

Making Connections

3. Elements are chosen for various uses. Research and write a summary paragraph explaining the following choices of elements:
   (a) Copper is better than aluminum in most electrical wiring.
   (b) Lead is no longer used in the manufacture of food containers.
   (c) Mercury is no longer used in most thermometers.
   (d) Titanium is used in aircraft wings.

Exploring

4. (7B) Record the substances described as minerals that are listed on the label of a multiple vitamin from your medicine cabinet or a local pharmacy. Make a graph and identify which elements are provided in the largest amounts.
5. (3A) Plumbers and electricians work with copper metal as well as solder, a mixture of metals used to join metals together. Find out how they choose particular metals to use for specific purposes.

Challenge

What examples would you display to illustrate how the properties of metals determine their use in everyday products? Which metals were not yet discovered in the 1800s?

2.4 Investigation

SKILLS MENU
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- ● Hypothesizing
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- ● Communicating

Breaking Compounds into Elements

When you eat your favourite candy bar, you probably don't give the ingredients too much thought. Maybe one day, though, you'll start thinking about the ingredients that make it taste so good: nuts, caramel, crispy wafers, chocolate, creamy fillings. You'll notice that different ingredients account for different flavours, textures, and smells. You may go further and ask yourself, for instance, what it is in chocolate that makes it sweet or allows it to coat the candy bar. Eventually you'll start asking questions that you can't answer by observation alone. You may even start imagining different models that could explain what the smaller and smaller particles of matter are in your candy bar.

The underlying notion of the models of matter we have considered is that all matter is made up of the same basic ingredients—elements—and that these can be combined in millions of different ways, producing substances with very different properties. For instance, hydrogen peroxide and water are both compounds made up of the elements hydrogen and oxygen, but they are very different liquids used for different purposes—one as an antiseptic on wounds and the other for drinking.

People were aware of water long before they were aware that it is made up of hydrogen and oxygen. In fact, early scientists assumed that water was an element because they had not discovered a way of breaking it down further. One way of breaking water down into hydrogen and oxygen is by **electrolysis**—the use of electricity to cause chemical changes in solutions. Water is a pure substance made up of only one kind of molecule, but this molecule can be broken down, releasing atoms of hydrogen and oxygen (**Figure 1**).

You may recall that chemical changes can be represented by a word equation—a short way of representing a chemical reaction that tells you simply what substances (reactants) are used up and what substances (products) are produced. For the electrolysis of water, the word equation is:

$$\text{water} \xrightarrow{\text{electrical energy}} \text{hydrogen} + \text{oxygen}$$

Materials

- safety goggles
- electrolysis apparatus
- water
- 5 g sodium sulfate
- power supply (6V DC)
- electrical leads
- wooden splints

⚠ Electrical devices can be hazardous.

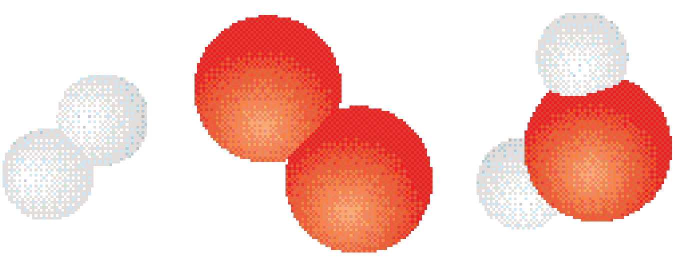


Figure 1

Hydrogen and oxygen molecules are made of two atoms each. Water molecules contain three atoms, two of hydrogen and one of oxygen.

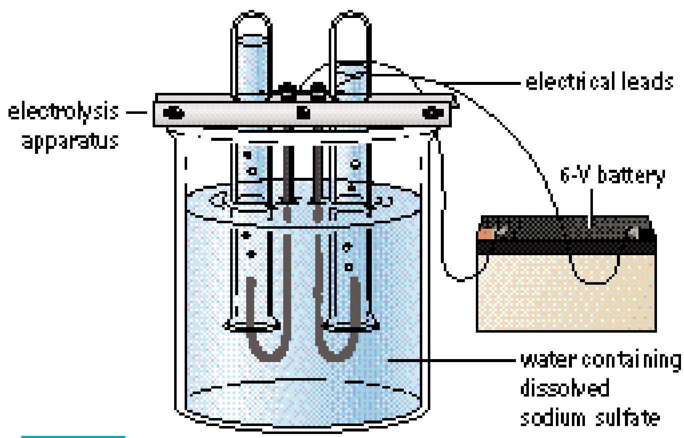


Figure 2

Apparatus used to show electrolysis of water

Question

(2A) **1** Write a question that is being investigated.

Hypothesis

2 Write a statement that compares the volumes of hydrogen and oxygen that will be produced.

Procedure

3 Put on your safety goggles.

4 Assemble the apparatus as shown in **Figure 2**. (Sodium sulfate or an equivalent solute is used to allow electric current to pass through the water.)

5 Turn on the power.

(a) Note what happens as soon as the power is turned on.

(b) Record your observations.

6 Turn off the power as soon as one of the test tubes is full of gas.

(a) What was the effect of turning off the power?

(b) Compare the relative amounts of gas in the tubes.

(c) Describe the physical properties of the gases without removing the tubes from the water.

7 Examine the tube containing a smaller volume of gas. Place your thumb over the mouth of the tube, remove it from the solution, and hold it mouth up. Light a wooden splint. Test the gas by uncovering the tube and quickly bringing the flaming splint close to the mouth of the tube.

(a) Record your observations.

8 Repeat the same process for the tube full of gas.

(a) Record your observations.

This test should be attempted on only a small amount of gas in an open-mouthed, shatter-proof container. It should be done only under teacher supervision. Safety goggles should always be worn.

9 Dispose of the contents of your apparatus and put away materials as directed by your teacher. Clean up your work station. Wash your hands.

Analysis and Communication

10 Analyze your observations by answering the following questions:

(a) What was the identity of the gas in the full tube? Explain.

(b) What must have been the identity of the gas in the partially filled tube? Explain.

(c) Write a word equation to describe each of the following: the electrolysis reaction; the reaction that occurred at the mouth of the full tube.

(d) What safety precautions did you take during this activity?

(e) What were the relative volumes of hydrogen and oxygen gases produced? Can you think of a possible explanation? (Hint: Consider the models of the molecules at the beginning of this section.)

11 Summarize the results of this investigation in a paragraph.

Exploring

1. Research how electrolysis is used in industry to produce hydrogen and other elements. Try an Internet search using key words "electrolytic + cells" and "electrolysis + water." Design a poster to present your research.
2. Hydrogen peroxide antiseptic slowly splits apart into oxygen gas and water. But this process can be made to happen much more quickly. Some contact lens cleaning systems use a disc that is coated with a substance that makes this happen. Get a disc from your local drug store and try the reaction.

Testing for Elements and Compounds

Imagine that you are a technician in a chemical lab. While cleaning up after a flood in the laboratory, you discover that the labels of three gas cylinders have been damaged. You suspect that the cylinders contain carbon dioxide, oxygen, and hydrogen. How could you find out which cylinder contains which gas and whether the cylinders have been contaminated by the flood water? Do they now contain water vapour? Four common tests are used to identify four common gases.

(a) Why would it be difficult to identify the three gases by their physical properties?

Oxygen—The Glowing Splint Test

One common chemical reaction is combustion (burning). Oxygen must be present for combustion to take place. Substances such as wood and oil burn readily in air, which is about 20% oxygen. In pure oxygen, they burn much more intensely. This chemical property of oxygen—supporting combustion—allows you to identify it. You could test for it as follows (**Figure 1**):

- Light a wooden splint.
- Blow out the flame but leave the splint glowing.
- Hold the glowing splint in a small amount of the unknown gas.
- If the splint bursts into flame, the gas is oxygen.

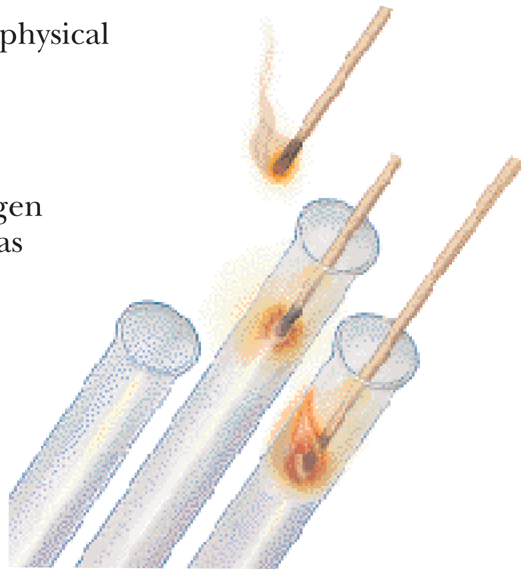


Figure 1
The glowing splint test for oxygen

(b) Why should you blow out the flame first?

(c) Why should you only test a small amount of the gas?

(d) Do you know of any other gases that would give a similar result?

Hydrogen—The Burning Splint Test

You may have already used the second test (**Figure 2**), based on hydrogen's explosive reaction in air.

This test should be attempted on only a small amount of gas in an open-mouthed, shatter-proof container. It should be done only under teacher supervision. Safety goggles should always be worn.

- Light a wooden splint.
- Hold the burning splint in a small amount of the unknown gas.
- If you hear a loud "pop," the gas is hydrogen.

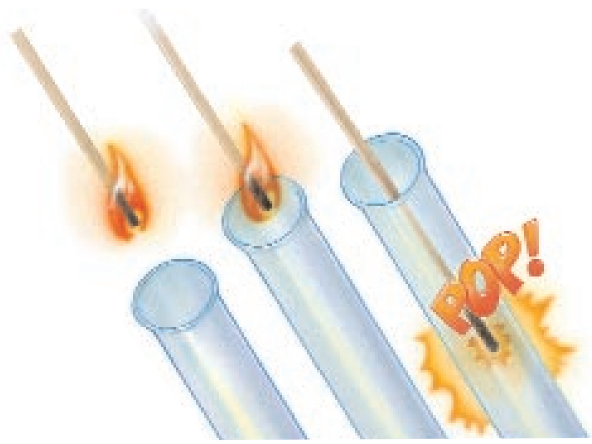


Figure 2
The flaming splint test for hydrogen

(e) What property of hydrogen are you testing for?

(f) Why should you only test a small amount of the gas?

(g) Which should you test for first: oxygen or hydrogen? Why?

(h) If the flame goes out, what can you say about the identity of the gas?

Carbon Dioxide—The Limewater Test

Carbon dioxide does not burn and does not allow other materials to burn. If you put a burning splint into carbon dioxide, the flame will go out.

The chemical test for carbon dioxide uses a liquid called limewater, a clear, colourless solution of calcium hydroxide in water. Carbon dioxide reacts with the dissolved calcium hydroxide, producing a precipitate (**Figure 3**). A **precipitate** is a solid, insoluble material that forms in a liquid solution. The precipitate causes the limewater to appear cloudy or milky. If you suspect that one of the cylinders contains carbon dioxide, carry out this test on a small amount of the gas in a test tube.

- Bubble the unknown gas through limewater solution, or
- Add a few drops of limewater to the gas and swirl it around.
- If the limewater turns cloudy or looks milky, the gas is carbon dioxide.

(i) Do you think oxygen or hydrogen would also turn limewater cloudy? Why?

(j) In what order would you carry out the three tests?

Figure 3
The limewater test for carbon dioxide

Did You Know

Natural gas is a common heating fuel. It is safe and efficient when used properly, but it is odourless. Gas companies add tiny amounts of a strong-smelling substance to the gas before it is piped to consumers. This enables you to detect escaping gas, well before the amounts in the air become dangerous.

Water Vapour—The Cobalt Chloride Test

Water is a liquid at room temperature, but many chemical reactions produce water vapour as a product. When water vapour touches a cold surface, it condenses to liquid water. To test for the presence of water, use the following test (**Figure 4**):

- Hold a cold surface near the suspected water vapour.
- Touch a piece of blue cobalt chloride paper to any liquid that condenses.
- If the paper changes from blue to pink, water is present.

(k) Is it likely that there would be water vapour in the cylinders? Why?

Understanding Concepts

1. How would you test for the gas produced in each of the following, and what observations would you expect to make?

(a) A can of pop fizzes.

(b) A nail added to a strong acid produces a combustible gas.

(c) When potassium chlorate is heated, a gas that supports burning is produced.

2. (a) If you placed a glowing splint in a test tube full of a clear, colourless gas, and the glowing stopped, which of the gases discussed here is most likely present in the test tube?

(b) How could you confirm the identity of this gas?

Exploring

3. Gases such as those mentioned in this case study can be a safety hazard, especially if people are not aware of their properties. Research how labelling, colour-coding, and other systems are used so that gases can be handled safely. Create a poster to communicate this safety information to others.

4. The gases hydrogen and helium are both less dense than air, so either gas may be used in lighter-than-air ships. Use references to research what properties hydrogen and helium have in common, and in what ways they differ. Explain why modern blimps are filled with helium gas instead of hydrogen.

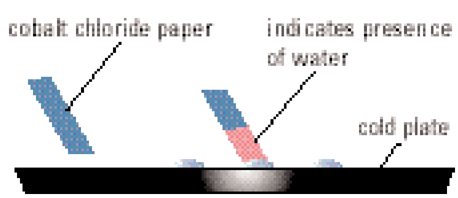


Figure 4
The cobalt chloride test for water

2.6 Investigation

SKILLS MENU
- ○ Questioning
- ● Hypothesizing
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Communicating

Identifying Mystery Gases

You have learned how to use chemical tests to detect oxygen, hydrogen, and carbon dioxide gases. In this investigation, you will observe some chemical reactions that produce gases and use the tests to infer which gas is produced.

Hydrochloric acid is corrosive. Any spills on the skin, in the eyes, or on clothing should be washed immediately with cold water. Report any spills to your teacher.

Hydrogen peroxide is poisonous and a strong irritant. Manganese dioxide is also toxic. Report any spills to your teacher.

Materials

- safety goggles
- apron
- 4 test tubes
- test-tube rack
- hydrogen peroxide (3% solution)
- manganese dioxide powder
- toothpick
- 3 wooden splints
- lighter for splints
- hydrochloric acid (5% solution)
- magnesium ribbon (3 to 5 cm long)
- tongs
- limewater solution
- sodium bicarbonate (baking soda)
- test-tube stopper

Question

Each of the following reactions produces a colourless, odourless gas. Which gas is produced in each reaction?

Hypothesis

1 After reading the Procedure, write a hypothesis to predict the gas that is produced in each reaction. (4A)

Procedure

Part 1: Hydrogen Peroxide and Manganese Dioxide

2 Put on your apron and safety goggles.

(6D) 3 Make a table to record your observations.

4 Put a clean, dry test tube in the test-tube rack. Pour about 4 mL of hydrogen peroxide solution into the test tube. Obtain a tiny amount of manganese dioxide powder on the blunt end of a toothpick. Observe the two reactants.

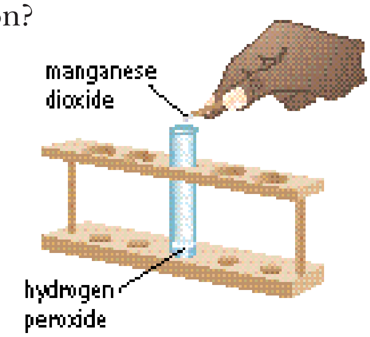
(a) Record your observations of the two substances in your table.

5 Add the manganese dioxide to the hydrogen peroxide. Allow the reaction to proceed for 15 s, noting any changes. Bring a burning splint close to the mouth of the test tube. If no reaction occurs, blow out the flame and insert the glowing splint halfway into the test tube.

(a) Record your observations of the reaction.

(b) Record the results of the splint tests.

(c) What gas was produced in the reaction?



Step 5

Part 2: Hydrochloric Acid and Magnesium

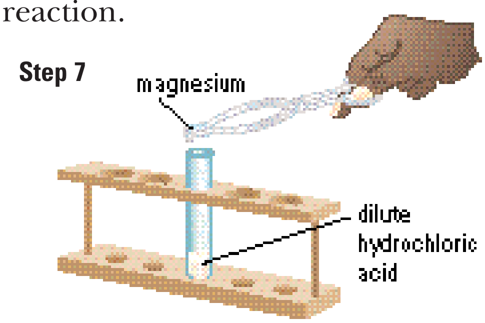
6 Put another clean, dry test tube in the rack. Carefully pour about 4 cm depth of hydrochloric acid solution into the test tube. Obtain about 3 to 5 cm of magnesium ribbon.

(a) Record your observations of the reactants.

7 Roll the magnesium into a ball and use tongs to add it carefully to the acid. Avoid splashing. Allow the reaction to proceed for 15 s, noting any changes. Bring a burning splint close to the mouth of the test tube. If no reaction occurs, blow out the flame, and insert the glowing splint halfway into the test tube.

SKILLS HANDBOOK: (4A) Asking Questions and Hypothesizing (6D) Creating Data Tables

(a) Record your observations of the reaction.



(b) Record the results of the splint tests.

(c) What gas was produced in the reaction?

Part 3: Hydrochloric Acid and Sodium Bicarbonate

8 Put two clean, dry test tubes into the rack. Pour about 4 mL of fresh limewater into the first test tube. Pour about 4 mL of hydrochloric acid into the second tube. On a piece of paper, obtain a small amount (about enough to cover a penny) of sodium bicarbonate.

(a) Record your observations of the reactants.

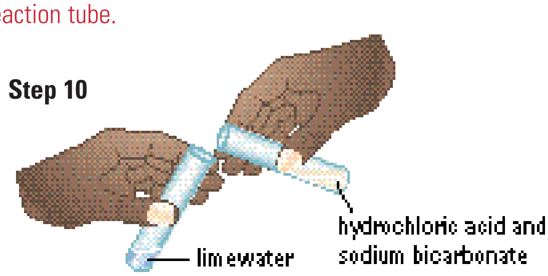
9 Slowly add the sodium bicarbonate to the test tube containing the hydrochloric acid. After about 5 s, put a burning splint close to the mouth of the test tube. If there is no reaction, blow out the splint and insert the glowing end into the tube.

(a) Record your observations.

(b) Record the result of the splint tests.

10 If the splint went out, carefully pour the product gas from the reaction tube into the limewater tube.

Be careful—do not allow any of the liquid to pour from the reaction tube.



11 Put a stopper into the limewater test tube to seal it. Mix the limewater and gas by turning the tube upside down several times.

(a) Record your observations.

(b) What gas was produced in this reaction? Do you know for certain? Explain.

12 Dispose of the mixtures in your test tubes as directed by your teacher. Clean up your work station. Wash your hands.

Analysis and Communication

13 Analyze your observations by answering the following questions:

(a) Why did you record your observations of the reactants before proceeding with each chemical reaction?

(b) What gas(es) were you testing for with the burning splint? the glowing splint?

(c) What gas were you testing for with limewater?

(d) What other indication did you have that this gas might be present?

(e) What kinds of changes occurred in each part of the investigation?

(f) What evidence do you have of each change?

14 Make a table listing the physical and chemical properties of the gases produced in this investigation.

Making Connections

1. Which gas seemed to be the most hazardous in this activity? Create a safety sheet outlining the steps you would take to handle this gas safely.

Reflecting

2. List any problems you encountered when following the procedure and suggest ways the procedure could be improved to eliminate the problems.

Chemical Symbols and Formulas

A Canadian chemical company that hopes to sell its products in Romania may need to hire an interpreter to communicate with potential customers. But the interpreter does not need to translate the formulas of any chemicals. That is because all countries use the same chemical symbols to represent elements and compounds, even when the name is different. For example, the same symbol, Fe, represents the element that people call *iron* in Canada, *fer* in France, and *fier* in Romania. A chemist in any country can identify the contents of the bottle in **Figure 1**.

Figure 1
Chemists rely on symbols and formulas to help them keep track of chemicals.

Chemical Symbols

The alchemists in the Middle Ages were among the first to recognize that it would be convenient to represent chemical substances using symbols. A circular chart of symbols, developed in China in the thirteenth century, linked the elements to a cycle of space and time. Another system of symbols of elements and compounds was devised by the English chemist, John Dalton, in 1808. He represented elements as circles with letters or designs inside them, but scientists found that Dalton's system was difficult to use. These symbols are compared in **Figure 2**.

Today, a common set of symbols for elements is accepted around the world, even though some names may vary. A **chemical symbol** is an abbreviation of the name of an element. Some symbols are shown in **Table 1**. The names and symbols for elements come from many sources.

Figure 2

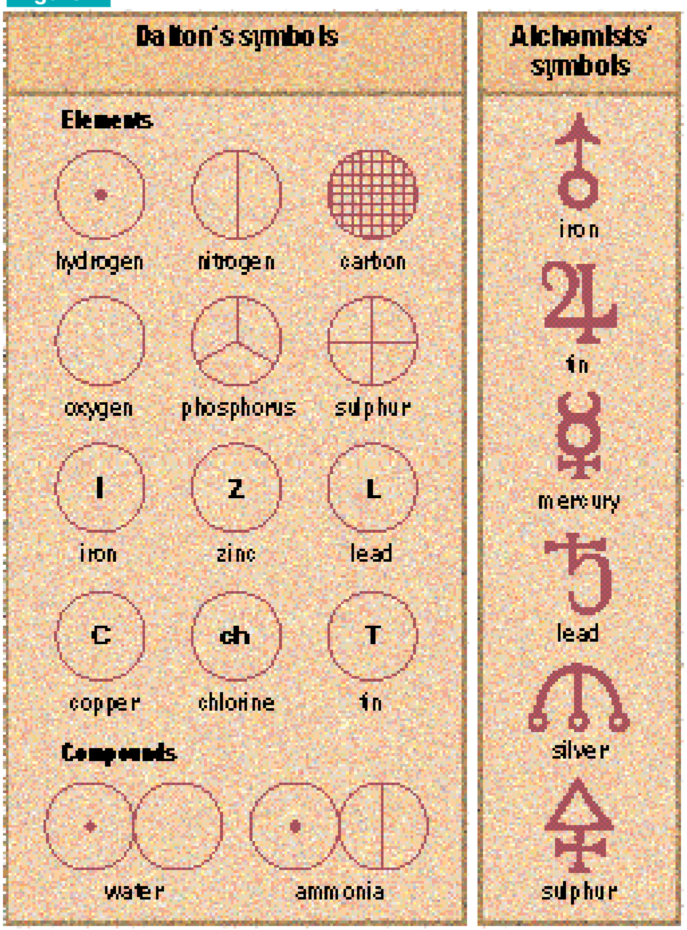


Table 1

Some Modern Symbols for Elements

aluminum	Al
bromine	Br
calcium	Ca
carbon	C
chlorine	Cl
copper	Cu
fluorine	F
gold	Au
hydrogen	H
iron	Fe
lithium	Li
magnesium	Mg
neon	Ne
nickel	Ni
nitrogen	N
oxygen	O
phosphorus	P
potassium	K
silicon	Si
silver	Ag
sodium	Na
sulfur	S

Hydrogen comes from the Greek word for "water-former." Mercury was named after a Roman god, but its symbol, Hg, comes from the Latin word *hydrargyrum* for "liquid silver." Sodium was named for sodanum, a headache remedy, and its symbol, Na, came from the Latin word *natrium*. Notice that a single-letter symbol is always capitalized, and that the first letter of a two-letter symbol is capitalized while the second letter is not.

Chemical Formulas

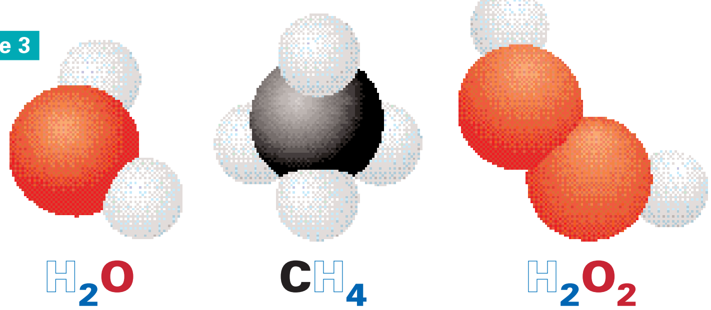
Just as single symbols are used to represent elements, combinations of these symbols are used to represent compounds. A **chemical formula** is the combination of symbols that represents a particular compound (**Table 2**). The chemical formula indicates which elements are present in the compound and in what proportion, as shown in **Figure 3**.

Table 2 **Some Examples of Chemical Formulas**

Name of substance	Formula
sodium bicarbonate (baking soda)	$NaHCO_3$
calcium carbonate (chalk)	$CaCO_3$
sodium nitrate (fertilizer)	$NaNO_3$
calcium phosphate (fertilizer)	$Ca_3(PO_4)_2$
sodium chloride (salt)	NaCl
acetylsalicylic acid (ASA or aspirin)	$C_9H_8O_4$
acetic acid (vinegar)	$C_2H_4O_2$

Each chemical symbol in a formula represents an element. If only one atom of an element is present in a compound, no number is included. If there is more than one atom of that element in the compound, the symbol is followed by a number written below the line. This number (called a *subscript*) tells how many atoms of that element are present in one molecule. For example, the formula for water—H_2O—tells you that the elements are present in the ratio of two atoms of hydrogen to one atom of oxygen. The formula for sodium bicarbonate—$NaHCO_3$—tells you that the elements are present in a ratio of one atom of sodium to one atom of hydrogen to one atom of carbon to three atoms of oxygen.

Figure 3



Understanding Concepts

1. Why are symbols useful in describing chemicals?
2. What are the symbols for the following elements?
   - **(a)** calcium
   - **(b)** iron
   - **(c)** chlorine
   - **(d)** phosphorus
   - **(e)** copper
3. Write a chemical formula for the following:
   - **(a)** a molecule of hydrogen gas that is made up of two atoms of hydrogen
   - **(b)** a molecule of propane gas that is made up of three atoms of carbon and eight atoms of hydrogen
4. For each of the compounds in **Table 2**, state the number of different elements present and the number of atoms of each element. What is the total number of atoms in each molecule?
5. Molecules of nitrous oxide, used by dentists as an anaesthetic, contain two atoms of nitrogen and one atom of oxygen. Write the chemical formula for nitrous oxide.

Making Connections

6. (3A) Research a common use for each of the following pure substances:
   - **(a)** helium gas
   - **(b)** sucrose
   - **(c)** acetone
   - **(d)** tartaric acid
   - **(e)** propane
7. Prepare a chart describing each substance above, where it is used, chemical formula, and the number of atoms in each type of element in the compound.

Challenge

What chemical symbols and formulas will you need in the challenge you have chosen?

Atoms, Molecules, and the Atmosphere

Slowly breathe in a lungful of air. As you do, think about the billions of molecules that you are inhaling. Air is mostly nitrogen and oxygen, but you are breathing in a mixture that contains other gases as well. In this section, you will learn about some of the gases found in air (**Figure 1**).

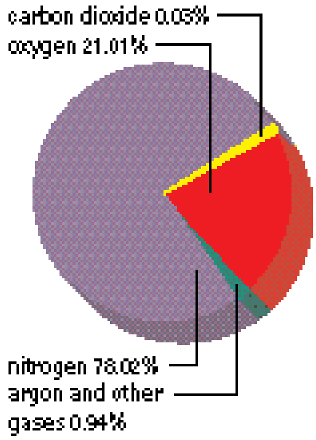


Figure 1
Gases in Earth's atmosphere

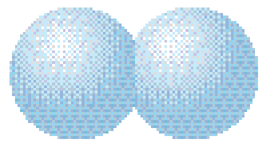
Nitrogen (N_2)

Two atoms of the element nitrogen combine to form a molecule of the gas nitrogen (**Figure 2a**). Nitrogen makes up approximately 80% of the atmosphere. It is not very reactive, which means we can breathe it safely without causing chemical changes in our lungs. However, under certain conditions, such as in a car engine, nitrogen gas reacts with oxygen to produce nitrogen dioxide (NO_2), a very toxic red-brown gas. Nitrogen dioxide in low concentrations causes the yellow haze of air pollution you may have seen in some cities.

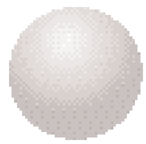
Argon (Ar)

Argon atoms do not combine with other atoms to form molecules. As a result, argon gas is composed of single atoms of argon (**Figure 2b**). Almost all of the argon in the atmosphere has leaked out from inside the Earth. This gas is completely harmless and quite useful, especially for filling electric light bulbs and fluorescent tubes.

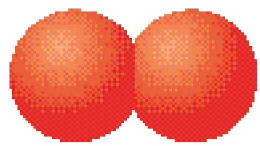
Figure 2



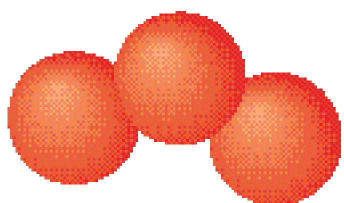
a nitrogen molecule



b argon atom



c oxygen molecule



d ozone molecule

Oxygen (O_2 and O_3)

Atoms of the element oxygen can combine to form two different molecules. The more common of these contains two atoms of oxygen. This is the form that makes up about 21% of the air you breathe and is what we commonly call oxygen gas (**Figure 2c**). Almost all organisms need oxygen to survive, as it is used in cellular respiration.

The less common oxygen molecule, called ozone (O_3), contains three atoms of oxygen (**Figure 2d**). Ozone is formed naturally in the upper layers of the atmosphere. It is very important to life on Earth because it absorbs most of the ultraviolet radiation from the Sun. If all of this radiation reached the surface of Earth, it would harm all living things exposed to it.

Unfortunately, air pollutants such as chlorofluorocarbons (CFCs) have been destroying the ozone layer at an alarming rate. Worldwide measures to stop this pollution have begun, but it will be years before the risk to the ozone layer is past. Because of damage to the ozone layer, more ultraviolet light is now reaching Earth's surface. Ultraviolet light damages skin. As a result, scientists now encourage people to protect their skin with clothing or sunscreen when they go out in the sunshine.

While the layer of ozone several kilometres up in the upper atmosphere is necessary for life, ozone at ground level is hazardous to living things. It can damage plants and causes respiratory problems in people and other animals because it reacts with lung tissue. It is produced when certain gases, produced mainly by vehicles, react with each other and with the more common O_2 molecule.

Carbon Dioxide (CO_2) and Carbon Monoxide (CO)

Two atmospheric gases contain only atoms of carbon and oxygen (**Figure 3**). One, carbon dioxide, is necessary for life on Earth. The other, carbon monoxide, is extremely poisonous to vertebrate animals.

When fossil fuels burn, the two main products are carbon dioxide and water. However, if there is a shortage of oxygen during combustion, carbon monoxide is also produced. How can the supply of oxygen be limited? If you burn propane indoors, for instance in a gas barbecue or heater, you might use up most of the oxygen from the air in the room. The same might happen if you run an automobile engine in a closed garage.

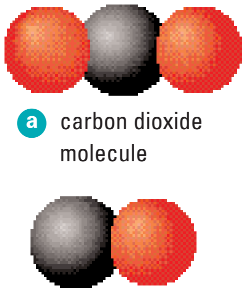
The carbon monoxide molecule (CO) is similar to the oxygen molecule (O_2). This similarity makes carbon monoxide poisonous. When carbon monoxide molecules enter the lungs, the body's red blood cells treat CO molecules as if they were O_2 molecules. Instead of oxygen, the cells carry CO through the body. The cells of the body are starved of the oxygen they need. Death can result.

In order to prevent accidental fatalities due to CO poisoning, many municipalities are passing bylaws that require CO detectors in every home.

Did You Know

A sign of carbon monoxide poisoning is that the skin turns redder than normal.

Figure 3



(a) carbon dioxide molecule

(b) carbon monoxide molecule

Try This: What Is Air?

Is air an element or a mixture of several substances? Moisten a piece of steel wool. Drop it into an empty jar and then invert the jar over a pan of water. Mark the liquid level in the jar. Leave the jar for 24 h. Mark the liquid level again. What has happened to the air in the jar? Test the jar for oxygen using a glowing splint. What do your observations suggest?

Understanding Concepts

1. Identify (as elements or compounds) each of the following molecules:
   - **(a)** carbon dioxide
   - **(b)** carbon monoxide
   - **(c)** oxygen
   - **(d)** ozone
   - **(e)** nitrogen
2. Carbon dioxide and carbon monoxide contain only carbon and oxygen. Which of these molecules is dangerous to breathe? Why is it dangerous?
3. **(a)** How is ozone formed at ground level?
   (b) What effect does this ozone have on living things?
4. If humans and all other animals are constantly producing carbon dioxide, and it is a fairly stable gas, why does it make up only a tiny percentage of Earth's atmosphere?

Exploring

5. People with some diseases, such as emphysema, are given air with an increased percentage of oxygen. Find out what proportion of oxygen is in this air. What safety precautions would you advise for people near the patient? Create an information brochure.
6. Visit an automotive service centre.
   - **(a)** What device is used to prevent any buildup of carbon monoxide inside the garage?
   - **(b)** How is fresh air brought into the garage?
   - **(c)** How would fresh air reduce the amount of carbon monoxide produced by cars?

Reflecting

7. Would you make any changes to the list of substances that you produced at the beginning of the chapter?

Building Models of Molecules

What do a toy car and the particle theory of matter have in common? Both are models. **Models** can be mental pictures, diagrams, or three-dimensional constructions. The particle, model helps us to understand how matter behaves, just as a model car helps a child to understand how an automobile works.

For example, engineers test models of new jet aircraft in wind tunnels to find out how well the design operates at supersonic speeds. Architects and designers make models of floor plans to design efficient buildings. Such three-dimensional models may be held together with nails or glue, or drawn on a computer screen.

In the same way, scientists make models of molecules in order to understand them and to predict how the molecules will behave (**Figures 1**, **2a**, **4a**). In these models, the atoms are held together by connections called **bonds**. The connections represent electrons that "glue" or bond the atoms together. The molecules can also be represented by drawings on paper called **structural diagrams**. In these diagrams (**Figures 2b**, **3**, **4b**), each atom is represented by its chemical symbol and each bond is represented by a straight line drawn between the symbols.

Each kind of atom generally forms a set number of bonds. For example, each hydrogen atom forms only one bond. Each oxygen atom forms two bonds: either two single bonds with two other atoms, or one double bond with one other atom. In this activity, you will build models of some common molecules and see how bonds can link atoms in molecules.

Materials

- molecular model kit, made up of "atoms" and connectors (the atoms may be represented by balls, soaked chickpeas, or small coloured marshmallows; connectors may be sticks, springs, or toothpicks)
- coloured pens

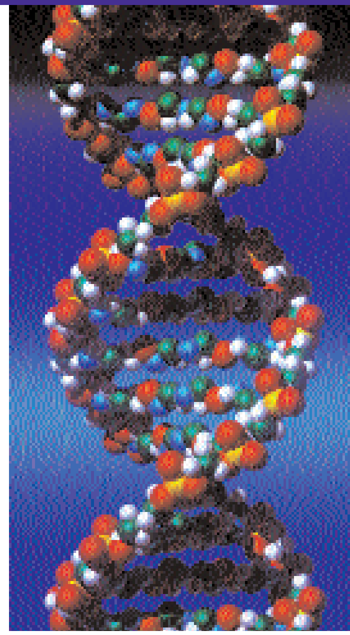


Figure 1
The structure of the DNA (deoxyribonucleic acid) molecule, which carries our genetic characteristics, was discovered by Francis Crick and James Watson. They figured out the structure by working with molecular models similar to yours.

Figure 2
Rubbing alcohol is actually named isopropanol. It can be represented by (a) building a ball-and-stick model or by (b) drawing a structural diagram.

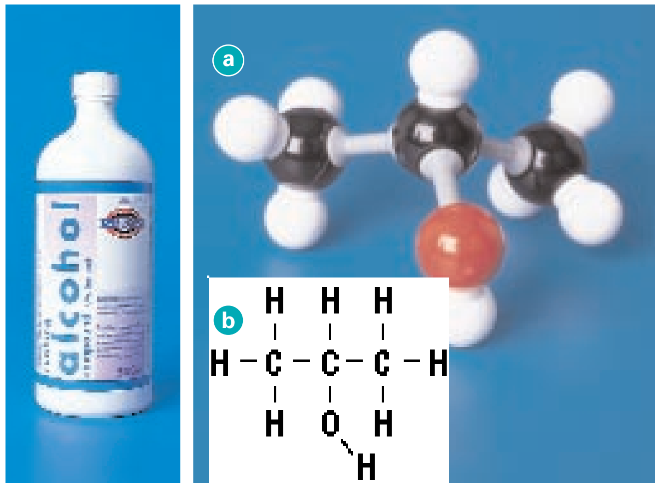
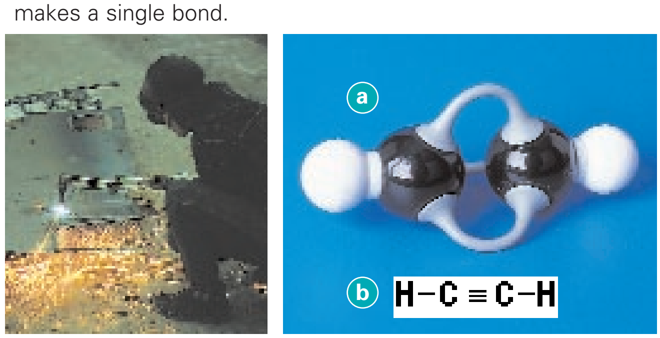


Figure 3
Structural diagrams of oxygen and water

Figure 4
The molecule acetylene, C_2H_2, is used to melt and join metals together. Note that each carbon atom still makes a total of four bonds, but one bond is a triple bond. Each hydrogen bond makes a single bond.



Procedure

1 Examine the model kit that you have been provided. If you have a ball-and-stick kit, you will notice that different atoms have different numbers of holes to represent the number of connections that they must make with other atoms. The number of connections for each atom is summarized in **Table 1**.

Table 1

Atom	Number of Connections per Atom
hydrogen	one
oxygen	two
nitrogen	three
carbon	four

2 Make a model of hydrogen gas by connecting two atoms of hydrogen with a connector.

(a) Draw a structural diagram of the molecule. Write the name and formula, H_2, beside your diagram.

3 Make a model of oxygen gas by joining two atoms of oxygen with two connectors, to represent the two connections that each oxygen atom usually makes.

(a) Draw a structural diagram of the model. Write the name and formula, O_2, beside your diagram.

4 Make models of the following molecules: nitrogen (N_2), ammonia (NH_3), methane (CH_4), water (H_2O), ethene (C_2H_4), and carbon dioxide (CO_2). Make sure that each atom makes the correct number of connections.

(a) Draw structural diagrams of the models. Write the formula beside each diagram.

5 If you have time, obtain three carbons and eight hydrogens. See how many different molecules you can make with some or all of the atoms. Remember how many connections each atom can have.

(a) Draw structural diagrams of the models. Write the formula beside each diagram.

Understanding Concepts

1. Why do chemists find making models of molecules useful?

2. Explain, with an example for each, how oxygen can make two single bonds with other atoms or one double bond.

3. Compare the advantages and disadvantages of representing molecules using space-filled models or structural diagrams.

4. Usually, more bonds between two atoms make a stronger connection. Which of all the molecules you made probably has the strongest bond?

5. Sulfur dioxide (SO_2) is an air pollutant that is one of the causes of acid rain. In this molecule, sulfur makes four bonds. Draw a structural diagram of the molecule.

6. Try to make molecules and draw structural diagrams of the following molecules: formaldehyde (H_2CO, used in preserving biological specimens), methanol (H_3COH, used as a de-icer), dimethyl ether (H_3COCH_3, used in refrigeration).

Exploring

7. Use a molecular computer program to build models of the molecules in this activity. Which type of model do you think is more useful? Explain your answer.

Reflecting

8. All simple models have limitations. Have you encountered any substances in this unit for which you cannot construct models using the number of bonds described above?

Challenge

What are some other examples of models? Why do people find models useful? How can you use models in the challenge you have chosen?

2.10

Names and Formulas for Compounds

You have learned that chemical formulas can be written to represent compounds. But how do we know the proportions of each element? For example, we may know that table salt, sodium chloride, contains the elements sodium (Na) and chlorine (Cl), but is the compound NaCl or $NaCl_2$ or Na_2Cl or some other formula? The key is in knowing how atoms combine. Some of the basic principles are summarized in **Table 1**.

Table 1 How Elements Combine

Rule 1: Metals combine with nonmetals in many compounds.
Rule 2: Write the name of the metal first and the nonmetal second.
Rule 3: Change the ending of the nonmetal to "ide."
Rule 4: Each atom has its own combining capacity.
Rule 5: Atoms combine so that each can fill its combining capacity.

Combining Capacity

After performing many experiments, scientists discovered patterns in the ability of different elements to combine to form compounds. They analyzed how many atoms of each element were present in a molecule of each of the compounds. This ability to combine with other elements is called the **combining capacity**. Combining capacity is similar to the number of connections that an atom can make.

Scientists have given a numerical value to the combining capacity of each metal or nonmetal to explain the compounds that they form. For example, both sodium and chlorine were assigned a combining capacity of 1. Sodium chloride has the formula NaCl: it contains one atom of sodium for each atom of chlorine. Calcium chloride has been found experimentally to have the formula $CaCl_2$. Each of the chlorine atoms has a combining capacity of 1, so the combining capacity of calcium must be 2.

You can better understand this idea by thinking of the work you have done with models. Aluminum has a combining capacity of 3. That is, it needs to make three connections. Each chlorine atom only needs to make one connection. Thus, when aluminum combines with chlorine, the resulting compound is aluminum chloride ($AlCl_3$), a compound used as an antiperspirant.

Tables 2 and **3** list the combining capacities of metals and nonmetals. You can use these numbers to predict the chemical formulas of the compounds that such elements form. Sodium bromide (**Figure 1a**), used in photography, is made up of sodium and bromine. Each of these elements has a combining capacity of 1. Thus, the chemical formula is NaBr.

The compound calcium oxide (**Figure 1b**), or lime, is made up of the elements calcium and oxygen. For both of these elements, the

Did You Know?

Somebody who gets a lot of public attention is described as being "in the limelight." This expression refers to calcium oxide or lime, which was used in stage shows decades ago to produce a brilliant white light for footlights.

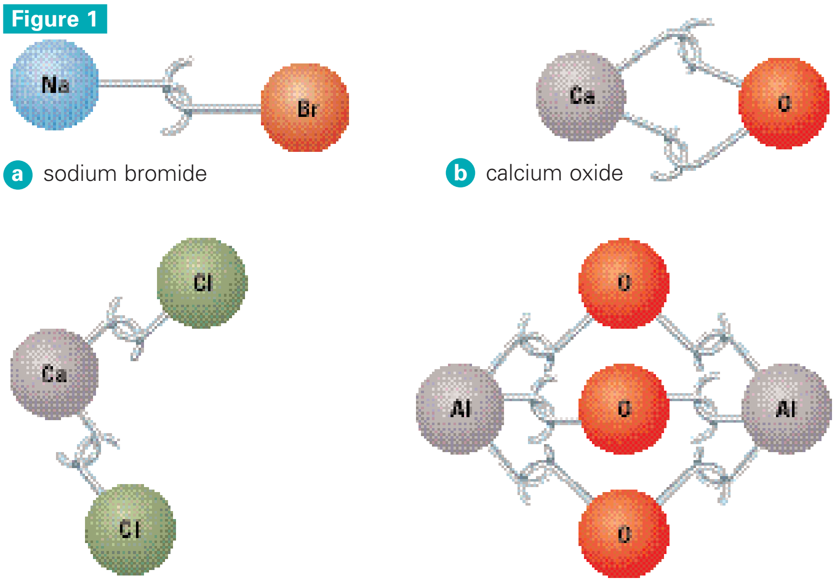
Table 2 Combining Capacities of Some Metals

Element	Symbol	Combining capacity
aluminum	Al	3
barium	Ba	2
calcium	Ca	2
magnesium	Mg	2
potassium	K	1
silver	Ag	1
sodium	Na	1
zinc	Zn	2

Table 3 Combining Capacities of Some Nonmetals

Element	Symbol	Combining capacity	Combined name
bromine	Br	1	bromide
chlorine	Cl	1	chloride
fluorine	F	1	fluoride
iodine	I	1	iodide
oxygen	O	2	oxide
sulfur	S	2	sulfide

Figure 1



(a) sodium bromide

(b) calcium oxide

(c) calcium chloride

(d) aluminum oxide

combining capacity is 2. Thus, one atom of calcium can combine with one atom of oxygen. The chemical formula of calcium oxide is CaO.

If the combining capacities of the elements are different, then the numbers of atoms are also different. For example, calcium has a combining capacity of 2, and chlorine has a combining capacity of 1. Therefore, in the compound calcium chloride (**Figure 1c**), one atom of calcium combines with two atoms of chlorine. The chemical formula of calcium chloride is $CaCl_2$.

Aluminum has a combining capacity of 3 and oxygen has a combining capacity of 2. Therefore, in the compound aluminum oxide (**Figure 1d**), two aluminum atoms must combine with three oxygen atoms. The chemical formula of aluminum oxide is Al_2O_3.

Metals with More Than One Combining Capacity

Some metals have different combining capacities in different compounds. You can see in **Table 4** that lead, copper, tin, and iron all have more than one possible combining capacity. In naming compounds of these metals, their combining capacity is shown in Roman numerals following the name of the metal. For example, there is a compound named iron(II) oxide ("iron-two-oxide") and another compound named iron(III) oxide ("iron-three-oxide"). Similarly, there are two compounds of copper and oxygen.

Table 4

Some Elements That Have More Than One Combining Capacity

Element	Symbol	Combining capacity
copper	Cu	1, 2
iron	Fe	2, 3
lead	Pb	2, 4
tin	Sn	2, 4

Understanding Concepts

1. What does the term combining capacity mean?

2. Elements can be classified as metals or nonmetals. Which elements change their names when they form compounds? Explain, with an example.

3. What are the names of the following compounds?

(a) $CaCl_2$, used in bleaching powder and for melting ice

(b) CaO, used in plaster for construction

(c) CuCl, used to make red-coloured glass

(d) KI, added to "iodized" table salt to prevent a condition called goitre

(e) AgCl, used in photography

4. Use the values for combining capacities shown in the tables to write chemical formulas and draw "hook-and-ball" diagrams for:

(a) sodium fluoride

(b) magnesium fluoride

(c) potassium bromide

(d) zinc oxide

(e) silver oxide

(f) aluminum fluoride

(g) aluminum sulfide

5. **(a)** Tin forms two different compounds with chlorine: $SnCl_2$ and $SnCl_4$. Build a simple model of each compound showing tin's combining capacity.

(b) Give the names and formulas of the two compounds that tin could form with oxygen.

Exploring

6. How do sodium chloride and calcium chloride melt ice? What are the advantages and disadvantages of each compound? Why is urea sometimes preferred to either of these compounds?

2.11

Plant Nutrients and Fertilizers

A farmer looks at a vegetable crop about to be harvested (**Figure 1**). The growing season has been a good one with lots of sunlight, warm weather, and rain. But the farmer has made some deliberate and important decisions to increase yield and make the plants as healthy as possible. The plants grow in soil that has been carefully enriched by the addition of chemical substances. These substances added to the soil to help plants to grow are called **fertilizers**. Why have fertilizers been added? What chemicals are in each type of fertilizer? How does the farmer choose which kind of fertilizer to use?

Figure 1
Farmers need to make decisions about how to increase the amount of vegetables or fruit that their fields can produce.

What Plants Need from Soil

Plants take in and process chemical compounds called **nutrients** in order to grow. The plants take in water through the roots, and carbon dioxide from the air through openings in the leaves. Using energy from the Sun, they combine these compounds in a chemical change called **photosynthesis** to produce sugars and oxygen gas. This change can be represented by the word equation:

$$\text{carbon dioxide + water} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{sugars + oxygen}$$

Table 1 Nutrient Elements Essential for Plants

Elements Needed...		
...in large amounts	**...in medium amounts**	**...in tiny amounts**
carbon	calcium	iron
hydrogen	sulfur	manganese
oxygen	magnesium	boron
nitrogen	copper	—
phosphorus	zinc	—
potassium	chlorine	—
—	cobalt	—

However, **Table 1** shows that all living things need elements other than carbon, oxygen, and hydrogen. These additional nutrients are dissolved in the water that the plant takes in through its roots. Some of the nutrients come from minerals in the soil and some from decomposing plant and animal matter. As the plants grow, they use more and more of these nutrients and the soil becomes less rich in the elements that plants need. Nutrients can also be lost as rainwater moves down through the soil to the water table, taking water-soluble nutrients with it.

The farmer must then decide how to replace these elements. One method is to remove just the useful part of the plant, leaving most of the plant to be ploughed back into the soil. Corn is often harvested in this way. Another choice is to add fertilizers to the soil to put back the elements that plants need (**Figure 2**). The fertilizers can be either chemical or organic. Don't be confused by the names: organic fertilizers have some of the same chemicals as chemical fertilizers, but they are produced naturally.

Figure 2
The crop on the left was given chemical fertilizer. The one on the right was not fertilized.

Chemical Fertilizers

The most important nutrient elements, after carbon, hydrogen, and oxygen, are nitrogen (N), phosphorus (P), and potassium (K) (**Figure 3**). But these elements have to be absorbed as compounds, not as elements. In a chemical reaction called nitrogen fixation, a few plants are able to change nitrogen from the air (N_2) into compounds called nitrates (for example, ammonium nitrate or NH_4NO_3). The nitrates can dissolve in water and be absorbed through the roots. Plants absorb phosphorus in the form of compounds called phosphates (for example, sodium phosphate or Na_3PO_4). Potassium forms many compounds that are soluble in water. It can even form compounds with nitrate or phosphate. Potassium phosphate is K_3PO_4 and potassium nitrate is KNO_3. Other sources of nutrients are summarized in **Table 2**.

Chemical industries mix these compounds together in very precise amounts depending on the particular crop or the time of year that the fertilizer will be spread on the fields. These three nutrients are so important that, typically, fertilizers used on the farm or in the home garden are described by three numbers corresponding to the percentages of these three elements in the mixture. For example, 15-10-5 fertilizer contains 15% nitrogen (as nitrate), 10% phosphorus (as phosphate), and 5% potassium.

SKILLS HANDBOOK: (8A) Reporting Your Work

Figure 3

The number rating on a bag of fertilizer indicates, in order, the ratios of nitrogen (as nitrate), phosphorus (as phosphate), and potassium in the mixture.

Table 2

Some Chemical Sources for Major Plant Nutrients

Element	Source
carbon	carbon dioxide (CO_2)
hydrogen	water (H_2O)
oxygen	water (H_2O)
nitrogen	ammonia (NH_3) ammonium nitrate (NH_4NO_3) urea (N_2H_4CO)
phosphorus	calcium dihydrogen phosphate ($Ca(H_2PO_4)_2$)
potassium	potassium chloride (KCl)

Try This — Read the Labels (8A)

Visit a garden supply centre, and note the information and instructions on the packaging for (a) at least three kinds of fertilizer that are not labelled "organic," and (b) at least one fertilizer that is labelled "organic." Select a label that has a high percentage of nitrogen and note which plants this fertilizer is recommended for. Repeat this step, looking for a fertilizer high in phosphorus. Note what other nutrients besides nitrogen (nitrate), phosphorus (phosphate), and potassium are mentioned on the labels. Note what the organic fertilizers are made from.

Organic or Chemical Farming?

When the farmer wants to add fertilizers to the soil, there are two choices: natural or chemical. The farmer can choose a natural fertilizer, such as manure or compost. Such fertilizers are often called "organic" fertilizers, because they are natural materials produced by living organisms. Many people favour this kind of fertilizer because it recycles materials that otherwise might be wasted. Such fertilizers can also save energy because the manure or compost may be produced on or near the farm and will probably not require transportation over long distances. A disadvantage of using natural fertilizers, apart from a rather powerful smell, is that farmers cannot know the exact amounts of nutrients that they are adding. Very large farms also may have difficulty obtaining enough natural fertilizer for their needs.

Organic farmers not only use natural fertilizers, but also avoid chemical pesticides and herbicides. Still, most farmers choose chemical fertilizers that are produced by industries. They can include exact amounts of any individual nutrient, so that the farmer can deliver just the right mixture of nutrients to a particular field or crop. These fertilizers are often packaged conveniently, and are so concentrated that a small amount of a chemical fertilizer can deliver a large amount of nutrients. Chemical fertilizers can also be mixed with water and delivered through pipes or sprayed over large areas of fields (**Figure 4**).

Figure 4

Fertilizer spreaders are used by farmers to add nutrient elements to the soil.

Table 3

Percentages of Nutrients Removed by Different Crops

Nutrient Element	N	P	K	Ca	Mg	S
wheat (for bread)	1.7	0.3	0.5	0.05	0.1	0.1
grass (for cattle feed)	1.4	0.3	1.5	0.3	0.1	0.1
potato	0.3	0.04	0.5	0.02	0.02	0.03

Understanding Concepts

1. What elements are needed in large amounts by plants?
2. What are the major natural sources of nutrients for plants?
3. Use **Table 2** to state what types of atoms and how many of each are found in a molecule of
   - **(a)** urea
   - **(b)** calcium dihydrogen phosphate

Making Connections

4. Plants take in nitrogen, phosphorus, and other atoms through their roots and use the atoms to build roots, stems, and leaves. The following questions are based on **Table 3**, which shows the percentage of nutrients removed from the soil in a growing season by different crops:
   - **(a)** Which element is most used up as crops grow?
   - **(b)** Which crop uses potassium (K) at the greatest rate?
   - **(c)** Which crop would require a fertilizer mix with the most calcium (Ca)?

Exploring

5. Find out from a fertilizer supplier which fertilizer mixtures are used at different times of the year and why. For example, one mixture might be used in the fall to promote strong root growth to help the plant survive the winter.
6. 3B Consider the following statement: "Chemical fertilizers are preferable to organic fertilizers." Decide whether you agree or disagree with this statement and write a persuasive essay putting together as many arguments as possible to support your point of view. Use arguments and evidence from this text or from research. Consider examples from large- and small-scale farming, city parks, home gardening, or any other situation where fertilizers are used.

SKILLS HANDBOOK: 3B Critical Thinking

Career Profile

Science Teacher

Anya Martin is a high school science teacher whose aim is not to produce scientists, but to produce science-minded people.

Her parents encouraged her interest in the world around her with frequent nature walks and family outings to the Ontario Science Centre: a great place for children with a love of discovery. She also attended many weekend environmental workshops for young people.

"Include science in all aspects of your life. It's there anyway."

Throughout high school her interest in science and the environment grew, leading Martin to enroll in the University of Toronto's Biology program. She followed this up with a teaching degree in Science and Environmental Science and has taught in Toronto-area high schools ever since.

How does Martin share her enthusiasm with her students? She tries to communicate her excitement and interest in the events—past, present, and future—that shape our view of how the world works. To make science more real and immediate, she relates it to our everyday lives. In chemistry, for example, she focuses on familiar reactions—"kitchen chemistry"—and helps her students realize that they already know a lot about the subject; they just need a little help interpreting what they see all around them.

She is fascinated by the fast-paced changes in so many areas of science but is concerned that we may be ignoring ethical issues in our rush toward achieving what used to be impossible. "Perhaps we should slow down; take control of the changes and developments," she suggests. "Students need to be comfortable with science; to understand it well enough to be able to participate in the debates on where science should go from here."

Martin advises students to seize the opportunity to study science. It feels good to be able to say "I know what that means!" Take that science class and enjoy yourself with it!

Exploring

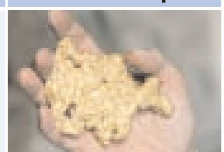
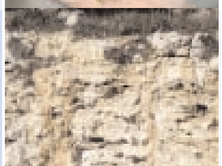
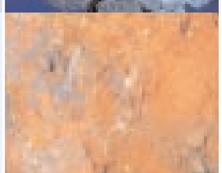
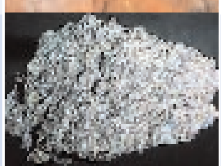
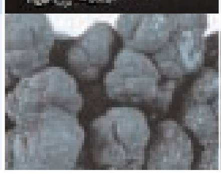
1. Martin has certain characteristics that make her well-suited to her profession. What are they?
2. Make a chart to illustrate the educational and life choices you would have to make if you wanted to become a science teacher.
3. Martin is concerned about the ethics of some recent science developments. List four aspects of science that have some ethical questions associated with them.

2.12

Metal Extraction and Refining in Canada

Think of all the materials around you that are made of metals. Very few of these metals occur naturally as elements. Gold nuggets are still panned from stream beds, and silver and copper are often found as elements. But most metals in nature are found in the form of compounds because they combine very readily with oxygen, sulfur, or other elements. These compounds are called **minerals** (**Table 1**). For example, most iron mines produce the compound iron oxide (Fe_3O_4) rather than the element iron. However, minerals are rarely found as pure substances in the ground. They are mixed with many less useful compounds in rocks called **ore** (**Figure 1**). How are minerals separated from the rest of the ore? How are elemental metals produced from the mineral compounds?

Table 1 **Types of Minerals**

Element	Mineral Name	Mineral Formula	Mineral Sample
silver, gold, platinum	silver, gold, platinum	Ag, Au, Pt	
calcium	limestone	$CaCO_3$	
aluminum	bauxite	Al_2O_3	
lead	galena	PbS	
mercury	cinnabar	HgS	
iron	magnetite	Fe_3O_4	
copper	malachite	$CuCO_3$	

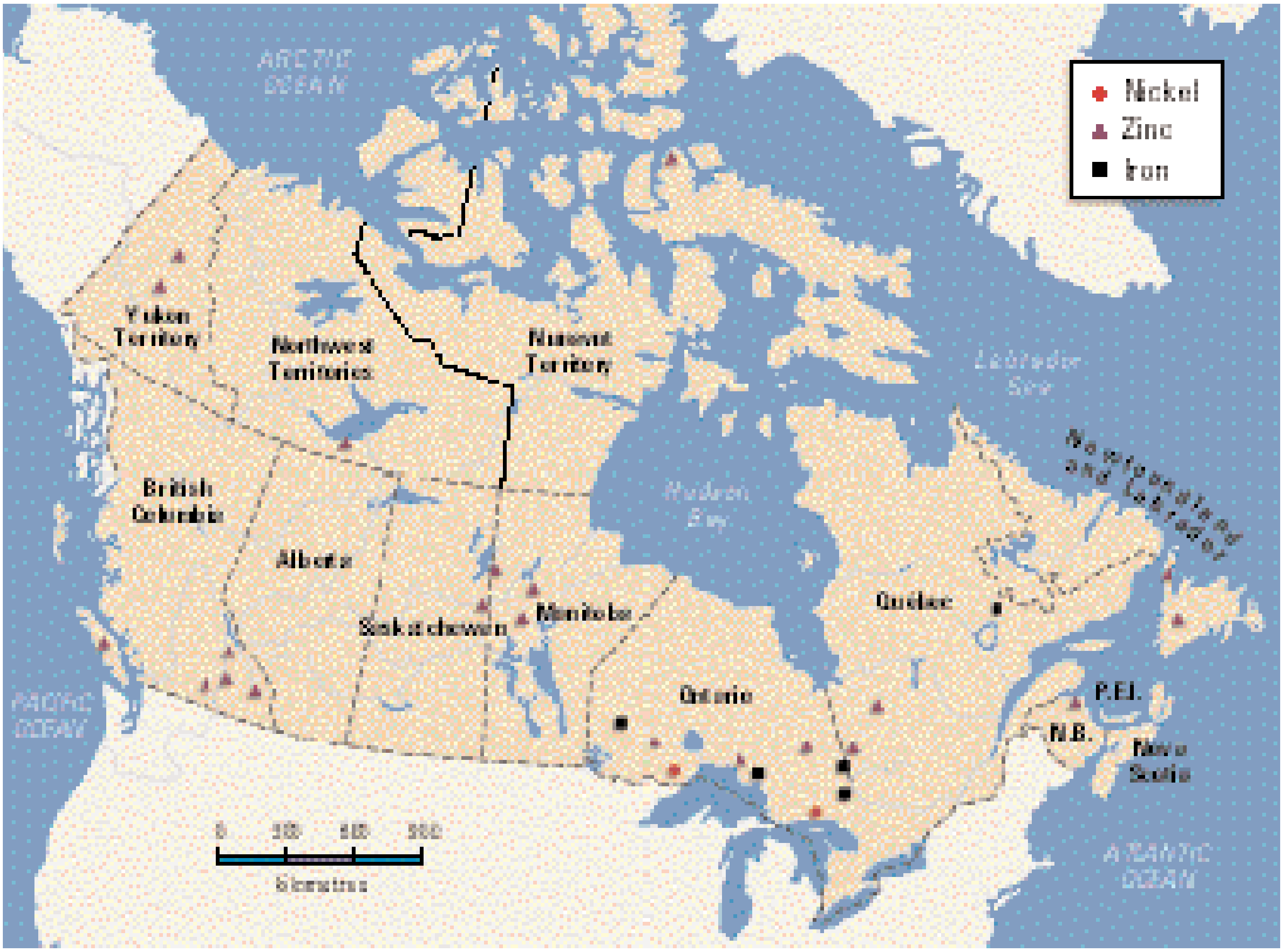


Figure 1

Mining of metals occurs across Canada. Some of the most important metals produced in Ontario are nickel, zinc, and iron.

Metals in History

In prehistoric times, people perhaps learned by accident how to make metals from minerals. Previously, they used stone and bone tools to plant crops, hunt animals, and chop wood. About 3500 B.C., people learned how to smelt copper—that is, to react the copper and draw it out of the other materials in the copper ore in a chemical change. Centuries later, when copper and tin were mixed together in the process, the result was a much harder, more flexible metal alloy called bronze. Over the centuries, other "new" metals were produced, each having new advantages of hardness, durability, or flexibility (**Figure 2**).

Figure 2

This furnace, called a *tatara*, is the type used to make Samurai swords. Making steel was a complex technology developed early in Japan's history. At a time when there was no written language, the process of sword making became part of a ritual, which was passed from generation to generation.

Mining and Metallurgy

Today metal production is one of the most important natural resource industries in Canada. Mining and metal refining employ thousands of people across the country and contribute billions of dollars to the economy (**Figure 3**). Canada is the world's top exporter of minerals such as iron, nickel, copper, aluminum, and zinc.

The technology of separating a metal from its ore is called **metallurgy** (**Figure 4**). It requires a knowledge of both the physical and chemical properties of minerals and metals.

Figure 3

Large ore carriers are used to remove nickel ore from this mine in Sudbury, Ontario, for further processing.

Preparing the ore involves crushing the rocks and separating the desired mineral from waste materials, often clay and other minerals. Magnets are used to separate the magnetic elements, such as iron. Gold and silver are dissolved in mercury to form alloys, which can be separated from the rocks.

Producing the metal from its mineral involves chemical changes. In iron production, the mineral iron oxide reacts with carbon monoxide to produce iron metal. This can be represented by the word equation:

iron oxide + carbon monoxide → iron + carbon dioxide

Metal production has many environmental implications. For example, the extraction of lead from galena involves two stages. The first step is to change lead sulfide into lead oxide. A second easier chemical reaction changes lead sulfide to pure lead. An environmental problem lies in the first reaction, which is shown by the word equation:

lead sulfide + oxygen → lead oxide + sulfur dioxide

Sulfur dioxide is one of the main sources of acid rain. Industries try to remove this gas from smokestacks in a process called scrubbing, instead of releasing it into the atmosphere.

Purifying the metal involves removing any impurities from the metal. The metal can be distilled if it has a low boiling point. (The metal is heated to evaporate it away from the impurities.) Electricity can also be used in a process similar to the electrolysis of water.

Did You Know?

How was the first metal produced? Historians speculate that herders warming themselves beside a firepit made from malachite rocks might have noticed a reddish liquid seeping out of the rocks. The combination of fiery heat and carbon from the burning wood could have freed copper metal from the malachite. When cold, the red liquid solidified, and could be made into different things.

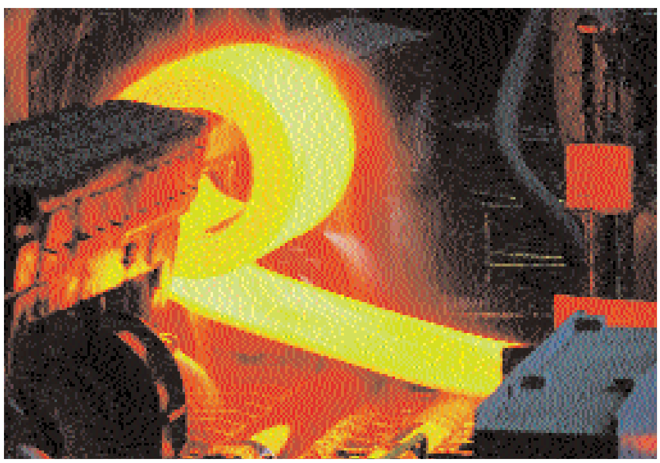


Figure 4

Iron metal is produced at temperatures of over 1000°C in a blast furnace.

Using Metals to Make Alloys

Many metals are more useful if they are melted and mixed with other metals to form alloys (**Table 2**). Changing the composition of the mixture, even by tiny fractions, can have dramatic effects on the properties of the alloy. For example, hundreds of different mixtures of elements are used to produce various steels.

Solder is an alloy of lead and tin that melts at a lower temperature than either of the pure metals (**Figure 5**). Electronic technologists, plumbers, and electricians melt it to join metal pieces such as electronic components, pipes, or wires.

Table 2 Examples of Alloys of Steel

Type of Steel	Composition	Uses
stainless steel	70% iron, 20% chromium, 10% nickel	cutlery
plain steel	98% iron, 2% carbon	car bodies
high-strength steel	95% iron, 2% manganese, 1% carbon, 1% chromium, 1% other metals	steam turbines

Figure 5

A technologist uses a soldering iron to align protective coatings over circuits in the manufacture of flexible, electronic circuits.

Understanding Concepts

1. Design a concept map on mining. Begin with (9D) the word "element."
2. Using **Table 1**, identify the elements in each of the following minerals: (a) bauxite, (b) cinnabar, and (c) galena.
3. What are the chemical symbols for the metals that can be obtained from the following minerals: (a) limestone, (b) magnetite, and (c) malachite?
4. **(a)** What are three steps in obtaining a metal from its ore?
   (b) Which step(s) include a (i) physical change? (ii) chemical change?
5. Using the word equations in this section as a guide, complete these word equations for metal production:
   (a) lead oxide + carbon monoxide → lead + ?
   (b) zinc sulfide + oxygen → ? + sulfur dioxide

Making Connections

6. What practical advantages would the discovery of bronze have given people?
7. Why are metals mixed together to form alloys? What are the environmental implications?

Exploring

8. Research the methods used to obtain one of the following elements in Canada: nickel, copper, iron, zinc, gold, silver, lead, or uranium. Use a variety of sources and media, and prepare a presentation.
9. Recycling of metals is an issue that presents many questions. What metals are recycled in Canada? What elements are in short supply and should be recycled? What problems are associated with recycling? How does the cost of recycling compare with the cost of producing a metal "from the ground"? What pollution issues are addressed by recycling? Develop your own research project on some aspect of metal production and recycling.
10. A car exhaust pipe made of stainless steel corrodes much more slowly than one made from normal steel. However, it costs more than twice as much as a normal exhaust pipe and is more difficult to attach to other metal components. How would you decide whether or not to use a stainless steel exhaust pipe? What factors would you consider? If you can, talk to your local muffler repair shop about these questions and report your findings.

SKILLS HANDBOOK: (9D) Concept Mapping

A Mine in the Community

In many communities, people are faced with making decisions that balance their need for the products provided by industries with their concerns about the environment. In this activity, you will use a graphic organizer called a "P-M-I" to consider the good and bad points of a project to build a mine in a northern Ontario community called Pemigon. "P" stands for "plus," "M" stands for "minus," and "I" stands for "interesting question."

Figure 1

Mining Council Stresses Benefits

Chris Beany, Information Officer with the Pemigon Mining Council, spoke yesterday to the Chamber of Commerce stressing the benefits that copper mining would bring to the community. "Mining has long been one of this province's most important natural resource industries. We need the minerals that mines provide to make the metal products that we use every day. Over 30 000 jobs in the province depend directly on mining today, and a new copper mine would provide more jobs in this area, too. The people who live here would have more money to spend, so local businesses—everything from hardware stores to car dealerships to house builders—would benefit. Mining companies donate to charities, hospitals, and universities; they pay taxes that support the services that governments provide; and the profits that we earn by selling copper to other countries helps Canada grow. Mining companies today are also very careful to protect the environment. Pemigon and Canada both need this new copper mine."

Figure 2

ENVIRONMENTAL GROUP Opposes Mine

Alex Green, spokesperson for P.A.M.P. (People Against Mining in Pemigon), spoke yesterday to a group of citizens about environmental damage that would be caused by a new copper mine. "Mines are always destructive of the environment. Open-pit or strip mining is the worst because huge areas of the land are ripped open and left bare. But even underground mines involve large amounts of land damage, because after the useful minerals are separated from the ore, large amounts of waste rock or "mine tailings" have to be stored above ground. Worse, both the ore and the tailings contain sulfide minerals. When the ore is refined in a process called smelting, sulfur dioxide is produced that combines with water in the clouds to produce sulfuric acid rain that kills trees. The tailings are equally dangerous, because rainwater and snowmelt dissolve the sulfide minerals, producing acids that run into the soil and get into groundwater. Acid mine drainage poisons plants, wildlife, and fish for many kilometres downstream. The Pemigon forests and animals are beautiful—they should be allowed to live in health. Conserve and recycle copper—don't build a mine."

Issue: Should the Mine Be Opened? (8B)

1. Imagine that you are a member of a citizens' group in Pemigon. Your cooperative group needs to help decide whether to establish a copper mine in the area. Read the information in the two newspaper articles provided (**Figures 1** and **2**).
2. Draw two vertical lines on a sheet of paper to divide it into thirds. Write P, M, and I in the spaces, as shown in **Table 1**.

Table 1

A New Mine for Our Area		
P (+)	M (–)	I (?)
?	?	?

3. Working with your group, brainstorm as many ideas about the mine as possible and write them in point form in the spaces. The newspaper articles will give you some hints, but use your own knowledge and imagination to add your own ideas. Plus (P) comments describe benefits and positive effects of building a mine. Minus (M) comments describe problems and negative effects of the mine. Interesting Questions (I) describe what the group would like to know about the topic or further information the group would like to have to help them make a decision.
4. Be prepared to present your ideas to the class.
5. Now, imagine that you are an individual member of the community, with a particular job, family situation, and age. Prepare a presentation to the Town Council in which you argue your position. Be prepared to answer questions from Councillors, to be played by class members. The following are some possible roles you might consider:
   - a boy, 13, whose parents are unemployed
   - a girl, 17, who works in a local grocery store
   - a man, 25, single, who sells lumber and building materials
   - a boy, 17, who is planning to go to college to become a lab technician
   - a woman, 38, who stays at home with three children
   - a man, 30, active in the aboriginal rights movement
   - a woman, 45, vice-president of a copper-mining company
   - a man, 52, who is a miner
   - a girl, 14, whose father works in the forestry industry
   - a man, 28, who works as a local fishing guide
   - a woman, 62, who is an environmental activist

Challenge

How would a P-M-I help you prepare a persuasive marketing proposal?

Chapter 2 Review

Key Expectations

Throughout the chapter, you have had opportunities to do the following things:

- Describe the uses and properties of some common elements. (2.2, 2.3, 2.5, 2.6, 2.8, 2.12)
- Explain the particle theory of matter. (2.1)
- Classify pure substances as either elements or compounds. (2.1, 2.4)
- Describe compounds and elements in terms of molecules and atoms, and recognize that compounds may be broken down into elements by chemical means. (2.1, 2.4, 2.8, 2.9, 2.12)
- Explain the value of models in explaining the behaviour of matter, and build physical models of some common molecules. (2.1, 2.9)
- Identify and use the symbols for common elements and the formulae for common compounds. (2.7, 2.10)
- Demonstrate knowledge of laboratory safety procedures while conducting investigations. (2.2, 2.4, 2.6)
- Investigate the properties of elements and compounds, and organize, record, analyze, and communicate results. (2.2, 2.4, 2.6)
- Formulate and research questions related to the properties of elements and compounds and communicate results. (2.2, 2.3, 2.4, 2.8, 2.11, 2.12)
- Compare the physical and chemical properties of elements and compounds in substances such as fertilizers and ores, and assess their potential uses and associated risks. (2.3, 2.8, 2.11, 2.12)
- Describe technologies that have depended on understanding atomic and molecular structure. (2.12)
- Describe methods used for mining and processing metals in Canada, and associated environmental and economic issues. (2.12, 2.13)
- Explore careers requiring an understanding of the properties of matter. (Career Profile)

KEY TERMS

atom
bond
chemical formula
chemical symbol
combining capacity
compound
electrolysis
element
fertilizer
heavy metal
heterogeneous mixture
matter
metal
metallurgy
mineral
mixture
model
molecule
nutrient
ore
photosynthesis
precipitate
pure substance
solution
structural diagram

Reflecting

- "We classify matter to organize the vast amount of information about elements and compounds." Reflect on this idea. How does it connect with what you've done in this chapter? (To review, check the sections indicated above.)
- Revise your answers to the questions raised in Getting Started. How has your thinking changed?
- What new questions do you have? How will you answer them?

Understanding Concepts

1. Make a concept map to summarize the material that you have studied in this chapter. Start with the phrase "pure substance."
2. The sentences in the following list contain errors or are incomplete. In your notebook, write your complete, correct version of each sentence.
   (a) Elements are made up of compounds.
   (b) Nonmetals are shiny and good conductors.
   (c) Electrolysis is the breaking down of water into hydrogen and nitrogen gases.
   (d) Ozone molecules contain three argon atoms.

(e) Three important fertilizer elements are nitrogen, phosphorus, and sodium.

(f) A mineral contains ore and waste rock.

3. Describe two compounds that contain atoms of the same elements, but in different proportions.

4. State the types of atoms and the numbers of each type that are present in the following molecules: copper phosphate (Cu_3PO_4) and sodium nitrate ($NaNO_3$).

Applying Skills

5. Match the description on the left with one term on the right. Use each term only once.

Description	Term
A smallest particle of an element	1 electrolysis
B mixture of rocks and minerals	2 element
C a poisonous gas	3 bond
D solid product produced when solutions mix	4 nutrient
E substance containing only one type of atom	5 carbon monoxide
F separation of water	6 atom
G connection between atoms	7 molecule
H material necessary to plants and animals	8 precipitate
I particle made of two or more atoms	9 ore

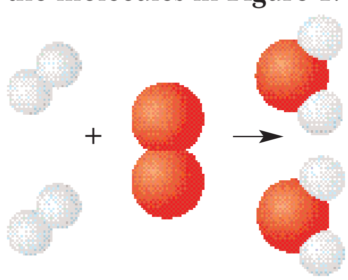
6. What safety precautions did you follow in investigations that you performed in this chapter?

7. Copy the tests in Column A into your notebook. Match each test with the appropriate gas in Column B.

Column A	Column B
limewater test	water vapour
cobalt chloride test	hydrogen gas
glowing splint test	oxygen gas
burning splint test	carbon dioxide

8. Examine the molecules in **Figure 1**.

Figure 1



(a) What substances could the drawings represent?

(b) Write a word equation for the reaction.

9. Use a sketch to show the molecules of two different compounds that contain only atoms of carbon and oxygen.

10. Identify the elements in the following compounds, state the relative numbers of atoms of the elements, and name each compound. You will need to look at **Tables 2** and **3** on page 64.

(a) Ag_2S (c) Na_2O (e) CaI_2

(b) $ZnBr_2$ (d) MgS

11. Write the formula, name, and structural diagram for the compound formed by each of the following combinations of elements:

(a) potassium and chlorine

(b) calcium and oxygen

(c) aluminum and sulfur

12. Write word equations to represent the following reactions:

(a) Potassium and water produce potassium hydroxide and a very flammable gas.

(b) Calcium carbonate and hydrochloric acid produce calcium chloride, water, and a gas that turns limewater milky.

(c) Potassium chlorate produces potassium chloride and a gas that causes a glowing splint to burst into flame.

Making Connections

13. Customs officials investigating a crate shipped from Central America wanted to know what it contained before allowing the crate into Canada. Although the labels were in Spanish, the following chemical formulas were printed on the crate: $NaHCO_3$, $NaNO_3$, $Ca_3(PO_4)_2$. Would you recommend that the officials allow the crate to continue or should they call the shipping company to ask for more information? Explain your reasoning.

14. Ozone is needed in the upper atmosphere and is produced as a pollutant at ground level. Why don't we just collect the ozone at ground level and carry it up in aircraft for release in the upper atmosphere?

15. Research and report on different mining techniques used in Ontario. For example, what is landfill mining? Include a description of the substances that are mined, and the reason for using a particular technique.