4.1 Studying Matter

Key Terms
matter
pure substance
mixture
element
compound

Look around you. Everything you see is **matter**. This book, your desk, and even your classmates are matter. But you do not have to see something for it to be matter. The air you breathe is also matter. By studying matter in its many forms, scientists can better understand the different properties of materials, which can determine their practical uses. In some cases, knowing about the properties of matter means knowing how hazardous certain materials are and how best to handle them in a safe and effective way. This is especially important when something goes wrong.

Knowing how to deal with a hazardous material was a top priority for Toronto's police officers and firefighters when a fire erupted at a propane depot in northwest Toronto on August 10, 2008, as shown in **Figure 4.1**. Huge blasts from exploding propane were heard far away, and fireballs erupted in the sky. Authorities closed major roadways and evacuated thousands of people. Knowing the properties of propane, a highly flammable and explosive gas, enabled emergency personnel to deal with the fire, as well as keep people safe.

matter anything that has mass and occupies space

Figure 4.1 The damage from a fire at this propane depot in Toronto demonstrates how the properties of some substances can make them hazardous.

How Good Are Your Safety Skills?

Making sure that you know how to handle materials safely in the laboratory is an essential part of studying chemistry. During previous science studies, you have learned and practised safe techniques and procedures. **Figure 4.2** will help to refresh your memory on some of the safety icons and WHMIS symbols that you are likely to see in this unit. The Safety in the Science Classroom section on page xiv has a more complete list of safety icons and WHMIS symbols. Also, as part of the WHMIS system, there are material safety data sheets (MSDS) that are available for each chemical that you will handle in the lab. Once you have reviewed the safety icons and symbols, complete Activity 4-2 to test your ability to apply them to various situations.

Figure 4.2 Safety icons (red and white) and WHMIS symbols (black and white) contain important information about materials and procedures.

Activity 4-2

Safety First!

When performing a chemistry experiment, you must be able to recognize the safety icons and symbols that are used and know the precautions you need to take. Can you easily recognize all the potential hazards associated with the instructions below?

Procedure

1. Read over the list of safety icons and the list of WHMIS symbols in the Safety in the Science Classroom section on page xiv.
2. The instructions below describe eight different lab procedures. As you read the instructions, draw the symbols that apply to each instruction. You should use every icon and symbol at least once in this activity.

Instructions

A. Make sure that your lab station is clear and dry. Then plug in the electric hot plate and turn it on.

B. Do not add water to the sugar before heating the sugar.

C. Light the Bunsen burner. Then heat the test tube gently by holding it above the flame.

D. Let the steel pin cool for 10 min. When the pin has cooled, put it into the container as the teacher has shown.

E. Heat the test tube with a Bunsen burner gently at first, and then more strongly. Do not breathe the irritating ammonia gas that forms.

F. Using a medicine dropper, add the acid, one drop at a time, to the base. Be careful that you do not spill either the acid or the base.

G. Add two drops of the solution. The solution can be absorbed into the skin, so be careful that you do not get any on you.

Questions

1. Which safety icons could be used for almost every laboratory procedure?
2. Write a "**Caution**!" statement for each instruction, to draw attention to one safety hazard. For example, "Caution! Wear safety goggles to protect your eyes."

Classification of Matter

When studying matter, scientists classify or group materials based on different characteristics. The chart in **Figure 4.3** represents one way you have learned to classify matter.

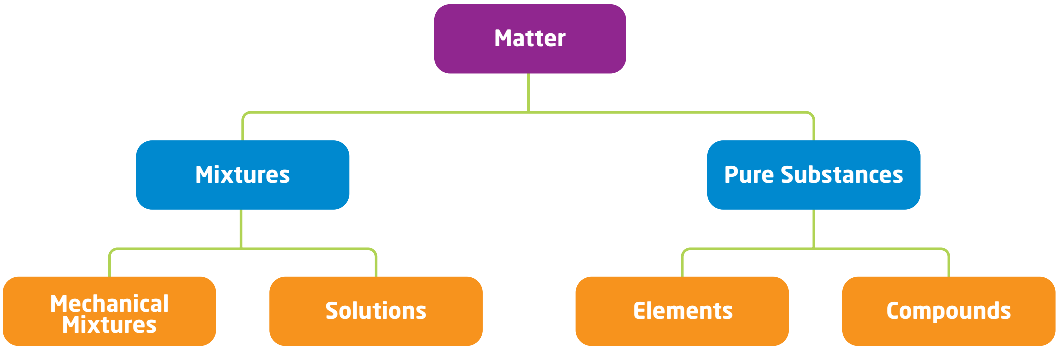


Figure 4.3 Matter can be classified according to whether it is a mixture or a pure substance.

The Particle Theory of Matter

One way that matter can be classified is according to the particle theory of matter.

The Particle Theory of Matter

- All matter is made up of tiny particles.
- Each pure substance has its own kind of particle, which is different from the particles of other pure substances.
- Particles attract each other.
- Particles are always moving.
- Particles at a higher temperature move faster, on average, than particles at a lower temperature.

pure substance matter that contains only one kind of particle

mixture matter that contains more than one kind of particle

Based on the particle theory of matter, matter can be classified as either a **pure substance** or a **mixture**. Pure substances contain only one kind of particle. Mixtures contain more than one kind of particle. So, for example, water is a pure substance, but salt water is a mixture of salt dissolved in water. Oxygen gas is a pure substance but the air we breathe is a mixture of gases that includes nitrogen, oxygen, carbon dioxide, and other components. The particle theory of matter is one example of a scientific model. It helps you to visualize the particles that make up matter and how the particles in different types of matter interact.

Pure Substances

Since a pure substance contains only one kind of particle, you may think that pure substances are rare and hard to find. Actually, many are very common. Two examples of pure substances that you may be familiar with are shown in **Figure 4.4**. Notice how the particles of helium look very different from the particles of water. According to the particle theory of matter, these pure substances have different properties because they are composed of different particles. Scientists have classified pure substances into two main groups: elements and compounds.

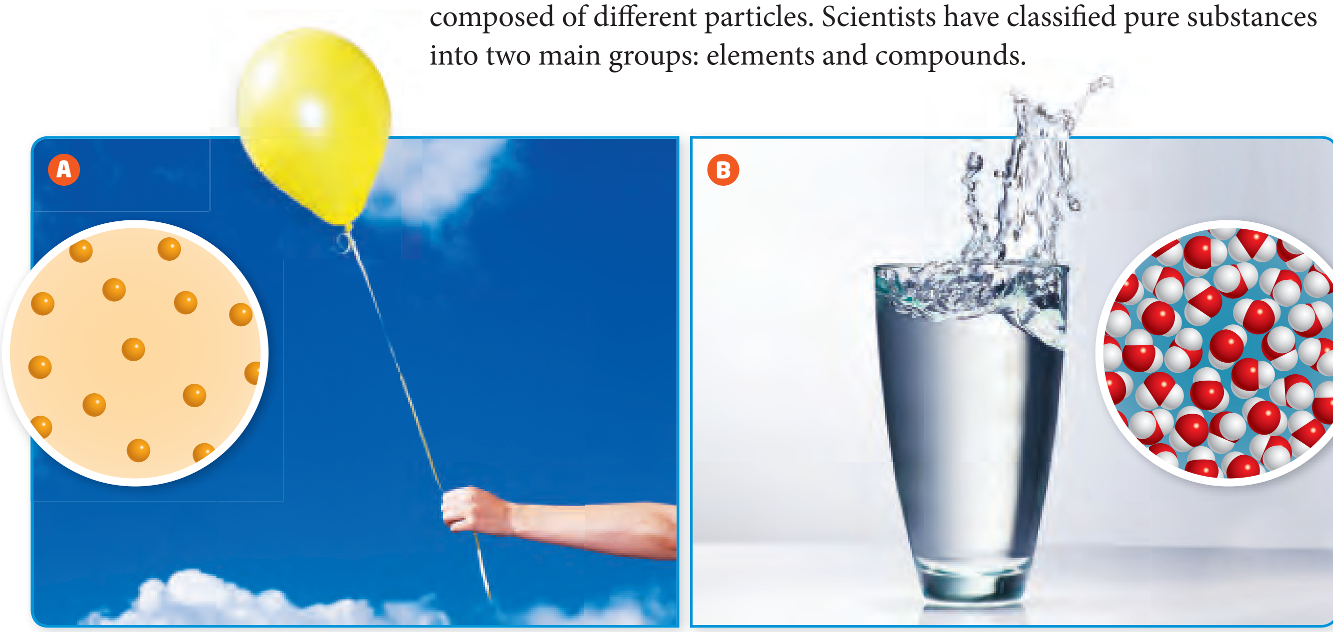


Figure 4.4 **A** Helium and **B** water are pure substances. The particles of helium are all the same, but they are different from the particles of water.

Elements and Compounds

An **element** is a pure substance that cannot be broken down further by chemical or physical methods. You could try heating, crushing, or grinding an element, but you would not change it into a simpler form.

If you look again at **Figure 4.4A**, you can see that helium consists of only one kind of particle. Helium is an element. This simple substance has many uses. As you may know, helium is used to inflate balloons and blimps. Helium also has many scientific applications that include thermometers, lasers, and superconducting magnets. Since the 1800s, scientists have organized elements into a table based on similar properties. You will learn about this table in Chapter 5.

A **compound** is a pure substance that is made of two or more different elements that are chemically combined. Water, in **Figure 4.4B**, is a compound made of the elements hydrogen and oxygen. Because the elements in a compound are chemically combined, a compound can be broken down into its elements only by chemical methods. For example, to break down water into hydrogen and oxygen, a chemical process called electrolysis must be used.

The scene in **Figure 4.5** illustrates that elements and compounds are not just chemicals in a laboratory. They are part of your daily life.

element a pure substance that cannot be broken down into simpler parts by chemical methods

compound a pure substance made of two or more different elements that are chemically combined

Study Toolkit

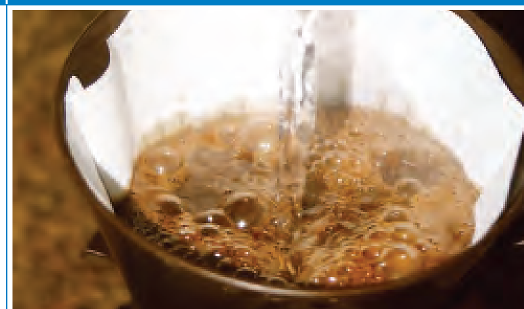
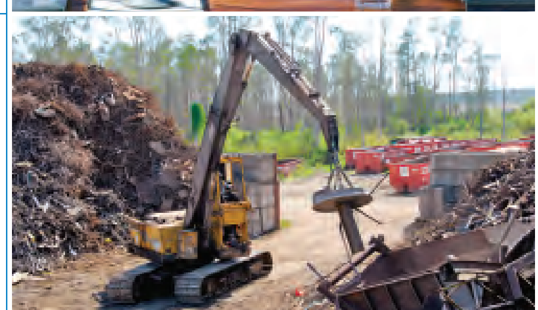
Multiple Meanings You have probably heard the word *compound* used in English class to mean a word composed of two or more other words. *Compound* also refers to a mixture of plaster used in home repairs. How are these related to the meaning of *compound* in chemistry? Draw a word map to show these three meanings. Use a dictionary if you wish.

Figure 4.5 Each day, you interact with and depend on many elements and compounds.

Compounds Versus Mixtures

What if hydrogen and oxygen are placed in a container without being chemically combined? What are they called then? As you have learned, anything that is made of more than one kind of particle is a mixture. Therefore, the gas in the container is a mixture of the elements hydrogen and oxygen. The components of a mixture are physically combined. As a result, a mixture can be separated by physical methods. Examples of methods that can be used to separate the components of a mixture are shown in **Table 4.1**.

Table 4.1 Separating Mixtures

A filter can be used to separate solids from liquids or gases. This filter separates coffee grounds from the brewed coffee that passes through.	
Distillation can be used to separate liquids in a mixture, based on boiling point. This apparatus shows how a liquid, with a lower boiling point than other components in a mixture, is vapourized, condensed, and collected in a beaker.	
A magnet will attract iron and steel objects and leave other objects behind. This machine has been fitted with a magnet to pull out certain objects from this pile of scrap metal.	

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Learning Check

1. Which two safety icons are you likely to see in almost every laboratory procedure?
2. According to the particle theory of matter, what is a pure substance?
3. Can a compound be separated into its elements by filtration? Explain.
4. Name an element that is a part of your everyday life, and describe how you use it.

Activity 4-3

Element, Compound, or Mixture?

Elements and compounds are both pure substances, based on the particle theory of matter. What is their relationship to mixtures, and how can they be used to make mixtures?

Materials

- 3 sets of paper clips, each a different colour

Procedure

1. Sort the paper clips into piles, by colour. Each paper clip represents one element. Each colour represents a different element.
2. Link the paper clips to create models of two different compounds with two different elements and three different compounds with three different elements. Where the paper clips have been linked represents where two elements are chemically combined.
3. Identify the elements in your models of compounds.
4. Use your models of elements and compounds to make a mixture.

Questions

1. How many different elements did you have?
2. Describe how you made your mixture in step 4. How did this differ from what you did in step 2? Is it possible to make more than one type of mixture? Explain.
3. How were your paper clip models similar to real-life elements, compounds, and mixtures? How were they different?

Chemistry, Society, and the Environment

In this unit, you will examine the properties of a variety of elements and compounds, as well as some of the social, economic, and environmental effects that these chemicals have—both positive and negative—on society. **Figure 4.6** summarizes some of the important issues related to the use and production of chemicals.

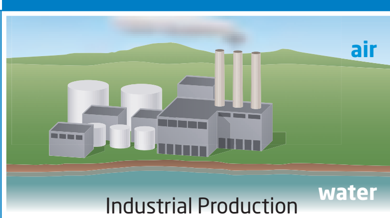
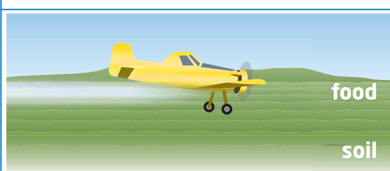
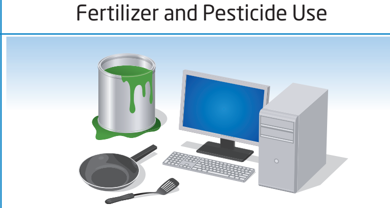
+		−
Production of energy and materials	 Industrial Production	Pollutants released into the atmosphere and waterways
Improvement in crop yields	 Fertilizer and Pesticide Use	Accumulation of toxic chemicals in soil and on food products
Increased variety of available products	 Consumer Products	Direct exposure of toxic chemicals to humans

Figure 4.6 It is important to find a good balance between the advantages and disadvantages that are associated with the use, production, and disposal of chemicals.

Advantages and Disadvantages

Suggested Investigation

Real World Investigation 4-D, CFC Production and Canada's Ozone Layer, on page 172.

Elements and compounds have many positive effects on society, such as making our lives healthier and safer, and allowing us to accomplish things that were once unimaginable. These accomplishments, however, have resulted in some negative consequences, which must be considered and dealt with. For example, toxic chemicals that are used or produced in the manufacture or isolation of certain elements and compounds can be released into the environment. Once in the environment, they can accumulate or react with other substances and result in harmful by-products. Throughout this unit, you will study specific examples of elements and compounds and learn how their properties can influence their practical uses.

STSE Case Study

What Is the Cost of Our Products?

Think about all the products that are part of your everyday life. For example, think about the clothes you wear, the personal hygiene products you use, and the various plastic-containing products you buy, such as electronic devices and school supplies. Now think about what your day would be like without them. These products are very useful and of economic advantage since many of them are produced in Ontario.

Canada's Chemical Valley

The city of Sarnia and the Aamjiwnaang [pronounced OMM-jew-nong] First Nation lie on the south shore of Lake Huron. They are bordered by one of the most highly industrialized areas in Canada, which is nicknamed Chemical Valley because of the large number of chemical plants.

In the 1960s, most of the world's largest oil and chemical companies built factories in this area. Canada's first commercial oil wells were near Sarnia. Transportation to nearby large markets in the United States and central Canada was easy, especially given Sarnia's deepwater ports. By the 1970s, the average income of people in the Sarnia area was 35 percent higher than the national average–primarily due to industrial development. The area was one of the most successful in Canada.

There is now evidence, however, that suggests the health of many Sarnia area residents may have been harmed by exposure to toxic chemicals from Chemical Valley. In addition to high rates of heart disease and breathing-related illnesses, cancer rates are higher than the provincial average. Each year, there are more pollutants released from Chemical Valley than the provincial totals for Manitoba, New Brunswick, and Saskatchewan. Community groups have come together to take matters into their own hands.

Sample Data Collected by the Bucket Brigade

Toxic Chemical	Measured Level (μg/m^3)	Acceptable Level (μg/m^3)
carbon disulfide (CS_2)	41	3-30
chloromethane (CH_3Cl)	130	1.1
benzene (C_6H_6)	9.9	0.25

These are only some of the toxic chemicals that have been detected by the Aamjiwnaang First Nation's bucket brigade. The acceptable levels provided are based on standards in the United States. Canada does not have comparable health-based standards for these chemicals.

Making a Difference

While in Grade 11, Meghana Saincher noticed that wooden pieces from local playgrounds had been replaced with plastic and steel materials. She questioned this change and discovered that it was done because preservatives in the wood were toxic. Meghana decided to find out if there were non-toxic wood preservatives that could be used instead. Upon receiving a research grant to carry out her studies at the University of British Columbia, Meghana showed oregano oil to be an effective and non-toxic wood preservative.

Meghana shared her experience with other students, and started a biotechnology club at her Surrey, BC, high school. Most importantly, she helped motivate her peers to conduct research. In 2006, Meghana was named one of Canada's Top 20 Under 20. She is now studying medicine at the University of Alberta.

Are there toxic chemicals in your community that could be replaced with safer alternatives?

The Bucket Brigade

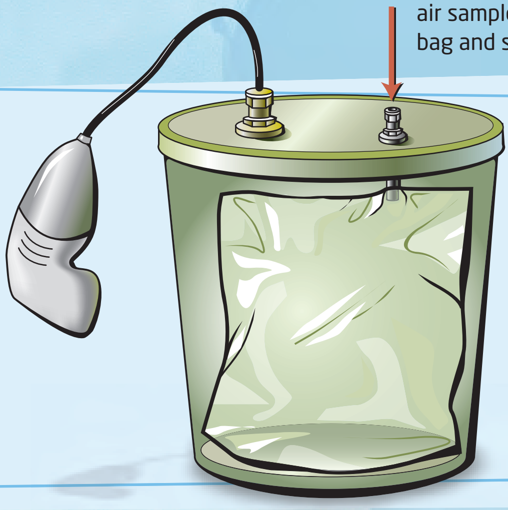
Since the early 1990s, the Aamjiwnaang First Nation has experienced the lowest rate of male births in the world. As well, health surveys indicate that almost all households have someone with a serious long-term or deadly illness. Believing that these effects are due to pollution, the Aamjiwnaang First Nation Health and Environment Committee decided to take action. Volunteers are using a "bucket brigade" to conduct regular monitoring of the air in the region. The data collected are scientific evidence that residents are being exposed to toxic pollutants. This has prompted more extensive research studies, support of the Environmental Commissioner of Ontario (the province's environmental watchdog), and the installation of a new air-monitoring station in the First Nation community by Ontario's Ministry of the Environment.

Your Turn

1. Ontario's chemical industry produces numerous products. These products include pharmaceuticals, paints, inks, adhesives, petrochemicals, soaps and other personal hygiene products, and chemicals for manufacturing products such as synthetic clothing and plastic containers. To reduce air pollution, what products would you be willing to give up?
2. It has been difficult to prove that pollution from Chemical Valley is the direct cause of certain illnesses in the Sarnia area. Why do you think this is so?
3. Research the toxic chemicals that are listed in this case study. What are some of the effects that long-term exposure to unsafe levels has on people's health?

How the Bucket Brigade Works

- A simple, portable device is contained within a plain 23 L plastic bucket–the reason for the name "bucket brigade."
- The device can detect almost 90 toxic gases.
- A sample of air is trapped and stored in a sealable bag. Then it is sent to a laboratory for analysis.



Section 4.1 Review

Section Summary

- When studying matter, it is important to know the location of safety equipment in your classroom and the meanings of the safety icons and WHMIS symbols.
- Matter can be classified according to its composition, as mixtures or pure substances.
- An element is a pure substance that cannot be broken down into simpler substances through physical or chemical methods.
- A compound is a pure substance that is composed of two or more different elements that are chemically combined. A compound can be broken down into its elements only by chemical methods.
- The production and use of new chemicals can have both negative and positive consequences. Benefits must be weighed against negative consequences.

Review Questions

T/I **1.** What hazards are associated with heating a liquid in a test tube that is tightly closed with a cork?

A **2.** Name an occupation that requires workers to know safety icons and WHMIS symbols.

C **3.** Using a diagram, apply the particle theory to explain why a drop of liquid water tends to be round.

K/U **4.** Name two classes of pure substances and give an example of each.

T/I **5.** Decide whether each of the following is a pure substance. Explain your reasoning.

   a. salt water

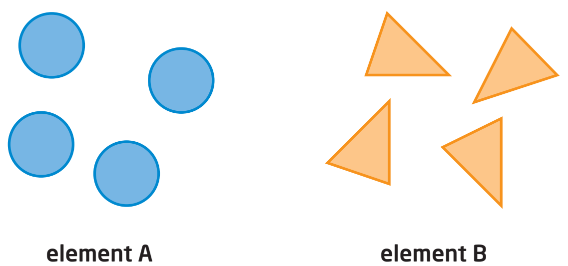
   b. gold

   c. a pencil

T/I **6.** Would a pure substance ever settle out and form two distinct layers? Explain your reasoning.

K/U **7.** Describe the relationship between an element and a compound.

T/I **8.** The circles and triangles in the diagram on the right represent two different elements. Use these shapes to draw a compound and a mixture. Is it possible to draw more than one compound? Explain why or why not.



Elements A and B can be used to make compounds and mixtures.