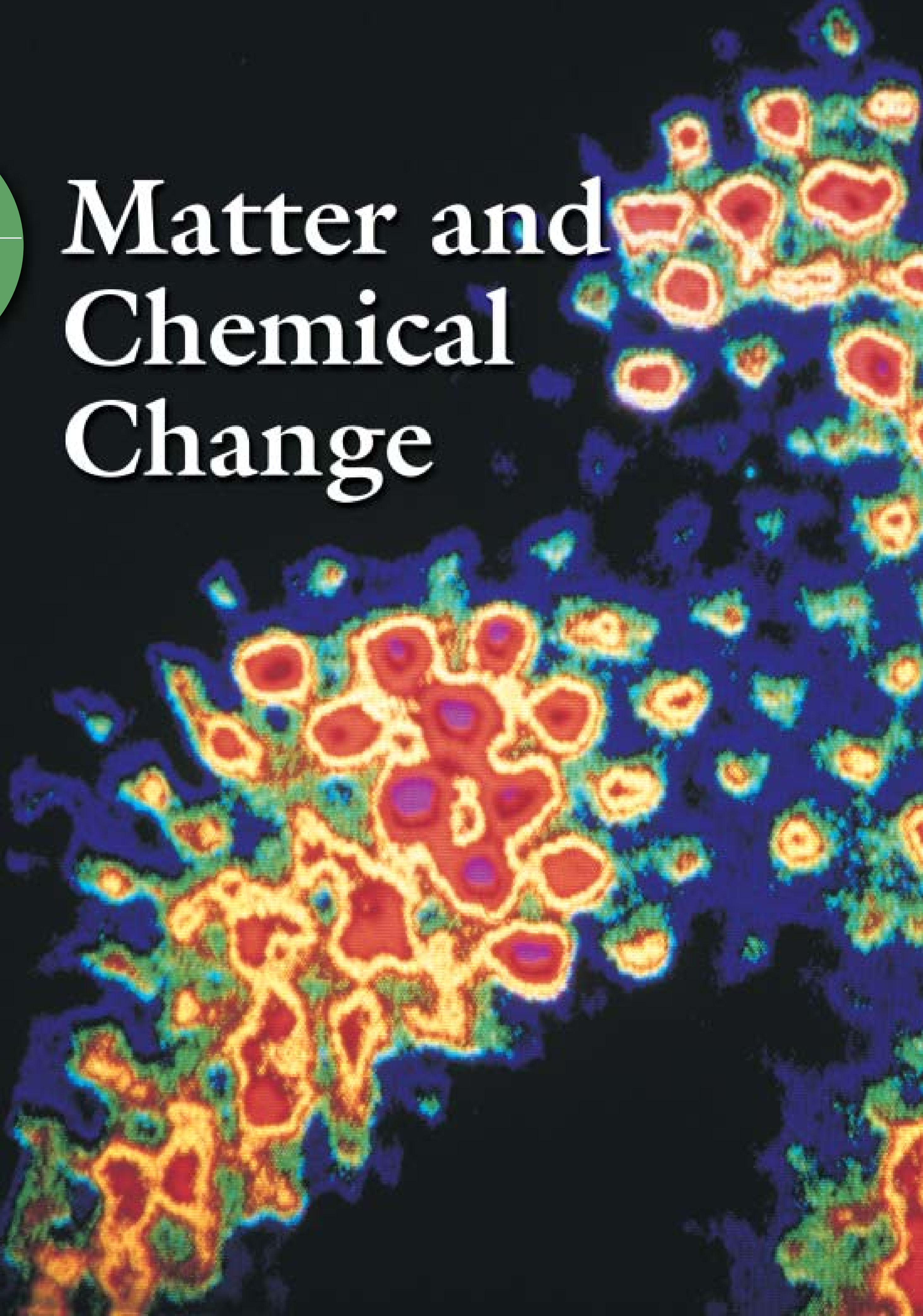
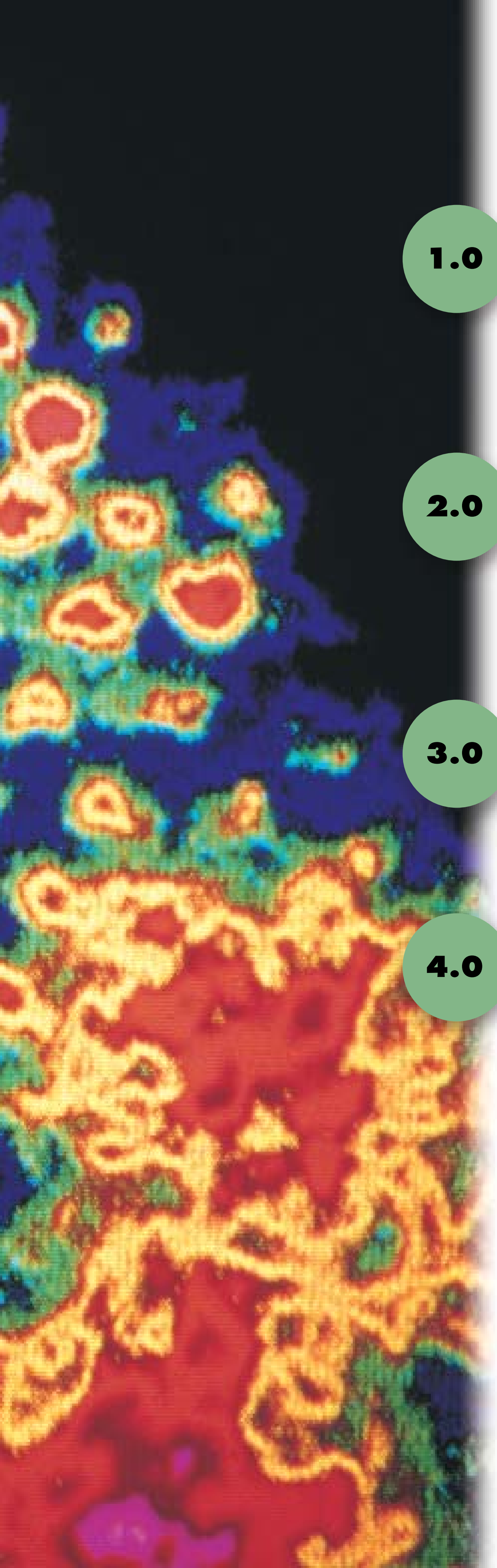
UNIT B

Matter and Chemical Change





In this unit, you will cover the following sections:

1.0 Matter can be described and organized by its physical and chemical properties.

1.1 Safety in the Science Class

1.2 Organizing Matter

1.3 Observing Changes in Matter

2.0 An understanding of the nature of matter has developed through observations over time.

2.1 Evolving Theories of Matter

2.2 Organizing the Elements

2.3 The Periodic Table Today

3.0 Compounds form according to a set of rules.

3.1 Naming Compounds

3.2 Ionic Compounds

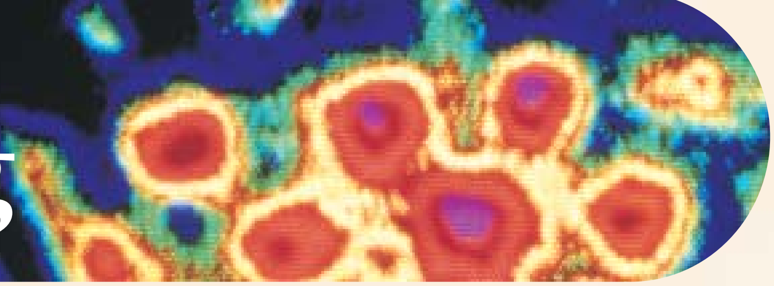
3.3 Molecular Compounds

4.0 Substances undergo a chemical change when they interact to produce different substances.

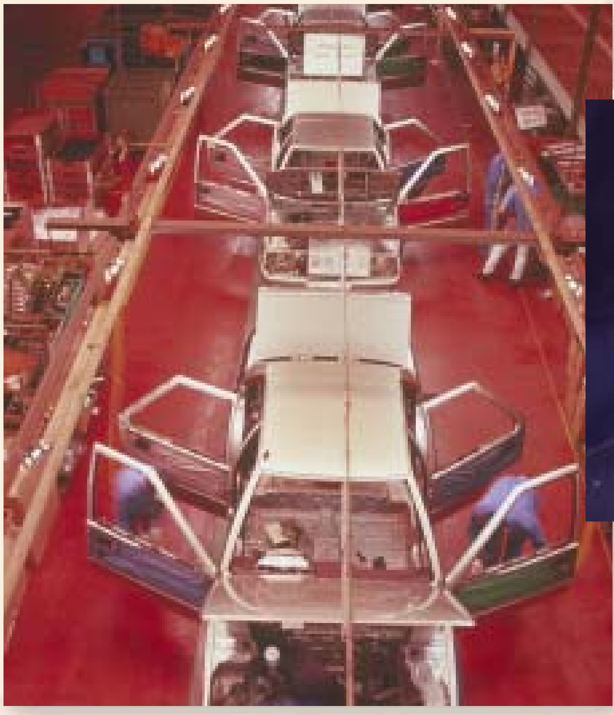
4.1 Chemical Reactions

4.2 Conservation of Mass in Chemical Reactions

4.3 Factors Affecting the Rate of a Chemical Reaction



Exploring



Aluminum foam

The next time you drink pop from a can, take a good look at the container. You probably know that it's made of the metal aluminum, which is light and flexible, yet strong. These characteristics, or **properties**, make aluminum useful for holding liquids. Aluminum has many other applications as well. For example, screen doors, cars, and airplanes all use aluminum. In these applications, the metal is usually used in sheets or formed into parts. But did you know that aluminum can also be made into a foam?

Aluminum Foam

Aluminum foam is an example of combining a variety of materials to create a new material with different properties from those of the original materials. Mixing powdered aluminum with a foaming material makes aluminum foam, a substance that can be 10 times stiffer and 50% lighter than aluminum. It can also float because it has air pockets.

Engineers use this new material to create lighter, safer cars. It may sound strange that a lighter car can be a safer car. However, compared to other materials, aluminum foam is able to absorb more impact energy when a car is in a collision.

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FOAM IN A CUP

Purpose

To observe what happens in a simple chemical reaction

Procedure

1. Pour 30 mL of corn syrup into a 250-mL beaker. Stir in 3 drops of one food colouring. Sprinkle 20 mL of baking soda on the corn syrup.
2. Tip the beaker slightly and carefully pour in 30 mL of water down one side. Add 30 mL of vegetable oil to the beaker in the same way.
3. Into a separate beaker, pour 20 mL of vinegar and add 3 drops of the other food colouring.
4. Fill the eyedropper with coloured vinegar. Squeeze 3 drops of coloured vinegar into the beaker containing the other substances. Record your observations. Repeat if necessary.
5. Push the eyedropper down to the bottom of that beaker, and release all the vinegar by squeezing the bulb of the eyedropper. Record your observations.

Questions

6. Describe how your observations were different in steps 4 and 5.
7. Work with the rest of the class to explain what is going on in the activity.

Materials & Equipment

- graduated cylinder
- 30 mL corn syrup
- two 250-mL beakers
- two different colours of food colouring
- stirring rod
- 20 mL baking soda
- 30 mL water
- 30 mL vegetable oil
- 20 mL vinegar
- eyedropper

Focus On THE NATURE OF SCIENCE

In this unit, you will be asked to observe how matter changes and interacts with other matter. You will collect evidence of changes by:

- investigating the properties of matter
- interpreting observations and data from experiments
- creating and interpreting models

Think about the following questions while you study how our understanding of matter and its interactions has developed. The answers to these and other questions about matter will help you understand the interactions among substances.

1. **How do we determine the properties of a variety of different substances?**
2. **How do different substances interact?**
3. **What evidence can be used to indicate that an interaction between substances has occurred?**

1.0 Matter can be described and organized by its physical and chemical properties.

Key Concepts

In this section, you will learn about the following key concepts:

- Workplace Hazardous Materials Information System (WHMIS) and safety
- substances and their properties
- elements, compounds, and atomic theory

Learning Outcomes

When you have completed this section, you will be able to:

- identify and evaluate dangers of caustic materials and potentially explosive reactions
- investigate and describe properties of materials
- describe and apply different ways of classifying materials based on their composition and properties

Imagine visiting a market where all the food is displayed in big bags, like the ones shown in the photo. How could you tell what was in each bag? One way would be to look at the colour and shape of each item. You also might handle each one to see whether it is hard or soft, rough or smooth, dense or light. If these clues still weren't enough to help you identify the unknown substances, then you might have to cut them open to see their composition. In all of this, you would be doing just what a chemist does: investigating matter.

Studying the properties of matter and how matter changes is part of the science called chemistry. **Matter** is anything that has mass and occupies space. In this section, you will first learn proper science lab safety. Then you will learn about some properties of matter and how those properties can be used to identify substances and to organize matter in a useful way.

For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

1.1 Safety in the Science Class

In any science activity, the safety of you, your classmates, and your teacher are of the utmost importance. It is essential that everyone in your science class act in a safe and responsible manner. Before you begin investigating chemical reactions, you should review some safety rules and basic lab skills.

SKILL PRACTICE

SAFETY IN THE SCIENCE LAB

Look at Figure 1.1. Some of the students are not following proper safety procedures. Work with a partner to identify and list the problem actions in a table. Then suggest a better, safer way to perform each action. After you have finished, share your observations with the class.

Figure 1.1 Students at work in the lab

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Symbol Shapes

These shapes and their colours indicate how dangerous a substance is.

Safety Hazard Symbols

Before you do any activity in this unit, read the directions and look for "Caution" notes that will tell you if you need to take extra care. There are two areas of special consideration for people working in the lab: understanding warning labels and following safety procedures.

Some of the materials you will use in science activities are hazardous. Always pay attention to the warning labels, and follow your teacher's instructions for storing and disposing of these materials. If you are using cleaning fluids, paint, or other hazardous materials at home, read the labels for special storage and disposal advice.

All hazardous materials have a label showing a hazard symbol. You may have seen these labels on chemical substances in your kitchen or garage. For example, many kinds of window cleaner contain ammonia, which is toxic and corrosive. Car batteries contain sulfuric acid which is also toxic and corrosive, and lead which is toxic.

Each hazard symbol shows two separate pieces of information. The shape of the symbol indicates how hazardous a substance is. A yellow triangle means "caution," an orange diamond means "warning," and a red octagon means "danger." These shapes are shown in the infoBIT on this page. The second piece of information in the symbol is the type of hazard, which is indicated by the picture inside the shape. Figure 1.2 shows the common hazard warnings.

Figure 1.2 These symbols warn you of specific hazards.

WHMIS Symbols

The Workplace Hazardous Materials Information System—or **WHMIS**—is another system of easy-to-see warning symbols on hazardous materials. These symbols were designed to help protect people who use materials that might be harmful at work. Figure 1.3 shows eight WHMIS symbols.

In several activities in this unit, you will encounter the symbols for poisonous material, dangerously reactive material, and corrosive (or caustic) material. For example, hydrogen peroxide is very reactive and can burn your skin, and battery acid is corrosive. Treat both chemicals with extreme care whenever you use them.

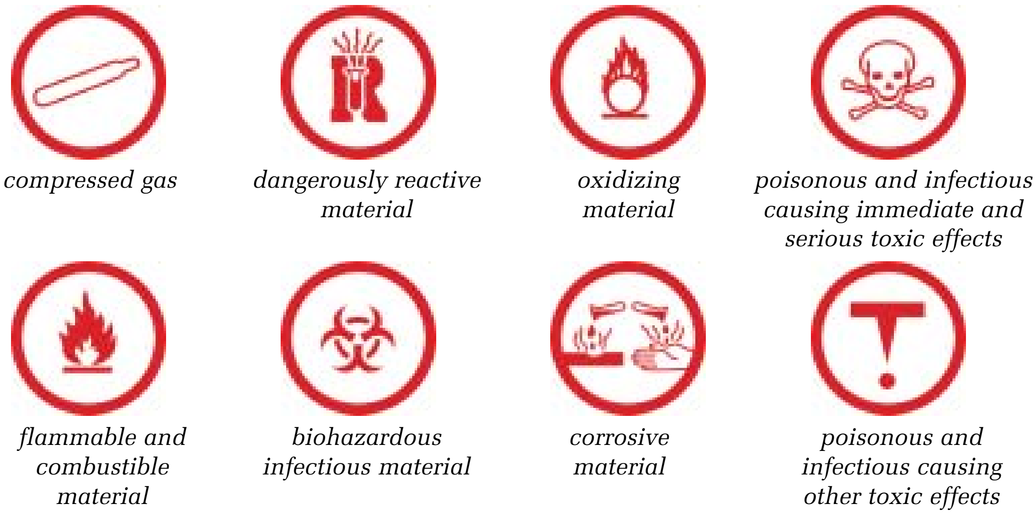

Figure 1.3 WHMIS symbols

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MSDS

Materials and Safety Data Sheets (MSDS) are information sheets about specific chemicals. Find out what type of information is on the MSDS. Begin your search at www.pearsoned.ca/scienceinaction.

Understanding the Rules

When you perform science activities of any kind, it is very important to follow the lab safety rules shown below. Not following one or more of these rules could result in injury to you or your classmates. Your teacher will also discuss any specific rules that apply to your classroom. For more information on lab safety, see Toolbox 1.

Lab Safety Rules

1. Read all written instructions carefully before doing an activity.
2. Listen to all instructions and follow them carefully.
3. Wash your hands thoroughly after each activity and after handling chemicals.
4. Wear safety goggles, gloves, or an apron as required.
5. Think before you touch. Equipment may be hot and substances may be dangerous.
6. Smell a substance by fanning the smell toward you with your hand. Do not put your nose close to the substance.
7. Do not taste anything in the lab.
8. Tie back loose hair and roll up loose sleeves.
9. Never pour liquids into containers held in your hand. Place a test tube in a rack before pouring substances in it.
10. Clean up any spilled substances immediately as instructed by your teacher.
11. Never look into test tubes or containers from the top. Always look through the sides.
12. Never use cracked or broken glassware. Make sure you follow your teacher's instructions when getting rid of broken glass.
13. Label any container you put chemicals in.
14. Report all accidents and spills immediately to your teacher.
15. If there are WHMIS (Workplace Hazardous Materials Information System) safety symbols on any chemical you will be using, make sure that you understand all the symbols. See Toolbox 1 at the back of this book.

Keep Safety in Mind

Remember that safety in the science class begins with you. Before you start any activity:

- Follow the safety instructions outlined by your teacher and in this textbook.
- Identify possible hazards and report them immediately.
- Show respect and concern for your own safety and the safety of your classmates and teachers.
- Read Toolbox 1: Safety in the Laboratory.

Check and Reflect

(a) (b) (c) (d)

Figure 1.4 Question 5. Warning labels on hazardous products.

Key Concept Review

1. Why is it important for all students to follow the safety rules while in a science class?
2. What does WHMIS stand for?
3. Why is there a need for a WHMIS program?
4. One area of special consideration for people working in a lab is understanding warning labels. What is the other special consideration?
5. What does each hazard warning label mean on the chemicals shown in Figure 1.4?

Connect Your Understanding

6. What type of WHMIS symbols would you expect to see on the following containers?
   a) a can of gasoline
   b) a tub of caustic cleaning chemical
   c) a bottle of oxygen gas
   d) a bottle of sulfuric acid
7. Explain the difference between WHMIS symbols and safety symbols used on commercial products.
8. List the steps a student should take before starting a science activity where safety is an issue.
9. Describe one problem that may occur with having different coloured safety symbols.

Extend Your Understanding

10. Divide the lab safety rules given on page 95 among members of your class. Have each person or group make a poster illustrating the rule. Display your safety posters in your classroom to remind everyone of the importance of following these rules.
11. What additional lab safety rules would you add to the list on page 95?

1.2 Organizing Matter

Matter exists as a solid, liquid, or gas. These are called the **states** of matter. The state of a substance—solid, liquid, or gas—depends on temperature.

Specific terms are used to describe changes of state in substances. A change from a solid to a liquid is **melting**. A change from a liquid to a gas is **evaporation** (also known as vaporization). A change from a gas to a liquid is **condensation** and from a liquid to a solid is **freezing**. A solid can also change directly into a gas; this process is called **sublimation**. A gas can change directly to a solid. This is called **deposition.**

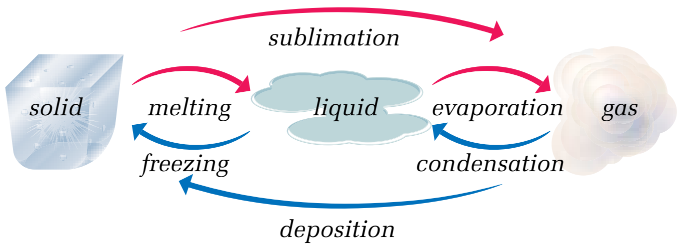

Figure 1.5 Changes in states of matter

To understand how substances differ, you need to observe their properties. **Properties** are characteristics that can be used to describe a substance. All matter has two types of properties: physical and chemical.

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Plasma

A fourth state of matter is the *plasma* state. Examples of plasmas are found in lightning, neon signs, and stars such as our Sun. Plasmas result when a large amount of energy is added to a gas.

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Organizing the Properties of Matter

Purpose

To describe and classify materials by their properties

Procedure

1. Cut a sheet of notepaper into eight equal pieces. These are your summary cards.
2. Your teacher will give you samples of the following materials: copper wire, vinegar, salad oil, aluminum foil, granite, graphite, rock salt, lemonade, and baking soda. At the top of each summary card, write the name of one of the materials (one card per material).
3. Study each material sample in turn, and write a short description of the material. Refer to as many different properties as you can to describe the material so you can show how it differs from the other materials you study.
4. Divide the materials into groups having similar properties. You should have at least four groups. Determine a name that best describes each of these groups, or classifications.

Questions

5. Compare your classification system with that of your classmates. What similar properties did everyone use? What different properties did everyone use?

Materials & Equipment

- paper
- pencil
- scissors

Some Physical Properties of Matter

- colour
- lustre
- melting point
- boiling point
- hardness
- malleability
- ductility
- crystal shape
- solubility
- density
- conductivity

Physical Properties of Matter

A variety of **physical properties** can be used to identify matter. Two examples are colour and lustre (shininess). The temperature at which a substance melts is also a physical property. It's important to remember that when a substance undergoes a **physical change**, such as melting, its appearance or state may be altered, but its composition stays the same. Melted chocolate ice cream has the same composition as frozen chocolate ice cream. The table on page 99 lists several of the key physical properties used to describe matter.

Figure 1.6 This ice cream has undergone a physical change. Even though it has melted, its composition hasn't changed.

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Observing a Physical Change

Purpose

To investigate a physical change and the factors that influence the rate of change

Procedure

1. Fill the two glasses about two-thirds full with soda pop.
2. Into one glass, drop a piece of the mint candy. Watch what happens in both glasses and record your observations.
3. Identify one variable you could manipulate to increase the rate of change that occurs.
4. Write a procedure to perform this test. Identify your control, the manipulated variable, and the responding variable. Also decide how you will measure your responding variable.
5. Ask your teacher to approve your procedure. Then, carry out the test.
6. Record your results.

Questions

7. Adding a candy to the pop causes a physical change to occur. The candy reduces the surface tension in the liquid, allowing gas to be released faster. Does the composition of the candy change after it is added to the pop?
8. Why were you required to fill two glasses with pop in step 1, but to add candy to only one glass in step 2?
9. What factors influenced the rate at which the gas was released from the pop? What data did you collect to support your answer?

Materials & Equipment

- soda pop
- 2 glasses (or large test tubes)
- chewy mint candy such as Menthos
- pencil and notebook

Some Physical Properties of Matter

Melting point	The melting point of a substance is the temperature at which it changes from a solid to a liquid. The melting point of ice is 0°C. At this temperature, it changes into water. Other substances have different melting points. For example, table salt melts at 801°C, and propane melts at −190°C.
Boiling point	The boiling point of a substance is the temperature at which its liquid phase changes to the gas phase. At sea level, water's boiling point is 100°C. Table salt boils at 1413°C, and propane boils at −42°C.
Hardness	Hardness is a substance's ability to resist being scratched. Hardness is usually measured on the Mohs' hardness scale from 1 to 10. The mineral talc is the softest substance on the scale (1). Diamond is the hardest (10). Figure 1.7 shows the scale.
Malleability	A substance that can be pounded or rolled into sheets is said to be **malleable**. Metals such as gold and tin are malleable. Aluminum foil is an example of a product made from a malleable substance.
Ductility	Any solid that can be stretched into a long wire is said to be **ductile**. The most common example of a ductile material is copper.
Crystal shape	The shape of a substance's crystals can help identify it. Silicon crystals, for example, are diamond shaped. Salt crystals form cubes.
Solubility	**Solubility** is the ability of a substance to be dissolved in another. For example, sugar is soluble in water, but cooking oil is not.
Density	**Density** is the amount of mass in a given volume of a substance. The density of water is 1 g/mL. The density of gold is 19 g/cm^3.
Conductivity	**Conductivity** is the ability of a substance to conduct electricity or heat. A substance that conducts electricity or heat is called a conductor. A substance with little or no conductivity is an insulator.

1	2	3	4	5
Talc	Gypsum	Calcite	Fluorite	Apatite

6	7	8	9	10
Feldspar	Quartz	Topaz	Corundum	Diamond

Figure 1.7 Mohs' hardness scale

ACTIVITY B-1

Inquiry

IDENTIFYING MYSTERY SUBSTANCES

The Question

How can the properties of a substance be used to identify it?

Materials & Equipment

- salt, baking soda, corn starch, sodium nitrate, sodium thiosulfate
- black paper
- hand lens
- water
- 5% acetic acid or 5% hydrochloric acid
- iodine solution
- wax paper or spot plate
- disposal containers

Figure 1.8 Step 7

Procedure

Part 1—Examining Five Substances

1. Copy the table shown on the next page into your notebook.
2. Collect five substances from your teacher.
3. Perform the tests described below to identify the properties of the substances. You do not have to do the tests in the order shown below, but you must do all of them.
4. Make sure the data table is completely filled in before you begin part 2 of the activity.

Test 1—Appearance

5. Use one sheet of black paper for all your samples. Place a small amount of each powder in different places on the same sheet of black paper. Make sure that your powder samples are not touching each other.
6. Describe the appearance of each powder. Record your observations in the data table.

Test 2—Crystal shape

7. Use a hand lens or microscope to examine the grains of each powder. Record your observations in the data table.
8. Dispose of the powders and the black paper in the container provided.

Test 3—Behaviour in water

9. Use one large sheet of wax paper or a spot plate for all your samples. Place a small amount of each powder on the wax paper or spot plate.
10. Add a drop of water to each powder. Record your observations in the data table.
11. Dispose of the powders and the wax paper in the container provided. Clean the spot plate.

Test 4—Behaviour in acid

12. Place a small amount of each powder on a new sheet of wax paper or a clean spot plate.
13. Add a drop of 5% acetic acid solution or 5% hydrochloric acid solution to each powder. Record your observations in the data table.
14. Dispose of the powders and the wax paper in the container provided. Clean the spot plate.

Test 5—Behaviour in iodine

15. Place a small amount of each powder on a new sheet of wax paper or a clean spot plate.
16. Add a drop of iodine solution to each powder. Record your observations in the data table.
17. Dispose of the powders and the wax paper in the container provided. Clean the spot plate thoroughly.

Part 2—Identifying Unknown Substances

18 Collect an unknown sample from your teacher. Record the letter or number of the sample in the data table next to the word "unknown."

19 Determine the properties of the unknown sample by repeating the five tests above, and record your observations in the data table.

Analyzing and Interpreting

20 For each substance, one or two tests clearly identified it as being unique from the other substances. What were those tests for each of the white powders?

21 Were some tests more useful than others? Explain your answer.

22 Were the results of some of the tests confusing? Explain your answer.

23 What substance or substances were in your unknown sample?

Forming Conclusions

24 Describe how you inferred what substance or substances were in your unknown sample. Use your data to support your conclusions.

Applying and Connecting

Knowing the properties of a substance is essential to finding practical uses for it. For example, corn starch can be used to make glue. If corn starch is cooked with an acid, a sticky, adhesive substance is produced. A similar substance can be produced from the solid materials that form after acid is added to milk. This substance is called *casein*. Casein can be mixed with a basic solution to form a strong glue.

Substance	State	Appearance	Crystal Shape	Behaviour in Water	Behaviour in Acid	Behaviour in Iodine
salt						
baking soda						
corn starch						
sodium nitrate						
sodium thiosulfate						
unknown						

Chemical Properties of Matter

Chemical Properties of Matter—Examples

- reaction with acids
- ability to burn
- reaction with water
- behaviour in air
- reaction to heat

A **chemical property** describes how a substance interacts with other substances such as acids. Chemical properties are observable only when a chemical change occurs. A **chemical change** always results in the formation of a different substance or substances. For example, if you make pancakes, you mix together flour, milk, baking powder, sugar, and other ingredients, each with its own set of physical properties. When you cook them, however, they form a completely new substance—a pancake. The pancake has different properties from those of its ingredients.

Figure 1.9 Cooking the pancake ingredients changes them into a different substance.

Pure Substance or Mixture?

All matter is either a pure substance or a mixture. Physical and chemical properties show us whether a substance is "pure" or a mixture.

Types of Pure Substances

A **pure substance** is made of only one kind of matter and has a unique set of properties that sets it apart from any other kind of matter. Mercury and sugar are two examples. A pure substance may be either an element or a compound.

- An **element** is a material that cannot be broken down into any simpler substance. Elements are the basic building blocks for all compounds. Later in this unit, you will learn how elements are organized into a **periodic table** according to their properties. Each element has its own symbol. For example, hydrogen is H, carbon is C, and oxygen is O.
- When two or more elements combine chemically—that is, in specific, fixed proportions—they form a **compound**. When the elements hydrogen and oxygen are combined in specific proportions, they form the compound water. Carbon and oxygen chemically combined form the compound carbon dioxide, the gas that is used to create the "fizz" in carbonated drinks. Later in this unit, you will learn that compounds have chemical names and formulas. For example, water is H_2O and carbon dioxide is CO_2.

The structural composition of elements and compounds is discussed further in Section 2.0.

Types of Mixtures

A **mixture** is a combination of pure substances. However, the substances in a mixture do not combine chemically as happens when a compound is formed. They remain in their original, pure form, even though they are not always easy to see distinctly once the mixture is made. There are four main types of mixtures:

- In a **mechanical mixture**, the different substances that make up the mixture are visible. Soil is an example of a mechanical (or *heterogeneous*) mixture. So is a package of mixed vegetables.
- In a **solution**, the different substances that make it up are not separately visible. One substance is dissolved in another, creating what looks like one *homogeneous* substance. Examples of solutions are shown in the table below.

Type of Solution	Example
Solid dissolved in liquid	sugar in hot coffee
Liquid dissolved in liquid	acetic acid in water (to create white vinegar)
Gas dissolved in liquid	carbon dioxide gas in water (to create carbonated pop)
Gas dissolved in gas	oxygen and smaller amounts of other gases in nitrogen (in the atmosphere)
Solid dissolved in solid	copper in silver (to create sterling silver)

Chemists call a substance dissolved in water an **aqueous solution**. Examples include fresh water, vinegar, and cleaning solvents.

- A **suspension** is a cloudy mixture in which tiny particles of one substance are held within another. Tomato juice is an example of a suspension. These particles can be separated out when the mixture is poured through filter paper.
- A **colloid** is also a cloudy mixture, but the particles of the suspended substance are so small that they cannot be easily separated out from the other substance. Milk and ketchup are examples of colloids.

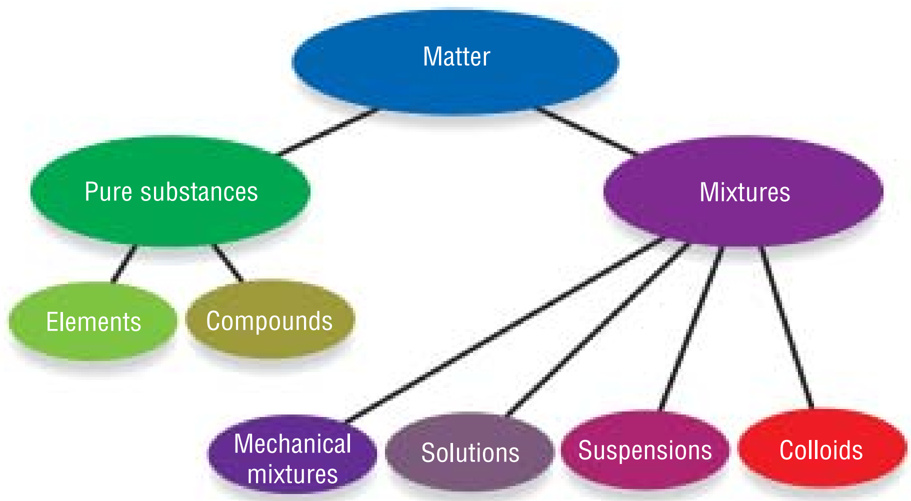

Figure 1.11 Classifying matter

Figure 1.10 You use many different kinds of mixtures and solutions each day.

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Other Types of Mixtures

Gels are colloids used in beauty products. Find out how these types of mixtures are created, and how they are used in various applications. Begin your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What physical properties could be used to describe a substance?
2. Give two examples to illustrate the difference between a physical and a chemical property.
3. How is an element different than a compound? Give an example of each.
4. What is the difference between a pure substance and a mixture?
5. How is a suspension different from a colloid?

Connect Your Understanding

6. The melting and boiling points of five chemical substances are shown in the table below. What state of matter does each exist in at room temperature (about 20°C)?

Substance	Melting Point (°C)	Boiling Point (°C)	State at Room Temperature
water	0	100	
oxygen	−218	−183	
ammonium nitrate	170	210	
ethanol	−117	79	
mercury	−39	357	

7. What physical property is described by each of the following statements?
   a) Solid oxygen melts at −218°C.
   b) A penny cannot scratch glass.
   c) Silver is shiny.
   d) Gold can be made into thin sheets.
   e) Both aluminum and copper can be used for making wire.
8. Classify the following substances as an element, compound, or mixture:
   a) Pop is composed of water, sugar, and carbon dioxide.
   b) Graphite in a pencil is composed of carbon.
   c) Carbon dioxide is composed of carbon and oxygen.
9. Someone sprinkles dilute acetic acid over your French fries. Are they safe to eat? Explain your answer.

Extend Your Understanding

10. Create a concept map to illustrate the different categories of matter. Use the following terms: matter, solution, element, homogeneous mixture, heterogeneous mixture. Include an example of each in your map.
11. Find out how mixtures can be modified to meet human needs. For example, a substance obtained from the sea weed carrageen is added to many brands of ice cream as a thickener.

1.3 Observing Changes in Matter

Think about the changes in matter you have observed in nature and elsewhere. For example, in the spring, you can see ice—solid water—become liquid water. At home, you can heat water in a kettle and watch it vaporize as steam. These changes are easy to see, but others are not. For example, the hemoglobin which carries oxygen in your blood changes colour when carbon dioxide and oxygen are exchanged in your lungs.

As you learned in section 1.2, changes in matter are classified as physical or chemical. A **physical change** is one in which a material changes from one state to another. The material can also physically change back into its original state. When frozen apple juice is thawed, it melts from a solid to a liquid. If you refreeze the juice, it will turn back into a solid. Its composition will remain the same in all states.

A **chemical change** occurs when two or more materials react and create new materials. The new materials have completely different properties from the original substances. How can you tell when a chemical change is underway or has taken place? The main pieces of evidence to look for are changes in colour, odour, state, or thermal energy during, or as a result of, the reaction between the original substances. Examples are shown below:

Evidence of Chemical Change	Example
Change in colour	When bleach is added to the dye on a denim jacket, a noticeable colour change occurs.
Change in odour	When a match is struck, the substances in the match head react and give off a distinctive odour.
Formation of a solid or gas	When vinegar (a liquid) is added to baking soda (a solid), carbon dioxide gas is formed.
Release or absorption of heat energy	When gasoline burns in a car engine, heat is released.

Sometimes, it can be unclear whether a material's change in state means that a chemical or a physical change has occurred. In such situations, chemical analysis in the lab is required to confirm the nature of the change.

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Detecting Changes in Blood

Canadian scientist Imant Lauks invented a device called the I-Stat. In 2 min, this device can perform 12 different tests to identify changes that have occurred in a person's blood. This process used to take hours or days.

SKILL PRACTICE

IDENTIFYING PHYSICAL AND CHEMICAL CHANGES

For each example in Figure 1.12, identify the change shown as either a physical change or chemical change. If you are not sure what type of change is happening, note that. Review all the examples again when you have finished working through this section.

Figure 1.12(a–e)

(a) (b) (c) (d) (e)

ACTIVITY B-2

Inquiry

INVESTIGATING PHYSICAL AND CHEMICAL CHANGES

The Question

What are some characteristics of physical changes and chemical changes?

Procedure

1. You will investigate four different reactions described below.
2. Copy the data table shown on the next page into your notebook. Fill it in as you complete each test.

Test 1—Sodium carbonate and hydrochloric acid

3. Put a pea-sized pile of sodium carbonate into a small beaker or plastic cup. In your data table, describe the appearance of the sodium carbonate.
4. Observe the dilute hydrochloric acid. If you are unable to see inside the container, use a clear eyedropper to remove a small sample of the acid. Record your observations.
5. Predict what you think will happen when you add the dilute hydrochloric acid to the sodium carbonate.
6. Add 5 to 8 drops of dilute hydrochloric acid to the sodium carbonate. Record your observations.

Test 2—Sugar and heat

7. Use a piece of aluminum foil to make a small cup shape. Put a pea-sized pile of sugar into the centre of the aluminum cup. In your data table, describe the appearance of the sugar.
8. Predict what you think will happen when the sugar is heated.
9. Stand a candle securely in some Plasticine, and light the candle.
10. Using tongs or a wooden clothespin, hold the aluminum cup containing the sugar over the candle's flame. Slowly move the cup back and forth over the flame to heat the sugar. Record your observations.
11. When you are finished, place the aluminum cup in a safe place to cool.

Test 3—Copper(II) sulfate and sodium carbonate

12. Place 5 mL of copper(II) sulfate solution in a test tube. Place 5 mL of sodium carbonate solution in another test tube. In your data table, describe the appearance of each solution.
13. Record your prediction of what will happen when the two solutions are combined.
14. Combine the two solutions and record your observations.
15. When you are finished, dispose of the solution as directed by your teacher.

Materials & Equipment

- sodium carbonate
- 250-mL beaker
- dilute hydrochloric acid
- aluminum foil
- sugar
- candle
- Plasticine
- matches
- wooden clothespin or tongs
- 3 test tubes
- sodium carbonate solution
- copper(II) sulfate solution
- 5-mL measuring spoon
- test-tube holder
- copper(II) sulfate (solid)
- water
- stirring rod

Caution!
Make sure long hair and loose clothing are tied back.

Caution!
Copper(II) sulfate is poisonous and can stain your clothes and skin.

Test 4—Copper(II) sulfate and water

16 Place a pea-sized pile of copper(II) sulfate in a clean test tube and place the test tube in a holder. In your data table, record the substance's appearance.

17 Record your prediction of what will happen when water is added to the copper(II) sulfate.

18 Add 15 mL of water and record your observations. Use a stirring rod to mix the water and copper(II) sulfate. Record your observations.

Figure 1.13 Test 4

Analyzing and Interpreting

19 Which of the changes that you observed were physical?

20 What observations helped you identify a physical change?

21 Which of the changes that you observed were chemical?

22 What observations helped you identify a chemical change?

Forming Conclusions

23 Create a summary, chart, or picture to illustrate the observations you might make to describe the characteristics of a chemical change and a physical change.

Change	Observations before Change	Predictions	Observations during Change	Observations after Change	Type of Change (Physical or Chemical)
Station 1: Sodium carbonate and dilute hydrochloric acid					
Station 2: Sugar and heat					
Station 3: Copper(II) sulfate and sodium carbonate					
Station 4: Copper(II) sulfate and water					

Controlling Changes in Matter to Meet Human Needs

In our everyday life, there are many examples of how understanding and controlling changes in matter help us meet our basic needs. One example you might be interested to read about is the freeze-drying of foods. Freeze-drying is a way to preserve foods so that they can be eaten months—and sometimes even years—later. As well, freeze-drying makes foods easy to prepare—all you have to do is add hot water.

In the freeze-drying process, the food is first frozen to convert the water content in the food to ice. The frozen food is then put in a pressure chamber and the pressure is reduced until the ice sublimes (changes from a solid to a gas). The result is that about 98% of the water in the original food item is removed. This leaves a food that is about 10% its original mass and that, once packaged, doesn't have to be refrigerated. When it's time to eat, all you do is stir in hot water!

Figure 1.14 If you've ever kayaked, you know the importance of keeping your supplies as light as possible. Freeze-dried foods weigh little and take only minutes to prepare.

Figure 1.15 A highly magnified photo of a "freeze-fractured" cell. In this process, plant or animal tissue is rapidly frozen. The ice formed within each cell is then removed by various evaporation techniques. The result is a clearly revealed cell structure: nucleus, pores, and membrane.

The technique of freeze-drying is also used by biologists to study tissue samples and by restoration experts to rescue important documents that are water damaged.

Another process, developed by the U.S. Army, makes freeze-dried food even more convenient. Instead of having to be heated over a fire or portable stove, the "Meal, Ready to Eat" (also referred to as an MRE) is heated in a special package called a "Flameless Ration Heater." This makes MREs especially useful for soldiers, astronauts, and mountain climbers. To be warmed up, the freeze-dried MRE is placed in the Flameless Ration Heater pouch. The pouch contains magnesium, iron, and salt. When a little water is added to these chemicals, the resulting chemical change releases heat—enough to warm the freeze-dried contents.

From Corn to Nail Polish Remover and Plastic Wrap?

Scientists are also able to change common materials into other useful products. For example, chemicals made from corn can be used to make soda pop bottles, remove paint or nail polish, and fuel some cars. Corn is put through a chemical change called fermentation. Once this chemical process is complete, the new substances are recovered, purified, and made into biodegradable plastics, solvents, and gasohol. Corn-based biodegradable plastics such as bottles and plastic wrap are better for the environment because they can be decomposed by bacteria. Corn-based solvents for removing paint and nail polish are not as harmful to the environment as other types of solvents. Gasohol provides a renewable type of fuel for automobiles.

reSEARCH

What Makes a Match Light?

When a match burns, the wood or paper undergoes combustion, but how does the match ignite? Find out about the chemical reactions that occur when a match is lit. Begin your research at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What is the difference between a chemical change and a physical change?
2. Copy the following table into your notebook and fill in the blanks:

Event	Changes in Matter	
	Observable Changes	Type of Change
Baking bread		
Burning wood		
Freezing water		
Mixing sugar and water		

Connect Your Understanding

3. Describe three indicators of a chemical change. Include examples of each.
4. An unknown white solid is heated for 1 min. It is observed that (a) the solid disappears, leaving a colourless liquid; and (b) after the liquid cools, a white solid appears. What kind of change is this? Explain the reason for your choice.
5. Describe an example of how humans control changes in matter to meet their basic needs.

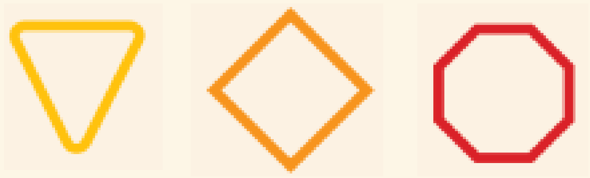
Extend Your Understanding

6. Find one example of a physical change and one of a chemical change not discussed in this section. Share your findings with the class.
7. Is popping popcorn a physical or chemical reaction? Explain your answer.

Assess Your Learning

Key Concept Review

1. Define matter.
2. What do the following symbol shapes represent?



3. Why does everyone working with hazardous materials use WHMIS?
4. Create a diagram illustrating the different states of matter. Name the process that makes the change in state possible.
5. Name at least six properties of matter that can be used to describe a substance.
6. Identify each of the following as either a physical or a chemical change:
   a) Acid is dropped on limestone and bubbling occurs.
   b) Snow turns into rain just before it reaches the ground.
   c) A strip of magnesium is ignited, and it burns brightly.
   d) Solid carbon dioxide, or dry ice, sublimes into carbon dioxide gas.
7. Define the terms physical change and chemical change. Include the words *water*, *baking soda*, *sugar*, and *vinegar* in your definitions.
8. Describe the four main types of mixtures that can be formed.
9. Explain the difference between deposition and freezing.
10. List three examples of physical changes you have observed today.

Connect Your Understanding

11. Describe two occupations in which knowledge of WHMIS is important.
12. What safety symbol would appear on the following?
    a) an aerosol can of hair spray
    b) an agar plate of bacteria culture
    c) a 4-L jug of bleach
    d) a gasoline can
13. What WHMIS symbol would be used in each case listed in question 12?
14. Compare and contrast physical properties with chemical properties.
15. What physical properties could be used to identify the following?
    a) copper metal
    b) water

16. Using the classification of matter chart as a guide (Figure 1.11), create a classification system for the following substances: chocolate chip cookies, coffee with milk in it, aluminum foil, potting soil, a gold medal, pizza, sugar, and garbage. Be sure to list the properties you used to guide your classification.
17. Explain the difference between a suspension and a colloid.

Extend Your Understanding

18. Why are there two different sets of safety symbols for labelling chemicals?
19. Your class is going to be doing a chemistry experiment with a grade 1 class. You are partnered with two students from the younger class. What would you tell them about safety before the activity begins?
20. You are given three unlabelled containers, each with a white powder. Your teacher tells you that the powders could be baking soda, corn starch, or sodium nitrate. Describe the chemical tests you need to perform to identify each powder.

Focus On THE NATURE OF SCIENCE

The goal of science is to develop knowledge about our natural world. This includes knowledge about the nature of substances, how they interact to form new substances, and how these interactions can be controlled and used in a practical way. Working with a partner or the whole class, consider the following questions:

1. Identify an example of a physical change. How do you know a physical change has occurred? What evidence do you have?
2. Identify an example of two or more substances interacting to produce a chemical change. How do you know a chemical change has occurred? What evidence do you have?
3. Describe several chemical changes that you think are useful either to you personally or to society in general. What characteristics or properties of each of these reactions make them useful?

2.0 An understanding of the nature of matter has developed through observations over time.

Key Concepts

In this section, you will learn about the following key concepts:

- substances and their properties
- elements, compounds, and atomic theory
- periodic table

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between observation and theory, and provide examples of how models and theoretical ideas are used in explaining observations
- demonstrate understanding of the origins of the periodic table, and relate patterns in the physical and chemical properties of elements to their positions in the periodic table
- use the periodic table to:
  - identify the number of protons and electrons in each atom, as well as other information about each atom
  - describe the relationship between the structure of atoms in each group and the properties of elements in that group

Humans have been warming themselves around campfires for thousands of years. You may have sat around a campfire and enjoyed the heat. You may even have cooked over a fire. What do you think early humans might have wondered about this mysterious flame that gives off heat and light? Some of them likely puzzled over why fire turns wood black or makes it smell different. Maybe they would have wondered what happened to the wood after the fire had burned out. By being curious about the world around them, these people were the first to try to learn more about substances and how they behave.

In this section, you will learn how our understanding of matter has changed over time. As you read, you will begin to appreciate how asking questions is a key first step we use in making sense of our world. Then, from our observations and experiments, we develop theories and build models to predict and explain what we see. We test these, adjust them, try out new ideas, and eventually reach what seems to be the reasonable answers to our questions. It all begins with curiosity.

2.1 Evolving Theories of Matter

As people observe the natural world around them, they try to make sense of their observations by suggesting explanations. They develop theories to explain what they see. Over time, the theories are modified as new evidence is discovered. The understanding of the structure of matter grew in this way.

Stone Age Chemists

The first chemists lived before 8000 B.C. in an area now called the Middle East. This period is known as the Stone Age because humans used only simple stone tools at the time. Metals had not been discovered.

Once these first chemists learned how to start and control fire, they learned how to change a range of substances to their advantage. For example, they could cook their food, fire-harden mud bricks to strengthen them, and make tougher tools. Eventually this ability to control fire led to the production of glass and ceramic material.

Figure 2.1 Humans in the Stone Age could make only simple stone and bone tools like these. Stone Age people improved their lives when they discovered how to start and control fires. They used fire mainly for cooking and warmth.

GIVE IT A **TRY**

Creating a Time Line Story of Matter

In this subsection, you will be learning how our understanding of the structure of matter has developed through history.

1. Make a time line that shows when the key ideas were proposed and who proposed them. Start your time line at 8000 B.C. and add to it as you read through the subsection. For each idea, be sure to include the observations the person made that led to the new theory.
2. Beneath your time line, sketch the model that resulted from the key idea.
3. Mark the final point in your time line "Today." Draw a diagram beneath this that shows your own understanding of the structure of matter.

EARLY INTEREST IN METALS AND LIQUID MATTER

Between 6000 B.C. and 1000 B.C., early chemists investigated only materials that had a high value to humans. Many of these materials were metals, such as gold and copper. Gold became highly valued because of its properties. It had attractive colour and lustre, and it didn't tarnish. Its softness made it easy to shape into detailed designs, form into wire, and beat into sheets. Because it is so soft, however, gold could not be used for tools or weapons.

Figure 2.2 The earliest use of gold was in jewellery, but it later became very important in the making of coins.

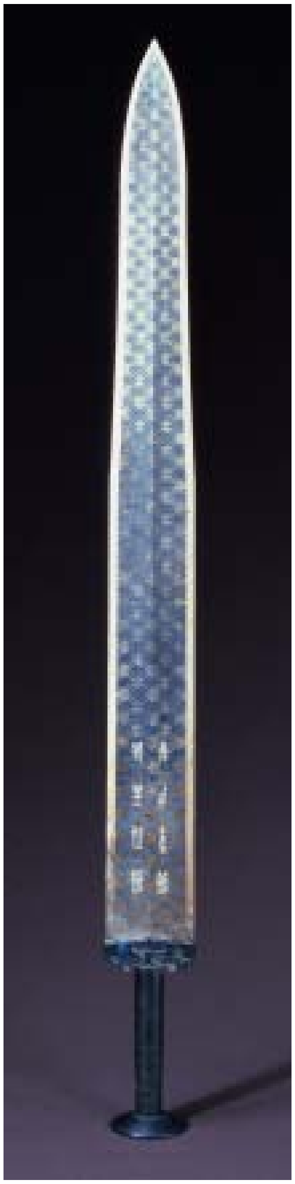


Figure 2.3 An ornate bronze sword dating from about 600 B.C.

Copper became valuable because it could be used to make pots, coins, tools, and jewellery. It was early chemists asking questions that led to an understanding of copper's properties and how the material could be controlled. A piece of natural, untreated copper is brittle—that is, it breaks easily. In that state, therefore, it isn't a useful material for making things. However, when copper is heated, it becomes very useful because it can be rolled into sheets or stretched into long wires.

The original discovery of the effect of heat on copper was possibly accidental. A chunk of copper may have fallen into a fire and whoever picked it out may have asked: Has the copper changed because it was heated? Testing it would have revealed how much softer it was and that it was less likely to shatter when hammered. Later experimenting with copper (about 4500 B.C.) led to the creation of a hard, strong material known as bronze, which is produced when copper and tin are heated together.

Figure 2.4 The discovery of copper's usefulness (such as in these copper spearheads) is a good example of how asking questions leads to scientific and technological development.

Around 1200 B.C., a group of people in the Middle East called Hittites discovered how to extract iron from rocks and turn it into a useful material. The Iron Age began. Eventually, people learned to combine iron with carbon to produce an even harder material—steel. Steel meant sharper blades could be fashioned for hunting and stronger armour could be built to protect soldiers in battle.

Metals were not the only form of matter that early people wanted to learn more about. Many cultures investigated the ways of extracting and using different types of liquids. Juices and oils were especially important both in everyday life and in rituals. (In fact, the word "chemistry" may be derived from the Greek word *khemeia*, meaning juice of a plant.) In ancient Egypt, human bodies were preserved after death by being wrapped in cloths soaked in natural pigments and resins from the juniper tree. Figure 2.6 shows a mummy preserved with this technique.

Figure 2.5 The knowledge and ability to process iron and use it to make stronger tools and weapons changed human society greatly.

Figure 2.6 The ancient Egyptians developed techniques for extracting and purifying juices and oils to use in mummifying bodies.

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Discovering Different Metals

Other metals besides gold and copper have also been long known. Find out when tin, silver, lead, and mercury were discovered and how they were first used. Begin your research at www.pearsoned.ca/scienceinaction.

infoBIT

Thinking About Matter
The first people who developed theories about the structure of matter were philosophers. Philosophers are people who think about the world and humans' place in it. Rather than performing experiments on the nature of matter, early philosophers just thought about the structure of matter. Their explanations and theories were based on their ideas, not on experimental evidence.

Emerging Ideas About the Composition of Matter

The idea that all matter is made up of particles started with the Greek philosophers about 2500 years ago. They observed that a rock could be broken into smaller and smaller pieces until it became a powder. But, they asked, how many times could you continue to break the particles of powder down until they couldn't be broken down any more? In about 400 B.C., the Greek philosopher Democritus used the word *atomos* to describe the smallest particles that could not be broken further. *Atomos* means "indivisible."

Democritus stated that each type of material was made up of a different type of *atomos*. These different particles, he believed, gave each material its own unique set of properties. By mixing different *atomos*, you could make new materials with their own unique properties. However, in about 350 B.C. another Greek philosopher, Aristotle, supported a different hypothesis. He stated that everything was made of earth, air, fire, and water. Because Aristotle was well known and well respected, his description of matter was preferred over Democritus's description for 2000 years.

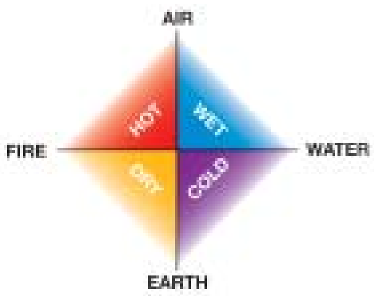


Figure 2.7 Until about A.D. 1600, most people believed Aristotle's view that matter was made up of earth, air, fire, and water. Each of these elements had two main features. For example, water was wet and cold, and earth was dry and cold.

From Alchemy to Chemistry

For the next 2000 years after Democritus's time, experiments with matter were mainly carried out by alchemists, people who were part magician, part scientist. (The word "alchemy" comes from the Arabic word *al-kimiya*, which translates as "the chemist.") Today, the study of alchemy would be called a pseudo-science (an activity that is not a real science because it includes the use of magic). Alchemists believed that it should be possible to change metals into gold. They were not interested in understanding the nature of matter.

Figure 2.8 Alchemists continued in their search for a way to make gold until about 1600.

Even though they weren't real scientists, alchemists performed some of the first chemistry experiments. In doing so, they invented many useful tools that we still use in labs today, such as beakers and filters. They also made practical discoveries. For example, the Arab alchemist al-Razi discovered what we now call plaster of Paris—a material that today's doctors still use to hold broken bones in place until they heal. In 1597, the German alchemist Andreas Libau published *Alchemia*, a book describing the achievements of alchemists. In it, however, Libau also explained how to prepare chemicals such as hydrochloric acid. This type of information made his book the first chemistry text ever printed.

Figure 2.9 Plaster of Paris is a white, powdery combination of chemical substances that, when mixed with water, becomes a quick-hardening paste.

New Interest in Atoms

From the late 1500s on, people investigating the world around them became more like scientists today. They had a greater interest in understanding the nature of matter and change than the alchemists had. And, unlike the philosophers, they based their theories on observations and experimentation.

In the 1660s, Robert Boyle experimented with the behaviour of gases. He was interested in what happened when gases were placed under pressure. He was also interested in determining the composition of gases and other substances. Through his experiments and observations, Boyle became convinced that matter was made up of tiny particles, just as Democritus had suggested in about 400 B.C.

Boyle believed that the tiny particles, existing in various shapes and sizes, would group together in different ways to form individual substances. Boyle felt that the purpose of chemistry was to determine the types of particles making up each substance.

Figure 2.10 Robert Boyle was an Irish aristocrat living in London. He devoted his life to scientific inquiry.

Chemistry Develops as a New Science

In the 1770s, the French scientist Antoine Laurent Lavoisier studied chemical interactions. By the late 1780s, he had developed a system for naming chemicals. This was significant, for now all scientists could use the same words to describe their observations. That made it easier to compare the results of their experiments. Using his naming system, Lavoisier defined some of the substances discovered to that time, including hydrogen, oxygen, and carbon.

Because of his experimental and theoretical work, Lavoisier is called the "father of modern chemistry." Unfortunately, he supported the losing side during the French Revolution and was executed by guillotine in 1794. After his death, Lavoisier's wife, Marie, continued his work. She had worked with him as his lab assistant.

Figure 2.11 Antoine Laurent and Marie Lavoisier worked together conducting scientific investigations into chemical interactions.

An Atomic Theory Takes Shape

In 1808, English scientist John Dalton used the observations from his experiments to develop his own theory of the composition of matter. Dalton suggested that matter was made up of elements. He was the first to define an element as a pure substance that contained no other substances. Gold, oxygen, and chlorine are examples.

Dalton also put forward the first modern theory of atomic structure. He stated that each element is composed of a particle called an **atom**. All atoms in a particular element, he said, are identical in mass, and no two elements have atoms of the same mass. For instance, all oxygen atoms have the same mass, which is different from the mass of chlorine atoms. Dalton's model is sometimes called the "billiard ball model" because he thought of the tiny atoms as solid spheres. While some of Dalton's ideas were later modified based on new evidence, his basic description of the structure of an element was correct.

Figure 2.12 In John Dalton's theory, atoms are like solid billiard balls. The atoms of each element have a different mass than atoms in other elements.

Adding Electrons to the Atomic Model

Dalton's work on the structure of the atom was continued by British physicist J.J. Thomson. He is credited with being the first person to discover a subatomic particle (a particle smaller than an atom). Thomson, experimenting with cathode rays, concluded that the rays were made up of streams of negatively charged particles. He showed that these particles were much smaller in mass than even a hydrogen atom. He named them **electrons**. Although Thomson inferred that these invisible electrons were part of atoms, many people did not agree with him at first. They believed that atoms were the smallest particle of matter and could not be broken down further.

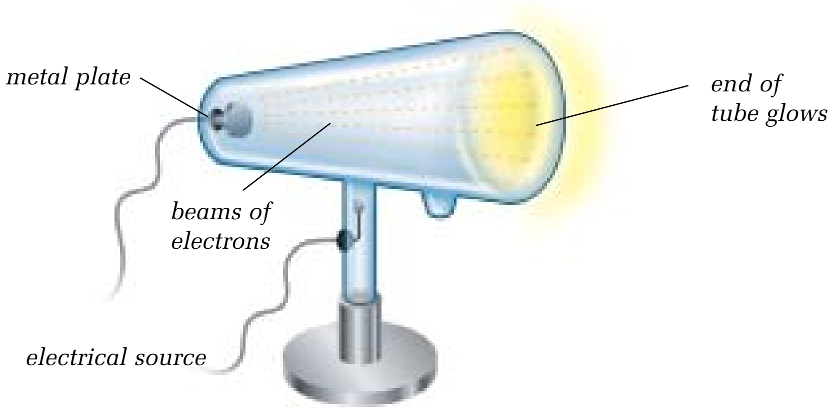


Figure 2.13 Cathode rays are produced when a piece of metal is heated at one end of a tube containing a gas. The heated metal sends out a stream of electrons toward the opposite end of the tube, causing the end of the tube to glow. Early scientists used a simple tube like the one shown here. Cathode ray tubes are now used in electrical devices such as televisions.

In 1897, Thomson proposed what is called the "raisin bun model" of the atom. He described the atom as a positively charged sphere in which negatively charged electrons were embedded like raisins in a bun. Figure 2.14 shows one way of representing this model. The negative electrons balance the positive sphere, so the whole atom has no electrical charge.

In 1904, the Japanese physicist Hantaro Nagaoka refined the model of the atom further. In his model, the atom resembled a miniature solar system (Figure 2.15). At the centre of the atom was a large positive charge. The negatively charged electrons orbited around this charge like planets orbiting around the Sun. Most scientists of the day did not agree with this model because existing theories could not explain it.

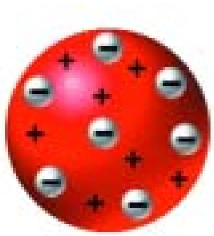


Figure 2.14 J.J.Thomson's model was the first one that described particles smaller than atoms. This model represented the atom as a positive sphere with electrons scattered throughout it—like raisins mixed in a baked bun.

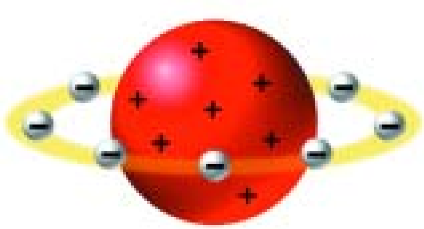


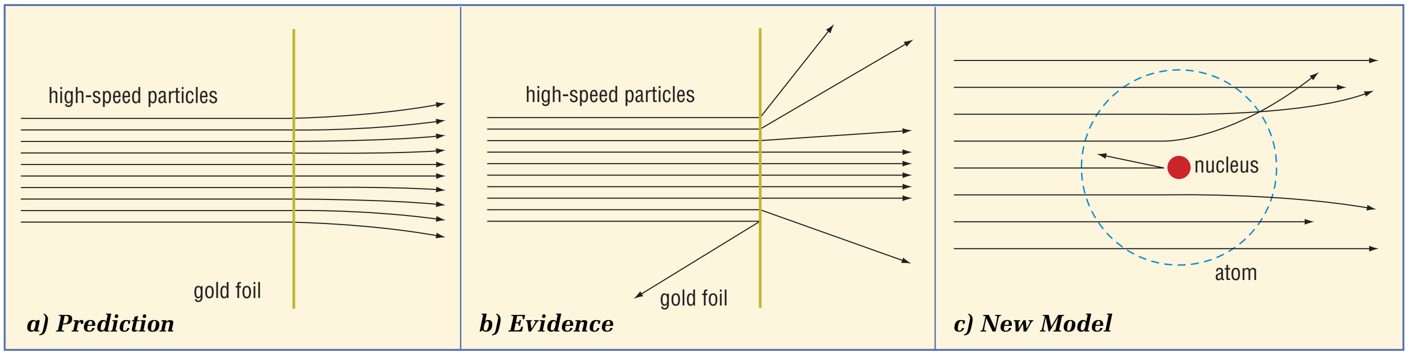
Figure 2.15 Hantaro Nagaoka's model showed the atom as a positive sphere around which electrons orbited in a ring, like Earth orbiting the Sun.

A Canadian Contribution to Atomic Theory

Support for the Nagaoka model and the idea of a central nucleus came from the British scientist Ernest Rutherford. Rutherford won a Nobel Prize in 1908 for his work in radioactivity, which he carried out at McGill University in Montreal from 1898 to 1907. This work contributed to the development of his model of the atom.

Using Thomson's model, Rutherford conducted experiments in which he shot positively charged particles through thin gold foil. He predicted that all the high-speed particles would pass straight through the foil without being affected by the gold atoms (Figure 2.16a). Instead, the results showed that while most particles did behave as predicted, some were greatly deflected (Figure 2.16b). To explain why this might happen, Rutherford proposed a new model. He suggested that atoms were mainly empty space through which the positive particles could pass, but at the core was a tiny positively charged centre. This he called the **nucleus** (Figure 2.16c). He also calculated that the nucleus was only about 1/10 000th the size of the atom—like a green pea in a football field.

Figure 2.16 From experiments with high-speed particles, Ernest Rutherford was able to infer the existence of an atom's nucleus.



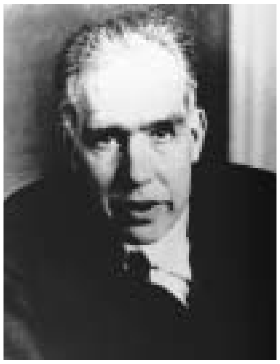


Figure 2.17 Niels Bohr was only 28 when he published his theory of the atom in 1913. In 1922, he won the Nobel Prize in physics.

Bohr's Model

It was Danish researcher Niels Bohr who, working with Rutherford, suggested that electrons do not orbit randomly in an atom. Bohr said that they move in specific circular orbits, or **electron shells**, as shown in Figure 2.18. He believed that electrons jump between these shells by gaining or losing energy. For his work in studying the atom, Bohr won the Nobel Prize in physics in 1922.

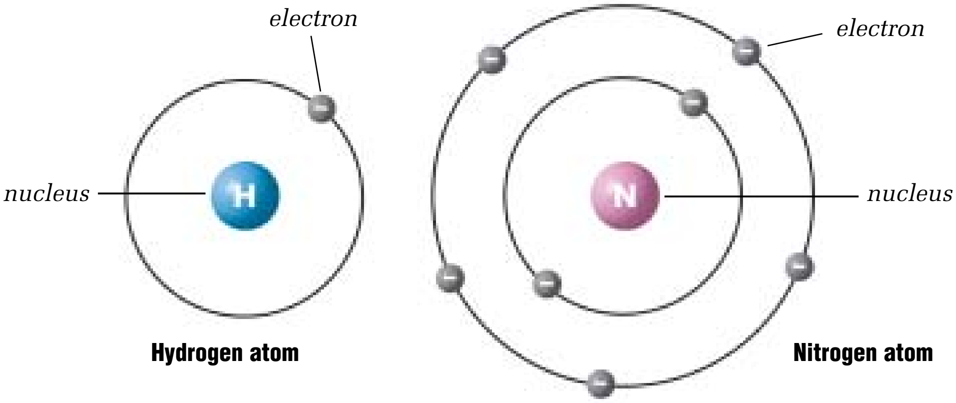


Figure 2.18 Bohr's model of the atom. Electrons orbit the nucleus in a regular pattern.

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The Quantum Atom

Find out more about the quantum nature of the atom. Use print and electronic resources to learn about orbitals and electron clouds. Begin your research at www.pearsoned.ca/scienceinaction.

Bohr's model was readily accepted, though with further refinements, by James Chadwick, another British physicist. Chadwick discovered that the nucleus contained positively charged particles called **protons**, and neutral particles called **neutrons**. The neutron has about the same mass as the proton but carries no electrical charge. An electron has only 1/1837th the mass of either a proton or a neutron.

Today, most people still use the Bohr model to describe the particles that make up the atom. However, further research in the area of quantum mechanics has found that the structure of the atom is different again from that model. The quantum mechanics model of the atom describes electrons as existing in a charged cloud around the nucleus, shown in Figure 2.19.

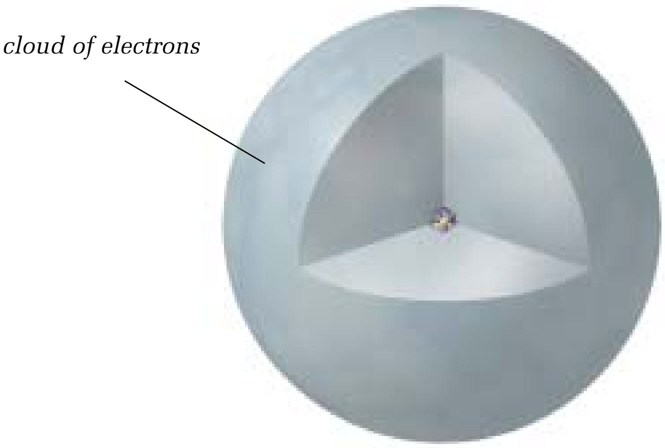


Figure 2.19 Today's quantum mechanics model describes the atom as a cloud of electrons surrounding a nucleus.

Check and Reflect

Key Concept Review

1. Gold and copper were the first forms of matter investigated by humans. Explain why.
2. Where did the word "chemistry" come from?
3. How did Democritus define the atom?
4. Why is Antoine Laurent Lavoisier considered to be the "father of chemistry"?
5. Name four examples of matter other than gold and copper that have been studied because of their value.

Connect Your Understanding

6. Describe one practical example of alchemists' work.
7. Explain the difference between J.J. Thomson's model of the atom and Ernest Rutherford's model.
8. Draw a diagram of Niels Bohr's atom, labelling the position of the three subatomic particles.
9. What was the significance of the work done by Andreas Libau?
10. What made Robert Boyle's study of matter different from the previous work done by philosophers?
11. What changes were made to Thomson's "raisin bun model"? What ideas of his remained the same?

Extend Your Understanding

12. Do you agree or disagree with the statement "In prehistoric times, people understood very little about matter"? Explain your answer.
13. Imagine you had interviewed one of the philosophers, alchemists, or scientists responsible for developing our understanding of the structure of matter. Write a one-page interview with that person.
14. Compare Boyle's model of the atom with Rutherford's model. Use a diagram and a brief description to support your comparison.
15. Scientists, like most people, have lives outside their work. Select one of the scientists discussed in this subsection and write a short biography about his or her life outside of science. Be prepared to read your biography to the class.
16. Innuit peoples are believed to have been using copper long before Europeans arrived in North America. Find out more about the Copper Inuit and present your findings to the class.

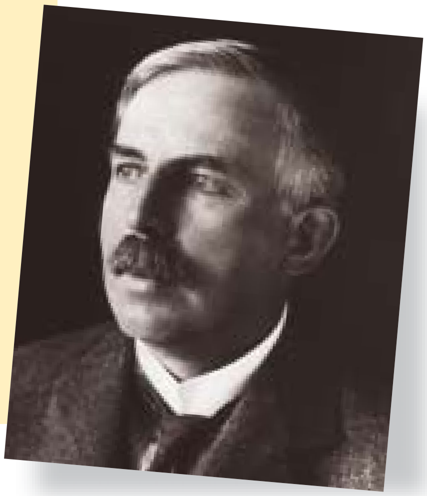


Figure 2.20 Ernest Rutherford proposed his nuclear theory of the atom in 1911.

infoBIT

Choose Your Carbon

Some elements exist in different forms as a solid. Carbon can be a soft black substance called graphite. Or it can be a hard, clear substance called diamond.

2.2 Organizing the Elements

Looking for patterns and classifying scientific information helps us bring order to unorganized ideas. It can also help us interpret what the information means. As you reviewed in section 1.2, matter can be organized in several different ways. It can be classified as solids, liquids, or gases; and, in any of those states, it can be classified as pure substances (elements or compounds) or mixtures (mechanical mixtures, solutions, suspensions, or colloids).

QUICKLAB

Meet the Elements

Purpose

To create a table of properties for a range of elements

Procedure

1. Draw a table in your notebook with the following properties listed across the top: colour, state, appearance, hardness, magnetism, and electrical conductivity. List the samples down the left side.
2. Your teacher will put out samples of different elements in the classroom, as well as the equipment you will need to make some of your assessments. Examine each element and fill in the table with the information you gather about the properties of each one. The guidelines below will help you in your investigation:

Colour

Record the colour of each element. If the element has no colour, call it colourless.

State

Record what state the element is in at room temperature.

Appearance

Describe the appearance of each element. Use words such as "lustre" (shine) and "texture."

Hardness

Determine the hardness of each solid element.

Magnetism

Use a magnet to determine whether the element is magnetic.

Electrical Conductivity

Test electrical conductivity with a simple electrical circuit and a light bulb. If the light bulb goes on when you touch the two wires to the element, the element is a conductor. If the light bulb does not go on, the element is an insulator.

Questions

3. Sort the elements into groups that have the same or similar properties.
4. For each of the groups that share similar properties, suggest a collective name to describe the elements.
5. List these elements under their collective group headings.

Organizing the elements in a meaningful way was a goal of many early chemists. In this subsection, you will learn about that effort and the origins of the periodic table. As well, you'll learn how important advances in this classification approach not only revealed trends in the properties of known elements, but also allowed scientists to predict the existence of elements not then known. To date, scientists have identified 112 elements. Several of the common ones have been mentioned in this unit already, including gold, copper, oxygen, hydrogen, nitrogen, and carbon. The characteristics of some of the common elements are listed in Toolbox 12 at the end of this textbook.

Looking for Patterns

Early chemists used symbols of the Sun and planets to represent the seven metallic elements known at the time. The definition of element that we use today was developed in the late 1700s. By the early 1800s, more than 30 elements had been identified, including oxygen, lead, and mercury. As the science of chemistry developed, more and more elements were identified. To help in the study of elements and compounds, chemists tried to group elements according to their properties. But this became confusing because different scientists organized elements in different ways. A new organization was needed so that everyone would be using the same system.

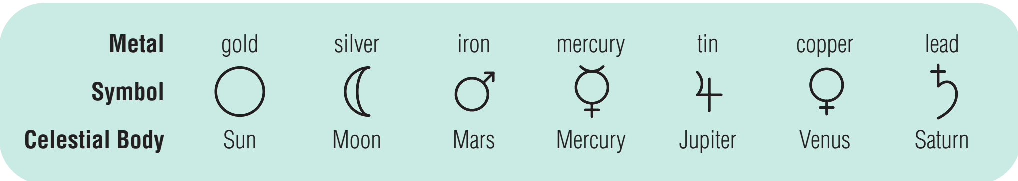


Figure 2.21 The symbols for the Sun and planets closest to Earth have long been used to represent the seven metals known from ancient times.

One of the first attempts by a scientist to create a better system for organizing the elements was made by John Dalton, an English chemist. In the early 1800s, he developed a new set of symbols for elements, as shown in Figure 2.22.

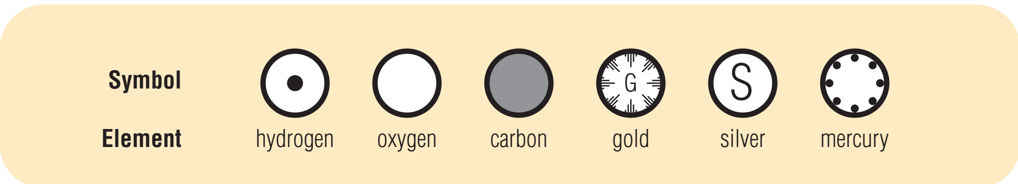


Figure 2.22 The element symbols devised by John Dalton, who lived from 1766 to 1844, were designed to improve communication between chemists.

Dalton's symbols were later modified by Swedish chemist Jöns Jacob Berzelius. In 1814, Berzelius suggested using letters rather than pictures to represent each element. The first letter (capitalized) of an element would become the symbol. For elements with the same first letter, such as hydrogen and helium, a small second letter would be added. Thus, "H" came to stand for hydrogen and "He" for helium. The new system—which remains the one used today—enabled scientists to communicate with each other in a precise and understandable manner. The next challenge was to find a way of putting the elements into an order that made sense.

*re*SEARCH

New Elements

Use electronic and print resources to find out about new elements that have been discovered or named in the past few years. Share this information with your class, using your choice of media. Begin your research at www.pearsoned.ca/scienceinaction.

An Order for the Elements

It was soon realized that the elements could be listed in order of increasing atomic mass. **Atomic mass** is the mass of one atom of an element. Scientists were able to determine the average mass of an atom of other elements by comparing it with the mass of a carbon atom (which is 12.0). Atomic mass is measured by *atomic mass unit* (amu).

In 1864, the English chemist John Newlands recognized a pattern when elements were listed by increasing atomic mass. He noticed that properties of elements seemed to repeat through this list at regular intervals. He called this pattern the "law of octaves," as the pattern was similar to the octave scale on a piano or other musical instrument. Many other scientists thought this law was silly and refused to accept the idea.

Not until 1869 did a clearer understanding of how to arrange the elements emerge. Russian chemist Dmitri Mendeleev was able to organize the elements in a way that reflected the patterns in the properties of the elements.

Finding a Pattern

Mendeleev collected the 63 elements known to exist in his time (the mid-1800s). These included lithium, carbon, nitrogen, oxygen, fluorine, sodium, silicon, phosphorus, sulfur, and chlorine. He then wrote down the properties of each element on a card, such as melting point, density, and colour. Using these cards, he tried to sort the elements into a pattern based on their properties. He also wanted to find a pattern that would allow him to predict the properties of elements not yet discovered. He felt that the ability to predict properties of new elements would prove that his pattern accurately reflected nature.

Mendeleev liked to play a form of the card game solitaire. In that game, a person looks for patterns in the layout of the cards. Mendeleev used his element cards like playing cards, laying them out and searching for patterns. Eventually, he found a pattern that seemed to work. It showed that the properties of elements vary periodically with increasing atomic mass. Figure 2.23 shows the chart that Mendeleev developed.

			Ti = 50	Zr = 90	? = 180.
			V = 51	Nb = 94	Ta = 182.
			Cr = 52	Mo = 96	W = 186.
			Mn = 55	Rh = 104,4	Pt = 197,4
			Fe = 56	Ru = 104,4	Ir = 198.
			Ni = Co = 59	Pl = 106,6	Os = 199.
H = 1			Cu = 63,4	Ag = 108	Hg = 200.
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Su = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,5	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204
		? = 45	Sr = 87,5	Ba = 137	Pb = 207
		?Er = 56	Ce = 92		
		?Yt = 60	La = 94		
		?In = 75,5	Di = 95		
			Th = 118?		

Figure 2.23 Dmitri Mendeleev's original data for the periodic table

Predicting New Elements

Mendeleev noticed some gaps in his chart of the elements, yet was convinced that his organization of the elements was correct. He predicted that new elements would be discovered that would have the properties and atomic mass needed to fit into the gaps. Many scientists didn't agree with Mendeleev's ideas and criticized his work. Within 16 years, however, the gaps were filled through the discovery of new elements that had the properties Mendeleev had predicted.

Figure 2.24 Dmitri Mendeleev, a Russian scientist, discovered a useful way of organizing the elements.

Check and Reflect

Key Concept Review TOOLBOX

1. What is the basic building block of all compounds?
2. a) Define the term atomic mass.
   b) Why is an understanding of atomic mass important to a person trying to organize elements?
3. List five properties used in describing an element.
4. Using Toolbox 12 as a guide, identify the elements in the following common substances:
   a) Aspirin
   b) battery acid
   c) MSG food additive
   d) vitamin C

Connect Your Understanding

5. What two properties make oxygen different from copper?
6. What properties did Dmitri Mendeleev use to identify patterns in the elements? Were any properties of greater value than others in helping him find patterns?
7. Why was it important for Mendeleev to predict the properties of elements not yet discovered?

Extend Your Understanding

8. How were the patterns in the elements that Mendeleev recognized different from the patterns that John Newlands recognized?

*info***BIT**

A New Element

One of the newest elements to be discovered is unubium. Scientists worked steadily for 24 days to find just two atoms of ununbium.

2.3 The Periodic Table Today

Dmitri Mendeleev's periodic table included the 63 known elements of his time. Since then, many more elements have been discovered. Today, about 112 elements are known (Figure 2.25).

One of the first important finds using Mendeleev's table was the element gallium. Discovered in 1875, gallium fit into one of the positions in the periodic table where Mendeleev had placed a question mark. It matched almost exactly his prediction of the properties of an element that would fit in that position.

Another question mark in the table wasn't filled until 1939 when the element francium was discovered by the French chemist Marguerite Perey. This element also matched Mendeleev's prediction almost exactly. This proved once again that the periodic table was a useful tool for organizing the elements.

Figure 2.25 The periodic table. The element oxygen is shown as an example of the information that the periodic table provides for each element.

Solid **S** | Liquid **Br** | Gas **He**

Metal | Metalloid | Non-metal

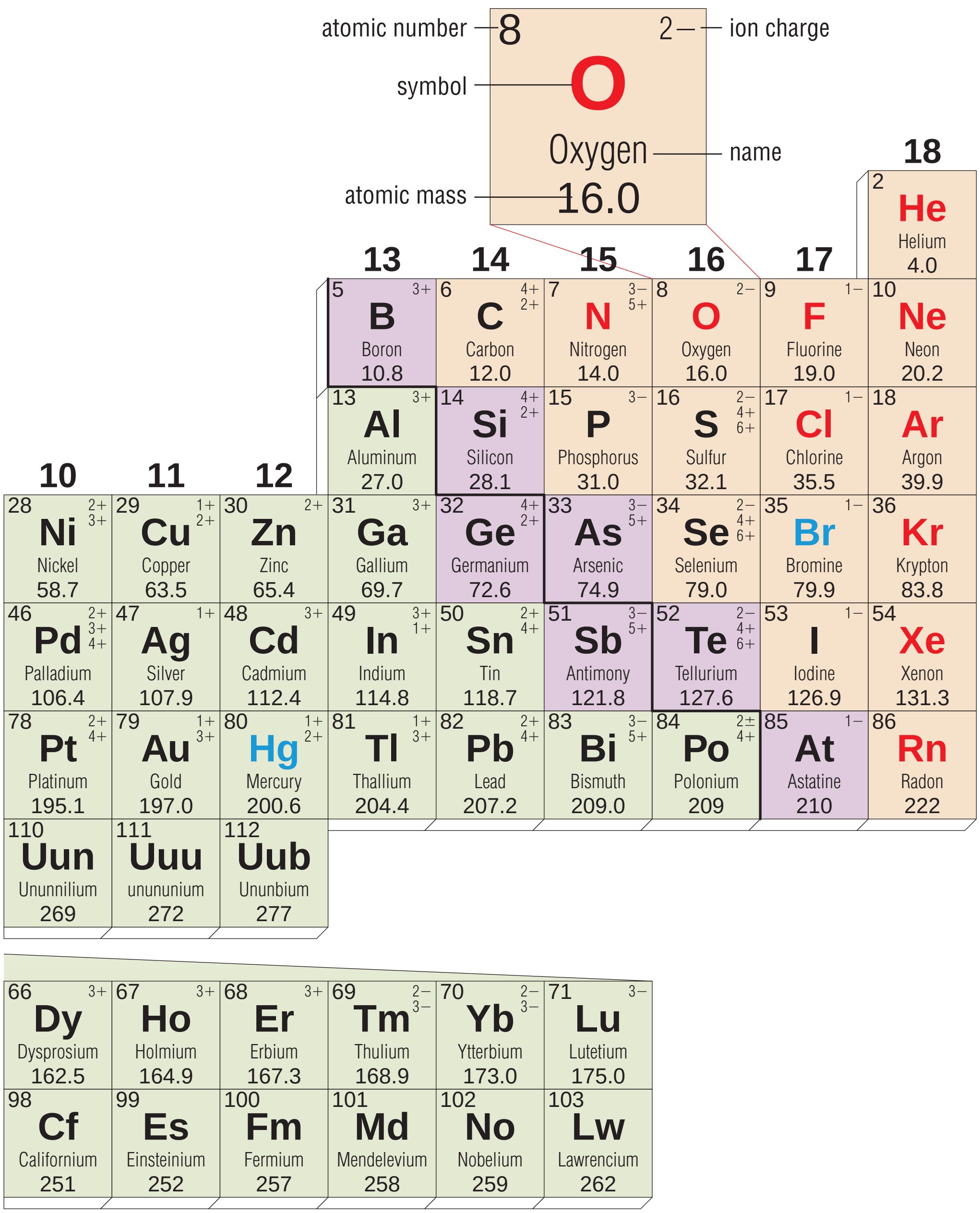
	1	2	3	4	5	6	7	8	9
1	1 1± **H** Hydrogen 1.0								
2	3 1+ **Li** Lithium 6.9	4 2+ **Be** Beryllium 9.0							
3	11 1+ **Na** Sodium 23.0	12 2+ **Mg** Magnesium 24.3							
4	19 1+ **K** Potassium 39.1	20 2+ **Ca** Calcium 40.1	21 3+ **Sc** Scandium 45.0	22 3+ 4+ **Ti** Titanium 47.9	23 2+ 5+ **V** Vanadium 50.9	24 2+ 3+ 6+ **Cr** Chromium 52.0	25 2+ 7+ **Mn** Manganese 54.9	26 3+ 2+ **Fe** Iron 55.8	27 2+ 3+ **Co** Cobalt 58.6
5	37 1+ **Rb** Rubidium 85.5	38 2+ **Sr** Strontium 87.6	39 3+ **Y** Yttrium 88.9	40 4+ **Zr** Zirconium 91.2	41 5+ 3+ **Nb** Niobium 92.9	42 6+ 2+ **Mo** Molybdenum 95.9	43 7+ 3+ **Tc** Technetium (98)	44 3+ **Ru** Ruthenium 101.1	45 3+ **Rh** Rhodium 102.9
6	55 1+ **Cs** Cesium 132.9	56 2+ **Ba** Barium 137.3	57 3+ **La** Lanthanum 138.9	72 4+ **Hf** Hafnium 178.5	73 5+ **Ta** Tantalum 180.9	74 6+ 2+ **W** Tungsten 183.8	75 7+ 3+ **Re** Rhenium 186.2	76 2+ 3+ 4+ **Os** Osmium 190.2	77 2+ 3+ 4+ **Ir** Iridium 192.2
7	87 1+ **Fr** Francium (223)	88 2+ **Ra** Radium (226)	89 3+ **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)

58 3+ 4+ **Ce** Cerium 140.1	59 3+ 4+ **Pr** Praseodymium 140.9	60 3+ **Nd** Neodymium 144.2	61 3+ **Pm** Promethium (145)	62 2+ 3+ **Sm** Samarium 150.4	63 2+ 3+ **Eu** Europium 152.0	64 3+ **Gd** Gadolinium 157.3	65 3+ 4+ **Tb** Terbium 158.9
90 4+ **Th** Thorium 232.0	91 4+ 5+ **Pa** Protactinium 231.0	92 3+ 4+ 5+ 6+ **U** Uranium 238.0	93 3+ 4+ 5+ 6+ **Np** Neptunium (237)	94 3+ 4+ 5+ 6+ **Pu** Plutonium (244)	95 3+ 4+ 5+ 6+ **Am** Americium (243)	96 3+ **Cm** Curium (247)	97 3+ 4+ **Bk** Berkelium (247)

Today, more new elements are being discovered, but many of these are not stable. They have been created in laboratories with special equipment and have never been found in nature. Still, no matter how the elements are identified, they all have their place in the periodic table.

Understanding the Periodic Table

Notice that the periodic table is a series of boxes in rows and columns. Each horizontal row is called a **period** (numbered from 1 to 7). Each vertical column forms a **group**, or **family**, of elements (numbered from 1 to 18). These groups have similar chemical properties. Every box in the table contains several useful pieces of information.



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A Different Version of the Periodic Table

Scientists continue to organize the elements in different ways. One recent example is the three-dimensional periodic table shown here.

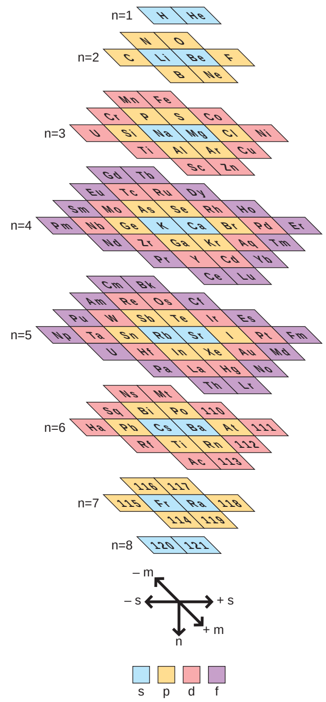


Figure 2.26 Not all scientists who contribute to the understanding of elements are recognized. Canadian Harriet Brooks is a case in point. One of her subjects of study was the radioactive element thorium. Brooks was able to measure the mass of what was thought to be a gas being given off by thorium. She showed that this "gas" was in fact a new element, and it was given the name radon.

Photo Miss Harriet Brooks, Nuclear Physicist, Montreal QC, 1898/Notman Photographic Archives/McCord Museum of Canadian History, Montreal/II-123880

Useful Information on Each Element

Element Symbol and Name

The large letter or letters in each box show the symbol for the element. In Figure 2.25, you can see that oxygen's symbol is O. For most elements, the symbol is an abbreviation derived from the element's modern chemical name. For example, the symbol for silicon is Si, and the symbol for manganese is Mn. However, there are exceptions. For example, the symbol for gold is Au, which is from *aurum,* the Latin word for gold. The symbol for iron is Fe, which is from *ferrum,* the Latin word for iron. The table below shows the word origin for several common elements.

Modern Name	Symbol	Latin Name
antimony	Sb	*stibium*
copper	Cu	*cuprum*
gold	Au	*aurum*
iron	Fe	*ferrum*
lead	Pb	*plumbum*
mercury	Hg	*hydrargyrum*
potassium	K	*kalium*
silver	Ag	*argentum*
sodium	Na	*natrium*
tin	Sn	*stannum*
tungsten	W	*wolfram*

Other Names for Elements

Not all elements are named for Latin words. Some elements are named after the location in which they were first discovered. For example, californium was discovered in 1950 at the University of California. Other elements are named after scientists who made important contributions to their field of study. For example, einsteinium, fermium, and curium are named after Albert Einstein, Enrico Fermi, and Marie Curie.

Atomic Number

The number above the element's symbol on the left is the **atomic number**. It shows how many protons are in the nucleus of one atom of the element. An oxygen atom, for example, always has eight protons. If you found six protons in an atom, the periodic table would show you that you were looking at carbon. Because atoms are neutral, the number of protons equals the number of electrons. Therefore, the atomic number also tells you how many electrons are in an atom of a particular element.

Notice that the atomic number increases by one for each element as you read across the periodic table from left to right.

Atomic Mass

The number below the element's name is the atomic mass. The atomic mass tells you the total mass of all the protons and neutrons in an atom. (Electrons are so tiny that they have very little effect on the total mass of the atom.) Recall that this is the average mass of the element's atoms. Not all atoms in an element have exactly the same mass: some have slightly higher values than others, and some have slightly lower values. This difference occurs because of the different number of neutrons from atom to atom. Atomic mass is measured by **atomic mass unit** (amu). One amu is defined as 1/12th the mass of a carbon-12 atom.

Associated with atomic mass is **mass number**. It represents the sum of the number of protons and neutrons in an atom. For example, the most common form of carbon atom has six protons and six neutrons. Its mass number is therefore equal to 12.

Not all carbon atoms are carbon-12, however. About 1% of carbon atoms have seven neutrons. The mass number of each of those atoms is 13. There is also one more naturally occurring form of carbon atom, and its mass number is 14. How would you find out how many neutrons it has? Subtracting the atomic number (6) from the mass number (14) shows you there are 8 neutrons in the nucleus of this type of carbon atom:

mass number (14) − atomic number (6) = number of neutrons (8)

Carbon-14 is present in nature in very low concentrations. That's good, because carbon-14 is *radioactive*, which means the atom is unstable and falls apart easily in a mini-nuclear reaction, releasing energy. Carbon-14 is present in small amounts in all living things. Scientists use it to find the age of biological materials, such as animal fossils. This technique is called carbon dating.

Element	Atomic Mass (amu)	Mass Number of Most Common Type of Atom of the Element	Mass Number of Second Most Common Type of Atom of the Element
hydrogen	1.0	1	2
carbon	12.0	12	13
bromine	79.9	79	81
iron	55.8	56	54
titanium	47.9	48	46
lead	207.2	208	206
uranium	238.0	238	235

SKILL PRACTICE

Using the Periodic Table

Use the periodic table to find out how many protons, electrons, and neutrons are in each of the following elements. The mass number is shown beside each element in parentheses. Make a table in your notebook to record your results.

a) vanadium (51)
b) nickel (58)
c) phosphorous (31)
d) bromine (79)
e) beryllium (9)
f) argon (40)
g) magnesium (24)
h) uranium (238)
i) silicon (28)
j) chromium (52)
k) titanium (48)

ACTIVITY B-3

Inquiry

BUILDING A PERIODIC TABLE

The Question

How can you use a model to represent the patterns in the periodic table?

Materials & Equipment

- 24 assorted nuts and bolts in a bag
- 1 extra nut or bolt
- 2 large sheets of paper
- balance
- element cards
- graph paper

Procedure

Part 1—Classifying Nuts and Bolts

1. Your teacher will give you a bag that contains 24 nuts and bolts. Take the nuts and bolts out of the bag and examine them.
2. Your bag originally contained 25 nuts and bolts, but your teacher removed one of them. Determine whether a nut or a bolt was removed, and provide as much detail as you can about the missing piece.
3. Share your ideas with your class. How were your ideas similar to your classmates? How were they different?
4. Collect the missing nut or bolt from your teacher. How close was your description to the missing object?
5. In step 2, each group probably used a slightly different method of classifying their nuts and bolts to help them identify the missing one. For step 6, everyone will use the same classification.
6. On a large sheet of paper, make a grid with five equal-size columns and five equal-size rows. Make sure the boxes are large enough to hold your largest nut or bolt. Number the boxes 1 to 25 starting on the top left at number 1 and working across the row from left to right. The first box in the second row should be number 6.

Figure 2.27 Step 7

7. Place the smallest bolt at number 1 and the largest nut at number 25. Now organize the rest of your nuts and bolts on the grid.
8. Measure the mass of each nut and bolt and record that information on your grid.

Part 2—Classifying Elements

9 Your teacher will give you a card that describes an element. Find classmates who have element cards that describe elements with properties similar to yours.

10 Tell the class about the properties that the members of your group all share. If the class agrees with your grouping, your teacher will assign your group a number.

11 After everyone in the class has been assigned to groups, arrange all the students in the class in order of atomic mass.

12 Make another five-by-five grid, as you did in step 6. Fill it in using the order of the elements in the class. In your grid, include the atomic mass for each element.

Analyzing and Interpreting

13 Using the data you collected in part 1, make a graph of nut or bolt mass (responding or dependent variable) versus nut or bolt number (manipulated or independent variable). (The number of each nut or bolt is the number of the box in the grid where the nut or bolt was placed.)

14 What patterns do you notice in this graph? Record your observations.

15 Using the data on the elements from part 2, make a graph of atomic mass versus atomic number. What patterns do you notice in this graph? Record your observations.

16 Compare the two graphs you made. What similarities do you see?

17 What similar patterns do you see between the two grids you made in parts 1 and 2?

Forming Conclusions

TOOLBOX

18 Using the periodic table in Toolbox 12, compare your arrangement of elements with the arrangement of elements in the periodic table. Describe their similarities and their differences.

Applying and Connecting

As the infoBIT on page 127 says, different versions of the periodic table have been developed in the past and are still being developed today. Find examples of these other periodic tables and present your findings to the class.

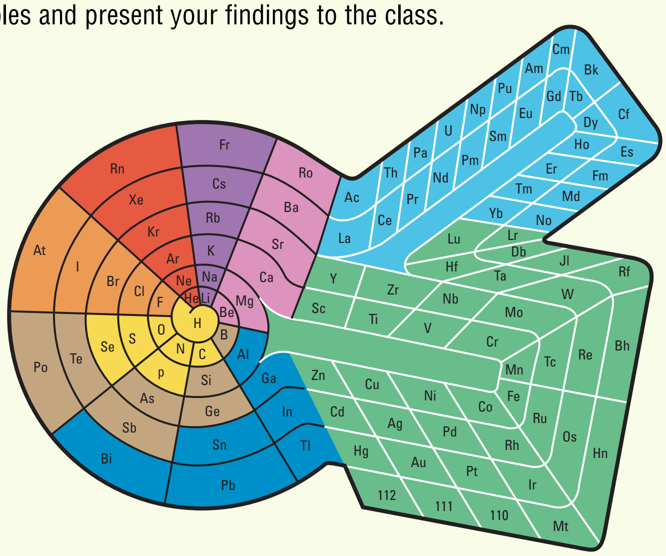


Figure 2.28 This is another version of the periodic table, created by Dr. Theodor Benfey, an American chemist.

Figure 2.29 Nickel is widely used in solution with other metals to create *alloys*. Some coins are made of copper-nickel alloys. Stainless steel is made of iron, nickel, and other elements.

Figure 2.30 Palladium is used in dental crowns, surgical instruments, and watch parts.

Figure 2.31 Platinum, highly valued as a precious metal, is more expensive than gold. It is also used in industry as a powder that enables chemical reactions to work better.

Patterns of Information in the Periodic Table

The periodic table contains a wealth of information related to the elements, in addition to their atomic number and atomic mass. By noticing where elements appear in the periodic table, you can tell something about their general nature.

Notice that a large part of the periodic table on pages 126–127 is green. All the elements in this area are metals. **Metals** are shiny, malleable, and ductile. They also conduct electricity. The elements in the orange area on the right are non-metals. **Non-metals** can be a solid or a gas. Solid non-metals are dull, brittle elements. Non-metals, except carbon, do not conduct electricity. Because they don't conduct electricity, they are called insulators. The diagonal purple row of elements between the metals and the non-metals contains elements called metalloids. **Metalloids** have both metallic and non-metallic properties.

Groups

Recall that Mendeleev arranged the periodic table to show a variety of patterns. The 18 columns in the table contain groups or families of elements with similar chemical properties.

These groups are numbered from 1 to 18 and are usually referred to by the first element in the column. For example, group 10 is the nickel group of elements because nickel is the first element at the top of that column. The other elements in that group are palladium and platinum. They have properties that are similar to those of nickel. There are a few exceptions to this pattern. Group 1 is divided into two parts—hydrogen and the alkali metals (see page 133). Hydrogen is considered to be a unique element, and in some periodic tables it is placed in a separate spot away from the other elements.

Periods

The rows in the periodic table, called periods, are numbered 1 to 7. The number of elements may vary from period to period. The first period has two elements. Periods 2 and 3 have eight elements, and periods 4 and 5 have 18 elements. You may have also noticed periods 6 and 7 have an additional 14 elements. These elements are placed separately at the bottom of the periodic table. This makes it easier to print a periodic table on a standard-sized page.

As you move from left to right across a period, you will notice that the properties of the elements change. Within the periods, there is a pattern. From left to right, the elements gradually change from metals to non-metals. So the first element in a period, on the far left, is a metal. The last element in a period, on the far right, is a non-metal. For example, if you look at period 4, you'll see that potassium (K) is a metal and krypton (Kr) is a non-metal. The most reactive metals start on the left. As you move right, the metals generally become less reactive.

Other Interesting Patterns

Group 1 elements, not including hydrogen, are called the **alkali metals**. These are the most reactive of the metals. They react when exposed to air or water. As you move down the group, starting with lithium, the reactivity increases. Group 2 elements are called the **alkaline-earth metals**. They react when exposed to air and water as well, but their reactivity is not as strong as that of the alkali metals.

Group 17 elements are called the **halogens**. They are the most reactive non-metals. For example, fluorine can etch glass, chlorine is commonly used to sterilize the water in swimming pools, and bromine gas is so corrosive it can burn skin. These elements are reactive and can combine with other elements to form new substances with useful properties. Sodium, for instance, can be highly reactive with fluorine, producing sodium fluoride—a chemical found in toothpaste.

Group 18 elements are the **noble gases**, the most stable and unreactive elements. In fact, it was long believed that noble gases could never combine with other elements. It wasn't until 1962 when that idea was proved incorrect. Canadian chemist Neil Bartlett and his colleagues at the University of British Columbia synthesized the first noble gas compound, combining xenon, platinum, and fluorine to create a new substance.

reSEARCH

Investigate an Element

Select an element from the periodic table and find as much information as you can about its properties and uses. Create a poster or Web page to illustrate your information. Begin your research at www.pearsoned.ca/scienceinaction.

SKILL PRACTICE

EXPLORING PATTERNS IN THE PERIODIC TABLE

TOOLBOX

Use the periodic table in Toolbox 12 to answer the following questions.

1 a) How many elements are gases at room temperature (20°C)? Write their chemical names and symbols.
   b) How many elements are liquids at room temperature (20°C)? Write their chemical names and symbols.

2 What element is found in group 2, period 3?

3 a) What is the symbol of the element with the atomic number 82?
   b) What is the atomic number of arsenic?

4 a) What is the symbol of the element with the atomic mass of 238?
   b) What is the atomic mass of silver?

5 Use the atomic number, atomic mass, and symbol of the elements to indicate the number of subatomic particles in an atom of the following elements:
   a) electrons in oxygen
   b) electrons in Li
   c) protons in Na
   d) protons in helium

6 Two of the most recent elements to be discovered are ununbium and ununquadrium. Ununbium has an atomic number of 112 and an atomic mass of 277. Ununquadrium has an atomic number of 114 and an atomic mass of 289. What do you think the atomic mass of the element with atomic number 113 will be?

Figure 2.32 High-energy subatomic particles leave telltale tracks in an experimental cloud chamber.

Check and Reflect

Key Concept Review

1. What is the difference between the atomic number and the atomic mass of an element?
2. If tin's mass number is 119 and its atomic number is 50, how many neutrons are in the nucleus of an atom of tin?
3. Correct the following statements about the periodic table.
   a) Neon has 11 protons.
   b) The symbol for sodium is So.
   c) Beryllium has 4 neutrons.
   d) Boron and aluminum are metals.
   e) Chlorine has 16 electrons.
4. Match the elements in the list below with one of the following two descriptions:
   i) shiny, ductile conductor of electricity OR
   ii) dull, brittle insulator
   a) P b) W c) Cu d) F e) Hg f) K
5. Match the term on the left with the description on the right.

a) alkali metal	i) a combination of two or more elements
b) halogen	ii) an unreactive non-metal
c) element	iii) very reactive metal
d) compound	iv) a pure substance of the same atoms
e) noble gas	v) very reactive non-metal

Connect Your Understanding

TOOLBOX

6. Use the periodic table in Toolbox 12 to answer the following questions:
   a) What two elements are liquids at room temperature?
   b) What element has the symbol K?
   c) What element has 50 protons?
   d) What element has a mass of 183.8 amu?
7. Hydrogen is considered to be a unique element. Describe three atomic properties that make it different from the other elements.
8. Why isn't atomic mass used to classify an element?

Extend Your Understanding

9. Three containers each hold a different "mystery" element. Four of their properties are shown below. Identify which element is (a) a non-metal, (b) an alkali metal, and (c) a noble gas.

	Colour	State at Room Temperature	Reactivity	Conductivity
Element X	green-yellow	gas	high	no
Element Y	colourless	gas	none	no
Element Z	silver-white	solid	high	yes

Careers and Profiles

Quality Control Analyst

Sona Arslan is a quality control analyst at a large pharmaceutical company.

A quality control analyst tests products to make sure that they meet manufacturing specifications before they are released to consumers. Quality control analysts use a variety of equipment during testing. For example, a quality control analyst testing medicines would use chromatographs, microscopes, lasers, pH meters, and other devices to test the properties of the substances. They also use many different computer applications to analyze the data. Sona Arslan is a quality control analyst for a major pharmaceutical company. Pharmaceutical companies make the wide range of medicines we use, from headache pills to chemotherapy treatments.

Q: Why did you choose the career of quality control analyst?

A: In high school, I liked and did well in chemistry, so I wanted to pursue a career in this field. Quality control analysts work in all types of industries. While at university, I became interested in working in the pharmaceutical industry. In 1998, after I graduated from university with an Honours B.Sc. in chemistry and physics, I obtained a one-year internship at Glaxo Wellcome Inc., one of the largest pharmaceutical manufacturing companies in the world. When I completed the internship, I was offered a position with the company to continue working as a quality control analyst.

Q: What types of skills are required in your work?

A: Some of the skills required are accuracy, attention to detail, organizational skills, and good computer, troubleshooting (problem-solving), and team-work skills.

Q: What do you enjoy most about your work?

A: I enjoy most the "hands on" aspect of my job, as well as the variety of work and challenges that are present. What I do on any given day depends on what test or tests I am working on. There is usually a lot of preparation work that is done before starting a test: glassware and reagents must be gathered, test solutions must be made, and instruments calibrated before testing can begin.

Q: Can you give an example of how a product is tested?

A: Here's what happens when we test an ointment. First, I conduct a physical examination to confirm the colour and consistency of the product. Next, I do a chromatography analysis to confirm that the ointment is homogeneous. This also confirms the identity and amount of the main active ingredient present in the product. Finally, I do a microscopic examination to make sure there is no foreign matter in the product. The test results are reviewed by a senior analyst and then signed off by a manager. The completed test results are sent to the Quality Assurance department. Staff there review the quality control test results before releasing the product for sale. If the sample fails the quality control test, an investigation is conducted to determine whether the failing result is related to analyst or instrument error, or to the product. If it is product related, the batch is rejected. According to Canadian law, no products can be released to market without first passing quality testing.

Q: What advice do you have for someone thinking about a career like yours?

A: You need a B.Sc., preferably in chemistry. It's also very helpful to obtain related work experience during the summer or through a co-op program.

1. Why do you think it's important for a quality control analyst to have a strong knowledge of the properties of matter?
2. What do you think quality control analysts would test for in the following industries?
   - candy making
   - soft drink production
   - synthetic fibre manufacturing (e.g., for clothing and furniture)
3. If you were a quality control analyst, what part of the job would you find most interesting?

Assess Your Learning

Key Concept Review

1. What is considered to be one of the first series of events in the study of chemistry? Explain why this was an important event.
2. How did an early understanding of gases lead to a better understanding of the atom?
3. What properties could you use to distinguish metals from non-metals?
4. Explain how knowing the boiling point and melting point of a substance can help you identify it.
5. For each statement below, explain why you think it describes an element or a compound.
   a) An odourless, colourless gas produces water and carbon dioxide when it burns.
   b) A shiny, ductile solid cannot be broken into smaller components.
   c) An odourless, colourless liquid can be broken into two different gases when electricity is passed through it.
   d) A toxic, green gas is very reactive with other metals and some non-metals.
6. What is the difference between a group and a period in the periodic table?

Connect Your Understanding

7. Human history is divided into ages. How did an understanding of matter help humans move from the Stone Age to the Iron Age?
8. Describe the atomic model developed by each of the following people:
   a) Democritus
   b) Nagaoka
   c) Bohr
   d) Chadwick
9. The diagram in Figure 2.33 is a box from the periodic table. Label each item of information in the box. What does each item tell you about the element?
10. Copy the picture of the atom shown in Figure 2.34 into your notebook. Use the models of the atom developed by Ernest Rutherford and James Chadwick to label its parts.
11. While making a dessert in your kitchen, you realize that the salt, baking soda, and cornstarch are in unlabelled containers. What properties could you use to identify each substance? No tasting allowed!

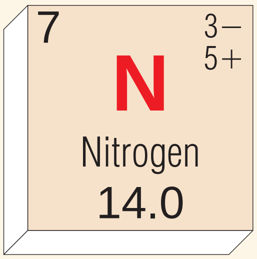


Figure 2.33 Question 9

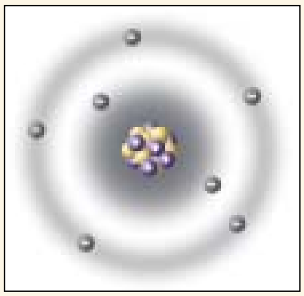
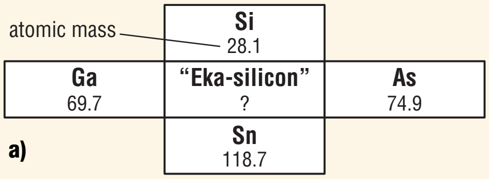


Figure 2.34 Question 10

Extend Your Understanding

12. Mendeleev believed that one of the gaps in his first periodic table would eventually be filled by an element he called *eka-silicon* (Figure 2.35a). Such an element had not yet been discovered. In 1871, he predicted what the properties of this undiscovered element would be. In 1886, he was proven correct.



b)

Some Properties of Selected Elements		
Element	**Colour**	**Atomic Mass**
Silicon	steel grey	28.1
Gallium	grey-black	69.7
Eka-silicon		
Arsenic	silver to grey-black	74.9
Tin	grey-white	118.7

Figure 2.35 Question 12

Use the information in Figure 2.35b to answer the following questions:

a) Which of the four elements in Figure 2.35b would you use to predict the properties of Mendeleev's new element? Explain your reasoning.
b) What atomic mass would you predict for *eka-silicon*?
c) What colour would you predict *eka-silicon* to be?
d) What do we now call *eka-silicon*?
e) Why do you think Mendeleev did not use the atomic number in his work?

Focus On THE NATURE OF SCIENCE

An idea, such as the description of the structure of an atom, develops through the contributions of many people over a long period of time. This is a common process for developing ideas in science. By sharing and collaborating with people all over the world, scientists make and investigate discoveries. Consider the following questions and, if possible, use examples from this section to support your answers.

1. What conditions or factors were necessary for ideas on the structure of the atom to be shared?

2. What is the value of sharing your discoveries with others?

3. Why would some people consider not sharing their discoveries with others?

3.0 Compounds form according to a set of rules.

Key Concepts

In this section, you will learn about the following key concepts:

- periodic table
- elements, compounds, and atomic theory
- chemical nomenclature

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between ionic and molecular compounds, and describe the properties of some common examples of each
- read and interpret chemical formulas for compounds of two elements, and give the IUPAC name and common name of these compounds
- identify/describe chemicals commonly found in the home, and write the chemical symbols
- identify examples of combining ratios/number of atoms per molecule found in some common materials, and use information on ion charges to predict combining ratios in ionic compounds of two elements
- assemble or draw simple models of molecular and ionic compounds

All the signs above tell you that this is where you can get gas for your car. If you were travelling in France, you would look for a sign that said "Gaz." If you were travelling in Britain, you would have to watch for a sign that said "Petrol." Even though Britain and Canada are both English-speaking countries, sometimes we use different words for the same things. For example, in England, potato chips are called "crisps" and the trunk of your car is called the "boot." If you travel to a non-English-speaking country, words can be even more confusing if you don't speak the local language.

Scientists studying the nature of matter encountered similar problems. At first, there was no common way of naming compounds. How could scientists understand each other's work if they weren't sure from the terminology what materials were being used? To help reduce the confusion, scientists have agreed on a common set of rules for naming compounds. Using these rules, a person can identify and describe any compound in the world—and be clearly understood by others. In this section, you will investigate how compounds are formed and how they are named.

3.1 Naming Compounds

Earlier in this unit, you learned how our understanding of the structure of the atom has gradually developed. At first, people thought the atom was the smallest particle possible (atom, you'll recall, comes from the Greek word *atomos*, meaning indivisible). Today we know that the atom is made of several much smaller particles.

Combining Elements to Make Compounds

Look around your home and you'll be amazed at the variety of chemicals in your cupboards and on your shelves. In the bathroom, you'll find water, soap, shampoo, and toothpaste—all chemicals. In the basement or garage, you may find cleaning products, such as ammonia and bleach, and perhaps painting and gardening products. In your kitchen, you'll likely find table salt, baking soda, and baking powder. Each of these compounds has a chemical name and a **chemical formula**. The formula identifies which elements, and how much of each, are in the compound. So, for example, table salt's chemical name is sodium chloride and its formula is NaCl. Baking soda's chemical name is sodium bicarbonate and its chemical formula is $NaHCO_3$.

Figure 3.1 Most homes contain a range of chemical compounds, such as the ones shown here.

info BIT

How Big Are Atoms?
Five-hundred-million gold atoms lined up side-by-side would form a line as long as a $10 bill.

SKILL **PRACTICE**

Make a Model of an Atom

Your teacher will give you some of the following materials: paper, bingo chips, coins, Plasticine, and rubber magnetic strips. Your task is to choose an element from the first 18 in the periodic table and construct a model of what you think that element's atom would look like. Remember to consider the information you learned in subsection 2.1 about the atom and evolving ideas about its structure.

Your model should clearly show the structure of the atom and should include the correct number of protons, neutrons, and electrons.

When you have completed your model, show it to your class. Compare your model with other models.

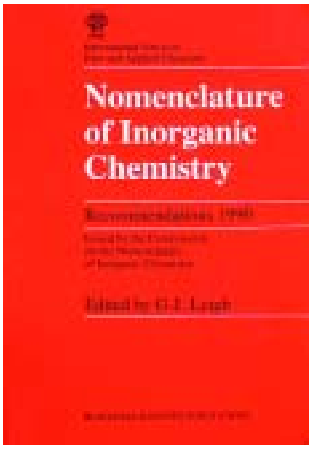


Figure 3.2 The IUPAC book contains the rules for naming chemical compounds.

Naming Chemical Compounds

Until the 18th century, no standardized system existed for naming chemicals. This created confusion because the names for chemical compounds varied from country to country and scientist to scientist. For example, hydrochloric acid and muriatic acid refer to the same thing. If you didn't know that, you might think they were two different chemicals. Today, some compounds are better known by their common name. Bleach, for instance, is almost always used instead of the chemical name aqueous sodium hypochlorite.

In 1787, a French chemist named Guyton de Morveau created a naming system, or nomenclature, for compounds. He decided to use the chemical name for each element in the compound, always putting the metal element first. For example, zinc and oxygen combine to form zinc oxide. Since 1920, the International Union of Pure and Applied Chemistry (IUPAC) has been the body responsible for agreeing on the appropriate name for every chemical compound discovered.

***QUICK*LAB**

Common Chemicals in Your Home

Purpose

To learn about the chemical formulas of compounds by "buying" common household substances with "element money"

Procedure

1. Your teacher will give your group a selection of element cards and an information sheet. The cards are your element money. The information sheet tells you how to interpret the chemical formula for each item.
2. At the front of the class are several common items with labels. Each item can be purchased from the storekeeper (your teacher) with the correct amount of element money. Each group will have an opportunity to purchase an item.
3. You may purchase any of these items with the cards you have. For example, one of the components of toothpaste has the chemical formula NaF. If you want to buy some toothpaste, you need one sodium card (Na) and one fluorine card (F).
4. Note that each item has a value. Compounds made of two or more elements are more valuable than items made of one element.
5. When you have bought all your items, your group may trade any remaining cards with other groups.
6. Calculate the total value of the items you purchased.

Questions

7. What was the cost for each item you bought?
8. Were some materials easier to purchase than others? Explain your answer.
9. Describe any patterns you observed between the chemical formula and the "cost." (Hint: Using the periodic table might help you with your answer.)

Interpreting Chemical Names and Formulas from Compounds

If you know only the formula of a chemical compound, you can determine its chemical name. If you know only its name, you can determine its formula. Table salt's chemical name, sodium chloride, indicates that the compound is made of one atom of sodium and one atom of chlorine (Figure 3.3). Its chemical formula, NaCl, indicates this too.

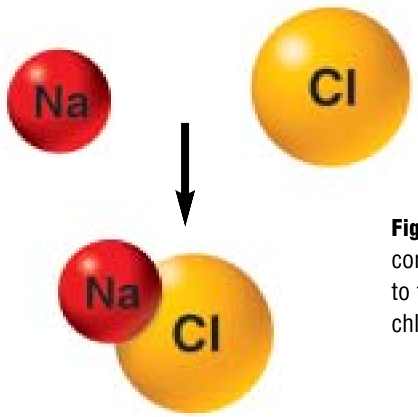


Figure 3.3 One sodium atom combines with one chlorine atom to form the compound sodium chloride, which we call table salt.

Now look at the formula for the compound water: H_2O. Notice that next to the H is a small 2 as a subscript. ("Sub" means below.) The 2 indicates that there are two atoms of hydrogen to go with every atom of oxygen in water. Figure 3.4 shows how the atoms in water are arranged. Subscript numbers in a chemical formula indicate the number of atoms of the elements that must combine to form the compound. No subscript number indicates that only one atom of that element is needed.

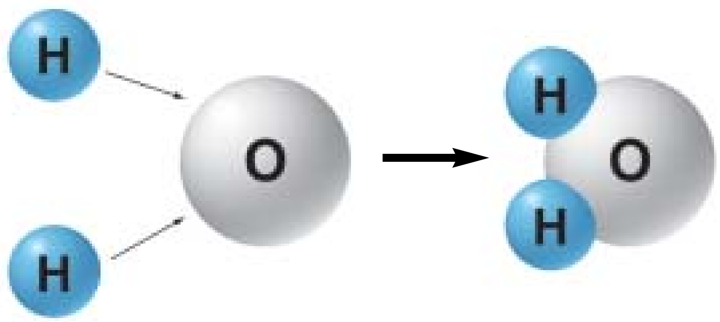


Figure 3.4 In water, two hydrogen atoms join with each oxygen atom.

Compound	Chemical Formula	Elements	No. of Atoms of Each	Total No. of Atoms
sodium chloride	NaCl	• sodium • chlorine	1 1	2
water	H_20	• hydrogen • oxygen	2 1	3

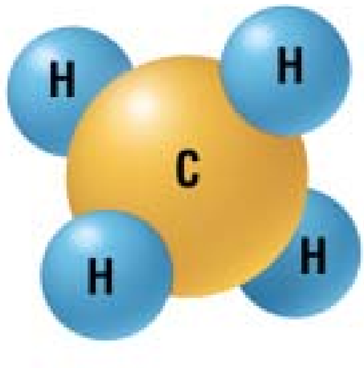
reSEARCH

Chemical Formulas of Household Products

Many household chemicals have a common name rather than a chemical formula. Find the chemical formula for some of these household chemicals. Begin your search at www.pearsoned.ca/scienceinaction.

INDICATING THE PHYSICAL STATE OF A COMPOUND

Another common notation added to chemical compounds indicates the state of the chemical at room temperature. After the chemical formula, a subscript *s* for solid, *l* for liquid, or *g* for gas is shown in parentheses. For example, sodium chloride is written as $NaCl_{(s)}$, water is written as $H_2O_{(l)}$, and natural gas (methane) is written as $CH_{4(g)}$. For aqueous solutions (substances dissolved in water), a subscript *aq* in parentheses is added to the formula. So, if sodium chloride was dissolved in water, the resulting aqueous solution would be written as $NaCl_{(aq)}$.



$CH_{4(g)}$

Figure 3.5 In methane, four hydrogen atoms combine with one carbon atom.

SKILL **PRACTICE**

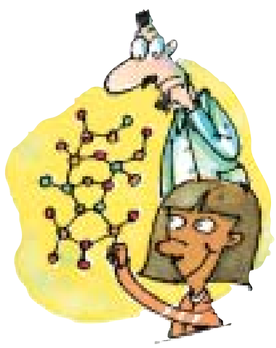
WORKING WITH COMPOUNDS

Referring to the compounds listed in the table below, complete the following.

- List the elements present in the compound.
- State the number of atoms of each element in the compound.
- In your notebook, draw what this compound would look like. Refer to Figures 3.3, 3.4, and 3.5 for your drawings. If time permits, create a model of each compound. Use materials of your own choosing.

Create a table like the one below to record your answers. Be sure to leave enough room to draw the compound in the far right column.

Compound	Elements in Compound	No. of Atoms in Each Element	Drawing of Compound
$CaO_{(s)}$			
$CaCl_{2(s)}$			
$Al_2O_{3(s)}$			
$Na_2O_{(s)}$			
$AlCl_{3(s)}$			
$KCl_{(s)}$			
$NaOH_{(s)}$			



Check and Reflect

Key Concept Review

1. What information can you determine from a chemical formula?
2. Identify the elements in each of the following compounds.
   a) $HF_{(g)}$
   b) $Li_2O_{(s)}$
   c) $K_3P_{(s)}$
   d) $Ni_2O_{3(s)}$
   e) $HgCl_{2(s)}$
3. How many atoms are indicated in the formula of each of the following compounds?
   a) Silver chloride—$AgCl_{(s)}$
   b) Calcium oxide—$CaO_{(s)}$
   c) Magnesium nitride—$Mg_3N_{2(s)}$
   d) Aluminum oxide—$Al_2O_{3(s)}$
   e) Scandium sulfide—$Sc_2S_{3(s)}$

Connect Your Understanding

4. Write the chemical formula for each of the following compounds:
   a) sodium sulfide, which has two atoms of sodium and one atom of sulfur
   b) aluminum fluoride, which has one atom of aluminum and three atoms of fluorine
   c) oxygen gas, which has two atoms of oxygen
   d) glucose, which has six carbon atoms, 12 hydrogen atoms, and six oxygen atoms

Extend Your Understanding

5. Acetylsalicylic acid, commonly called Aspirin, has the chemical formula $C_9H_8O_{4(s)}$. Urea, also called carbamide, has the formula $H_2NCONH_{2(s)}$. Compare and contrast the two formulas in terms of total elements and atoms.

3.2 Ionic Compounds

(a) (b) (c)

Figure 3.6 Sodium, shown in (a), is a metal. Sodium combines with chlorine gas in a violent reaction (b). The product is table salt, $NaCl_{(s)}$ (c).

Most people are familiar with common table salt and know that it is a white substance composed of tiny crystals. You might be surprised to learn that table salt is formed when a very reactive metal—sodium—is placed in a container with a poisonous, green non-metal—chlorine gas. When the two chemical elements are combined, the sodium metal explodes in a bright yellow flame. As the sodium burns, a white, coarse-grained powder is produced. That powder is table salt, or what you now know is sodium chloride ($NaCl_{(s)}$).

Sodium chloride is called an **ionic compound**. Ionic compounds are pure substances formed as a result of the attraction between particles of opposite charges, called ions. Table salt is formed from positively charged sodium ions and negatively charged chloride ions. Other properties of ionic compounds include their high melting point, good electrical conductivity, and distinct crystal shape.

All ionic compounds are solids at room temperature. In fact, table salt will not melt until it is heated to 801°C. When an ionic compound is melted or dissolved in water, it will conduct electricity. This property of ionic compounds led to the study of electrochemical cells (cells that either convert chemical energy into electrical energy or electrical energy into chemical energy). And that work in turn eventually led to the invention of batteries.

This new technology allowed scientists to investigate the structure of matter in greater depth.

How does an ionic compound actually form? When the ions are combined, they form a crystal.

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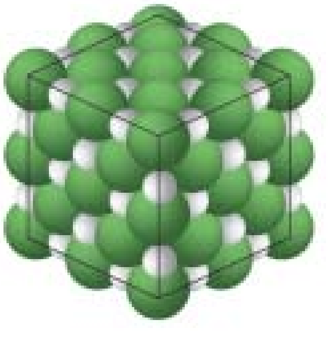
"Ion" Origin

The word "ion" comes from a Greek word meaning "to go" or "wander."

Figure 3.7 The crystals in this table salt are held together by ionic bonds.



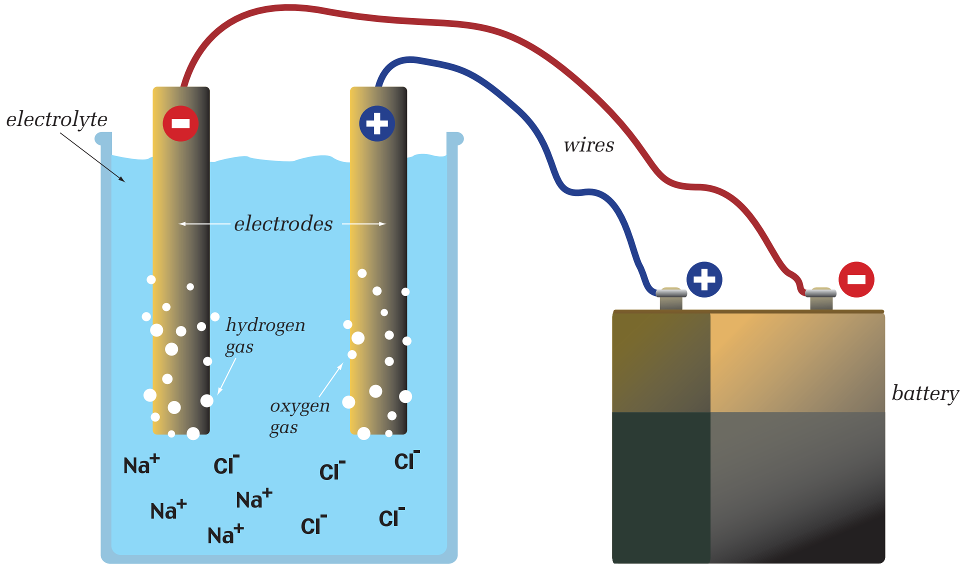


Figure 3.8 Two electrodes are placed in an electrolyte, water containing a little $NaCl_{(s)}$ forming $NaCl_{(aq)}$. The salt helps the electrical charge flow through the solution. At the negative electrode, positively charged hydrogen forms hydrogen gas. At the positive electrode, negatively charged oxygen forms oxygen gas. Chlorine gas may also be formed. In school laboratories, $Na_2SO_{4(s)}$ is used instead of $NaCl_{(s)}$.

QUICKLAB

Using Batteries to Investigate a Chemical Reaction

Purpose

To investigate the behaviour of ions

(Note: Your teacher may demonstrate this activity on the overhead projector.)

Procedure

1. Fill a Petri dish about two-thirds full with water. Add two to four drops of universal indicator.
2. Attach the end of one wire to the graphite at one end of a pencil. Attach the other wire to the second pencil in the same way. Make sure both ends of the pencils are sharpened so that the graphite is exposed. Attach the other ends of the wire to the battery.
3. Place the other sharpened ends of the pencils into the Petri dish, keeping the ends well apart. Record your observations.
4. Remove the pencils and place them in a safe spot.
5. Add several crystals of sodium sulfate to the Petri dish and stir until dissolved.
6. Repeat step 3. Do you observe any additional changes if you add a little more sodium sulfate?

Questions

7. What changes did you observe after the sodium sulfate was added to the Petri dish?
8. What evidence was there of a chemical change?
9. What do you think would happen if you added a non-ionic compound such as sugar to the Petri dish?

Materials & Equipment

- clear Petri dish
- water
- universal indicator
- 2 pencils sharpened at both ends
- 2 wires with alligator clips
- 9-V battery
- sodium sulfate ($Na_2SO_{4(s)}$)

reSEARCH

Ions and the Body

Metal ions such as Na^{+}, K^{+}, Mg^{2+}, Sn^{2+}, and Ca^{2+} are important in enabling our bodies to function properly. Find out the role of these ions in the human body. Begin your search at www.pearsoned.ca/ scienceinaction.

When the ionic compound is dissolved in water, the metal and non-metal form an aqueous solution of **ions**. An ion is an atom or a group of atoms that has become electrically charged through the loss or gain of electrons. The table below shows some examples of ion charges for various elements.

Element	Ion Charge	Ion Notation
Hydrogen	1+	H^{+}
Lithium	1+	Li^{+}
Nitrogen	3−	N^{3-}
Oxygen	2−	O^{2-}
Fluorine	1−	F^{-}
Sodium	1+	Na^{+}
Magnesium	2+	Mg^{2+}
Aluminum	3+	Al^{3+}
Sulfur	2−	S^{2-}
Iron	2+ or 3+	Fe^{2+} or Fe^{3+}
Copper	1+ or 2+	Cu^{+} or Cu^{2+}
Lead	2+ or 4+	Pb^{2+} or Pb^{4+}

Ion Charges

To indicate ions in written notation, a plus sign (+) or a minus sign (−) is placed to the upper right of the element symbol. This is a superscript position (*super-* means "above"). For example, a sodium ion is written as Na^{+} and a chlorine ion as Cl^{-}.

Some ions can also form when certain atoms of elements combine. These ions are called **polyatomic ions** (*poly-* means "many"). Polyatomic ions are a group of atoms acting as one. For example, one atom of carbon and three atoms of oxygen form the polyatomic ion called carbonate or CO_3^{2-}. When carbonate reacts with calcium ions, the product is calcium carbonate, or limestone ($CaCO_{3(s)}$). Other examples of compounds with polyatomic ions include copper(II) sulfate ($CuSO_{4(s)}$) and sulfuric acid ($H_2SO_{4(aq)}$).

Naming Ionic Compounds

When naming an ionic compound, there are two rules to remember. First, the chemical name of the metal or positive ion goes first, followed by the name of the non-metal or negative ion. Second, the name of the non-metal negative ion changes its ending to *ide*. This is the reason that the chemical name for $NaCl_{(s)}$ is not sodium chlorine, but sodium chloride.

There is one exception to these naming rules. Where negative ions are polyatomic ions, the name remains unchanged. Limestone's chemical name therefore remains calcium carbonate.

You'll notice in the table above that iron, copper, and lead have more than one ion charge. Some elements have this property. To show clearly which ion is being used in a chemical name, a Roman numeral is added. For example, iron(II) oxide is a compound containing the Fe^{2+} ion. Iron(III) oxide contains the Fe^{3+} ion.

Using Ion Charges and Chemical Names to Write Formulas

Once you know the ion charge and the chemical name of a substance, you can determine its chemical formula. The following steps will help you write the formulas for ionic compounds.

Step 1 Print the metal element's symbol with its ion charge. Next to it, print the non-metal element's symbol with its ion charge.	Ca^{2+} Cl^{1-}
Step 2 Balance the ion charges. The positive ion charge must balance the negative ion charges. In our example, this means that there must be two chlorine atoms each with an ion charge of 1− to balance the 2+ ion charge of one calcium atom. Now you know how many atoms of each element you need to include in the formula.	Ca^{2+} Cl^{1-} Cl^{1-}
Step 3 Write the formula by indicating how many atoms of each element are in it, as shown. Do not include the ion charge in the formula. Place the number of atoms of each element in a subscript after the element's symbol. If there is only one atom, no number is used.	$CaCl_{2(s)}$

Ion Charges and the Periodic Table

Take a moment to look at the periodic table in section 2.3 and the common ion charge. Do you see a pattern? The first group of elements on the left side of the table is the alkali group of metals—lithium and sodium. They each have an ion charge of 1+. The halogens, on the right of the table—fluorine and chlorine—have an ion charge of 1−. Generally, all the elements in a group form ions with the same charge. This pattern is the most consistent at either end of the periodic table. Figure 3.9 illustrates the ion charges of the elements that follow this pattern the best.

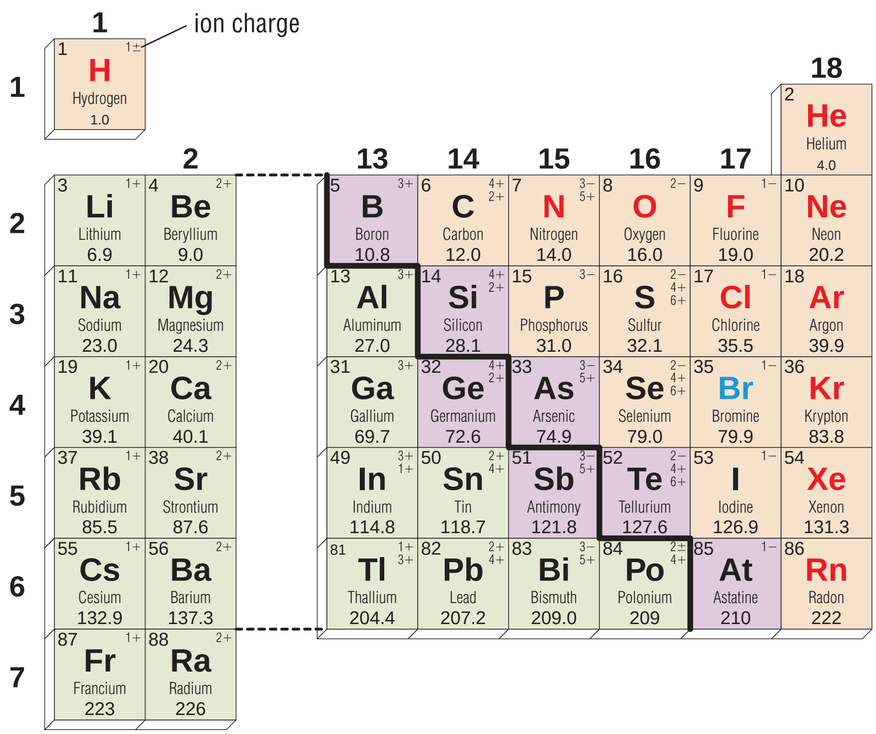


Figure 3.9 Ion charges of some of the groups in the periodic table

Activity B-4

Inquiry

Modelling Ionic Compounds

The Question

How can you create a model to illustrate an ionic compound?

Materials & Equipment

- marshmallows, marbles, Styrofoam balls, egg cartons, or a molecular model kit
- glue
- large sheet of paper
- felt pens

Figure 3.10 Step 4

Procedure

1. Working with a partner, select one metal and one non-metal element from the periodic table. Your task is to create a model illustrating the ionic compound that forms from combining these two elements. This type of ionic compound is called a binary compound because it consists of just two elements.
2. Determine how you will represent the atom of each element.
3. Decide which materials you will use to build your model.
4. Build your model to show one formula unit.
5. State the appropriate name for your compound, write out its chemical formula, and describe its combining ratio.
6. Repeat steps 1 to 5 to create three additional ionic compounds. Ensure that at least one of them is an example of a metal with multiple ion charges.
7. When you are finished, share your models with the class.

Analyzing and Interpreting

8. What did your models have in common with other models?
9. How were your models different from other models?

Forming Conclusions

10. Describe how you created models that illustrate ionic compounds.

Check and Reflect

Key Concept Review

1. What is an ionic compound?
2. List three properties of all ionic compounds.
3. How is an ion formed?
4. What is the difference between Fe^{2+} and Fe^{3+} ?
5. If an element has more than one ionic charge, how is that piece of information represented in a chemical name?

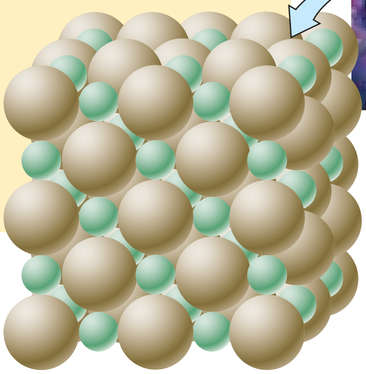
Connect Your Understanding

6. Outline the steps for writing the chemical formula of an ionic compound.
7. Write the formula for the following compounds:
   a) sodium fluoride
   b) magnesium sulfide
   c) lithium oxide
   d) iron(III) chloride
   e) copper(II) phosphide
   f) magnesium iodide
   g) iron(II) phosphide
   h) aluminum nitride
8. Write the chemical name for the following formulas:
   a) $LiCl_{(s)}$
   b) $Ca_3P_{2(s)}$
   c) $AlBr_{3(s)}$
   d) $PbS_{2(s)}$
   e) $Fe_2O_{3(s)}$
   f) $Na_2O_{(s)}$
   g) $CaS_{(s)}$
   h) $CuSO_{4(s)}$

Extend Your Understanding

9. What ion charge patterns are there in the periodic table?

sodium chloride crystals



Na^+ ions and Cl^- ions arranged in a crystal of sodium chloride

Figure 3.11 Each substance has a different crystal shape. Knowing the type of crystal a substance forms can help in identifying it. Pictured here are sodium chloride crystals.

*info***BIT**

Carbon Compounds
Scientists have discovered more than 10 million compounds. At least 9 million are molecular compounds containing the element carbon.

3.3 Molecular Compounds

When non-metals combine, a pure substance called a **molecule** or a **molecular compound** is formed. Molecular compounds differ from ionic compounds in several ways. They can be solids, liquids, or gases at room temperature. They tend to be insulators, or poor conductors of electricity. They also have relatively low melting and boiling points because the forces between the molecules are weak. Examples of molecular compounds include sugar, acetylene, and water.

Figure 3.12 Sugar ($C_{12}H_{22}O_{11(s)}$) is a common molecular compound.

*QUICK***LAB**

Ionic or Molecular Compound?

Purpose

To determine through experimentation whether a substance is an ionic compound or a molecular compound

Procedure

1. Set one of the 100-mL beakers in the dish or large bowl.
2. Using tongs, place several pieces of solid air freshener into the beaker.
3. Put the watch glass or Petri dish on top of the beaker and cover with ice.
4. Pour hot water into the dish to a depth of 2 cm. The water does not have to be boiling, but must be above 45°C (use the thermometer if necessary).
5. Record your observations every 5 min for 30 min.
6. In a second beaker containing water, place another piece of air freshener. Record your observations.
7. Test the conductivity of the air freshener.

Questions

8. From your observations, do you think the air freshener is an ionic compound or a molecular compound?
9. Did you collect any evidence that seemed to contradict the conclusion drawn in question 8?

Materials & Equipment

- two 100-mL beakers
- dish or large bowl
- tongs or forceps
- several small pieces of solid air freshener
- watch glass or Petri dish
- ice
- hot water
- thermometer
- pencil and notebook

Caution!
Handle the air freshener with tongs, not directly with your fingers. Do not directly inhale the vapour.

ACTIVITY B-5

Inquiry

MODELLING MOLECULAR COMPOUNDS

The Question

How can you create a model to illustrate a molecular compound?

Materials & Equipment

- marshmallows, Styrofoam balls, egg cartons, or a molecular model kit
- glue
- large sheet of paper
- felt pens

Procedure

1. Working with a partner, select two non-metal elements from the periodic table. Your task is to create a model illustrating a molecular compound that forms from combining these two elements.
2. Determine how you will represent the atom of each element.
3. Decide which materials you will use to build your model.
4. Build your model.
5. State the appropriate name for your compound, write out its chemical formula, and describe its combining ratio.
6. Repeat steps 1 to 5 to create three additional molecular compounds.
7. When you are finished, share your models with the class.

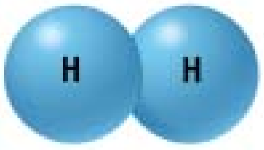
Analyzing and Interpreting

8. What did your models have in common with other models?
9. How were your models different from other models?

Forming Conclusions

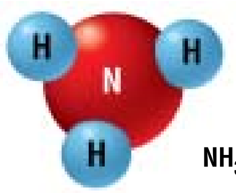
10. Describe how you created models that illustrate molecular compounds.

Figure 3.13 Step 4



$H_{2(g)}$

Figure 3.14 In a molecule of hydrogen gas, two hydrogen atoms combine to form the molecule. The formula is $H_{2(g)}$.



$NH_{3(g)}$

Figure 3.15 In a molecule of ammonia, each hydrogen atom is attached to the nitrogen atom. The formula is $NH_{3(g)}$.

Writing Formulas for Molecular Compounds

Writing formulas for molecular compounds is similar to writing formulas for ionic compounds, except that no ions are present and the ion charge is not used in the formulas. This makes it hard to predict how non-metals combine. However, the formulas still clearly show what elements are present, and how many of each type of atom make up the molecule. For example, hydrogen gas is usually found as H_2. Each molecule has two atoms of hydrogen connected to each other.

For ammonia ($NH_{3(g)}$), the situation is similar. Three hydrogen atoms combine with the nitrogen atom.

Naming of Molecular Compounds

Many molecular compounds are often known by their common names. Two compounds you have encountered in this section are water and ammonia. The names of these compounds do not give any indication of the elements they are made from. All molecular compounds, except those containing hydrogen, can be named using the following rules. Common names are used for molecular compounds containing hydrogen.

1. The first element in the compound uses the element name—just like ionic compounds.
2. The second element in the compound has the suffix 'ide'—just like ionic compounds.
3. When there is more than one atom in the formula, a prefix is used which specifies the number of atoms. Some prefixes are listed below.
4. An exception to rule 3 is when the first element has only one atom, the prefix *mono* is not used.

Number of Atoms	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta

Using the above rules, molecular compounds are named using this format:

Prefix + First Element **Prefix** + Second Element (with 'ide' ending)

Here are some examples: (Note that the coloured numbers in the formula correspond to the prefixes in the name.)

CO_2 carbon **di**oxide
N_2O **di**nitrogen **mono**xide
N_2O_3 **di**nitrogen **tri**oxide
NF_3 **ni**trogen **tri**fluoride
CCl_4 carbon **tetra**chloride
PF_5 phosphorus **penta**fluoride

reSEARCH

Bonding Forces

Use your library and the Internet to find out about other types of forces that create bonds between atoms. Begin your research at www.pearsoned.ca/scienceinaction.

Comparing Ionic and Molecular Compounds

The table below and the one on the next page list the melting and boiling points for some common ionic and molecular compounds. By comparing the information in these tables, you will see several differences between the two types of compounds. For example, baking soda, an ionic compound, boils at 1550°C. Carbon dioxide, a molecular compound, boils at −78.5°C.

Figure 3.16 Examples of ionic compounds

Ionic Compound	Formula	Melting Point (°C)	Boiling Point (°C)
lye	$NaOH_{(s)}$	318°	1390°
silver nitrate	$AgNO_{3(s)}$	212°	440° (decomposes)
baking soda	$NaHCO_{3(s)}$	455°	1550°
salt	$NaCl_{(s)}$	801°	1413°

Molecular Compound	Formula	Melting Point (°C)	Boiling Point (°C)
carbon dioxide	$CO_{2(g)}$	(changes directly from solid to gas)	−79°
water	$H_2O_{(l)}$	0°	100°
sugar	$C_{12}H_{22}O_{11(s)}$	185°	(decomposes)
rubbing alcohol	$C_3H_8O_{(l)}$	−90°	82°

Figure 3.17 Examples of molecular compounds

Check and Reflect

Key Concept Review

1. Define a molecular compound and give an example of one.
2. List three properties of a molecular compound.
3. Draw a simple model to show a molecule for each of the following:
   a) chlorine gas ($Cl_{2(g)}$)
   b) phosphorus trichloride ($PCl_{3(g)}$)
   c) nitrogen monoxide ($NO_{(g)}$)
   d) iodine bromide ($IBr_{(g)}$)
4. Describe one test that can be performed to determine whether a substance is ionic.

Connect Your Understanding

5. Which of the following compounds are molecular?
   a) $H_2O_{(l)}$
   b) $NaCl_{(s)}$
   c) $NH_{3(g)}$
   d) $F_{2(g)}$
   e) $CuCl_{2(s)}$
   f) $CCl_{4(l)}$
6. Write the chemical formula for the following molecular compounds:
   a) dinitrogen trioxide
   b) sulfur trioxide
   c) carbon tetrachloride
   d) phosphorus pentachloride
   e) carbon disulfide

Extend Your Understanding

7. Create a Venn diagram that compares the properties of a molecular compound with those of an ionic compound.

Section Review

Assess Your Learning

Key Concept Review

1. Explain the two rules to follow when naming an ionic compound.
2. For each substance below, name the elements and indicate the number of each kind of atom present in one formula unit.
   a) $HgF_{(s)}$
   b) $O_{2(g)}$
   c) $Na_2S_{(s)}$
   d) $B_2O_{3(s)}$
   e) $FeCl_{3(s)}$
3. When an ionic compound forms, what must be the sum of the ionic charges?
4. What kind of elements form molecular compounds?
5. Identify how many atoms of each element are present in the following compounds:
   a) glucose: $C_6H_{12}O_{6(s)}$
   b) ethanol: $C_2H_5OH_{(l)}$
   c) hydrogen peroxide: $H_2O_{2(l)}$
   d) rust remover: $H_3PO_{4(aq)}$
   e) fatty acid: $C_{17}H_{35}COOH_{(aq)}$
6. Which of the following compounds are ionic and which are molecular?
   a) $PbO_{(s)}$
   b) $Al_2S_{3(s)}$
   c) $F_{2(g)}$
   d) $H_2O_{(l)}$
   e) $NH_{3(g)}$
7. What is the formula for the ionic compounds with the following combinations of elements?
   a) potassium and bromine
   b) barium and oxygen
   c) aluminum and selenium
   d) calcium and nitrogen
   e) copper and phosphorous
8. Write the formula for the following molecular compounds:
   a) carbon monoxide
   b) carbon dioxide
   c) nitrogen dioxide
   d) dinitrogen monoxide
   e) disulfur dichloride

Connect Your Understanding

9. Describe a pattern of ion charges in the periodic table.
10. Write the formula for the following ionic compounds:
   a) magnesium bromide
   b) sodium phosphide
   c) lithium fluoride
   d) nickel(II) chloride
   e) lead(IV) nitride
   f) copper(I) sulfide
   g) silver oxide
   h) nickel(III) oxide

11. In terms of ion charges and chemical change, what is the difference between $CuF_{(s)}$ and $CuF_{2(s)}$?

12. Sketch simple models to show the following molecular compounds:
- a) sulfur and oxygen (SO_2)
- b) nitrogen and chlorine (NCl_3)
- c) oxygen and bromine (OBr_2)
- d) carbon and fluorine (CF_4)

Extend Your Understanding

13. Which of the following formulas is/are not correctly written?
- a) Li_3O
- b) CuO
- c) Mg_3O_2
- d) $HgCl_2$
- e) FeCl

14. Using the periodic table, find the elements iron, mercury, and bromine. Make a chart to answer the following questions as related to each element.
- a) Is it a metal or non-metal?
- b) What is the common ion charge?
- c) Will it conduct electricity?
- d) What state will it be in at room temperature?
- e) What state will it be in at room temperature if it combines with a non-metal?

15. An unknown ionic compound is formed with the formula $Z_2S_{3(s)}$.
- a) What is the common ion charge of element Z?
- b) What would be the new chemical formula of the unknown compound if the S (sulfur) was replaced with fluorine?
- c) What would be one property of these two compounds?

Focus On THE NATURE OF SCIENCE

Scientific ideas can be difficult to represent in a way that is easily understandable. To help explain their ideas, scientists often use models. In this section, you investigated and developed models to explain how atoms form compounds. Answer the following questions, using examples from your work in this section to support your answers.

1. How can a model help explain your observations?

2. Can a model be used to predict future observations?

3. Why is it important to understand chemical symbols, and to ensure that everyone uses these symbols correctly?

4.0 Substances undergo a chemical change when they interact to produce different substances.

Key Concepts

In this section, you will learn about the following key concepts:

- endothermic and exothermic reactions
- reactants and products
- conservation of mass
- factors affecting reaction rates

Learning Outcomes

When you have completed this section, you will be able to:

- identify conditions under which properties of a material are changed, and critically evaluate if a new substance has been produced
- observe and describe evidence of chemical change in reactions between familiar materials
- distinguish between materials that react readily and those that do not
- observe and describe patterns of chemical change
- describe familiar chemical reactions, and represent these reactions by using word equations and chemical formulas and by constructing models of reactants and products

Fireworks burst into the night sky in brilliant patterns caused by chemical reactions. The different colours that we see result from reactions between different substances within the fireworks. For example, barium compounds create green fireworks, strontium compounds create red ones, copper creates blue ones and sodium yellow. Fireworks are also launched by the chemical reaction that results from the fuse being lighted. The heat of the fuse ignites the chemicals that propel the fireworks into the sky.

In this section, you will investigate a variety of chemical reactions and how different factors affect the rate of these reactions. Think about safety as you do each activity.

For Web links relating to 4.0, visit **www.pearsoned.ca/scienceinaction**

4.1 Chemical Reactions

At first it may seem that the launch of a space shuttle and the activation of air bags in a vehicle have very little in common. In fact, both of these events require a **chemical reaction** to work. A chemical reaction takes place when two or more substances combine to form new substances. A chemical change in a substance results from a chemical reaction.

The chemical reaction occurring in launching a space shuttle involves almost 1 500 000 L of liquid hydrogen and 545 000 L of liquid oxygen combining to form water. During this reaction, enough energy is released to put the shuttle into orbit around Earth. In a vehicle equipped with air bags, the chemical reaction occurs on a smaller scale, but the results are also dramatic. Air bags, packed inside the frame of a vehicle, contain the explosive chemical sodium azide ($NaN_{3(s)}$). When the vehicle is in a collision, the sodium azide reacts and forms large volumes of nitrogen gas and sodium. The sodium quickly reacts with another compound in the air bag to make less dangerous compounds. Fifty grams of sodium azide can produce 30 L of nitrogen gas in milliseconds—a reaction that releases a burst of energy. The nitrogen gas inflates the air bags instantly, cushioning the impact of the collision for the driver and front-seat passenger.

infoBIT

Dr. John Polanyi
In 1986, Canadian Dr. John Polanyi won the Nobel Prize in chemistry for his work investigating the properties of chemical reactions.

QUICKLAB

Rocket Science

Purpose

To use a chemical reaction to create a film canister rocket

Procedure

1. Half fill the film canister with water.
2. Place a quarter tablet of Alka-Seltzer in the canister and quickly snap on the lid.
3. Place the canister upside down on the ground and stand at least 5 m back. CAUTION: If the rocket does not launch after about 1 min, slowly approach it and kick it over with your foot. If the lid doesn't come off, carefully remove the lid, keeping the canister pointed **away** from everyone.
4. Record your observations.
5. Try changing the variables to make the rocket go as high as possible. For example, change the amount of water, the amount of Alka-Seltzer, or the position of the canister on the ground. Record your observations each time.

Questions

6. How did you make a film canister rocket?
7. Did a chemical reaction occur inside the film canister? Provide evidence to support your answer.
8. What combination of materials made the rocket go the highest?

Materials & Equipment

- plastic film canister with inside snapping lid
- water
- Alka-Seltzer tablet, cut into quarters
- pencil and notebook

Figure 4.1 The reactants potassium iodide and lead(II) nitrate are both clear. The chemical reaction that takes place when they are combined results in a colour change in the product.

The materials at the start of a reaction are called the **reactants**. Think of a campfire. The burning wood undergoes a combustion reaction. In this case, the reactants, or substances being combined in the reaction, are wood and oxygen. The new materials produced by the reaction are called **products**. In a campfire, the products are carbon dioxide and water, formed while energy is released.

This chemical reaction can be written as a chemical word equation, as shown below. Note that in such equations, the reactants always appear to the left of the arrow and the products to the right.

$$\text{wood} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy released}$$

Plus signs separate the reactants from each other and the products from each other. The arrow indicates the direction in which the reaction is most likely to occur. When you take more advanced science courses, you will learn about situations where the reaction can occur in either direction.

Recall from section 1.3 that when a chemical reaction occurs, a new substance forms and evidence of the reaction may include one or more of the following:

- a colour change
- the formation of an odour
- the formation of a solid or a gas
- the release or absorption of heat

While colour change and formation of an odour are usually good indicators that a chemical reaction has taken place, care must be taken in interpreting some of the other types of evidence. For example, the formation of bubbles in a solution doesn't always mean that a new gas is being produced in a chemical reaction. The bubbles may simply mean that the solution has begun to boil. Evidence of heat being released or absorbed may also indicate a physical change rather than a chemical change. Some solids, for example, release heat when they are dissolved.

GIVE IT A TRY

IDENTIFY THE REACTION

Below are three different reactions. Identify the reactants and products for each reaction. Write out the chemical word equation.

Reaction 1. When hydrogen peroxide is left out in the sun, it changes to water and oxygen gas.

Reaction 2. A silver spoon is exposed to air. Over time, it turns a dark brown colour.

Reaction 3. Sodium and bromine react explosively to produce sodium bromide.

ACTIVITY B-6

Inquiry

OBSERVING CHEMICAL REACTIONS

The Question

How will different materials react with each other?

Materials & Equipment

- 3 test tubes
- test-tube holder
- 5% or 1.0 mol/L sulfuric acid
- magnesium ribbon
- matches
- splint
- 2% or 0.2 mol/L copper(II) sulfate
- steel wool
- stirring rod
- 3% or 0.2 mol/L iron(III) chloride
- 3% or 0.8 mol/L sodium hydroxide
- 5 g baking soda
- vinegar
- 500-mL beaker
- thermometer

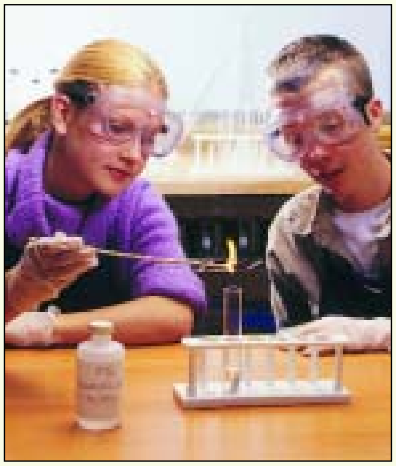


Figure 4.2 Step 4

Procedure

1. Before you start, your teacher will review the safety guidelines with you.
2. Draw a table in which to record your observations.

Reaction 1—Sulfuric acid and magnesium ribbon

3. Place a test tube in the test-tube holder. Pour the dilute sulfuric acid into the test tube to a depth of about 3 cm.
4. Add a 2-cm strip of magnesium ribbon to the dilute sulfuric acid in the test tube.
5. Light a splint and hold it so that the burning end is in the test tube. Make sure the test tube is pointing away from you and your classmates. Record your observations in the table.

Reaction 2—Copper(II) sulfate and steel wool

6. Place a clean test tube in the test-tube holder. Pour the copper(II) sulfate solution into the test tube to a depth of about 3 cm.
7. Add a small piece of steel wool to the copper(II) sulfate solution. You may need to use a stirring rod to push the steel wool down into the solution. Record your observations.

Reaction 3—Iron(III) chloride and sodium hydroxide

8. Place a clean test tube in the test-tube holder. Pour the iron(III) chloride solution into the test tube to a depth of about 3 cm.
9. Add a similar amount of the dilute sodium hydroxide solution to the test tube. Record your observations.

Reaction 4—Baking soda and vinegar

10. Pour 40 mL of vinegar into a 500-mL beaker. Measure and record the temperature of the vinegar.
11. Slowly add 5 g of baking soda to the vinegar. Measure and record the temperature.

Caution!
Be sure to wear your safety goggles, apron, and gloves. Iron(III) chloride is a strong irritant, and is corrosive and toxic. Sulfuric acid and sodium hydroxide are corrosive.

Analyzing and Interpreting

12. For each combination of materials you investigated, identify whether a chemical or physical change took place. Explain your answers.
13. For each chemical reaction, describe the evidence that you used to determine if new products were formed.

Forming Conclusions

14. Look back at the question at the beginning of this activity. Write a conclusion that answers that question by describing what you did, why you did it, and what you found.

reSEARCH

Changing Chemical Bonds

Endothermic and exothermic reactions involve the forming or breaking of chemical bonds. Find out how energy is used to form or break these bonds, and give examples. Begin your research at www.pearsoned.ca/scienceinaction.

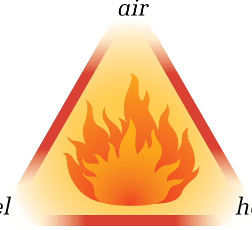


Figure 4.3 This fire triangle shows the three factors that keep a fire going. If any one of them is missing, the fire will not continue burning.

ENDOTHERMIC AND EXOTHERMIC REACTIONS

A chemical reaction that releases heat energy is called an **exothermic reaction**. When you burn an object in the presence of oxygen, energy in the form of heat is given off. Heat is also emitted when your body metabolizes food.

A chemical reaction that absorbs heat energy is an **endothermic reaction**. If you observed the chemical reactions in Inquiry Activity B-6, you noticed that the temperature in the baking soda and vinegar reaction dropped during and just after the reaction. Chemical cold-packs found in first aid kits are another example of where an endothermic reaction occurs. The reactants in the cold-packs must be crushed together to start the reaction. As the chemical change occurs and new products form, energy is absorbed from the liquid in the bag, and the bag becomes very cold.

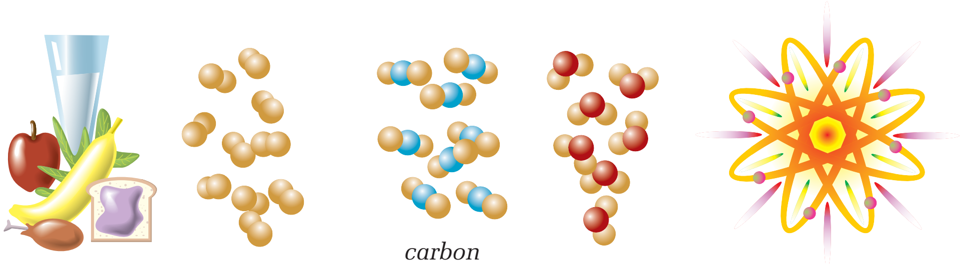
CHEMICAL CHANGES INVOLVING OXYGEN

Chemical changes occur because some substances react with each other when they come into contact. Among the most common types of chemical reactions are those involving oxygen. Three examples of reactions in which oxygen reacts with other substances are combustion, corrosion, and cellular respiration.

Combustion is a chemical reaction that occurs when oxygen reacts with a substance to form a new substance and give off energy. Fire is a common example of a combustion reaction. In burning, wood reacts with oxygen to give off heat and light and produce carbon dioxide and water. Recall that earlier in this unit you read about the significance of early humans discovering how to start fires. Combustion could be considered the first chemical reaction used by humans. Today, it is still one of the most important chemical reactions we use.

Corrosion is the slow chemical change that occurs when oxygen in the air reacts with a metal. A common example of corrosion is rusting. Rusting occurs when iron reacts with oxygen to form iron oxide.

Cellular respiration is a chemical reaction that takes place in the cells in your body. Food (glucose) reacts with oxygen to produce energy, water, and carbon dioxide. Figure 4.4 shows the word equation for cellular respiration.



food ($C_6H_{12}O_{6(s)}$) + *oxygen* (O_2) ⟶ *carbon dioxide* (CO_2) + *water* (H_2O) + *energy that can be used by living things*

Figure 4.4 The word equation for cellular respiration

ACTIVITY B-7

Experiment **on your own**

REACTIONS FOR UPSET STOMACHS

Before You Start

Many different types of medications are available to soothe an upset stomach. A common one is antacid. Antacids can be solid tablets or liquids.

For this activity, you will use an Erlenmeyer flask containing 75 mL of dilute hydrochloric acid and 3 drops of methyl orange indicator. This is a model of an upset stomach. You will add antacids to the model stomach. When the orange colour disappears, the stomach is no longer upset. In this reaction, carbon dioxide gas is produced. To capture the gas, you can place a balloon over the flask.

In this activity, you will determine which antacid works best and the most effective way to take it. You may wish to use Toolbox 2 to help you plan your experiment.

Figure 4.5 Adding antacid to an Erlenmeyer flask containing hydrochloric acid

The Question

Which antacid medication works best? What is the most effective way to take it?

Design and Conduct Your Experiment

1. Write a hypothesis about the most effective method for taking antacid medication.
2. Decide what materials you will need to test your hypothesis.
3. Plan your procedure. Ask yourself questions such as:
   a) How will I determine which antacid is best?
   b) How will I determine what is the best way to take this antacid?
   c) What type of chart will I need to record data?
   d) Is the test I've designed fair? How do I know?
   e) What are the variables in my experiment? Which is the manipulated variable? Which is the responding variable? Which variables will I control?
   f) How long do I have to complete my experiment?
4. Write up your procedure. Show it to your teacher before continuing.
5. Carry out your experiment.
6. Compare your results with your hypothesis. Did your results support your hypothesis? If not, suggest possible reasons for this.
7. Share and compare your experimental plan and findings with your classmates. Did anyone plan an experiment exactly like yours or similar to yours? How do your results compare with theirs?

Check and Reflect

Key Concept Review

1. What is the difference between a chemical reaction and a physical change?

2. How are reactants different from products in a chemical reaction?

3. Describe three observations you might make when a chemical change occurs.

4. Chemical fire starter ignites as a result of from the following reaction:

$$2\ CH_3OH_{(l)} + 3\ O_{2(g)} \longrightarrow 2\ CO_{2(g)} + 4\ H_2O_{(g)}$$

a) What are the reactants?
b) What are the products?
c) What could be one observation you could make to conclude a chemical reaction has occurred?

5. What is the difference between an exothermic reaction and an endothermic reaction?

6. How are the reactions in the items shown in Figure 4.6 useful to humans?

Figure 4.6 Question 6

Connect Your Understanding

7. a) In what ways are combustion and corrosion similar?
b) In what ways are they different?

8. Write the chemical word equations for the following reactions:
a) Zinc and hydrochloric acid are added together. A bubbling reaction creates hydrogen gas and zinc chloride.
b) When sugar and sulfuric acid are combined, carbon, water, and sulfur dioxide are formed.
c) Rust is formed when iron reacts with oxygen.

9. Rewrite the following chemical reactions into chemical equations using the appropriate chemical formulas.
a) Magnesium and sulfur combine to form magnesium sulfide.
b) When calcium is added to chlorine gas, calcium chloride is formed.
c) Water is formed when hydrogen and oxygen are combined.

Extend Your Understanding

10. Create a step-by-step procedure describing how to write a chemical equation.

11. Compare and contrast combustion, corrosion, and cellular respiration.

4.2 Conservation of Mass in Chemical Reactions

In a chemical reaction, products are formed when the reactant (or reactants) undergoes a change. These products usually look very different from the reactants. However, the total mass of these products is always the same as the total mass of the reactants. This law is called the **conservation of mass**. It states that matter is not created or destroyed in a chemical reaction. For example, combining 24.3 g of magnesium and 32.1 g of sulfur creates a new substance called magnesium sulfide. The law of conservation of mass predicts that the mass of the product will be the sum of these two masses: 56.4 g. Careful experiments have been made on this and many other reactions. These experiments have been done in **closed systems**, where no additional material is allowed to enter or leave. The result? No exceptions to this law have ever been found in any chemical reaction.

$$\underset{24.3\text{ g}}{Mg_{(s)}} + \underset{32.1\text{ g}}{S_{(s)}} \longrightarrow \underset{56.4\text{ g}}{MgS_{(s)}}$$

$Fe_{(s)}$ *iron* + $S_{(s)}$ *sulfur* $\longrightarrow$ $FeS_{(s)}$ *iron sulfide*

Figure 4.7 The total mass of the reactants and the total mass of the products are equal.

Some reactions may not seem to follow the principle of the conservation of mass. For example, adding 10 g of Alka-Seltzer to 100 g of water in a beaker causes carbon dioxide gas to be given off. When the reaction is complete, the mass of the products left in the beaker is only 106 g, not 110 g. This doesn't mean that mass was not conserved. The carbon dioxide gas was also one of the products of the reaction, but it escaped from the open beaker into the air. This is an example of an **open system**. If it had been trapped, it would have been found to have a mass of 4 g.

infoBIT

Einstein, Matter, and Energy

In a nuclear reaction, some of the mass is converted to energy, as Albert Einstein expressed in his famous $E = mc^2$ relation.

mathLink

Two reactants undergo a chemical reaction and produce one product. The mass of one of the reactants is 20 g and the mass of the product is 45 g. Write an algebraic equation representing this reaction, and solve the equation to find the mass of the second reactant.

ACTIVITY B-8

Inquiry

CONSERVING MASS

Materials & Equipment

- balance
- 4 g baking soda
- 4 g calcium chloride
- large self-sealing plastic bag
- 5-mL measuring spoon
- 5 mL water
- 5 mL bromothymol blue
- film canister

The Question

Does the mass of reactants and products change during a reaction?

Procedure

1. Put the baking soda and calcium chloride in the self-sealing plastic bag.
2. Put the water and bromothymol blue in the film canister.
3. Place the canister in an upright position in the bag. Carefully seal the bag. Measure and record the mass of the bag.
4. Predict what you think will happen when all the substances mix together. Record your prediction.
5. Without opening the bag, tip the canister over and allow the liquids and solids to mix. Record as many observations as you can while the reaction is occurring. Be sure to hold the bag to observe the temperature changes.
6. When the reaction is complete, measure and record the mass of the bag.
7. When you have finished the activity, clean up and return the materials as instructed by your teacher.

Caution!
If the bag seems ready to burst, open it up.

Analyzing and Interpreting

8. What evidence do you have that a chemical reaction occurred?
9. How did the mass before the reaction compare with the mass after the reaction?
10. Was the reaction exothermic, endothermic, or both?

Forming Conclusions

11. Use your observations and the data collected during this investigation to answer the question posed at the beginning of the activity.

Figure 4.8 Step 3

reSEARCH

Chemical Reaction Laws

In addition to the law of conservation of mass, two other laws apply to chemical reactions. Find out what the law of definite composition and the law of multiple proportions are. Begin your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. Define the law of conservation of mass.
2. What is a closed system in terms of a chemical reaction? Give an example.
3. What is an open system in terms of a chemical reaction? Give an example.
4. If you were to compare (i) the mass of a car with a full tank of gas to (ii) the mass of the same car with an empty tank of gas *plus* the mass of the exhaust fumes produced while the car burned the gas, would mass (i) and mass (ii) be different or would they be equal? Explain your answer.

Connect Your Understanding

5. A solid mass of 25 g is mixed with 60 g of a solution. A chemical reaction takes place and a gas is produced. The final mass of the mixture is 75 g. What was the mass of gas released?
6. If 100 g of one substance reacts with 70 g of another substance, what will be the mass of the products after the reaction?
7. A student adds 15 g of baking soda to 10 g of acetic acid in a beaker. A chemical reaction occurs and a gas is given off. After the reaction, the mass of the products remaining in the beaker is 23 g. Has mass been conserved in this reaction? Explain your answer.

Extend Your Understanding

8. Select a chemical reaction you have read about or observed in this section. Use the chemical formulas of the reactants and products to prove the law of conservation of mass.
9. Does a glass of pop have a greater, smaller, or identical mass after it has sat out on the table overnight? Explain your answer.
10. Is Earth a closed system or an open system? Explain your answer.

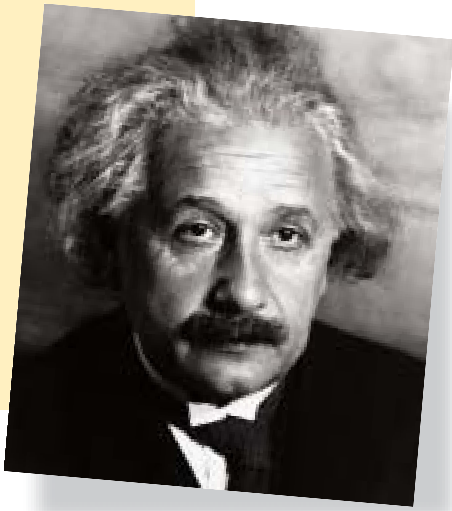


Figure 4.9 Albert Einstein was the first person to propose that in a nuclear reaction, some mass is converted into energy.

4.3 Factors Affecting the Rate of a Chemical Reaction

Figure 4.10 Chemicals can be used to change hair colour.

You may know someone who tried to change his or her hair colour, but the process didn't quite work out as planned. Colouring hair is the result of a chemical reaction. If the reaction is not controlled properly, unintended effects can occur, such as unexpected hair colours or burning of the scalp. Another common example of a chemical reaction is making a cake. It's important to use the right amount of each ingredient. If you add too much baking powder, for example, you can end up with a batter that rises more than it should.

It is important to understand how a chemical reaction works and the factors that affect the rate of the reaction. The four factors that can affect the rate of a chemical reaction are:

- the presence of a catalyst
- the concentration of the reactants
- the temperature of the reactants
- the surface area of the reactants

Catalysts

Catalysts are substances that help a reaction proceed faster. They are present with the reactants of a reaction, but they are not consumed during the reaction. Chemical reactions involving catalysts can be found in both living and non-living things. The most common example in living things is in your body. Many reactions, such as the breaking down of food, require a catalyst called an **enzyme**. Without enzymes, many reactions would require much higher temperatures—a situation that would be deadly to the human body.

Enzymes can help get rid of poisons in the body quickly. For example, one product of reactions in cells is hydrogen peroxide (H_2O_2). Hydrogen peroxide is poisonous. An enzyme called *catalase*, which is found in many different types of animal and plant cells, speeds up the breakdown of hydrogen peroxide into harmless oxygen and water. Figure 4.11 shows a model of how an enzyme like catalase functions.

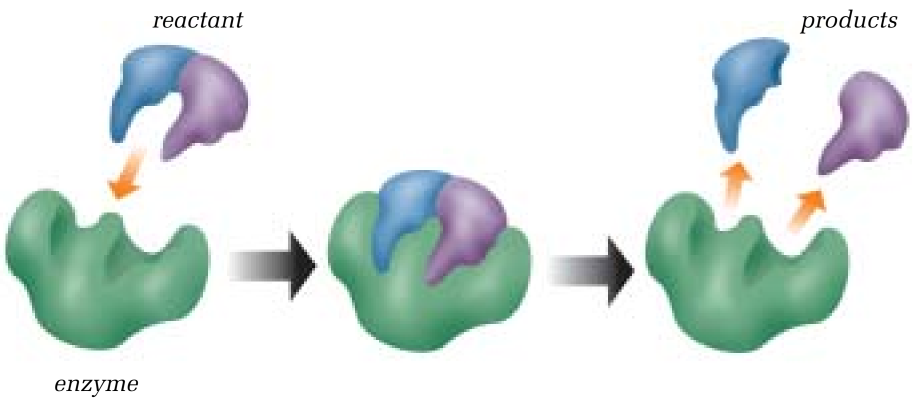


Figure 4.11 The shape of the enzyme molecule helps the reactant molecule break down.

QUICK**LAB**

Hydrogen Peroxide and the Catalyst Manganese(IV) Oxide

(Teacher Demonstration)

Like catalase, the catalyst manganese(IV) oxide ($MnO_{2(s)}$) also speeds up the reaction that breaks down hydrogen peroxide and produces a gas. To test if the gas is present, a glowing splint is placed in the test tube holding the reaction.

Purpose

To observe the effects of a catalyst on the rate of a chemical reaction

Procedure

1. Pour hydrogen peroxide into a test tube to a depth of 4 cm. Wait 30 s.
2. Light a wooden splint. After 5 s, blow it out. Immediately hold the glowing splint in the test tube. Record your observations.
3. Add 1 g of the catalyst manganese(IV) oxide ($MnO_{2(s)}$) to the hydrogen peroxide in the test tube.
4. Observe the test tube for 30 s.
5. Light another wooden splint and blow it out after 5 s. Immediately place the glowing splint into the test tube. Record your observations.

Questions

6. Describe how the catalyst manganese(IV) oxide affects the rate of reaction in this demonstration.
7. What gas was given off by the reaction? What evidence do you have to support your answer?
8. If a piece of fresh liver is dropped into hydrogen peroxide, a similar reaction occurs. What can you infer about the chemicals found in liver?
9. If you were to cool the hydrogen peroxide before you added the catalyst, what do you think would happen to the rate of reaction? Explain your answer.

Materials & Equipment

- hydrogen peroxide
- test tube
- wooden splint
- matches
- manganese(IV) oxide

*info***BIT**

Fuel Cells

Fuel cells use a platinum catalyst to generate electricity from the reaction of hydrogen and oxygen. These cells can now be found in cars and other devices.

ACTIVITY B-9

Inquiry

RATES OF REACTION

Materials & Equipment

- graduated cylinder
- water
- 500-mL beaker
- 15-mL plastic measuring spoon
- copper(II) chloride
- stirring rod
- thermometer
- aluminum foil

Figure 4.12 Step 6

The Question

What factors can be changed to increase the rate of a reaction?

Procedure

Part 1—Investigating the Reaction

1 Using the graduated cylinder, measure 50 mL of water and place it in the beaker.

2 Measure 15 mL of copper(II) chloride.

3 Add the copper(II) chloride to the water and stir until the solid has dissolved. Record your observations of the solution.

4 Measure the temperature of the solution.

5 Crumple a piece of aluminum foil so that it will fit into the beaker. Using the stirring rod, push the aluminum foil into the solution. Observe and record any changes.

6 Record the temperature (in °C) every 30 s until the temperature begins to drop.

Part 2—Changing the Rate of the Reaction

7 In this part of the activity, you will design a procedure using only the materials you used in part 1. Your task is to create a reaction that will give you the highest temperature as quickly as possible.

8 Working with your lab partner, design your procedure and write it down. Remember that you will have to measure the temperature every 30 s as in step 6 in part 1.

9 Have your teacher approve your procedure.

10 Carry out your plan and record your results.

Analyzing and Interpreting

11 What evidence do you have that a chemical change occurred when aluminum was added to the copper(II) chloride?

12 Graph the temperatures you measured in part 1 against the time that you measured them. On the same graph, graph the temperatures you measured in part 2. Use a different colour for your second graph.

13 What products do you think were produced from the reaction?

14 What factors did you change to increase the rate of the reaction?

15 Was there a difference in the highest temperatures you measured in parts 1 and 2? Why do you think this occurred?

16 If the challenge was to create the lowest temperature possible, what factors would you change?

Forming Conclusions

17 Describe how you would create a reaction to get the highest temperature as quickly as possible, given the materials you used in this activity.

Other Factors Affecting the Rate of Reaction

A catalyst is one factor that can affect the rate of a reaction. Three other factors are concentration, temperature, and surface area.

Concentration

The greater the concentration of the reactants, the faster the reaction. The increased concentration of the reactants means that there are more atoms of each reactant available to react. For example, adding more aluminum to a copper(II) chloride solution will cause the reaction between the two substances to proceed faster.

Temperature

The temperature of the reactants can also affect the rate of a reaction. The more heat added to the reactants, the faster the reaction. The added heat causes the atoms of each reactant to move faster, which increases the chances of their colliding with each other. For example, if you were investigating the copper(II) chloride–aluminum reaction, you could heat the copper(II) chloride solution to make the reaction proceed more quickly.

Surface area

Increasing the surface area of the reactants is another factor that can increase the rate of a reaction. The greater surface area of the reactants means that more area is available for reaction. In the copper(II) chloride and aluminum example, cutting the aluminum foil into tiny pieces would increase the surface area, causing the reaction to proceed faster.

Figure 4.13 This grain elevator blew up when the extremely fine grain dust in the air was ignited accidentally. The fine dust means a large surface area of grain was available for the combustion reaction.

reSEARCH

Controlling Industrial Reactions

Find examples of industrial chemical reactions that require the rate of the reaction to be controlled. Begin your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What is an enzyme?
2. Explain how an enzyme is different from other catalysts.
3. What are four factors that can affect the rate of reaction?
4. Give one example, not discussed in the book, of a reaction where the rate was increased because of changes in the four factors mentioned above.

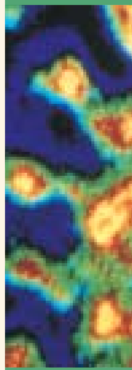
Connect Your Understanding

5. What is the purpose of storing food in a cooler with ice when you go camping or on a picnic? Explain your answer in terms of rate of chemical reaction.
6. Why does chewing your food make it easier to digest?
7. Why should batteries be stored in the fridge when they are not being used?
8. For each of the following reactions, how could the rate of chemical change be increased?
   a) a block of wood burns slowly
   b) an Alka-Seltzer tablet fizzes slightly
   c) ice-cold hydrochloric acid reacts slowly with powdered zinc

Extend Your Understanding

9. The catalyst manganese(IV) oxide is able to increase the rate at which hydrogen peroxide decomposes into oxygen and hydrogen. The enzyme catalase is found in animal livers and can perform the same function. If the hydrogen peroxide is heated to 60°C first, the catalase doesn't work. Why?
10. Plan and write a procedure to test how the concentration of yeast will affect the rising of bread.

Figure 4.14 Dyeing a shirt to create the varying colour tones shown here requires controlling the reaction rate of the various chemical dyes used.



Assess Your Learning

Key Concept Review

1. Define a chemical reaction and give an example.
2. Create a chemical word equation using the following: reactants, products, $\longrightarrow$
3. Which of the following observations would not be evidence of a chemical reaction?
   a) precipitate (solid) formed
   b) heat released
   c) substance melted
   d) colour changed
4. How does the fire triangle describe the chemical reaction called combustion?
5. Define the law of conservation of mass in your own words.
6. What is the difference between an open and a closed system?

Connect Your Understanding

7. Write the following reactions as chemical word equations.
   a) Calcium and water combine to form calcium hydroxide and hydrogen.
   b) Hydrogen gas and sulfur are products created when hydrogen sulfide decomposes or breaks down.
   c) Methane and oxygen react to produce carbon dioxide, water, and energy.
   d) If there is not enough air for all the methane to react in c), carbon and water are formed.
8. How can you determine if a reaction is exothermic?

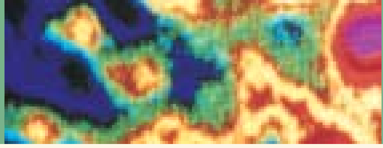
Extend Your Understanding

9. A reaction occurs in a closed system. The mass of the products is 25 g. What was the mass of the reactants? How do you know?

Focus On THE NATURE OF SCIENCE

At the start of this unit, you were introduced to the idea that the goal of science was to develop knowledge about our natural world. This knowledge includes how substances interact to form new substances. Now that you are at the end of this unit, work with your partner or your class to consider the following questions.

1. Identify an example of two or more substances interacting to produce a change. How do you know a change has occurred?
2. Describe several chemical changes or reactions that you consider useful. What are some characteristics or properties of each of these reactions that make them useful?
3. Describe two chemical changes or reactions where it is important to control the rate of the reaction. Why is this important in each case?
4. Review your answers in Section 1.0, Focus on the Nature of Science. How has your understanding of matter and its interactions changed over time?



Unit Summary: Matter and Chemical Change

Key Concepts

1.0

- Workplace Hazardous Materials Information System (WHMIS) and safety
- substances and their properties
- elements, compounds, and atomic theory

2.0

- substances and their properties
- elements, compounds, and atomic theory
- periodic table

3.0

- periodic table
- elements, compounds, and atomic theory
- chemical nomenclature

4.0

- endothermic and exothermic reactions
- reactants and products
- conservation of mass
- factors affecting reaction rates

Section Summaries

1.0 Matter can be described and organized by its physical and chemical properties.

- Recognition of WHMIS symbols is important to lab safety.
- Matter can be organized in different ways. One way is as solids, liquids, and gases. Another way is as mixtures and solutions.
- Physical properties of matter such as colour, hardness, boiling point, and density are used to identify substances. Chemical properties describe how a substance interacts with other substances.

2.0 An understanding of the nature of matter has developed through observations over time.

- Human understanding of matter grew as people suggested explanations for their observations of the natural world. Theories were confirmed or rejected as people learned more about matter.
- The Greek philosopher Democritus stated that matter was made up of tiny indivisible particles called *atomos*. This theory was not widely accepted for 2000 years.
- Investigations by scientists, such as Robert Boyle, in the 1600s confirmed that matter is made up of tiny particles. Further investigation by researchers gradually developed the understanding we have today that matter is made up of atoms. Each atom has a nucleus containing protons and neutrons. Electrons orbit the nucleus.
- Elements are pure substances made up of only one type of atom. The periodic table organizes the elements according to their atomic number and atomic mass. The atomic number is the number of protons in the nucleus. The atomic mass is the average mass of an atom of an element.
- Patterns of information on the periodic table include groupings of metals, metalloids, and non-metals.

3.0 Compounds form according to a set of rules.

- Every chemical compound has a chemical formula and chemical name. The chemical formula identifies the elements in the compound and their proportions.
- An ion is an atom or a group of atoms that has become electrically charged through the loss or gain of electrons from one atom to another.
- Ionic compounds form between atoms of metals and non-metals.
- Molecular compounds form between atoms of non-metals.

4.0 Substances undergo a chemical change when they interact to produce different substances.

- A physical change may change the appearance or state of a substance but not its composition (e.g., melting). A chemical change results in the formation of one or more different substances.
- Reactions involving oxygen are some of the most common types of chemical reactions. These include combustion, corrosion, and cellular respiration.
- A chemical reaction occurs when substances called reactants interact to produce different substances called products.
- According to the principle of the conservation of mass, the mass of the products in a chemical reaction equals the mass of the reactants.
- An exothermic reaction gives off energy. An endothermic reaction takes in energy.
- The rate of reaction can be affected by the addition of a catalyst, or an increase in the concentration, temperature, or surface area of the reactants.

Metal Contamination of the Environment

Equipment operators must wear special protective gear when cleaning up contaminated soil.

The Issue

Humans have many uses for metals. Copper for wire, aluminum for pop cans, and lead for batteries are just a few examples. Some metals, such as lead, are poisonous to humans if exposure occurs over a long period of time. This exposure may result from metals finding their way into the groundwater or from unsafe storage. In many cases, the people or companies responsible for the contamination are no longer present to take responsibility for the cleanup. The problem of metal contamination in the environment leads to several questions.

What should be done with contaminated soil?

When metals from factories, mines, and dumps contaminate soil, the area is closed to human access. This prevents immediate harm to people. However, the soil must be made safe for the future. There are two common options for cleaning up contaminated soil. The first option involves removing the top layer of contaminated soil. However, the contaminated soil must then be cleaned or stored in another area. The second option is to cover the contaminated soil with a thick layer of clean soil. In theory, the new layer seals the contaminated soil from the environment.

How much of the contaminated soil needs to be cleaned up?

Cleaning up a contaminated site is costly. Some people suggest that only toxic sites where people may live or work should be cleaned up. Others suggest that only areas where people live should be cleaned. To save money, only a partial cleanup of the workplace is necessary. Other people feel that all toxic areas should be cleaned, as it is hard to predict where people will live or work in the future.

Who should be responsible for the cleanup?

Cleaning a contaminated area may require removal of soil, buildings, and trees, and the addition of clean soil. This is an expensive process. Since many of these waste sites have been abandoned, it is difficult to determine who should be responsible for cleaning them up. All levels of government—municipal, provincial, and federal—have a role in determining how these sites should be rehabilitated.

Go Further

Now it's your turn. Look into the following resources to help you form your opinion.

- Look on the Web: Check the Internet for information on examples of metal contamination in Alberta and what is being done about them.
- Ask the Experts: Try to find an expert on metal contamination, such as a chemical engineer or an environmental geologist. Experts can be found in various places: city hall, universities, environmental consulting companies, and government agencies.
- Look It Up in Newspapers and Magazines: Look for articles about metal contamination.

Analyze and Address the Issue

Summarize your opinion of what should be done about cleaning up contaminated soil and who should do it as one of the following:

- a newspaper article for your local or school newspaper
- a speech to be presented at a public forum on the issue

PROJECT

WHAT'S IN THE BOTTLE?

You can use the well in a spot plate for a micro-scale reaction.

Getting Started

There's a problem in the science lab. A bottle containing an unknown solution has been found. Because the contents are unknown, it is difficult to determine how to dispose of it.

Your Goal

In this activity, you will perform a variety of micro-scale reactions to gather information about how various solutions react. You will then use this information to identify an unknown sample.

What You Need to Know

Micro-scale reactions occur when very small amounts of reactants are used. Usually the reaction takes place in a small depression or well on a spot plate. By filling the well half full with one solution or solid reactant and then adding a second reactant, you can observe if a reaction has occurred.

The following observations can help you determine that a reaction has occurred:

- bubbles form or a gas is given off
- the colour changes
- a solid substance called a precipitate forms

If the spot plate is clear and colourless, you may need to put a piece of white paper under the plate. This will help you observe any reaction that occurs.

Steps to Success

Part 1—The Tests

1. Collect the necessary equipment for this activity:
   - 1 spot plate
   - bottles of solutions labelled A, B, C, D, E, F
   - paper towel
2. Combine two solutions in all possible ways, using the table below as your guide.
3. Record your observations in a table like this one.

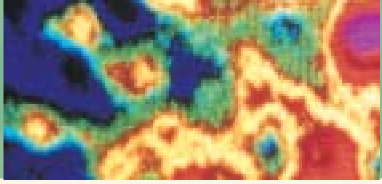
A	B	C	D	E	F	Unknown
A						
	B					
		C				
			D			
				E		
					F	
						Unknown

Part 2—The Identification of the Unknown

4. Your teacher will give you an unknown solution.
5. Using a clean spot plate, combine each of the known solutions with the unknown solution. Record your results in each case.

How Did It Go?

6. Using your data from part 1, determine what you think the unknown sample in the bottle is. Remember to support your answer with your data.
7. Write your conclusion in a short paragraph. Make sure it answers the following questions:
   - What did you do in this activity?
   - Why did you do this activity?
   - What did you find?
   - What is one new thing you learned?



Unit Review: Matter and Chemical Change

Unit Vocabulary

1. Define the following terms in full sentences using your own words.
WHMIS
matter
elements
periodic table
atomic mass
atomic number
ion charge
ionic compound
molecular compound
exothermic
endothermic
law of conservation of mass

Key Concept Review

1.0

2. Match the WHMIS symbol to the following descriptions.


(i)


(ii)

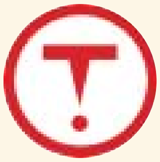

(iii)


(iv)


(v)


(vi)


(vii)


(viii)

a) poisonous and infectious causing other toxic effects
b) corrosive material
c) dangerously reactive material
d) flammable and combustible material
e) oxidizing material
f) biohazardous infectious material
g) poisonous and infectious causing immediate and serious toxic effects
h) compressed gas

3. If you had to describe an unknown green solid, what properties could you use?

4. What is the difference between a physical change and a chemical change?

5. Create a chart or picture to illustrate the differences among a pure substance, a mechanical mixture, and a solution. Include examples in your chart or picture.

2.0

6. Why must copper be heated before it can be made into something?

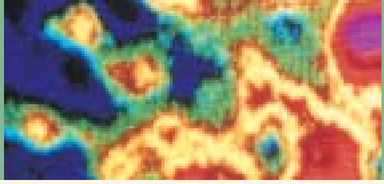
7. What was Ernest Rutherford's contribution to the understanding of the atom?

8. How are metals and non-metals organized in the periodic table?

9. What is the difference between a family and a period in the periodic table?

3.0

10. a) Explain what "ion charge" means.
b) How can the ion charge be used to determine the chemical formula of compounds?



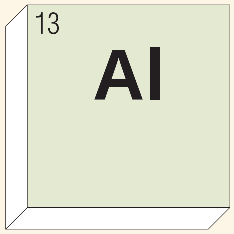
11. Name the elements in the substances below.
    a) $LiCl_{(s)}$
    b) $Al_2S_{3(s)}$
    c) $AgF_{(s)}$
    d) $ZnO_{(s)}$
    e) $Br_{2(l)}$
12. Which of the following compounds are ionic and which are molecular?
    a) beryllium oxide
    b) lithium phosphide
    c) water
    d) sodium fluoride
    e) carbon dioxide
    f) copper(I) chloride
13. Write the chemical formula for each compound in question 12.

4.0

14. Rewrite the chemical reactions below as word equations.
    a) A solid piece of sodium metal is placed in water, and it reacts explosively to form sodium hydroxide and hydrogen gas.
    b) Hydrogen peroxide is placed in sunlight and reacts slowly to form oxygen and water.
    c) Iron(II) chloride is formed when iron and chlorine gas are combined.
    d) When aluminum is exposed to oxygen, aluminum oxide forms.
15. For each reaction in question 14, suggest a different method for increasing the rate of reaction.
16. How is cellular respiration similar to combustion? How is it different?
17. Is there a difference between a catalyst and an enzyme? Explain your answer.

Connect Your Understanding

18. What contribution to the field of chemistry was made by:
    a) alchemists
    b) Robert Boyle
    c) John Dalton
    d) J.J. Thomson
19. Compare Democritus's understanding of the atom with Niels Bohr's understanding.
20. Why was Dmitri Mendeleev's periodic table accepted as a useful way to organize the elements?
21. Explain how J.J. Thomson's "raisin bun model" of the atom is different from Niels Bohr's model of the atom.
22. Describe two patterns found in the periodic table.
23. Below is a box from the periodic table that is missing information. Copy the box into your notebook and fill in the missing information.



24. Copy the following table into your notebook. Use the periodic table to fill in the blanks.

Element	Mass Number	Protons	Electrons	Neutrons
H	1			
	166	82		
Ca	41			
Ag	109			
U	238			
	4			2
	21		10	

25. Write the name for the following formulas, including the correct Roman numerals where necessary:
   a) $MgBr_{2(s)}$
   b) $Ba_3N_{2(s)}$
   c) $FeP_{(s)}$
   d) $PbI_{4(s)}$
   e) $Cu_2S_{(s)}$
26. Why do we use kindling (small sticks of wood) to help start a fire?

Extend Your Understanding

27. How were the first "chemists" in the Stone Age different from "chemists" in the Iron Age?
28. Give three examples of how an understanding of the properties of a type of matter has benefited humans.
29. How can the periodic table be used to determine the ion charge of elements?
30. What is the chemical symbol of the element that has 14 neutrons in its nucleus?

Practise Your Skills

31. Create a mnemonic or "safety slogan" that can be used to remind people of the proper techniques for handling and disposing of laboratory materials.
32. In the following reactions, calculate the mass of the unknown product.
   a) How much water is produced when a spark creates an explosive reaction between 4 g of hydrogen and 32 g of oxygen?
   b) In a 100-g beaker, a student added 25 g of lead(II) nitrate to 15 g of sodium iodide. In her notebook, she recorded the mass of reactants as 40 g. During the chemical rection between the two materials in the beaker, the student noted a colour change but no gases being given off. When she weighed the products of the reaction, she found the total mass to be 140 g. Did this reaction conserve mass? Explain your answer.

Self Assessment

33. Scientific investigations usually require many people to work together as a team. Why is collaboration an important part of scientific work?
34. In this unit, you investigated many different questions and issues related to chemistry. Describe one idea that you would like to find out more about. Explain why you want to learn more about it.

Focus On The Nature of Science

In this unit, you investigated the nature of science related to matter and chemical change. Consider the following questions.

35. Scientific knowledge results from the shared work of many people over time. Describe the development of an idea in this unit that resulted from the work of many people over time.
36. Was an alchemist really a scientist? Explain your answer.
37. It is often said that science cannot provide complete answers to all questions. Describe a situation in this unit where you felt this statement was true.
38. Reread the three questions on page 91 about the nature of science related to matter and chemical change. Use a creative way to demonstrate your understanding of these questions.