



Matter

CHAPTER 1

Matter and Change

CHAPTER 2

Elements and Compounds

CHAPTER 3

Models for Atoms

CHAPTER 4

The Periodic Table

Unit 1 Overview

What do stars and dust have in common? What do they have in common with the thousands of substances we encounter every day? All of these things are matter. Learning about matter helps us to understand why ice melts, rocket fuel burns, and cars rust. Understanding matter helps us make decisions about manufacturing and using products.

1. Matter and Change

Matter has characteristic physical and chemical properties. Understanding these properties can enable us to make useful products.

In this chapter, you will be able to:

- conduct experiments to identify physical and chemical properties of matter
- observe and classify changes that can occur in substances
- handle chemicals safely
- describe how properties of matter can lead to useful technology

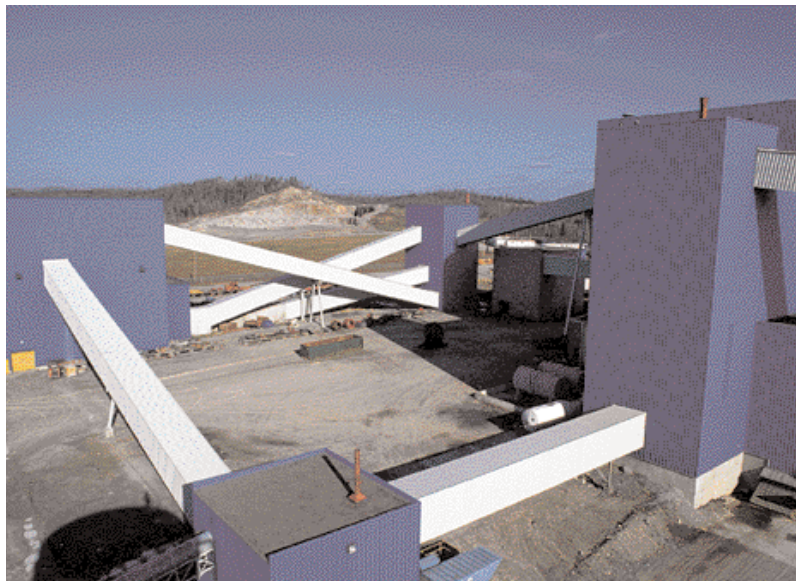


2. Elements and Compounds

Everything is composed of pure substances, which can be classified as elements or compounds. We classify matter to organize the vast amount of information about elements and the thousands of compounds in our world.

In this chapter, you will be able to:

- describe different classifications of matter
- interpret models, symbols, formulas, and names to describe pure substances
- assess some economic and environmental aspects of the production of these substances in Canada

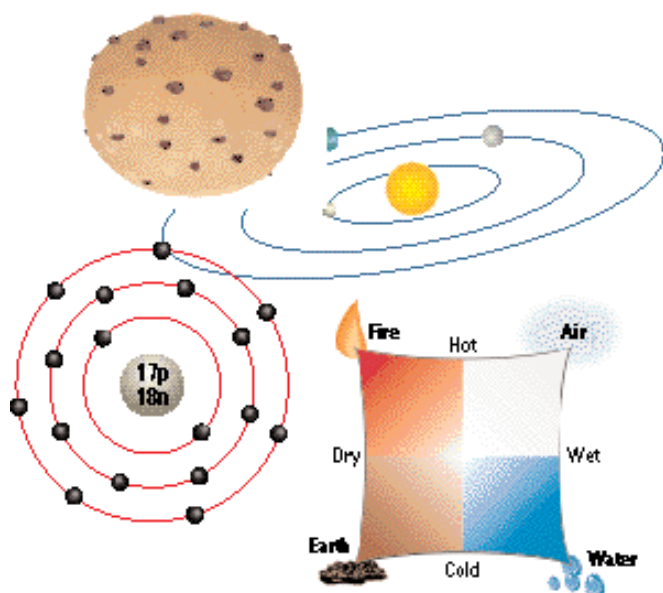


Challenge

In this unit, you will be able to...
demonstrate your learning by
completing a Challenge.

Building from the Past to the Present

- As you learn about elements and compounds and ways of explaining the behaviour of matter, think about how you would accomplish these challenges.



1 Models for Matter


2 Marketing Matter

3 A "Time Machine" Simulation

To start your own Challenge
see page 128.

Record your ideas for the Challenge when you see

Challenge

- relate properties of elements to their atomic structure and to their position in the periodic table
 - investigate ways of organizing elements into families or groups
 - describe and identify properties and applications of elements that make them valuable substances
- 
- | | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|--|--|--|--|--|--|--|
| H | | | | | | | | | | | | | | | | |
| Li | Be | | | | | | | | | | | | | | | |
| Na | Mg | | | | | | | | | | | | | | | |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | | | | | | | |
| Rb | Sr | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | | | | | | | |

| | | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| H | | | | | | | | | | | | | | | | | He |
| Li | Be | | | | | | | | | B | C | N | O | F | Ne | | |
| Na | Mg | | | | | | | | | Al | Si | P | S | Cl | Ar | | |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr |
| Rb | Sr | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | I | Xe |
| Cs | Ba | La | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn |
| Fr | Ra | Lr | | | | | | | | | | | | | | | |

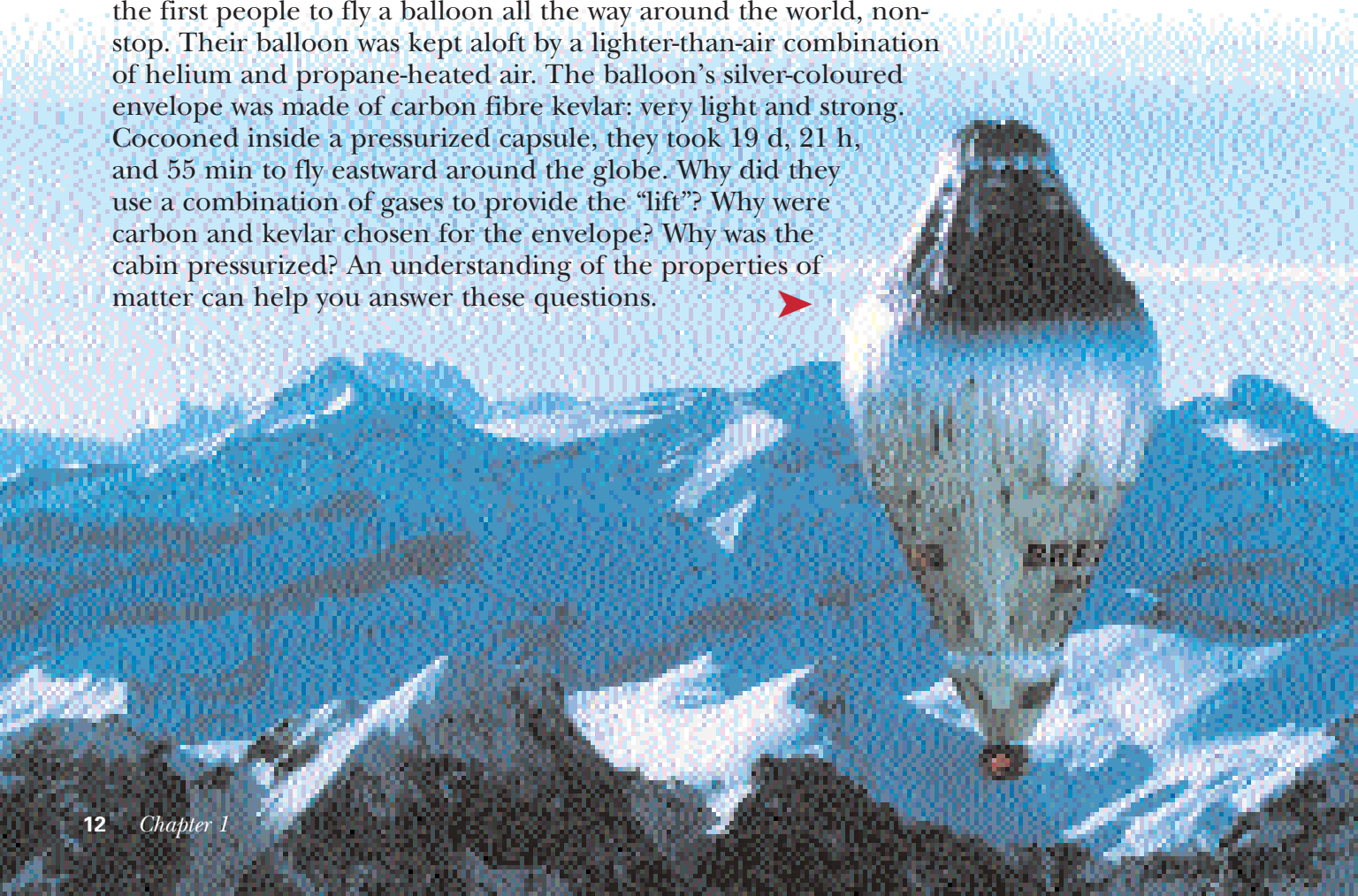
Matter and Change

Getting Started

1 What is matter? Matter is the leather in a soccer ball and the air that is used to inflate it. Matter is anything that has mass and takes up space. Inquiring about the nature of the visible world often starts with observations of matter and leads to attempts to organize those observations. What makes the particles different from each other? What are some different ways in which matter could be classified? Each kind of matter has different properties. Make a list of adjectives that describe some of these properties.



2 How can we use the various properties of matter? In March 1999, Bertrand Piccard and Brian Jones were very glad of the special properties of their balloon. The two European adventurers became the first people to fly a balloon all the way around the world, non-stop. Their balloon was kept aloft by a lighter-than-air combination of helium and propane-heated air. The balloon's silver-coloured envelope was made of carbon fibre kevlar: very light and strong. Cocooned inside a pressurized capsule, they took 19 d, 21 h, and 55 min to fly eastward around the globe. Why did they use a combination of gases to provide the "lift"? Why were carbon and kevlar chosen for the envelope? Why was the cabin pressurized? An understanding of the properties of matter can help you answer these questions.



3 Imagine you are sitting around a campfire with some friends. You put a pot of water near the fire. When the water begins to bubble and steam, you add some powdered hot chocolate mix and stir until the powder dissolves. Meanwhile, your friends are toasting hotdogs and marshmallows. Suddenly, one marshmallow catches fire, burning brightly for an instant. Your friend blows out the flame and looks at the black crispy chunk left on the stick. Several changes took place around this imaginary campfire. You made a mixture of several substances with water. Some water changed state from a liquid to a gas. But the marshmallow did not change state—it was still a solid at the end. However, the marshmallow seemed to become something else: a black substance. There was a change in the chemical makeup of the marshmallow.

In a small group, brainstorm a list of as many changes in matter as you can. Use a different action word for each change (for example, concrete *hardens*, wood *rots*, snow *melts*, paper *yellowes*, fireworks *explode*). In which changes do you think a new substance is formed? Which changes do you think add materials to the air? Indicate these with a check mark and an asterisk, respectively.



Reflecting

Think about the questions in **1,2,3**. What ideas do you already have? What other questions do you have about matter and how it changes? Think about your answers and questions as you read the chapter.

Try This

Fill a Balloon

Examine some samples of baking soda and vinegar. Add one spoonful of baking soda to a glass holding two spoonfuls of vinegar. Describe the change that occurs. Use what you observe to design an apparatus that can blow up a balloon without using your breath. Produce a labelled diagram of your apparatus. As you do this activity, consider the following questions:

1. Describe each substance you started with.
2. What happened when the vinegar and baking soda were mixed?
3. How would you describe the products of the change?
4. If you were evaluating another group's balloon-inflating apparatus, what characteristics would you be looking for in the group's product?

1.1 Activity

Chemicals and Safety

Matter includes both helpful and harmful solids, liquids, and gases. For example, oxygen is a gas that all animals must take in to survive, but nitrogen dioxide gas from car exhaust is poisonous. Among liquids, water is essential for human survival, but sulphuric acid can cause serious burns if it contacts skin. We put salt crystals (sodium chloride) on our food, but crystals of sodium cyanide are a lethal poison.

How do we know whether or not a given substance is safe to use? How do we work safely with any chemical in the laboratory, at home, or at work? One source of information about hazardous substances is the warning symbols that are placed on containers of potentially dangerous materials. **Tables 1 and 2** show these symbols. In this activity, you will learn about these warning symbols, and you will identify hazards in your own laboratory. You will also learn how to deal with hazards and set some rules for working safely.

Materials

- samples of laboratory chemicals with WHMIS labels
- samples of household products with hazardous product labels

Procedure

Part 1: Safety Scavenger Hunt

- 1 Copy **Table 3** into your notebook.
- 2 Look around you and find each of the safety devices listed in **Table 3**. Record the location of each safety device in the table along with any information you found with the device.
- 3 Examine the samples of chemicals and household products provided. For each sample, record the name of the product, the active ingredient (if listed on the label), and a description of the warning symbol.







Table 1 Hazardous Household Product Symbols

The warning symbols on household products were developed to indicate exactly why and to what degree a product is dangerous.

| | poisonous | flammable | explosive | corrosive |
|---------|---|---|---|---|
| danger |  |  |  |  |
| warning |  |  |  |  |
| caution |  |  |  |  |

Table 2 WHMIS Symbols

The Workplace Hazardous Materials Information System (WHMIS) symbols were developed to standardize the labelling of dangerous materials used in all workplaces, including schools. Pay careful attention to any warning symbols on the products or materials that you handle.

| | | | |
|---|------------------------------------|---|---|
|  | compressed gas |  | dangerously reactive material |
|  | flammable and combustible material |  | biohazardous infectious material |
|  | oxidizing material |  | poisonous and infectious material causing immediate and serious toxic effects |
|  | corrosive material |  | poisonous and infectious material causing other toxic effects |




Part 2: Setting Safety Rules

4 In groups, or as a class, record answers to the following questions.

- Must safety goggles be worn for all activities? Explain.
- Are normal glasses ever an acceptable substitute for safety goggles?
- Should you inform your teacher if you receive a cut during an activity? Explain.
- What should you do if you have an allergy, medical condition, or physical problem?
- Is it acceptable to bring food or drink into the science classroom?
- When can you touch, taste, or smell chemicals in a science activity?
- What should you do if you accidentally touch chemicals during normal activity?
- What procedure should you follow if chemicals accidentally splash into your eyes?
- How should you dispose of chemicals, broken glass, or sharp scalpels?
- What should you do if any of your equipment is damaged or defective?

5 In your notebook, draw a map of the route your class should follow when the fire alarm sounds.

Table 3 Safety in Science—Precautions and Devices

| Hazard | Some precautions | Safety device | Location of device | Device information |
|---|---|--|--------------------|--------------------|
| Fire  | <ul style="list-style-type: none"> tie back loose clothing and long hair avoid contact with the flame or the hot part of the burner avoid sudden movements | <ul style="list-style-type: none"> fire extinguisher fire blanket fire alarm switch | ? | ? |
| Splashes  | <ul style="list-style-type: none"> wear safety goggles wear an apron avoid sudden movements | <ul style="list-style-type: none"> safety goggles aprons eye wash station | ? | ? |
| Broken glass  | <ul style="list-style-type: none"> keep glass containers away from edge of counters avoid sudden movements | <ul style="list-style-type: none"> beaker clamp disposal container for broken glass | ? | ? |

Understanding Concepts

- Why is it important to standardize safety symbols?
- Briefly describe the procedure to follow if exposed skin comes in contact with any chemical substance.
- Do you think it is always safe to pour waste chemicals and solutions down the sink with lots of water? Explain.
- Think about safety precautions that are taken in different industries.
 - Why do people wear face masks when spraying a car?
 - Why do hairdressers wear gloves when using chemicals to straighten hair?
 - Why do firefighters wear breathing apparatus when entering a burning building?

Exploring

- Investigate the containers of products in your home for hazardous product symbols.
 - Make a table to summarize your findings, with headings: Brand Name of Product, Type of Product, Type of Container, Hazard Symbol.
 - Do you see any similarities in the types of containers that are used for hazardous materials? Explain.
 - Do you see any similarities in the types of hazards that seem to be associated with particular groups of products? Explain.

Challenge

What types of hazards or safety issues should you consider when marketing a new substance?

Properties of Matter

When you choose your clothes, your lunch, or your shampoo, you are making choices based on the properties of matter. Considering how important these properties are to our daily lives, it's not surprising that people have always been curious about matter and how it changes. Through observation, scientists have found it useful to categorize properties as physical or chemical.

Physical Properties

When you observe matter—whether you see it, touch it, hear it, smell it, or taste it—you are observing its characteristics, called physical properties. A **physical property** is a characteristic or description of a substance that may help to identify it. Unlike a chemical property, a physical property does not involve a substance becoming a new substance. For instance, colour is a physical property. A substance simply has a certain colour: its colour has no relationship to the substance's ability to change into new substances.

Some physical properties that can be observed by using your senses are summarized in **Table 1**. Pick one of the materials shown in **Figure 1** and describe it, mentioning all of the properties listed in **Table 1**.

There are other physical properties you might choose to describe. Simple tests and measurements can aid your senses in observing these properties.

Table 1

Physical Properties Observed with the Senses

| Property | Describing the Property |
|----------|--|
| colour | Is it black, white, colourless, red, blue, greenish-yellow...? |
| texture | Is it fine, coarse, smooth, gritty...? |
| odour | Is it odourless, spicy, sharp, burnt...? |
| lustre | Is it shiny, dull...? |
| clarity | Is it clear, cloudy, opaque...? |
| taste | Is it sweet, sour, salty, bitter...? |

Figure 1



The States of Matter

One of the physical properties of matter is its state—whether it is solid, liquid, or gas at room temperature.

Example

Solid



Shape

Definite: has a fixed (unchanging) shape.

Volume

Definite: has a fixed volume.

Liquid



Indefinite: always takes the shape of its container.

Definite: has a fixed volume.

Gas



Indefinite: always takes the shape of its container.

Indefinite: always fills the entire container.

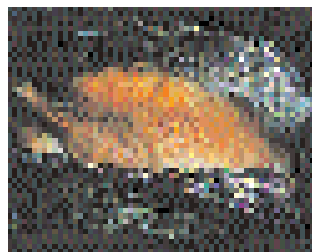
Hardness

Because they are harder than glass, diamonds are used to cut glass. **Hardness** is a measure of the resistance of a solid to being scratched or dented. A harder material will scratch or dent a softer one. For instance, a diamond stylus is used to cut a large sheet of glass into different sizes. Rank the following substances by hardness: steel nails, chalk, glass, diamond.



Malleability

Gold can be hammered into thin sheets, so it is said to be **malleable**. If a solid is malleable, it can be hammered or bent into different shapes. Aluminum foil is malleable, which makes it useful for wrapping food as it cooks. Many materials, glass for example, are not malleable. Instead of flattening out when hammered, they shatter. **Brittle** objects shatter easily.



Ductility

One of the reasons copper is used for electrical wiring is that it can be drawn out into long, thin wires. If a solid is **ductile**, it can be pulled into wires. What other materials can you think of, besides copper, that are ductile?



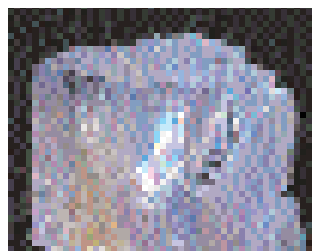
Melting and Boiling Points

The temperatures at which substances change state are characteristic physical properties. For example, under controlled conditions, water always changes from solid ice to liquid water at 0°C —its melting point is 0°C . Similarly, the boiling point of water, when it changes from liquid to vapour, is 100°C .



Crystal Form

Solids can exist in different forms. **Crystals** are the solid forms of many minerals in which you can see a definite structure of cubes or blocks with a regular pattern. For example, when you look closely at salt crystals, you can see that they are tiny cubes.



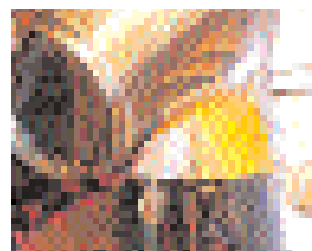
Solubility

When salt and pepper are added to water, the salt dissolves but the pepper does not. **Solubility** is the ability of a substance to dissolve in a solvent such as water. Salt is described as soluble and pepper as insoluble. Drink mixes, for example, contain powdered substances that are soluble in water.



Viscosity

Maple syrup is “thicker” than water—it flows more slowly than water when you pour it. **Viscosity** refers to how easily a liquid flows: the thicker the liquid, the more viscous it is.



Density

When people describe lead as “heavier” than feathers, what they really mean is that lead is more dense than feathers.

Density is the amount of matter per unit volume of that matter. This is usually expressed in kilograms per cubic metre (kg/m^3) or grams per cubic centimetre (g/cm^3). For example, the density of water is $1.0 \text{ g}/\text{cm}^3$. (It can also be expressed as g/mL and g/L .)



Chemical Properties

In nature, substances often combine or react with each other. When one substance can interact with another, that characteristic behaviour can be called a chemical property. For example, dynamite explodes when exposed to a flame because the dynamite combines with oxygen in the air. This reaction produces new substances. A **chemical property** describes the behaviour of a substance as it becomes a new substance.

Combustibility

Combustibility is a property that describes the ability of a substance to react with oxygen to produce carbon dioxide, water, and energy. When a flame is brought close to a mixture of gasoline and air, the gasoline ignites and burns. However, water not only does not burn, but can be used to put out some fires. If a substance is **combustible** or **flammable**, it will burn when exposed to a flame. A substance that will not burn is described as nonflammable. What other materials can you think of that are combustible?

Did You Know



Combustible, flammable, and inflammable all mean the same thing! A substance that will not burn is described as nonflammable or noncombustible.



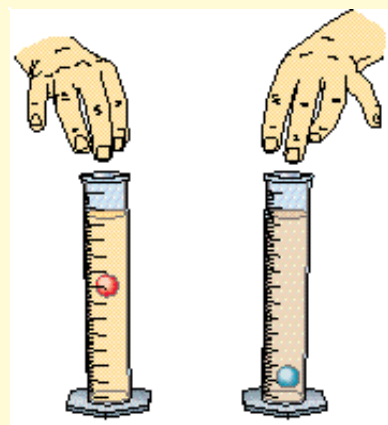
Try This

Just How Thick—Comparing Viscosity

You will need an apron, safety goggles, rubber gloves, a stopwatch, a marble, and a graduated cylinder to compare the viscosity of water, several cooking oils, syrups, and liquid detergents.

As a measure of viscosity, you can time how long it takes the marble to fall from the top of each cylinder to the bottom when the cylinder is filled with each of the liquids. (If you use water in your first trial, that will give you a standard for comparing the other liquids.)

1. Before you get started, which liquid do you think has the highest viscosity? Comment on the accuracy of your prediction: which liquid is the “thickest”?
2. Could you identify a liquid based on your data? Try it out: ask a friend to bring you an unidentified liquid, and then use the marble test to identify the liquid.



Reaction with Acid

When magnesium metal is added to acid, it produces bubbles of gas and the metal quickly disappears. However, when gold is added to acid, no visible change occurs. The ability of a substance to react with acid is a chemical property. For example, geologists use acid to test samples of rock. A chemical property of limestone is that it reacts with acid to produce bubbles of gas.



Using the Properties of Matter

Matter can be grouped as metals and nonmetals. Metals are suitable for different uses because of their special properties.

Metals have been used by people for thousands of years: first copper, then bronze, iron, and steel. Now, many different mixtures of metals, called **alloys**, are used. Whatever the purpose, whether for airplane parts, the bottoms of cooking pots, or braces for teeth, the metal chosen has properties useful for the job.

The metals used in the braces in **Figure 2**, for instance, must have specific chemical properties: they must not react with saliva or chemicals in food. They must also have specific physical properties. Some of these are shown in **Table 2**.



Figure 2

Braces should not be made from toxic metals!

Table 2 Physical Properties of Some Metals Used in Braces

| Metal | Stiffness | Springiness | How easily does it bend? | How easy is it to join? |
|-----------------------|-----------|-------------|--------------------------|-------------------------|
| stainless steel | high | good | fair | fair |
| gold alloy | medium | fair | fair | easy |
| nickel/titanium alloy | low | excellent | poor | difficult |

Understanding Concepts

- What property is described by each of the following statements?
 - Copper metal can be bent into different shapes.
 - A steel blade can scratch glass.
 - Alcohol boils at 60°C.
 - Under a magnifying glass, sugar appears to be made of tiny cubes.
 - A nickel coin is shiny.
- Make a chart listing physical properties that you can observe qualitatively by using your senses or by doing some simple tests.

Qualitative Observations

| Using Senses | Doing Tests |
|--------------|-------------|
| ? | ? |
| ? | ? |

- Distinguish between a physical property and a chemical property.

Exploring

- Think of one use of metal.
- 3A** Research the suitability of two different metals for that use, considering the advantages and possible risks. Explain.

Reflecting

- What are some other properties of matter that were not discussed in this section? For example, do any substances change when they are exposed to air? Can any substances carry electricity?
- Look at the list of adjectives that you made for Getting Started **1** on page 12. Do any of these adjectives represent the properties in this section? What other properties are suggested in your list?

Challenge

List the materials used in some everyday products, and identify their useful physical and chemical properties. How would you display this information?

1.3 Investigation

SKILLS MENU

- Questioning
- Hypothesizing
- Planning
- Conducting
- Recording
- Analyzing
- Communicating

Identifying Substances Using Properties

Have you ever confused the salt and sugar in your home? Because they look the same, you must use other properties to distinguish between them. A mechanic working on a car uses many different solutions. Gasoline, oil, transmission fluid, antifreeze, and brake fluid are just a few of these solutions. Different colours are added to these solutions to make it easier to identify leaks. For example, antifreeze is often green and transmission fluid is red. Physical and chemical properties are the key to identifying substances.

In this investigation, you will determine the identities of five unknown substances, using your laboratory skills. The substances are all white solids, but have other different properties that are described in **Table 1**.

Materials

- safety goggles
- apron
- original containers for salt, baking soda, chalk, sodium nitrate, and sodium thiosulphate
- numbered samples of five unknown solids
- toothpicks
- hand lens
- spot plate or microtray
- medicine dropper
- small beaker with distilled water
- small beaker with dilute hydrochloric acid (3–5%)



Acids are corrosive. Spills of any of these solutions on the skin, in the eyes, or on clothing should be washed immediately with cold water. Inform your teacher of any spills. Similarly, no solid chemicals should contact the skin or be left on bench tops.



Never use your sense of taste to identify substances—they may be poisonous.

Table 1 Data About Solids

| Property | Salt | Baking Soda | Chalk | Sodium Nitrate | Sodium Thiosulphate |
|-----------------------------|-------------|------------------------------|---------------------------|----------------|---------------------|
| state (at room temperature) | solid | solid | solid | solid | solid |
| colour | white | white | white | white | white |
| clarity | clear | opaque | opaque | clear | clear |
| crystal shape | small cubes | powder | powder | granular | hexagons |
| behaviour in water | soluble | soluble | insoluble | soluble | soluble |
| behaviour in acid | dissolves | fizzes and dissolves quickly | fizzes and some dissolves | dissolves | turns cloudy yellow |

Question

How can physical and chemical properties be used to identify substances?

Hypothesis

An unknown substance can be identified by testing its properties and comparing them with those of known substances.

Procedure



- 1 Observe the WHMIS labels on the materials that you will be using in this investigation.
 (a) Record the information for each substance.
- 2 Make a table in your notebook similar to **Table 2** to record your observations.
- 3 Put on your apron and safety goggles.

Table 2 Data Table for Identifying Substances

| Property | Unknown Substance | | | | |
|--------------------|-------------------|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| state | ? | ? | ? | ? | ? |
| colour | ? | ? | ? | ? | ? |
| clarity | ? | ? | ? | ? | ? |
| crystal shape | ? | ? | ? | ? | ? |
| behaviour in water | ? | ? | ? | ? | ? |
| behaviour in acid | ? | ? | ? | ? | ? |
| identity of solid | ? | ? | ? | ? | ? |

4 Obtain a small sample of each of the five unknown solids on separate numbered scraps of paper.

5 Look at the samples using a hand lens. Describe their appearance.

 (a) Record your description of state, colour, clarity, and crystal shape in your table.

(b) Without specific directions from your teacher, which of your five senses is the only one you can use for your observations? Why?

6 Using the hand lens and a toothpick, count out roughly 20 crystals of whichever solid appears to be salt. Measure out roughly equal amounts of each of the other solids. Place each sample in a different well of the spot plate or microtray. Make sure you have numbered the samples 1 to 5.

7 Using a medicine dropper, add two drops of water to each sample. Observe what happens to the solids.

Step 7



 (a) Record your observations in the table.

(b) What kinds of solids dissolved or mixed with water faster?

8 Rinse and dry the spot plate. Repeat steps 6 and 7, using dilute hydrochloric acid in the medicine dropper instead of water.



(a) Record your observations in the table.

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

Analysis and Communication

10 Analyze your observations by answering the following questions:

(a) What was the identity of each of the five solids? Record their names in your data table. Do your results support your hypothesis?

(b) For each of the five solids, explain how you decided on its identity.

(c) Which physical properties did you examine in this activity?

(d) Which chemical properties did you examine?

(e) Which samples were the most difficult to identify? Explain.

11 Write your investigation as a lab report. 

Understanding Concepts

1. Describe three everyday situations in which it would be useful to identify unknown substances. Explain how you would identify the substances.

Exploring

2. At home, collect five small samples of white powder. Choose from flour, cornstarch, icing sugar, baking powder, cream of tartar, citric acid, powdered milk, and coffee whitener. Put each sample in a small bottle and label the bottles A to E. Keep a list of your samples, labelled with the correct letters. Trade samples with a friend and design an experiment to identify each other's samples.



Do not use your sense of taste when you identify these substances.

In Search of Safer Paint

What does an artist have in common with a house painter? Both work with paints—mixtures of substances that have been carefully chosen for their special physical and chemical properties. These properties include not just colour but also the ability to flow and stick to the canvas, walls, or other surfaces. People who work with these chemicals also have to consider safety issues.

You may have noticed a strong smell in a freshly painted room. This odour means that particles of solvent—the liquid part of the paint—have evaporated into the air and entered your nose. The solvent is just one of many different substances that have been mixed together to make the paint.

As the solvent evaporates into the air, the solid components of paint are left behind to coat the wall or other surface. Unfortunately, when some solvents evaporate, their fumes are more than just strong or unpleasant—they are dangerous. These fumes may burn, or even

explode if concentrated in a poorly ventilated room. Many solvents are also toxic and can poison a person who inhales large amounts.

- (a) What are two problems associated with solvents in paint?

Inside a Can of Paint

Paint is a mixture of pigments, resins, and solvent. Each substance in the mixture is chosen for its physical and chemical properties. The components of paint are summarized in **Table 1**.

- (b) What are the three components of paint and the purpose of each?

Latex Paints





Water is the major solvent in latex paint, so the fumes from latex paint are harmless. However, water is not very good at dissolving resins, the part of paint that provides strength and durability. As a result, latex paint contains less resin than alkyd paint, and is less strong and durable. Latex paints are not as sticky and so cannot be used on all surfaces. The water in latex paints damages some surfaces. On the other hand, latex paints dry very quickly and you can use water to clean the brushes or rollers.

- (c) What are two advantages and two disadvantages of latex paint?

Alkyd Paints

Alkyd paint does not contain water as a solvent. Instead it uses mineral spirits and/or turpentine. These solvents are able to dissolve the resins that make this type of paint useful. Alkyd paint is strong and durable. These properties make it useful on surfaces that are often washed, such as kitchen cabinets. It sticks to metal and other surfaces. But the solvent fumes are hazardous, so very good

Table 1 Inside a Can of Paint

| What Is in Paint | Comes from | Properties | Possible Hazards |
|------------------|--|--------------------------------|---|
| pigment | soil, metals, other coloured substances | long-lasting colour | some components harmful if consumed  |
| resin | plant or insect secretions, plastics (alkyds, acrylics, urethanes) | forms hard film that sticks | some components harmful if consumed  |
| solvent | water, mineral spirits, turpentine (from plants) | dissolves other parts of paint | fumes may be toxic  fumes may burn easily (combustible)  |

ventilation is necessary when painting. Cleaning up requires the same solvents, adding more fumes to the air.

- (d) What are two advantages and two disadvantages of alkyd paint?

Choosing a Paint

Think about the decisions you would have to make if you had to do some painting. Painters need to choose products that have the properties they require. Examine the label for “Colour Depot Enviro-safe Paint,” shown in **Figure 1**. The label makes claims about the paint that you may or may not agree with.

- (e) In a group, list the advantages of Enviro-safe Paint that are claimed in the advertisement.
- (f) Discuss these claims. Consider the following questions:

- What evidence is presented to support each claim?
- What evidence would you need to be convinced the claim is accurate?
- Are there any confusing or incorrect statements in the advertisement? If so, why do you think this has happened?

- (g) Rank the claims as very important, less important, or not important to health and safety.
- (h) Rank the claims as very important, less important, or not important to the function of the paint (colouring and protecting a wall).

Figure 1



Understanding Concepts

1. What are three types of physical properties that are important for paint?
2. When is paint most hazardous to human health: while it is in the can, while it is being applied, or after it is dry? Explain your reasons.

Making Connections

3. Which paint would you buy for painting each of the following areas? Explain your choice.
 - (a) the walls of a hospital
 - (b) the walls of a school hallway
 - (c) the window sills in a home
4. What WHMIS or Hazardous Household Product Symbols would you expect to see on a can of (a) latex paint? (b) alkyd paint?
5. Would you prefer to use Enviro-safe Paint or regular latex paint if you were painting your room? Why? If you are not sure, what other issues are important in making this decision?

Exploring

6. Research some of the changes that scientists **3A** have made to make paints safer. For example, paint used to contain lead. Why? Now it does not. Why? What replaces the lead and why is it better? Can you think of any ways to make paint safer still?

Challenge

What are the health and environmental issues related to the substance you are marketing?

Identifying Substances Using Density

Which is heavier: a kilogram of feathers or a kilogram of lead? Once you think about it, the answer is obvious. They have the same mass but very different volumes and therefore different densities. As you have learned earlier, density is a physical property of matter (**Figure 1**). Each substance has its own characteristic density. Look at **Table 1** to see the densities of some common solids, liquids, and gases.

Density is the amount of matter per unit volume of that matter. Density can be expressed as a formula:


$$\text{Density } (D) = \frac{\text{Mass } (m)}{\text{Volume } (V)}$$

If you know the value of any two of the three variables (D , m , or V) in this formula, you can solve for the third. For example, if a metal has a mass of 30 g and occupies a volume of 6 cm³, its density can be calculated as

$$D = \frac{m}{V} = \frac{30 \text{ g}}{6 \text{ cm}^3} = 5.0 \text{ g/cm}^3$$

In this investigation, you will use density calculations to identify unknown liquids.

Materials

- samples of glycerol, vegetable oil, and isopropanol, labelled Unknown A, Unknown B, and Unknown C
 - 3 beakers, each 100 mL
 - balance
 - graduated cylinder
-  Isopropanol (rubbing alcohol) is flammable and toxic.

Question

- 1** The labels have fallen off three bottles of liquid. The liquids are glycerol, vegetable oil, and isopropanol. Write a testable question for determining the identity of the unknown liquids.

Hypothesis

- 2** The densities of the unknown liquids can be compared with the known densities of...
The unknown densities can be calculated if experimental measurements are made of...
(a) Copy these statements into your notebook and complete the sentences.

Experimental Design

- 3** You will be given samples of three liquids, identified as Unknown A, Unknown B, and Unknown C.
- 4** Design an experiment to determine the identity of the three unknown liquids, using the materials in the list above.
(a) Write out the design as a series of numbered sentences.
- 5** Include with your design a fully labelled data table to record your observations.
(a) Make a ruled table for observations.
- 6** Note that your design must include suggestions on appropriate safety procedures.

Table 1

Approximate Densities of Some Common Materials

| Substance | Density | |
|-----------------|-------------------|-------------------|
| | kg/m ³ | g/cm ³ |
| gold | 19 300 | 19.3 |
| silver | 10 500 | 10.5 |
| aluminum | 2700 | 2.7 |
| ice | 920 | 0.92 |
| wood (birch) | 660 | 0.66 |
| wood (cedar) | 370 | 0.37 |
| glycerol | 1260 | 1.26 |
| distilled water | 1000 | 1.0 |
| vegetable oil | 920 | 0.92 |
| isopropanol | 790 | 0.79 |

- 1B (a) Make a list of safety precautions that you will follow.

- 7 Show your procedure, data table, and safety suggestions to your teacher.


Procedure

- 8 When your design has been approved by your teacher, obtain the necessary materials and perform your experiment.

-  (a) Record observations in your data table.

- 9 Calculate the densities of the unknown liquids.

- (a) Show calculations, including formula, substitution, and units.

-  (b) Record your results on a class data sheet, if your teacher suggests you do so.

Analysis and Communication

- 10 Analyze your observations by answering the following questions:

- (a) What were the identities of Unknowns A, B, and C?

- (b) What other physical properties might have helped you decide what the unknown liquids were?

- (c) List any difficulties that you experienced when making measurements.

- (d) How would you modify your experimental design to improve it?

- (e) Determine the average of all the density values obtained by the groups in your class. How does your class average compare with the expected values for glycerol, vegetable oil, and isopropanol?

- 11 Write your investigation report.

Figure 1

Although these three substances all have the same volume, their masses are very different.

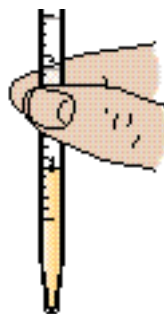


Making Connections

- You are designing a new transparent bottle for an oil and vinegar salad dressing. Vinegar is mostly water. Some spices dissolve into the oil, some into the vinegar, and some spices remain separate. Look for the densities of oil and water in **Table 1**. Where in the bottle would you expect to find the oil layer? How would this affect the design of your bottle? Explain, using a sketch of your bottle design and label.
- Calculate the densities of the following substances, given mass and volume information:
 - mass = 200 g and volume = 40 cm³
 - mass = 4 g and volume = 3.20 cm³
 - mass = 36 g and volume = 54 cm³
- The density formula can be used to calculate mass or volume if density is given. Use the densities of substances given in **Table 1** to calculate:
 - the mass of 100 cm³ of silver
 - the volume of 270 g of aluminum
 - the mass of a 20 cm³ block of birch wood
- An unknown metal has a volume of 20 cm³ and a mass of 54 g. Use **Table 1** and calculations to guess the likely identity of the unknown metal.
- Which do you think is more dense: an **2A** unpeeled orange or a peeled orange? You may be surprised to find that one floats in water and the other does not. Design and perform an experiment, using “home apparatus,” to determine their densities.

Challenge

Identify two instances in which an understanding of density is important in our lives. Consider how to include these examples in your display.



1.6 Investigation

SKILLS MENU


- | | | |
|-------------------------------------|---|--|
| <input type="radio"/> Questioning | <input checked="" type="radio"/> Conducting | <input checked="" type="radio"/> Analyzing |
| <input type="radio"/> Hypothesizing | <input checked="" type="radio"/> Recording | <input checked="" type="radio"/> Communicating |
| <input type="radio"/> Planning | | |

Chemical Magic

A chemical property, such as combustibility, describes the ability of a substance to interact with another substance. These interactions result in change. Change can be subtle—a leaf slowly changes colour from green to yellow in the fall. Change can be dramatic—gasoline explodes in a fireball. Experimenting with different substances and recording observations have led scientists to form new hypotheses to classify some of these changes. This investigation will allow you to identify some changes in chemical properties as new substances are formed. It may also lead you to hypothesize about what kinds of changes you observe.

Materials

- safety goggles
- apron
- 2 small test tubes
- test-tube rack
- 4 labelled medicine droppers
- 2 mL distilled water
- indicator solution (phenolphthalein) in a dropper bottle
- 2 mL of Solution A (0.5% sodium hydroxide)
- 2 mL of Solution B (2.0% sulfuric acid)
- 2 mL of Solution C (2.0% calcium chloride)
- 2 cm² of aluminum foil
- 10-mL graduated cylinder
- 2 mL of Solution D (2.0% copper (II) chloride)

 Solutions A–D are corrosive. Specifically, Solutions A, B, and C are drain cleaner, car battery acid, and de-icing salt, respectively. Spills of any of these solutions on the skin, in the eyes, or on clothing should be washed immediately with cold water. Inform your teacher of any spills.

  Phenolphthalein solution is flammable and harmful if ingested. Inform your teacher of any spills.

Question

How do various substances interact with each other?

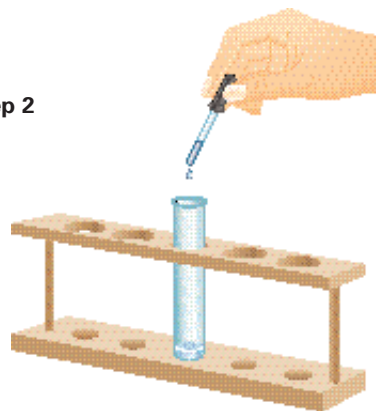
Hypothesis

When some substances are mixed, they will form new substances with new properties.

Procedure

- 1 Put on your apron and safety goggles.
- 2 Obtain a test tube and put it in a test-tube rack. Use one of the medicine droppers to add 5 drops of water to the test tube. Then add 2 drops of indicator solution to the water.

Step 2



- (a) Record your observations.
 - (b) Is there any evidence that a new substance was produced? Explain.
- 3 Use a second dropper to add 5 drops of Solution A to the water/indicator solution.
 - (a) Record your observations.
 - (b) Is there any evidence that a new substance was produced? Explain.
- 4 Use a third dropper to add 5 drops of Solution B to the solution.
 - (a) Record your observations.
 - (b) Is there any evidence that a new substance was produced? Explain.
- 5 Use the fourth dropper to add 5 drops of Solution C to the solution.
 - (a) Record your observations.

(b) Is there any evidence that a new substance was produced? Explain.

- 6** Crumple a small piece of aluminum foil and place it in a second test tube. Place the test tube in a rack. Using a graduated cylinder, measure 2 mL of Solution D and add it to the test tube.

(a) Describe the initial colour of Solution D.

(b) Describe the colour of the solution after 3 min.

(c) Describe the change in the aluminum foil.

(d) Other than any colour changes, what evidence do you have that a chemical change has occurred?

- 7** Dispose of the contents of your test tubes and put away your materials as directed by your teacher. Clean up your work station. Wash your hands.

Analysis and Communication

- 8** Analyze your observations by answering the following questions:

(a) How could you tell when a new substance was produced?

(b) Describe two particular physical properties of substances that changed during this activity.

- 9** Write a summary paragraph explaining to others how you can tell when a new substance is produced.

Challenge

How would you display the information in your summary paragraph so that it makes sense to a younger audience?

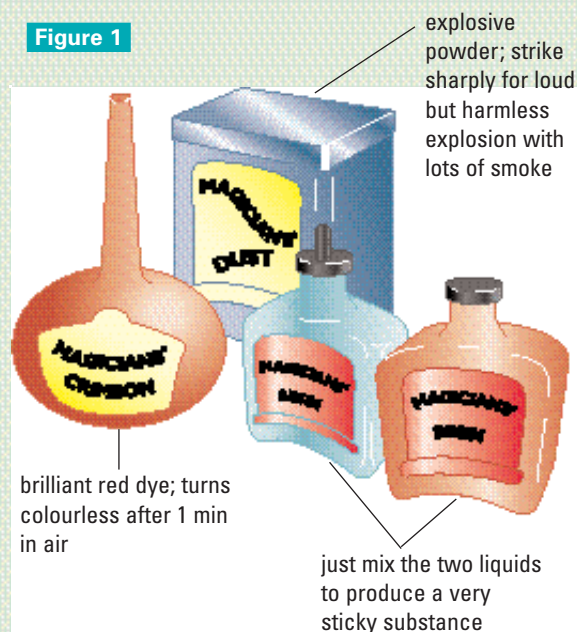
Understanding Concepts

1. List all the changes in matter you can think of that might occur in a kitchen. Do any of the products of these changes have new properties? Explain.

Making Connections

2. Imagine that you are a magician and that you want to design a new magic trick to amaze your audience. You go to a magicians' supply store and discover three new products, illustrated in **Figure 1**. Write a script describing how you could use any or all of these products to create a magic trick.

Figure 1



Exploring

3. In the investigation you just completed, what would happen if you changed the order in which water, indicator, and Solutions A, B, and C were mixed? Design an experiment to test this idea, and predict the observations you would expect. Check your design and predictions with your teacher before mixing any substances. Compare your results with your predictions.

Reflecting

4. After observing different kinds of changes, can you suggest a way of categorizing changes in matter?

Physical and Chemical Changes

Some of the most useful and powerful properties are those related to how and why matter changes. countless changes in matter that affect us every day. For example, applying heat to an egg, burning gasoline, freezing water, and mixing oil and vinegar, to name a few. Understanding and categorizing kinds of change are an important first step to making use of change.

You can discover a great deal about matter simply by observing a candle. The physical properties of the candle include its colour, texture, and density—properties that do not affect the ability of the wax to change in any way. However, some other physical properties do change wax. For example, the wax melts at a definite temperature called the melting point and then changes to vapour at a temperature called the boiling point. These physical properties affect the ability of wax to undergo physical change—the wax, whether solid, liquid, or vapour, is still the same substance.

As the candle burns, you can observe another kind of property that affects change in the wax—combustibility. Candle wax burns, producing heat and light. Combustibility is a chemical property: it describes the ability of the wax to react with oxygen to produce new substances. Unlike physical properties, chemical properties always involve change in a substance. Some of these changes are illustrated in **Figure 1**.

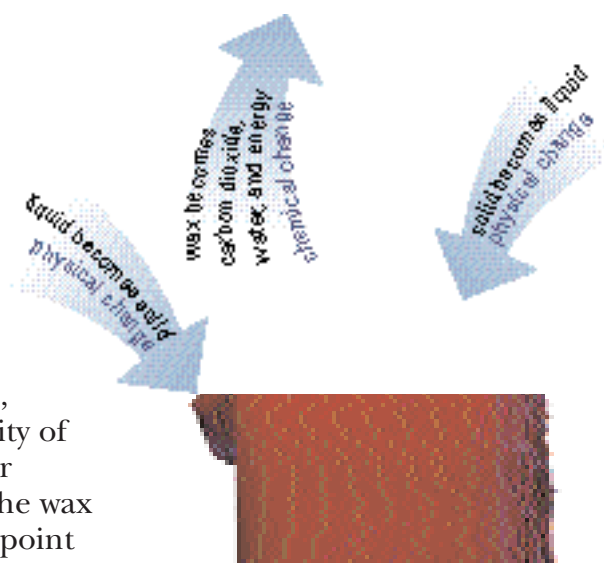


Figure 1

The wax of this candle is undergoing both physical and chemical changes. Which change results in new substances? Which does not?

Physical Change

In a **physical change**, the substance involved remains the same substance, even though it may change state or form. When the candle wax has melted or vaporized, it is still wax.

Changes of state—melting, boiling, freezing, condensation, sublimation—are physical changes (**Figure 2**). You can see a physical change when you pour melted chocolate over ice cream. Liquid chocolate forms a thin, even coating over the ice cream. The chocolate becomes solid as the ice cream cools it, but once it's in your mouth, it tastes the same in both states because its particles have not changed.

Dissolving is also a physical change. When you dissolve sugar in water, the sugar particles spread out, but they are still there, as sugar particles. You can reverse the process by evaporating the water and collecting the sugar. Most physical changes are easy to reverse.

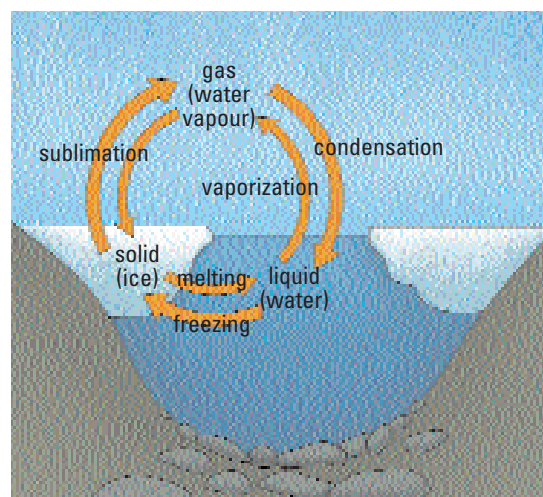


Figure 2

Changes of state

Chemical Change

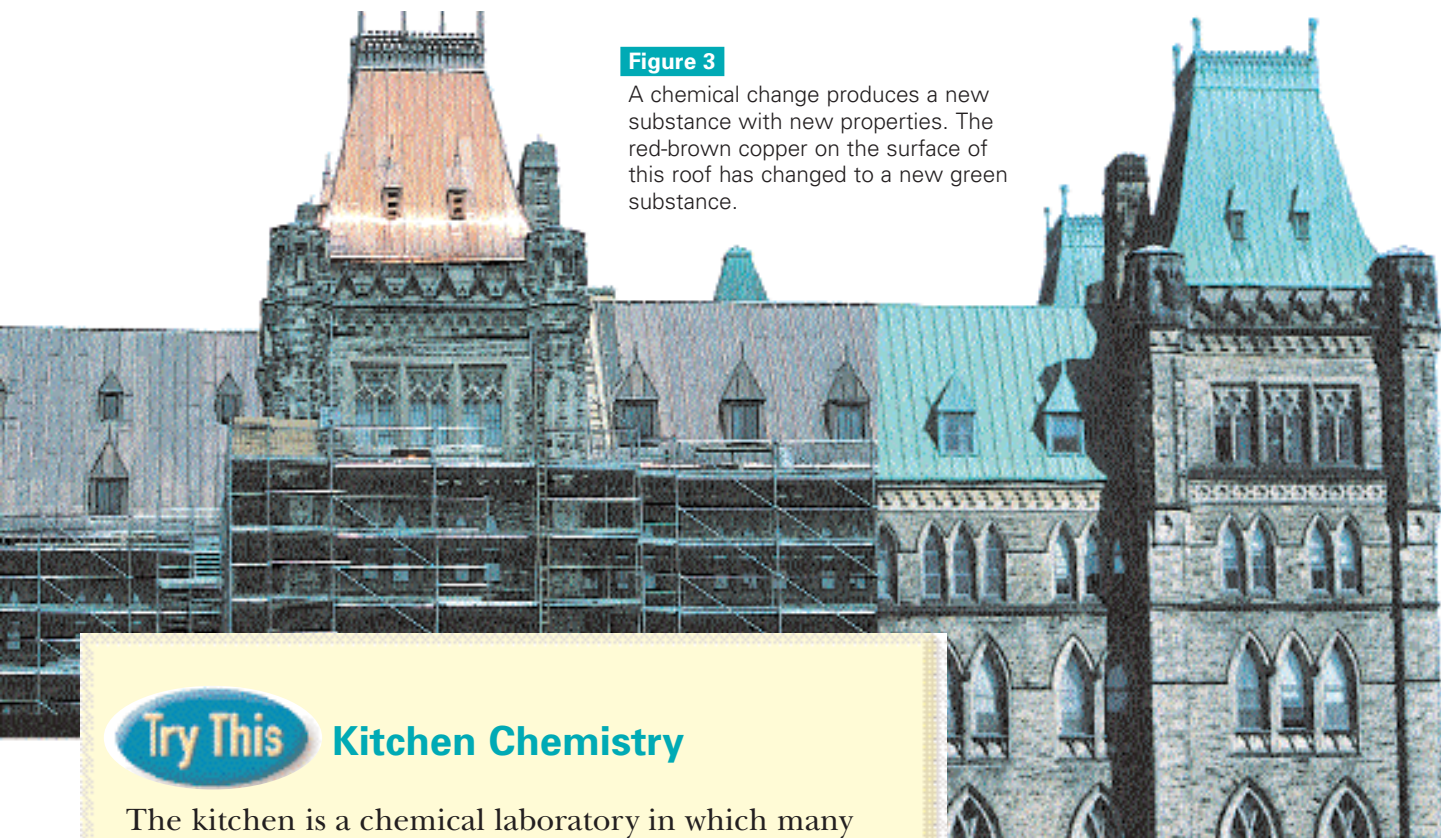
In a **chemical change**, the original substance is changed into one or more different substances that have different properties.

As the wax in a candle melts and vaporizes, some of the wax particles join up with oxygen from the air. The result of this chemical change is the production of water vapour, carbon dioxide gas, heat, and light. The wax particles that seem to disappear are actually changing into something else.

Chemical changes always involve the production of new substances. Most chemical changes are difficult to reverse. Burning, cooking, and rusting are all examples of chemical changes, as is the change shown in **Figure 3**.

Figure 3

A chemical change produces a new substance with new properties. The red-brown copper on the surface of this roof has changed to a new green substance.



Try This

Kitchen Chemistry

The kitchen is a chemical laboratory in which many changes in matter occur. Obtain samples of the following substances: salt, water, baking soda, baking powder, and vinegar. Try mixing together small amounts of the substances in combinations of two. Create a table like **Table 1** to record your results.


 Some household chemicals form dangerous products when mixed together. Check with your teacher before mixing any substances other than those listed.

Table 1 Mixing Kitchen Chemicals

| Substances Mixed | Observations | Evidence of a new substance? |
|------------------|--------------|------------------------------|
| salt and water | ? | ? |
| ? | ? | ? |

Chemical or Physical?

You can't see the chemical change in the wax just by looking at a burning candle. So how can you tell if a chemical change has occurred? The clues listed in **Table 2** can help you decide. But do not come to a conclusion too quickly. All of these clues *suggest* that a new substance has been produced, but any one of them could also accompany a physical change. You must consider several clues in order to determine what type of change has taken place.

Table 2 Clues That a Chemical Change Has Happened




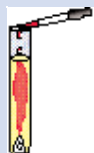

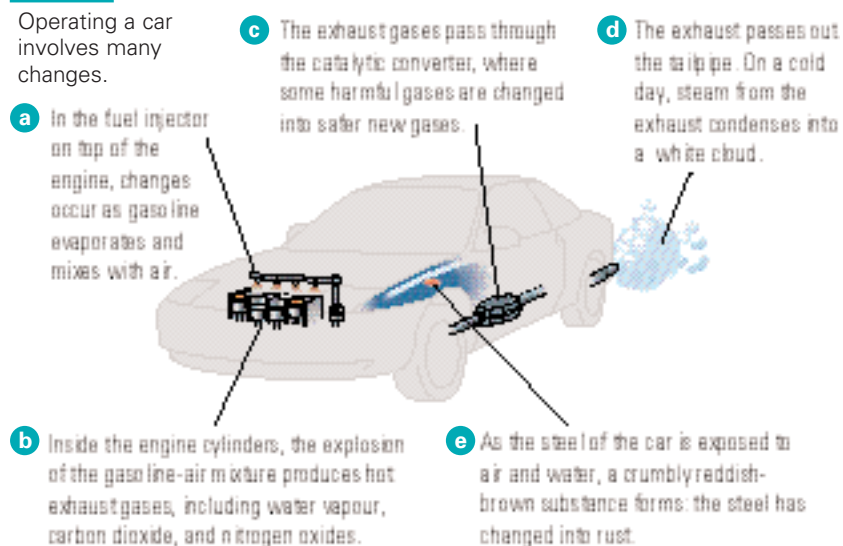
| | | | |
|---|---|---|---|
| A new colour appears. | | Heat or light is given off. | |
|  | |  | |
| Bubbles of gas are formed. | A solid material (called a precipitate) forms in a liquid. | | The change is difficult to reverse. |
|  |  | |  |

Figure 4

Operating a car involves many changes.



Challenge

Identify physical and chemical changes that are useful to us. How would you display these examples?

In what ways can the substance you are marketing change physically or chemically? How does this make it useful?

Understanding Concepts

1. Explain how a physical change differs from a chemical change.
2. Classify each of the following as a physical or a chemical change. Explain why.
 - (a) garbage rotting
 - (b) cutting up carrots
 - (c) a silver spoon turning black
 - (d) making tea from tea leaves
 - (e) bleaching a stain
 - (f) boiling an egg
3. During a power failure, Blair lit four identical candles. He placed three candles very close together on a table, and one on a different table. When the power came back on an hour later, Blair was surprised to see that the candles in the group were much shorter than the one by itself. There was also more melted wax around the base of each of the three candles. Account for Blair's observation. What kind of candles should you keep on hand for emergencies?

Making Connections

4. Which of the changes described in **Figure 4** involve chemical changes? Which involve physical changes? For each identified change, determine the impact it could have on the environment. Which changes must car designers pay attention to in order to minimize damage to the environment?

Reflecting

5. Go back to the list you brainstormed for Getting Started **3** on page 13. Write beside each change on your list whether it is chemical or physical. If you are not sure of any, just leave a blank space. You can return to your list as you work through this chapter.



Hair Colourist

If you have the right personality and an interest in the aesthetic side of chemistry, then Helder Sousa recommends the job of colour technician. After studying for 10 months in a school for hair stylists, he soon

gravitated to the technician side of the work.

While his high school chemistry helped give him an understanding of chemical processes, Sousa did most of his learning as an apprentice at a well-known Toronto salon. He started as an assistant, doing the shampooing and sweeping while he learned about colour theory. Gradually, by working with an experienced colourist, he learned how to achieve the effects the clients wanted. In many ways, learning how to colour hair is more complex than cutting. “Now, I have no nervousness about it. With the years comes more knowledge, like any job.”

The business begins and ends with the clients. “You may have an idea of what auburn means, but the client may mean something else—and you have to figure out just exactly what colour they want.”

People tend to confide in their colourists, so psychological skills are in order too. “Good listening skills are a must. This is not the industry for someone who doesn’t enjoy working with people.” But if you do like working with people, and you’re good at matching the right colours to the client, you can follow a range of careers—in film, television, or magazines. Sousa’s advice: “Study long and hard and work in a good salon.”

“You have to love what you do—it’s hard work to become good at it, and people are very picky about their hair.”

Exploring 3A

1. There are two basic types of hair colour: temporary and permanent. Research how they differ chemically and how they affect the hair.
2. Find out if there are any courses for hair stylists in your area. What background is required? How long is the training?
3. What are the advantages of apprenticing, compared with college courses?
4. Create a pamphlet to inform others who may be interested in a career as a colour technician.

1.8 Investigation

SKILLS MENU

- Questioning
- Conducting
- Analyzing
- Hypothesizing
- Recording
- Communicating
- Planning

Observing Changes


Using their knowledge of physical and chemical properties and current technology, chemists cause many useful changes, including transforming crude oil into plastics, and changing minerals from the ground into copper and iron.

In this investigation, you will learn more about physical and chemical changes. Remember that a change is probably physical unless there is almost certain evidence that a new substance has been produced.

Materials

- safety goggles
- apron
- 4 test tubes
- test-tube rack
- distilled water
- 2-mL measuring spoon
- copper(II) sulfate powder
- test-tube stopper
- iron (a piece of steel wool about 1 cm × 1 cm × 2 cm)
- stirring rod
- dilute sodium carbonate (5% solution)
- dilute hydrochloric acid (3% solution)
- magnesium ribbon (2-cm strip)
- tongs


 Copper(II) sulfate is poisonous. Report any spills to your teacher.

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

Question

How can we recognize physical and chemical changes?

Hypothesis

-  **1** Write a statement to answer the question.

Procedure

Part 1: Copper(II) Sulfate and Water



- 2** Put on your apron and safety goggles.
-  **3** Make a table similar to **Table 1** to record all your observations and inferences.

Table 1 Physical and Chemical Changes

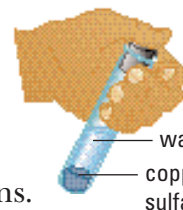
| Part | Starting Substances | | Observations after Mixing | Inference Physical? Chemical? | Evidence |
|------|---------------------|------------|---------------------------|-------------------------------|----------|
| | Name | Properties | | | |
| 1 | water | ? | ? | ? | ? |
| | copper(II) sulfate | ? | ? | ? | ? |
| 2 | ? | ? | ? | ? | ? |



- 4** Obtain a small amount of copper(II) sulfate in a test tube. Put the test tube in the test-tube rack. Obtain some distilled water.

 (a) In your table, describe the water and the copper(II) sulfate.

- 5** Pour distilled water into the test tube containing the copper(II) sulfate, to a depth of about 4 cm. Put a stopper in the test tube to seal it. Take the tube out of the rack and mix the contents by turning the tube upside down several times. Return the test tube to the rack.


Step 5



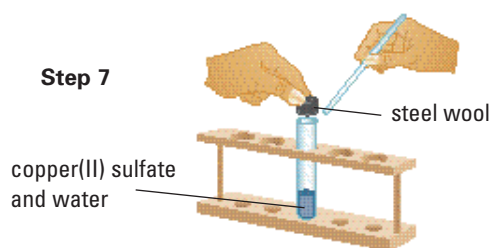
-  (a) Was there a change? Record your observations.
-  (b) Make an inference based on your observations: if there was a change, was it physical or chemical? How do you know? Record your inference and the evidence to support it.

Part 2: Copper(II) Sulfate and Iron

- 6** Into another clean, dry test tube in the rack, pour some of your mixture of copper(II) sulfate and water, to a depth of about 2 cm. (Save the remainder of your copper(II) sulfate mixture to use in Part 3.) Obtain a piece of steel wool (iron).

 (a) Describe the steel wool and the solution before you continue.

- 7 Using a stirring rod, push the steel wool into the copper(II) sulfate mixture.



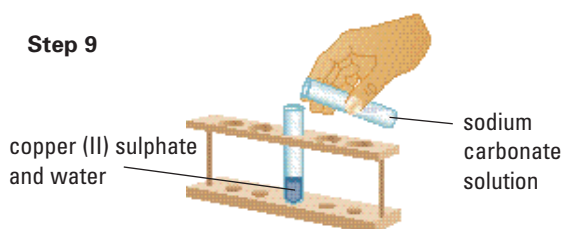
- (a) Record your observations.
- (b) Was there a physical or a chemical change? What is the evidence?

Part 3: Copper(II) Sulfate and Sodium Carbonate

- 8 Into another clean, dry test tube, pour sodium carbonate solution to a depth of about 1 cm.

- (a) Describe the sodium carbonate solution and the remainder of your copper(II) sulfate mixture.

- 9 Pour one solution into the other.



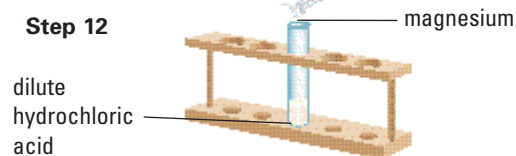
- (a) Record your observations.
- (b) Was there a physical or chemical change? What is the evidence?
- 10 Dispose of the mixtures in the test tubes as instructed by your teacher.

Part 4: Hydrochloric Acid and Magnesium

- 11 Into another clean, dry test tube, pour dilute hydrochloric acid to a depth of about 2 cm. Obtain a small piece of magnesium ribbon.

- (a) Describe the dilute hydrochloric acid and the magnesium.

- 12 Using tongs, carefully add the magnesium ribbon to the test tube without splashing. As any change occurs, feel the bottom of the tube to check for any temperature change.



- (a) Record your observations.
- (b) Was there a physical or chemical change? What is the evidence?
- 13 Dispose of the mixtures as instructed by your teacher. Wash your hands.

Analysis and Communication

- 14 Analyze your observations using your completed table by answering the following questions:
- (a) What kind of change took place when you mixed the substances in each part of the investigation? What evidence do you have? Does this support the hypothesis?
- (b) In each part of this investigation, identify what physical properties changed?
- (c) Look at **Table 2** on page 30. Which of those clues did you observe?
- (d) Which of the changes you observed might be reversed? Explain how.

Understanding Concepts

1. What are some examples of physical and chemical changes in the home? Give reasons for your classification.

Reflecting

2. If you wanted to test more properties of a new substance formed in Part 2, how could you separate it from other materials in the test tube?

Corrosion

Have you ever wondered why metal car bodies rust but plastic bumpers do not? As you know, different substances have different physical properties, such as colour and hardness, and different chemical properties, such as combustibility and reactivity with acid. One chemical property that has great economic importance is the tendency of a substance to undergo **corrosion**—the slow chemical change that occurs when a metal reacts with oxygen from the air to form a new substance called an oxide.

Kinds of Corrosion

The most dramatic example of corrosion is rusting—the reaction of iron with oxygen to form iron oxide. Iron is usually found in the form of steel, a mixture of iron, carbon, and other substances. This alloy or mixture of metals is much harder and tougher than the original iron.

Rusting is a chemical change that involves iron, oxygen from the air, and water, as well as the salts or other minerals dissolved in the water. Every year, millions of dollars of damage are caused to building structures, vehicles (like the car in **Figure 1**), and other iron and steel products due to this process. Rust is particularly damaging because of one of its physical properties: rust is porous, absorbing water almost like a sponge. As a result, it dissolves or flakes off, leaving another layer of fresh metal underneath to be attacked by oxygen. The process continues until the rust has eaten its way through the metal.

By contrast, aluminum has a similar chemical property in that it also reacts with oxygen, but the aluminum oxide that forms is strong and unaffected by water. The corrosion stops and the oxide acts as a protective coating. If you have aluminum cooking pans at home, you will be familiar with the grayish, dull coating of aluminum oxide.

Even silver develops a surface coating of tarnish if it comes into contact with sulfur-containing foods such as eggs or mustard. The black coating seen in **Figure 2** is silver sulfide. Silver tarnishes slowly if left out in the air; the more sulfur-containing pollutants in the air, the more quickly it tarnishes. The black layer can be removed by polishing the silver.



Figure 1

Rust damages many steel car bodies.



Figure 2

Silver slowly corrodes in air.

Preventing Corrosion

There are several ways to prevent corrosion. One method is to paint the surface of the metal (**Figure 3**). As long as the painted surface is not broken or cracked, oxygen in the air cannot get at the metal. For the same reason, cars are often sprayed with oil to coat the bottom and inner surfaces of the car body. Iron can also be protected by coating it with other metals.

Some metals have the chemical property of being easier to corrode than iron. This property is used to protect the hulls of ships and boat motors. For example, as seen in **Figure 4**, a plate of zinc is attached to steel boat motors. The steel motor parts remain untouched as the zinc is slowly used up. The zinc is replaced when it has completely corroded.

A special alloy of steel, made by mixing iron with nickel and copper, is now used in some building structures. The metals corrode quickly but the nickel and copper oxides form a protective layer that prevents further rusting.

Another way to prevent corrosion is to use materials that have different chemical properties. Plastics are being used increasingly in car bumpers and panels that get frequent bumps and scratches. Steel loses its strength if air and water penetrate through a scratch in the paint, but plastics never corrode and remain strong and flexible.

Figure 3

Some bridges are so large that painters take years to finish the whole structure. Then they have to begin again!



Figure 4

Another metal attached to a boat motor can protect it from corrosion in a process called cathodic protection.

Understanding Concepts

1. What is "corrosion"?
2. How is an oxide formed?
3. Describe two processes that form two different oxides.
4. Make a poster describing three ways to protect a metal from corrosion.

Making Connections

5. Corrosion of automobiles causes millions of dollars of damage every year. Which parts of the automobile corrode the most? Why? Describe how car owners and manufacturers can help to reduce the effect of corrosion.
6. Make a list of the products that you have in your home that can corrode. What decisions or steps can you take to protect these products from corrosion?

Reflecting

7. Engineers design pipelines to carry oil or natural gas over hundreds of kilometres. These pipelines are made of steel, but do not corrode. The engineers attach other metals to the pipelines every kilometre or so. How does this protect the steel?

Preventing Corrosion

What kinds of decisions do designers and engineers make when they design products for people to buy? And what kinds of research do they do to help them with those decisions? You have learned that corrosion is a kind of chemical change that affects many everyday products. Being able to design and conduct experiments on corrosion is part of research and development for many companies. In this activity you will take on the role of someone in one of these industries and design an experiment to try to improve a product.

Part 1: Designing Engineering Team 2A

You are part of the design engineering team for PDQ Automobile Corporation that has just designed a revolutionary commuter car (**Figure 1**). It is very lightweight and, therefore, fuel-efficient because it uses metals such as aluminum and magnesium instead of steel in the frame and body. However, critics have suggested that these metals are more likely to corrode, especially in Canadian winters when salt is used on the roads.

Materials

- sample strips of aluminum, magnesium, and steel
- a sheet of emery paper (to polish the metal)
- 6 beakers
- labels and marking pens
- salt
- water



Figure 1

Question

- 1 What question does your design team need to answer to support its choice of materials?

Hypothesis

- 2 Write a hypothesis for this experiment, based on the claims of PDQ's critics.

Experimental Design

- 3 Design an experiment, using the materials provided, to test your hypothesis.

Procedure

- 4 When you have your teacher's approval for your design, make a data table that you can use to record observations.
- 5 Assemble the necessary materials and conduct your experiment.

Analysis and Communication

- 6 Analyze your observations by answering the following questions:
 - (a) Describe the appearance of the materials before you started.
 - (b) Describe the appearance of the materials at various times during the testing period.
 - (c) How did you design your experiment to make sure that the type of metal was the only variable?
- 7 Present your data and conclusions to the 8C Board of Directors at PDQ. You may want to design a logo, motto, or mission statement for PDQ Corporation as part of your presentation.

Part 2: Corrosion Laboratory Team 2A

You are part of a small corrosion laboratory which has a contract with Ace Rust-Prevent Corporation. Your research team has been told to investigate the effectiveness of various methods of rust prevention, especially in Canadian winter conditions.

Materials

- steel nails
- a sheet of emery paper (to polish the metal)
- 6 beakers
- salt
- water
- rust-proofing chemicals (if available)
- motor oil
- paint
- paint brush

Question

- 1 What question does your laboratory need to answer for Ace Rust-Prevent Corp?

Hypothesis

- 2 Write a hypothesis for the experiment your laboratory will perform.

Experimental Design


- 3 Design an experiment, using the materials provided, to test your hypothesis.

1B  Include safety precautions in your design.


Procedure

- 4 When you have your teacher's approval for your design, make a data table that you can use to record observations.
- 5 Assemble the necessary materials and conduct your experiment.

Analysis and Communication

- 6  Analyze your observations by answering the following questions:
 - (a) Describe the appearance of the materials before you started.
 - (b) Describe the appearance of the materials at various times over the testing period.

- (c) How did you design your experiment to make sure that the different types of protection were tested fairly?
- (d) Compare the effectiveness of the different methods of protection.

- 7  Discuss your data with your team and write a proposal for the most effective method. You may want to design a name and logo for your research laboratory as part of your presentation.

Reflecting

1. Review the scientific inquiry process outlined in section 2A of the Skills Handbook.
 - (a) Which steps did you follow in this investigation?
 - (b) Which steps were easiest, and which were most challenging. Explain why.
2. How did you organize your team? How successful were you?
3. What improvements would you make in your design or investigation if you were to do it again?

Challenge

What factors made the proposals effective? How can you use them to market your substance?

Combustion

What chemical reaction occurs in the gas furnace that heats your home? What kind of chemical reaction occurs when you light a match? What caused the forest fire in **Figure 1**? What makes a car engine work? These, and the fires shown in **Figures 2** and **3**, are examples of an important type of chemical reaction called combustion. In **combustion**, a substance reacts rapidly with oxygen and releases energy. The energy is observed as heat and light. Many substances, such as wood, kerosene, and diesel oil, burn readily in air, which is only about 20% oxygen. This makes them useful as fuels.

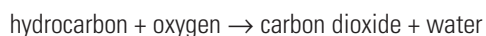
The three necessary components of combustion are illustrated in **Figure 4**, called the fire triangle.

Fossil Fuels and Combustion

Coal, oil, natural gas, and gasoline are all fuels. They are called **fossil fuels** because they were formed from plants, animals, and microorganisms that lived millions of years ago. When these organisms died, they did not decompose completely. Instead, they were buried by sediments and the energy in their cells remained “locked up.”

Human technology, developed over the centuries, depends on these long-buried organisms. Their stored energy powers homes, industries, and various means of transportation.

When any fossil fuel burns, the main products of the reaction are carbon dioxide and water vapour. The particles that make up fossil fuels are called **hydrocarbons**. To represent the combustion of a fossil fuel simply, the following word equation can be used:



In a **word equation**, the substances you start with are written on the left and are called the **reactants**. The resulting substances, written on the right, are called **products**.



Figure 1

Some combustion reactions are destructive. Forest fires consume thousands of hectares of trees every year in Canada.



Figure 2

The quick reaction of magnesium with oxygen is combustion. Magnesium is often used as a component of emergency flares, which produce a bright light even in rain or snow.



Figure 3

Fires can rage for months when oil wells burn out of control. The fires can be extinguished using explosives and other methods that seal the leaking oil. Which component of the fire triangle is removed to stop the fire?

Figure 4

The fire triangle is a convenient way to remember the three components of any combustion reaction. Removing any one of these makes the triangle incomplete and puts out the fire.



Combustion and Air Pollution

Under ideal conditions, the combustion of hydrocarbons produces only carbon dioxide and water. But ideal conditions rarely exist. Fossil fuels are not pure hydrocarbons but rather are mixtures of many different substances. Also, the chemical action of combustion can be less efficient if there is not enough oxygen or heat. When not enough oxygen is available, two other products may be produced: carbon monoxide and carbon. Carbon monoxide is a poisonous gas that you will learn more about in Section 2.8.

When gasoline burns in an automobile engine, the carbon dioxide that is produced increases the greenhouse effect, which may be causing global warming (**Figure 5**). Other products include carbon monoxide, smaller hydrocarbons, sulphur dioxide, and nitrogen oxides, all of which can harm people and the environment. In fact, combustion is the major source of air pollution in the environment.

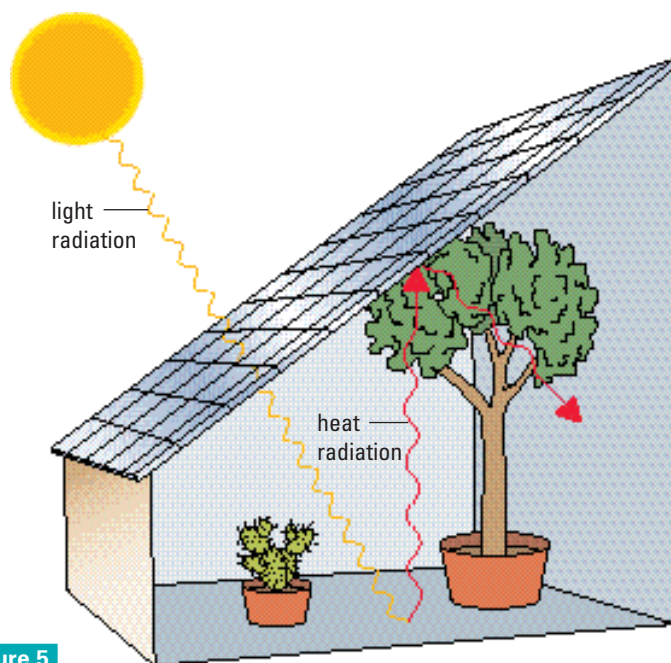


Figure 5

Carbon dioxide gas produced by combustion in industry and automobile engines increases the so-called greenhouse effect. The glass panes of a greenhouse allow sunlight to pass through but prevent heat from escaping. A similar situation occurs in the atmosphere: carbon dioxide in the atmosphere acts like the glass in a greenhouse, trapping heat close to Earth's surface. Many scientists believe this is causing a gradual increase in Earth's temperature.

Understanding Concepts

1. What is "combustion"?
2. (a) When fossil fuels burn, what are the reactants?
(b) What are the two main products of this combustion?
(c) Why are other products also formed?
3. Illustrate which part of the fire triangle is removed when each of the following methods is used to stop combustion.
 - (a) closing the valve on a propane tank that supplies propane to a barbecue
 - (b) dropping and rolling if your clothing catches fire
 - (c) pouring water on a campfire
 - (d) pouring baking soda on a grease fire
 - (e) blowing on a flaming marshmallow

Making Connections

4. Why should you never operate a gas or charcoal barbecue inside a building?
5. Explain why building codes require an external source of air for fireplaces in new homes.

Exploring

6. Fossil fuels may be obtained from the black oil that is pumped from oil wells. Use the Internet or CD-ROM database to find out how these substances are found and separated. Some key words you might want to use in your search are: petroleum, fractionation, fractional distillation, and oil refining.

Reflecting

7. Wood is combustible but chalk is not. Is combustibility a physical or chemical property of substances? Explain.

Chapter 1 Review

Key Expectations

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

- Recognize physical and chemical properties of everyday substances, such as solubility and combustibility. (1.2, 1.3, 1.9, 1.11)
- Distinguish between physical and chemical changes. (1.7, 1.8)
- Distinguish between metals and nonmetals. (1.2, 1.9)
- Describe chemical changes using indicators such as change in colour, or the production of a gas, precipitate, heat, or light. (1.8, 1.9, 1.11)
- Use density calculations to identify unknown substances. (1.5)
- Investigate physical and chemical properties, and organize, record, analyze, and communicate results. (1.3, 1.5)
- Investigate physical and chemical change, and organize, record, analyze, and communicate results. (1.6, 1.8, 1.10)

- Formulate and research questions related to the properties of matter and communicate results. (1.1, 1.4, 1.11)
- Compare the physical and chemical properties of substances and assess their potential uses and associated risks. (1.2, 1.4, 1.9, 1.11)
- Explore careers requiring an understanding of the properties of matter. (Career Profile)

KEY TERMS

| | |
|----------------------------|-------------------|
| alloy | hardness |
| brittle | hydrocarbon |
| chemical change | malleable |
| chemical property | physical change |
| combustible (or flammable) | physical property |
| combustion | precipitate |
| corrosion | products |
| crystal | reactants |
| density | solubility |
| ductile | viscosity |
| fossil fuel | word equation |

Reflecting

- “Matter has characteristic physical and chemical properties. Understanding these properties enables us to make useful products.” Reflect on this idea. How does it connect with what you’ve done in this chapter? (To review, check the sections indicated above.)
- Revise your answers to the questions raised in Getting Started. How has your thinking changed?
- What new questions do you have? How will you answer them?

Understanding Concepts

1. Make a concept map to summarize the material that you have studied in this chapter. Start with the word “matter.”
2. Look again at the Getting Started activity at the beginning of this chapter. Classify the changes as physical or chemical.
3. (a) What is the difference between a physical property and a chemical property?
(b) Give an example of one physical property and one chemical property for each of the following: wood, gasoline, and baking soda.
4. For each of the following, replace the description with one or two words:
 - (a) the starting substances in a reaction
 - (b) the substances formed in a reaction
 - (c) a change in which a new substance is produced
 - (d) a change in which no new substance is produced
 - (e) able to dissolve in a solvent
 - (f) breaks when hit against a hard surface
5. The sentences below contain errors or are incomplete. Write complete, correct versions.
 - (a) A physical change produces a new substance.

- (b) The formation of frost is a chemical change.
 - (c) A chemical change may produce a new substance called a predominate.
 - (d) A new colour indicates a physical change.
 - (e) Ability to react with acid is an example of a physical property.
 - (f) Some substances are safe to taste in the lab.
 - (g) Malleability is a chemical property.
 - (h) A chemical change is a change of state or form.
 - (i) Corrosion is the reaction of a metal with nitrogen in the air.
 - (j) Goggles may be taken off if a student has finished his or her experiment.
6. Suggest five clues you could consider before deciding whether a change is physical or chemical.
 7. Indicate whether each of the following is a physical or a chemical change. Give a reason for each.
 - (a) water freezing on a pond
 - (b) soap removing grease from hands
 - (c) an electric bulb glowing
 - (d) a cake baking
 - (e) wood burning
 - (f) kitchen scraps composting
 - (g) a paper clip bending
 - (h) dynamite exploding
 8. Copy the properties in Column A (Table 1) into your notebook. Match each set of properties with the appropriate substance in Column B.

Table 1

| Column A | Column B |
|--|----------|
| colourless, low viscosity, liquid at 20°C, noncombustible | salt |
| white, crystalline, solid at 20°C, soluble in water | sulfur |
| yellow, powdery, solid at 20°C, insoluble in water, burns in air with a blue flame | alcohol |
| colourless, low viscosity, liquid at 20°C, combustible | water |

9. Which of the properties described in the previous question were (a) physical properties? (b) chemical properties?

Applying Skills

10. Name four materials or pieces of equipment that you used in your investigations to ensure lab safety. Explain the function of each.
11. Find the missing quantity in each of the following density problems, given any two of mass, volume, and density. Show the appropriate formula and units.
 - (a) mass = 40 g; volume = 2 mL
 - (b) mass = 8 kg; density = 2 kg/L
 - (c) density = 5 kg/m³; mass = 400 kg
12. A yellow solid is heated and is observed to change to a brown liquid. Analyze whether the change is physical or chemical.
13. A white solid is heated and is observed to change to a liquid at 65°C. When the solid is cooled, it becomes a white solid again at 65°C. Analyze whether the change is physical or chemical. Explain.

Making Connections

14. Carbon dioxide ejected from a fire extinguisher is so cold that it changes to snow.
 - (a) Is this a physical or chemical change?
 - (b) The carbon dioxide snow, when applied to a burning object, is said to smother the flame. What kind of chemical change is the carbon dioxide snow preventing? How does the carbon dioxide stop the fire?
 - (c) Are there any potential risks of using carbon dioxide in this way?
15. A welder uses heat from the combustion of acetylene (a fossil fuel) to weld steel plates together.
 - (a) Name all the physical changes that occur during and after this process.
 - (b) Describe the chemical change that produces the heat the welder needs.
 - (c) What safety precautions must the welder take?
16. Corrosion is the reaction of metals with oxygen in a chemical change. What kinds of changes occur in other substances over time? For example, what happens to plastic products left out in sub-zero temperatures or in intense sunlight for long periods of time? In what instances could the use of plastics practically replace the use of metals?