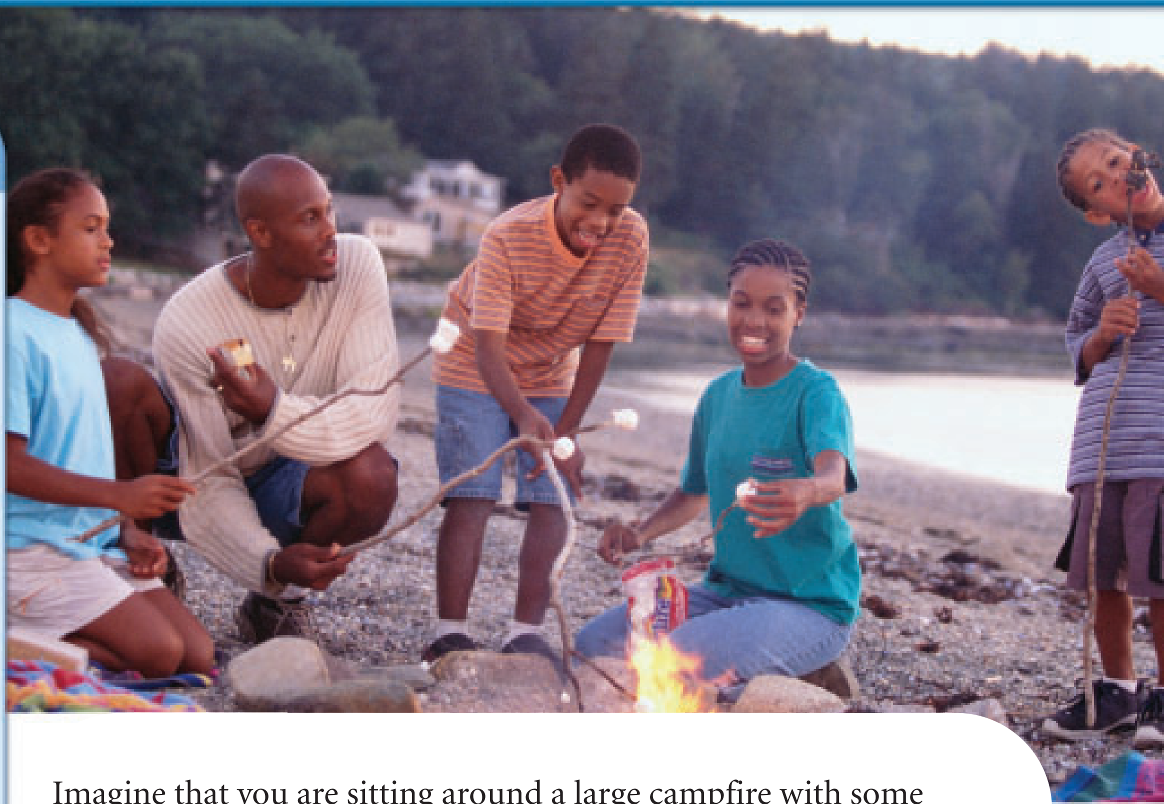
CHAPTER 5

Matter is made up of moving particles.



KEY IDEAS

- The behaviour of matter can be explained using the particle model.
- Matter can undergo physical and chemical changes.
- Changes in matter can be reversible or non-reversible.
- Chemical changes can be distinguished by observable clues.
- Chemical changes occur in our living and non-living environments.

Imagine that you are sitting around a large campfire with some friends. You put a pot of water over the campfire. 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 wieners and marshmallows. Suddenly, one marshmallow catches fire and burns brightly for an instant. Your friend blows out the flame and looks at the black crispy chunk that is left on the stick.

Several changes took place around this campfire. Water changed state from a liquid to a gas. You made a drink by mixing the water with a powder. A marshmallow underwent some type of change and turned black, but remained a solid.

In this chapter, you will learn about a model that explains the behaviour of matter. You will investigate changes in various substances, like the changes described above. As well, you will learn how to identify different kinds of changes and how to explain what happens when matter changes.

The Particle Model of Matter

5.1

More than 2000 years ago in Greece, a philosopher named Democritus suggested that matter is made up of tiny particles too small to be seen. He thought that if you kept cutting a substance into smaller and smaller pieces, you would eventually come to the smallest possible particles—the building blocks of matter.

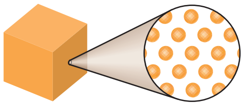
Many years later, scientists came back to Democritus' idea and added to it. The theory they developed is called the **particle model** of matter.

LEARNING TIP

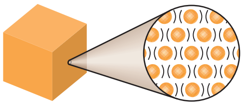
Are you able to explain the particle model of matter in your own words? If not, re-read the main ideas and examine the illustration that goes with each.

There are four main ideas in the particle model:

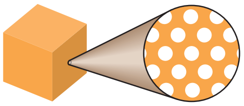
1. All matter is made up of tiny particles.



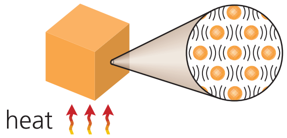
2. The particles of matter are always moving.



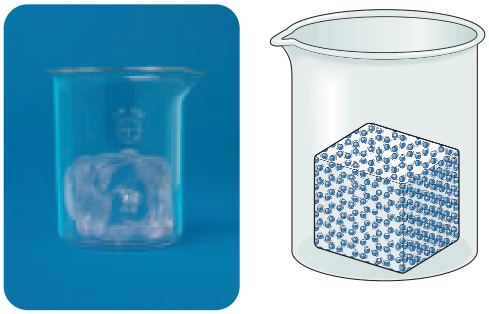
3. The particles have spaces between them.



4. Adding heat to matter makes the particles move faster.

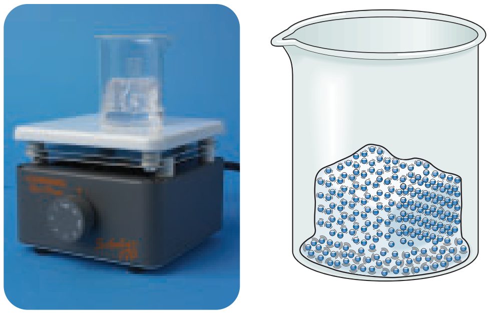


Scientists find the particle model useful for two reasons. First, it provides a reasonable explanation for the behaviour of matter. Second, it presents a very important idea—the particles of matter are always moving. Matter that seems perfectly motionless is not motionless at all. The air you breathe, your books, your desk, and even your body all consist of particles that are in constant motion. Thus, the particle model can be used to explain the properties of solids, liquids, and gases. It can also be used to explain what happens in changes of state (**Figure 1** on the next page).



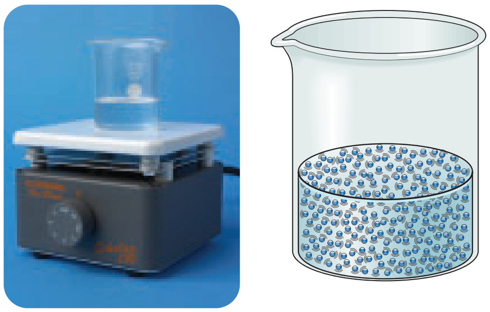
The particles in a solid are held together strongly. The spaces between the particles are very small.

A **solid** has a fixed shape and a fixed volume because the particles can move only a little. The particles vibrate back and forth but remain in their fixed positions.



As a solid is heated, the particles vibrate faster and faster until they have enough energy to break away from their fixed positions. When this happens, the particles can move about more freely. The change from a solid to a liquid is called **melting.**

The reverse of melting is called **freezing** or solidification. This is the change from a liquid to a solid. As a liquid cools, the particles in the liquid lose energy and move more and more slowly. When they settle into fixed positions, the liquid has frozen or solidified.



The particles in a liquid are separated by spaces that are large enough to allow the particles to slide past each other.

A **liquid** takes the shape of its container because the particles can move around more freely than they can in a solid. They are held close together, however. Therefore, a liquid has a fixed volume, like a solid.

When a liquid absorbs heat energy, the particles move about more and more quickly. Some of the particles gain enough energy to break free of the other particles. When this happens, the liquid changes to a gas. The change from a liquid to a gas is called **evaporation.**

The reverse process—the change from a gas to a liquid—is called **condensation.** As a gas cools, the particles in the gas lose energy and move more and more slowly until the gas condenses to a liquid.

The particles in a gas are separated by much larger spaces than the particles in a liquid or a solid. Therefore, a gas is mostly empty space.

A **gas** always fills whatever container it is in. Since the particles are moving constantly in all directions, they spread throughout their container, no matter what volume or shape their container is.

Figure 1

Explaining changes of state using the particle model

Sublimation: A Special Change of State

Some solids can change directly to a gas without first becoming a liquid. This change of state is called **sublimation** [sub-luh-MAY-shun]. In sublimation, individual particles of a solid gain enough energy to break away completely from the other particles, forming a gas.

For example, sublimation occurs as the solid material in a room deodorizer gradually "disappears" into the air. Sublimation also occurs as a block of dry ice (frozen carbon dioxide) in an ice-cream cart "disappears" (**Figure 2**). If you live in a cold climate, you may have seen wet laundry hung outside in the winter go from frozen solid to dry because of sublimation.

Figure 2
Dry ice (frozen carbon dioxide) seems to disappear as it changes directly from a solid to a gas.

All States Have Fixed Mass

When matter changes state, it does not lose or gain mass. The mass of water vapour that is produced by melting an ice cube and then boiling the water is the same as the mass of the original ice cube.

When a liquid is poured from one container to a different-shaped container, its shape changes, but its mass does not change (**Figure 3**). If a volume of a gas is squeezed into a smaller volume, its mass does not change (**Figure 4**). We say that the mass of a specific amount of a solid, liquid, or gas is fixed.

LEARNING TIP

Look at these photos and read the captions. Then check for understanding. Ask yourself, "What is the main idea here?"

Figure 3
Even though the shape of water changes as it is poured from one container to another, the mass of the water stays the same.

Figure 4
Gases can be squeezed into smaller containers, but the mass of the gas does not change.

CHECK YOUR UNDERSTANDING

1. Copy **Table 1** in your notebook. Complete the table by writing "yes" or "no" in each space.

Table 1 Summary of States

State	Fixed mass?	Fixed volume?	Fixed shape?
solid			
liquid			
gas			

2. Use diagrams and words to explain what happens to the particles of matter in each of the following situations. Are the particles moving faster or slower? Are they getting farther apart or closer together?
   a) Butter is warmed on a stove.
   b) Water vapour cools and forms raindrops.
   c) Liquid wax hardens.
   d) Water boils.
   e) Frost forms on a window.

Physical and Chemical Changes

5.2

Every day, you experience changes in matter. Cooking eggs, burning leaves, freezing water, and mixing oil and vinegar to make salad dressing involve changes in matter. Understanding and categorizing these changes are an important first step in learning how to use them.

TRY THIS: BRAINSTORM CHANGES

Skills Focus: observing, communicating, recording

1. In a small group, brainstorm a list of changes in matter. Use a different action word for each change. For example, concrete *hardens*, wood *rots*, snow *melts*, paper *yellows*, and fireworks *explode*.
2. Which changes do you think result in a new substance being formed? Indicate these with a check mark (4).
3. Which changes do you think add materials to the air? Indicate these changes with an asterisk (*).

Physical Changes

In a **physical change,** the substance that is involved remains the same, even though its form or state may change. A piece of wood cut into pieces is still wood (**Figure 1(a)**). When ice melts, it is still ice (**Figure 1(b)**). Changes of state—melting, freezing, evaporation, condensation, and sublimation—are physical changes.

a) Sawing wood

b) Melting ice

Figure 1
Physical changes

In a physical change, the particles of a substance may move closer together or farther apart, or they may mix with particles of other substances. However, no new kinds of particles are produced. Dissolving is a physical change. When you dissolve sugar in water, the sugar particles spread out and mix with the water particles, but they are still there. You can reverse the process by evaporating the water and collecting the sugar.

Changes that can be reversed are called **reversible changes.** Physical changes are often reversible, but not always. You can reverse the physical change that occurs when you melt ice by cooling the water until it freezes again. You cannot reverse the physical change that occurs when wood is sawed into pieces. Changes that cannot be reversed are called **non-reversible changes.**

Chemical Changes

In a **chemical change,** the original substance is changed into one or more different substances with different properties. When a candle burns, it becomes shorter. Some wax may melt down the side of the candle, but some seems to disappear. Where does the wax go? As the wax burns, some wax particles react with oxygen in the air to produce water vapour, carbon dioxide gas, heat, and light. The wax particles that seem to disappear are actually changing into other substances.

Burning a log and frying an egg are also chemical changes (**Figure 2**). When you fry an egg, the liquid egg white part of the egg changes colour and becomes solid. The cooked egg has properties that are different from the properties of the uncooked egg. When you burn a log, you can see it getting smaller. You can feel the heat and see the light given off. You can also see new materials, such as ash and smoke.

Chemical changes always involve the production of new substances. Most chemical changes are difficult to reverse.

a) Burning wood

b) Cooking eggs

Figure 2
Chemical changes

The Importance of Chemical Changes

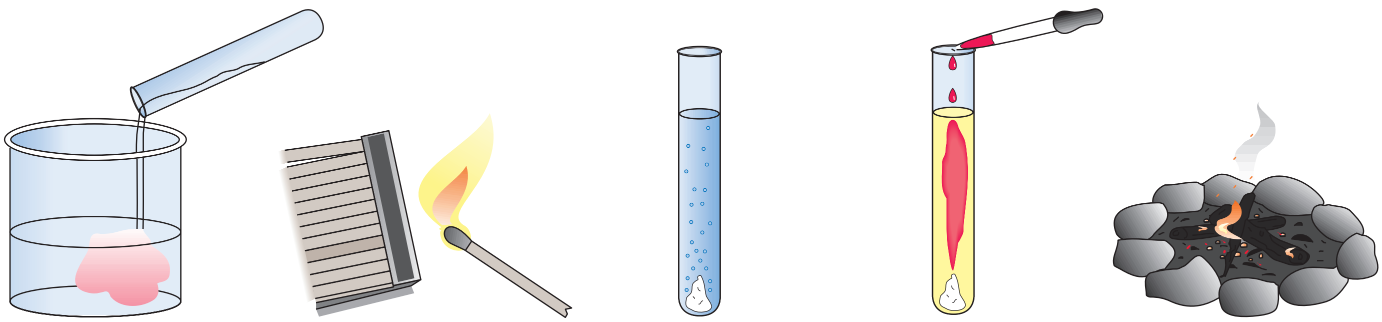
You rely on chemical changes to survive. The clothes you wear and the food you eat are the results of chemical changes. There are millions of chemical changes going on around you. Some are even happening in your body. Plants use energy from the Sun to combine water and carbon dioxide, which react to form sugar and oxygen. When you eat these plants and inhale oxygen from the air, the sugar and oxygen react in your cells to produce water, carbon dioxide, and energy. You need the energy from this reaction for your daily activities.

Determining Whether a Change Is Physical or Chemical

You cannot see the chemical change in wax by looking at a burning candle. You can often see the results of a chemical change, however. You can see the light from a candle, and the colour and firmness of a cooked egg. So, how can you tell if a chemical change has occurred? How can you tell the difference between a chemical change and a physical change? **Figure 3** shows five clues that a chemical change has occurred.

LEARNING TIP

Make notes on evidence of chemical change in a five-column chart. Copy the illustrations and captions from **Figure 3** as the column headings. Add examples under each heading.



A new colour appears.

Heat, light, or sound is given off (or absorbed).

Bubbles of gas are formed. A new odour may be noticed.

A solid material (called a precipitate) forms in a liquid.

The change is difficult or impossible to reverse.

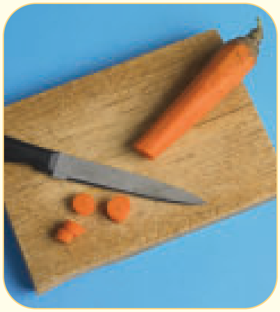
Figure 3
Evidence of a chemical change

When classifying changes, do not jump to conclusions too quickly. The clues in **Figure 3** 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.

TRY THIS: CLASSIFY CHANGES

Skills Focus: observing, classifying

Look at each of the following photos. Classify the change that is shown as physical or chemical, and reversible or non-reversible.



CHECK YOUR UNDERSTANDING

1. Explain how a physical change differs from a chemical change. Present your explanation in a table.

2. Give three examples of reversible physical changes that were not mentioned in this section. Give one example of a non-reversible physical change that was not mentioned in this section.

3. What clues might you observe if a chemical change is occurring?

4. In an experiment, Ethan and Deepa tested different combinations of substances. They made the following conclusions. Are their conclusions valid? Explain your reasoning.

a) When we opened a can of cola, it fizzed. This showed that a chemical change had occurred.

b) When Ethan's Dad sawed through a piece of wood, smoke came up around the blade of the power saw. The sawdust was blackened around the edges of the blade. A chemical change had occurred, because the sawdust appeared different from the original wood.

c) Heat and light were given off by a light bulb. A chemical change took place in the light bulb.

5. When you mix sugar in water, the sugar crystals disappear. Explain why this is an example of a physical change rather than a chemical change.

Fireworks—Extreme Chemical Changes

Have you ever been to a fireworks display and wondered how the colours and sounds are produced? They are produced by chemical changes in the different substances in the fireworks. Each firework is a carefully controlled series of chemical changes, which occur at just the right times and produce large amounts of heat.

A typical firework contains a fuel, a source of oxygen, a fuse (a source of heat to set off the reaction), and a colour producer. Suppose that a firework is expected to rise 50 m and then produce a red burst of fire, followed by a bright flash. This firework would have to contain three different combinations of substances to produce three different chemical changes: one to lift the firework and two to create the two explosions.

The main part of a firework is the fuel and the source of oxygen. When these react with substances such as aluminum or sulfur, a large amount of heat, a loud bang, and flashes of light are produced.

Different substances produce different effects. For example, iron filings and charcoal (carbon) produce gold sparks. Strontium carbonate produces a red flame. Potassium benzoate produces a whistling sound. **Table 1** summarizes some of the other chemicals involved in fireworks. The next time you go to a fireworks display, think about the chemistry involved!

Table 1 Some Chemicals Used for Special Effects

Materials	Special Effect
magnesium metal	white flame
sodium oxalate	yellow flame
barium chlorate	green flame
potassium nitrate and sulfur	white smoke
potassium perchlorate, sulfur, and aluminum	flash and bang

5.3 Conduct an Investigation

SKILLS MENU

○ Questioning	● Observing
○ Predicting	○ Measuring
○ Hypothesizing	● Classifying
○ Designing Experiments	● Inferring
○ Controlling Variables	● Interpreting Data
○ Creating Models	● Communicating

Name the Change

You have learned that there are two types of changes: physical changes and chemical changes. It is not always easy to tell the difference between a physical change and a chemical change. Each clue must be carefully interpreted. In this investigation, you will combine samples of familiar matter. Then you will decide if a physical change or a chemical change has occurred.

Question

Can you tell the difference between a physical change and a chemical change?

Materials

- safety goggles
- apron
- small beakers or small glass jars
- medicine dropper
- vinegar
- water
- baking soda
- milk
- small piece of eggshell
- 2 pieces of uncooked spaghetti
- lemon juice
- paper
- oven mitts
- hot plate
- yeast
- sugar

Wear safety goggles and an apron.

Procedure

1 Make a table like the one below to record your observations.

2 Observe and record the properties of the substances before you combine them.

Data Table for Investigation 5.3

Procedure	Observations before	Observations after	Physical change or chemical change?
vinegar and baking soda	Vinegar is clear and colourless, and smells sharp. Baking soda is ...		
water and baking soda			

3 Using a medicine dropper,
- add vinegar to a small sample of baking soda
- add water to a small sample of baking soda
- add vinegar to a small sample of milk
- add water to a small sample of milk
- add vinegar to a small piece of eggshell
- add water to a small piece of eggshell

Observe and record your results and whether you saw a physical or chemical change.

Use non-flammable oven mitts for step 4. Do not let the paper touch the hot plate.

4 Dip a piece of uncooked spaghetti in water. Use the spaghetti like a pen to write your initials on a piece of paper. Dip another piece of uncooked spaghetti in lemon juice and write your initials on another piece of paper. Put on oven mitts, and heat both papers gently over a hot plate. Observe and record your results.

5 Mix yeast and a small amount of warm water in two containers. Stir some sugar into one of the containers. Observe and record your results.

Analyze and Evaluate

1. Which combinations produced physical changes? Which combinations produced chemical changes? What clues did you use to decide?
2. Is appearance a good clue to the type of change that has occurred? Why or why not?

Apply and Extend

3. Based on your observations, why do you think recipes call for baking soda?
4. Give one example of a physical change and one example of a chemical change that might occur when preparing a meal.

CHECK YOUR UNDERSTANDING

1. Why did you add both water and vinegar to the baking soda, milk, and eggshell? Why did you write with both water and lemon juice on the paper?

LEARNING TIP

For a review of variables, see "Controlling Variables" in the Skills Handbook.

5.4 Chemical Changes in the Environment

Changes are constantly occurring in the environment. Matter may become part of the atmosphere, sit in a landfill, be washed away to an ocean, or be buried underground. However, matter is never completely gone. It remains on Earth. Matter can turn into something else and be used again and again because of chemical changes. One change is followed by another and another.

Chemical Changes in the Living Environment

There are many examples of chemical changes in the living environment. One of the most spectacular examples is a forest fire. A forest fire is not only the end of a forest; it is also the beginning of a new forest (**Figure 1**). In a forest fire, huge trees seem to disappear in minutes. They have not actually disappeared, however. The materials in the trees have been changed into other materials. The leaves and trunks have become gases and smoke in the air, and ashes on the ground. How do you think these new materials can be used as new growth begins?

Figure 1
Whole forests can be consumed by fire, which is a chemical reaction. Chemical reactions are also involved in the gradual regrowth of the forest.

Not all chemical changes are as spectacular as burning. Many are so slow that you cannot see them happening. For example, the new growth in a burned-over area is the result of many chemical changes that go on inside living organisms. Similarly, when the trees in a forest die and decay, chemical changes slowly return the matter in the trees to the environment.

Chemical Changes in the Non-Living Environment

Many chemical changes that do not involve living things also occur in nature.

One very common chemical change is what happens to metals that contain iron, especially when they are wet. This change is called rusting (**Figure 2**). You can see the product of this change—rust—on old bicycles, metal gardening tools, and old cars that have been through many seasons of rain and snow. The rust is soft and flaky—very different from the original shiny metal. When iron rusts, it combines with oxygen in the air to form a new substance.

LEARNING TIP

Compare this information with what you already knew about rusting. Ask yourself, "Is there any information here that is new to me?"

Figure 2

Iron reacting with oxygen to produce rust is an example of a chemical change. Rust damages objects made of metal, such as bicycles and cars.

Figure 3
When silver reacts with oxygen, the silver turns black. Silver tarnishing is a chemical change.

Figure 4
When copper tarnishes, it turns green, like the roof of Hotel Vancouver.

Other metals, such as silver and copper, also combine with oxygen in the air. The new substances that are formed are a different colour than the original silver and copper (**Figures 3** and **4**).

Many industries carry out chemical changes to make the materials that you use every day. Plastics (including vinyl and polyester) are all products of chemical changes. In the mining industry, chemical changes are carried out to separate valuable metals from rock.

CHECK YOUR UNDERSTANDING

1. How is a forest fire an example of a chemical change? List specific clues that support your answer.
2. What is rusting?
3. Name three chemical changes that do not require living organisms.

Materials Scientists

Materials scientists research the structures and chemical properties of various materials in order to develop new materials, or enhance existing materials to fit new applications.

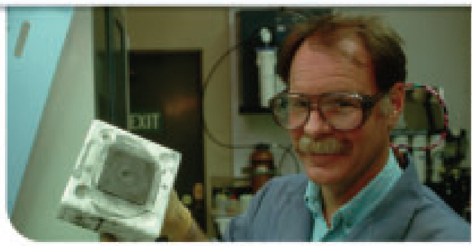


Figure 1

Many materials scientists work in research and development (R&D). In basic research, they investigate the properties, structure, and composition of matter and how elements and compounds react to each other. In applied R&D, they use the knowledge from research to create new products and processes, or improve existing ones.

Chemistry plays a big role in materials science, because it provides information about the properties, structure, and composition of matter. But materials science covers a broad range of sciences. For example, materials scientists have worked with medical professionals to develop materials that can be used to repair and replace body parts. Together they have developed artificial joints, heart valves, ears, and even cochlear implants that allow deaf people to hear.

Sometimes materials scientists find diverse uses for similar materials. The Teflon used to coat non-stick frying pans, the polyester Dacron used in clothing, and the Gore-Tex used for rain jackets are all also used to make artificial blood vessels.

Space exploration depends on materials scientists developing materials that can withstand the temperature extremes, radiation, and other hazards of space (**Figure 1**).

Research in materials science has led to improvements in common materials as well. Coatings and paints (**Figure 2**) that resist corrosion have been developed. However, most paints that resist corrosion contain chromate, a very poisonous chemical that can pollute water supplies. Materials scientists are working on a new corrosion resistant paint with a "smart" pigment that absorbs corrosion-causing chemicals, and releases a safer corrosion inhibitor that forms a protective film over cracks in the paint.

Figure 2

Some of the most exciting materials science research is in the field of electronics. Materials scientists have found ways to dramatically reduce the size of integrated circuit chips (**Figure 3**), allowing for smaller and smaller electronic goods.

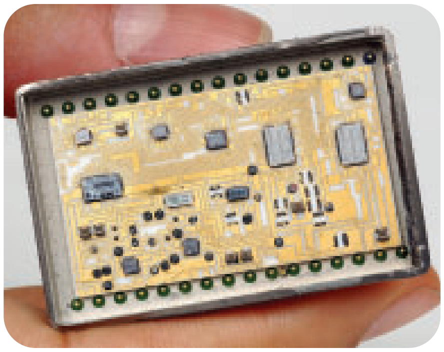


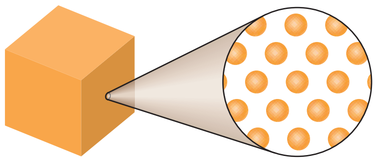
Figure 3

From non-stick bandages to nanotechnology, it is a very exciting time to have a career in materials science.

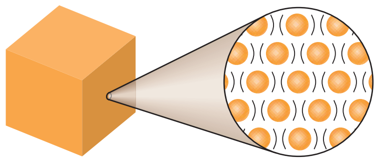
5 Chapter Review

Matter is made up of moving particles.

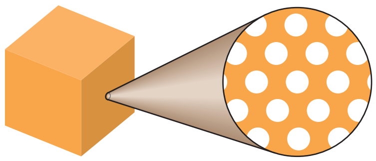
Key Idea: The behaviour of matter can be explained using the particle model.



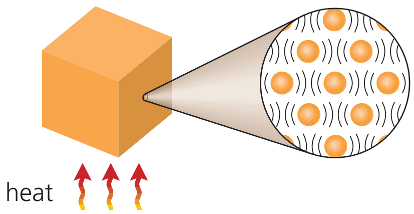
All matter is made up of tiny particles.



The particles of matter are always moving.



The particles have spaces between them.



Adding heat to matter makes the particles move faster.

Vocabulary

particle model p. 117
solid p. 118
melting p. 118
freezing p. 118
liquid p. 118
evaporation p. 118
condensation p. 118
gas p. 118
sublimation p. 119

Key Idea: Matter can undergo physical and chemical changes.

Physical change

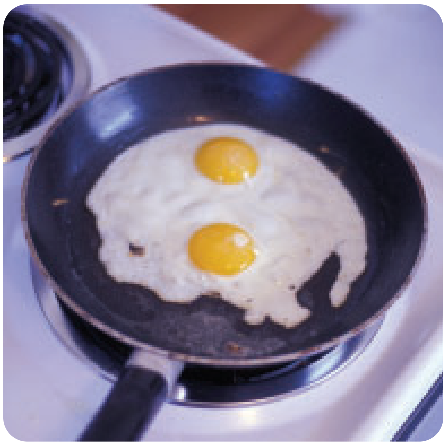
Chemical change

Vocabulary

physical change p. 121
chemical change p. 122

Key Idea: **Changes in matter can be reversible or non-reversible.**

Reversible change



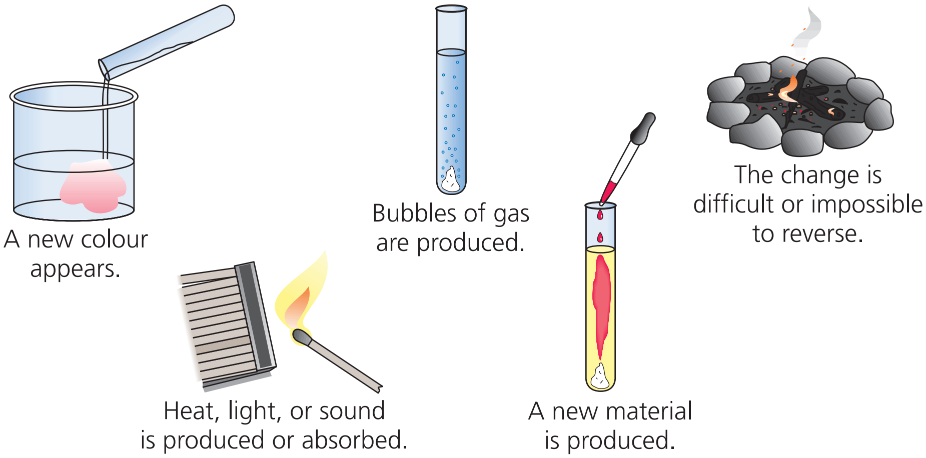
Non-reversible change

Vocabulary

reversible changes p. 122

non-reversible changes p. 122

Key Idea: **Chemical changes can be distinguished by observable clues.**



Key Idea: **Chemical changes occur in our living and non-living environments.**

Review Key Ideas and Vocabulary

When answering the questions, remember to use vocabulary from the chapter.

1. Copy the following table into your notebook, and complete it.

1. State	solid	liquid	gas
Type of particle movement	back and forth		
Spaces between particles		wider	

2. Using the particle model, explain what happens to water as it is gradually heated and changes from ice to steam.
3. Give an example of a physical change that is reversible and a physical change that is not reversible.
4. Suggest five clues that you would consider before deciding whether a change is a physical change or a chemical change.
5. State whether each change is a physical change or a chemical change. Give at least one reason for your answer.
   a) Frost forms on windows.
   b) Tea is made using hot water and a tea bag.
   c) A firecracker explodes.
   d) Concrete becomes hard after it is poured.
   e) The burner on an electric stove glows red.
   f) Coffee changes colour when cream is added.
   g) Liquid nitrogen boils at –196°C.
   h) Butter is heated in a frying pan until it turns brown.
   i) When a flame is brought near hydrogen gas in a test tube, there is a loud pop.
6. Give an example of a chemical change that occurs in your living environment and a chemical change that occurs in your non-living environment.

Use What You've Learned

7. Use the particle model of matter to explain why it is easier to move your hand through air than through water.
8. Solids are described as having a fixed volume. Most solids expand (increase volume) slightly when heated, however.
   a) Use the particle model of matter to explain this observation.
   b) Many bridges have expansion joints in them (**Figure 1**). Research expansion joints. Determine what would happen to a bridge on a hot day if it did not have expansion joints.

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Figure 1
Why do bridges have expansion joints?

9. Microwave ovens cook food quickly (**Figure 2**). Research how microwave ovens work. Use the particle model to explain why they cook food so quickly.

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Figure 2
How do microwave ovens work?

10. Give examples of physical and chemical changes that are useful to you. Think of a way to display your examples.

11. What affects how quickly a certain type of metal rusts (**Figure 3**)? Design an experiment, using iron nails, to test what speeds up this chemical change. Put each nail in a separate jar. Add water, lemon juice, vinegar, salt water, and other liquids. Observe what conditions make the nail rust more quickly. Make a poster to illustrate your experiment and your results.

Figure 3
What would make these nails rust quickly?

Think Critically

12. Which of the changes described in **Figure 4** involve a chemical change? Which involve a physical change? Determine the impact each change could have on the environment. Which changes must car designers consider in order to minimize damage to the environment?

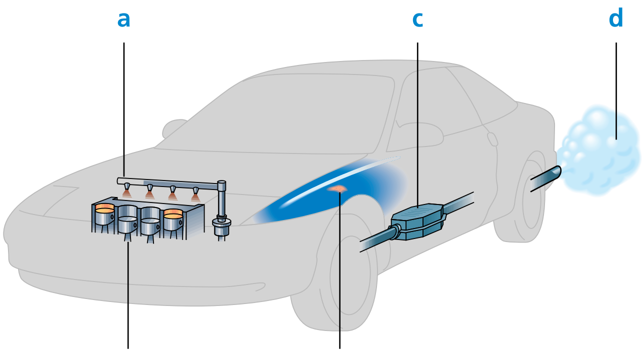

Figure 4

a) In the fuel injector on top of the engine, liquid gasoline is evaporated and mixed with air.
b) Inside the engine cylinders, the gasoline burns very rapidly, producing hot exhaust gases, including water vapour, carbon dioxide, and nitrogen oxides.
c) The exhaust gases pass through the catalytic converter, where some harmful gases are changed into different gases that are less harmful to our environment.
d) The exhaust passes out the tailpipe. On a cold day, steam from the exhaust condenses into a white cloud.
e) As the steel of the car is exposed to air and water, a crumbly reddish-brown substance forms: the steel has changed into rust.

13. Are physical changes in matter or chemical changes in matter more important to your life? Explain your answer.

Reflect on Your Learning

14. How has learning about the particle model changed how you think about matter in your environment?