UNIT B

CHEMISTRY

CHAPTER 4 Matter can be described using properties.

CHAPTER 5 Matter is made up of moving particles.

CHAPTER 6 Matter can be classified.

Preview

The beautiful frost crystals in the photograph might inspire a poet. They might also inspire a scientific mind. You probably know that frost is made of frozen water, but how is it formed? Under what circumstances can frost form large crystals like the ones shown here? How would you describe these frost crystals poetically? How would you describe them scientifically?

In this unit, you will learn about matter (such as frost) and ways to describe matter scientifically. You will observe, measure, and compare many different types of matter. You will learn how to safely conduct investigations using matter and how to communicate your results. Investigations are extremely important to the study of chemistry. You must be able to follow procedures carefully, handle chemicals safely, make detailed observations, and come to conclusions.

To help you understand your observations, you will learn about a model that explains the behaviour of matter. You will find out how scientists classify matter and how physical and chemical changes affect your daily life. By the end of this unit, you will have a greater understanding and appreciation of the influence of chemistry on the world around you.

TRY THIS: MAKE A KWL CHART

Skills Focus: communicating

Before you start this unit, make a three-column K-W-L chart. Record what you already know about chemistry in the first column. Record what you wonder about chemistry in the second column. After you finish the unit, write some things you learned in the third column.

Frost crystals on a windowpane.

CHAPTER 4

Matter can be described using properties.

KEY IDEAS

- Matter can be described using observable properties.
- Matter can be described using measurable properties.
- Matter is anything that has mass and volume.

LEARNING TIP

As you read the first two paragraphs, try to answer the questions using what you already know.

Eulachons (or oolichans) are sometimes called candlefish because a dried eulachon can be burned like a candle. They are also called oilfish because their bodies are 20% oil by weight. For hundreds of years, many Aboriginal peoples have collected and used the oil—often called grease—from eulachons. How would you describe the eulachon grease in the photograph? Is it a solid or a liquid? What colour is it?

Aboriginal peoples use eulachon grease to season food, preserve fruit, and lubricate tools. They also use it as a medicine. They had practical knowledge of the chemical characteristics or properties of eulachon grease that allow it to be collected and used in these ways. Scientists explain the scientific principles behind people's working knowledge of things. In this chapter, you will learn how all matter—from eulachon grease to the air you breathe—can be described scientifically.

Properties of Matter

4.1

When you choose your clothes, your lunch, and even your toothpaste, you are making choices based on the properties of matter. A **property** is a characteristic that may help to identify a substance. You can observe properties using your five senses, or you can determine properties using simple tests and measurements.

LEARNING TIP

Before reading this section, "walk" through it and make a note of the headings and subheadings. Use these to take point form notes as you read.

Properties You Can Observe with Your Senses

You can use your five senses—sight, touch, hearing, smell, and taste—to observe matter (**Figure 1**).

Figure 1
Which senses would you use to describe the properties of an ice-cream sundae?

Some of the properties you can observe with your senses are summarized in **Table 1**.

Table 1 Properties Observed with the Senses

Property	Describing the property
colour	Is it black, white, colourless, red, blue, greenish-yellow …?
taste	Is it sweet, sour, salty, bitter …?
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, translucent …?

States of Matter

You can also use your five senses to observe whether a substance is a solid, a liquid, or a gas. These are called the **states** of matter. A substance may be found in all three states. For example, water can be found as a solid (ice), a liquid (water), or a gas (water vapour in the air), depending on the temperature. You can easily observe the state of a substance at room temperature.

TRY THIS: OBSERVE PROPERTIES

Skills Focus: observing, communicating

Play "I spy" with a partner using the observable properties of matter. Use the format, "I spy something that is (pick a state) and is (pick one or more properties from **Table 1**) …" For example, "I spy something that is a solid, and is blue and shiny. What is it?"

Check with your teacher before you taste anything other than your own lunch.

Properties You Can Measure

Some properties can be determined using simple tests and measurements. For example, you could put a substance in water to see if it dissolves. You could also put a variety of substances in water to see which ones float and which ones sink. Later in this unit, you will measure properties of matter using both of these tests.

LEARNING TIP

The key vocabulary words in this section are illustrated with photographs.

Melting and Boiling Points

One of the properties of matter that can be measured is the temperature at which a substance changes state. Most substances have two temperatures at which they change state.

The **melting point** of a substance is the temperature at which the solid form of the substance changes to a liquid (**Figure 2**). For example, water changes from solid ice to liquid water at 0°C. Thus, the melting point of solid water (ice) is 0°C.

Figure 2
The melting point of ice is 0°C.

The **freezing point** of a substance is the temperature at which the liquid form changes to a solid. If water is cooled, it will freeze at 0°C. The freezing point of a substance is the same as its melting point.

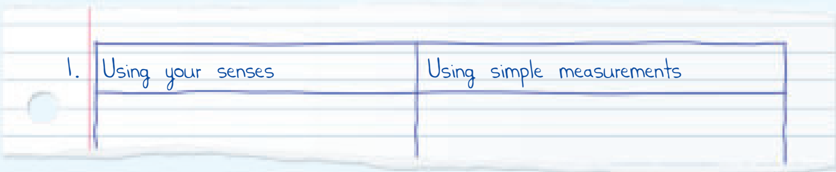
The **boiling point** of a substance is the temperature at which the liquid form of the substance changes to a gas. For example, at the boiling point of water, 100°C, liquid water changes to water vapour, a gas (**Figure 3**).

Figure 3
The boiling point of water is 100°C.

Melting point and boiling point are properties that can be used to help identify a substance.

CHECK YOUR *UNDERSTANDING*

1. Make a chart, like the one below, that lists properties you can observe using your senses and properties you can observe using simple measurements.



2. Describe what happens to the state of a substance when it reaches
   a) its melting point
   b) its freezing point
   c) its boiling point

4.2 Conduct an Investigation

SKILLS MENU

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

LEARNING TIP

To review line graphs and writing a hypothesis see the Skills Handbook sections "Graphing Data" and "Hypothesizing."

Ice to Water to Steam

Suppose that you leave an ice cube at room temperature (20°C). Heat from the surrounding air will melt the ice and turn it into water. Then, if you heat the water enough, it will boil and change into water vapour. In this investigation, you will explore what happens to the temperature of water as it changes state (**Figure 1**).

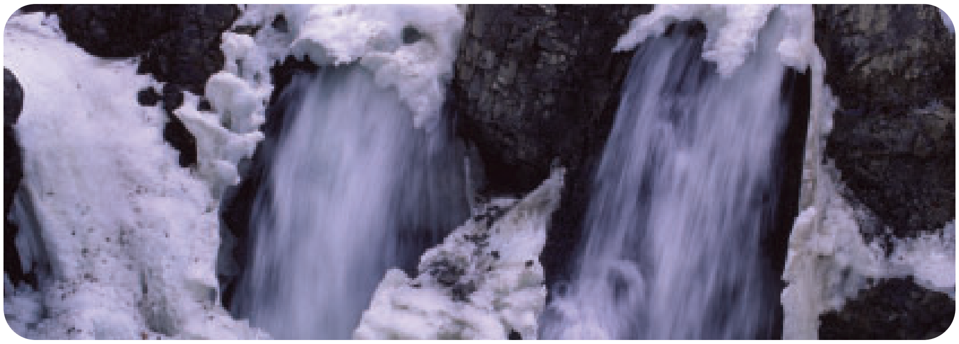


Figure 1
In winter, you can easily find water in all three states. Look at this photo of Pine Creek Falls in northern British Columbia. Solid water is found as ice and snow, liquid water runs under the ice, and some gaseous water (water vapour or steam) is always present in the air.

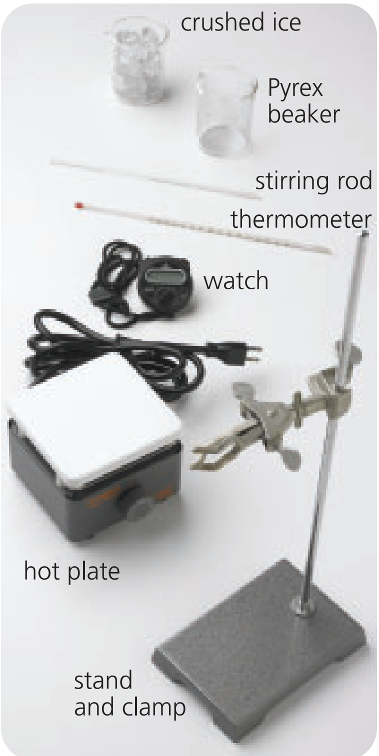
Question

What will happen to the temperature of water as it changes state? Make a prediction by drawing a line graph of temperature versus time. Put temperature on the y-axis and time on the x-axis. Use your graph to predict what you think will happen to the temperature of water as it is heated from ice to liquid to water vapour. Make sure that your graph includes any important temperature values.

Hypothesis

Write a hypothesis based on your prediction. Use the form "If … then …."

Materials



- 250 mL crushed ice
- 250-mL Pyrex beaker
- stirring rod
- thermometer
- watch or clock that displays minutes and seconds
- hot plate
- stand and clamp apparatus

Procedure

Part 1: Ice to Water

1 In your notebook, draw a table like the one below.

Data Table for Investigation 4.2

Time (min)	Temperature (°C)	Other observations
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

Thermometers break easily. Remove the thermometer from the beaker before stirring the ice. Do not let the thermometer touch the bottom of the beaker. Do not leave the thermometer in the beaker, as it may be too heavy and tip the beaker.

2 Place the crushed ice in the beaker. Stir the ice with the stirring rod. Place the thermometer in the beaker, and measure the temperature. Record this temperature in your table as the temperature at 0 min. Remove the thermometer. Record your observations of any changes you see in the right-hand column of your table.

3 After 1 min, stir the ice again. Then measure and record the temperature. Record your observations of any changes you see in the right-hand column of your table.

4 Repeat step 3 every minute, until 5 min after all the ice has melted. Record your observations of any changes you see in the right-hand column of your table.

Part 2: Water to Steam (Teacher Demonstration)

5 To find out what happens to the temperature of water as it boils, your teacher will do a demonstration, as shown on the left. Record the temperature every minute as the water is heated and for at least 5 min after it begins to boil. Record your observations of any changes.

Analyze

1. Use your data to create a line graph of temperature versus time. Describe the shape of your graph.
2. Describe how temperature changes as ice melts. Describe how temperature changes as water boils.
3. Predict what your graph would look like if you could continue to heat the water vapour.

Write a Conclusion

4. How did your predicted graph compare with your actual graph? Was your hypothesis correct? Why or why not? Did your observations support, partly support, or not support your hypothesis? Write a conclusion for your investigation.

Apply and Extend

5. Based on your observations, do you agree with the following statement? Explain your answer.

   "When heat is added to a solid, it can cause a change of state or an increase in temperature."

6. Suppose that you are camping in the fall. You leave some water in a pail overnight. The next morning, you notice a layer of ice on the top of the water. What is the temperature of the water just below the ice?

7. In section 4.1, you learned about boiling point and melting point. Melting point is the temperature at which a solid changes to a liquid. Boiling point is the temperature at which a liquid changes to a gas. **Table 2** lists the boiling points and melting points of some common substances.

   What was the melting point of your ice in this investigation? What was the boiling point of your water? If your values are different from those in **Table 2**, what are some possible reasons for the difference?

Table 2 Melting Points and Boiling Points of Some Common Substances

Substance	Melting point (°C)	Boiling point (°C)
ethanol	–114	78
copper	1084	2336
oxygen	–218	–183
sodium chloride (table salt)	801	1465
sulfur	113	445
water	0	100

CHECK YOUR UNDERSTANDING

1. Why did you need to stir the ice-water mixture?
2. Where did you put the bulb of the thermometer to get the most accurate reading? Why?
3. Why was it important to measure the temperature at regular intervals?

Plasma

A gas that has electricity running through it is called plasma. Plasma is sometimes considered to be a fourth state of matter. It is found mainly in the stars and nebulas within our universe.

Figure 1
The northern lights (aurora borealis)

Figure 2
Neon lights contain plasma.

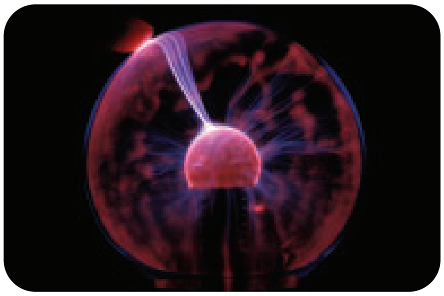


Figure 3
You can see plasma balls at science centres or science stores.

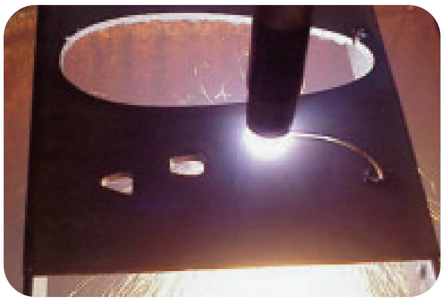


Figure 4
A plasma cutter cutting metal.

Plasma has fascinated people for thousands of years. The northern lights (aurora borealis) are an example of plasma in nature (**Figure 1**). In ancient times, the Inuit people believed that the northern lights were the torches of spirits guiding souls to a land of happiness and plenty.

Today you can find plasma in many manufactured items, such as fluorescent lights, neon signs (**Figure 2**), and plasma balls (**Figure 3**). The wonder that you experience when looking at a plasma ball is like the wonder the ancient Inuit people experienced when looking at the northern lights.

Plasma can even be used to cut and shape metal. Plasma cutters (**Figure 4**) were developed almost 50 years ago, during World War II, to help speed up the process of cutting and welding metal together to build airplanes for the war. Plasma cutters are now used to shape car frames, to cut large beams of metal at construction sites, and are even used by artists to cut and shape metal for sculptures.

Television screens are one of the newest technologies that involve plasma. Plasma displays are not a new invention—research on plasma displays dates back a decade or more. It is only recently, however, that the technology has been developed to manufacture plasma displays at a lower cost.

So how does a plasma screen television work? A plasma screen is quite different from a regular television screen. A plasma screen works by suspending an inert (inactive) gas, such as neon or xenon [ZEE-non], between two panes of transistor-covered glass that are meshed together. An electric charge is applied to the gas, turning it into plasma. This creates ultraviolet light. The ultraviolet light illuminates phosphors that are built into the glass, creating light that you can see (**Figure 5**).

In less scientific terms, think about one million very small light bulbs arranged between two glass plates. The light bulbs are lit by plasma and produce the spectrum of colour needed to view an image. The light bulbs are turned on or off by the television's processor.

Why do so many people wish to have a plasma screen television? Plasma screen televisions are so thin and light that they can be hung on a wall (**Figure 6**). This means you can get a clear view of a plasma screen from almost any angle in a room. As well, there is very little reflection off a plasma screen. These characteristics make plasma screen televisions very desirable.

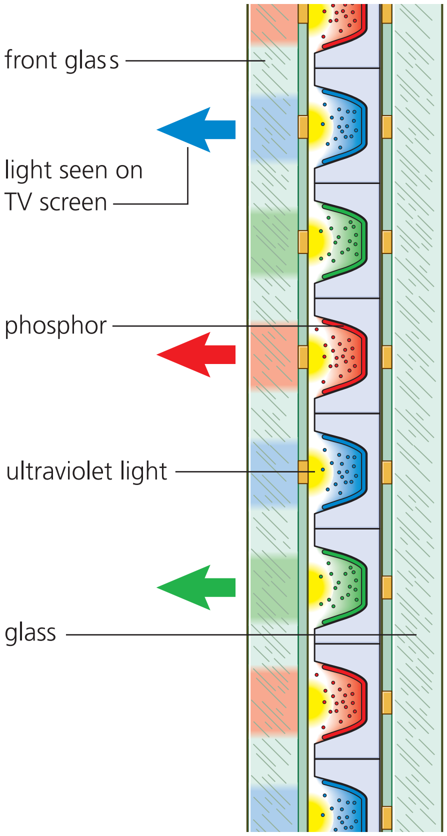


Figure 5
How a plasma screen works

Figure 6
Plasma screen televisions are very light and very thin.

4.3 Mass and Volume

LEARNING TIP

The word "matter" comes from the Latin word *materia*, which means "material" or "stuff."

In this chapter, you are investigating some of the properties of matter. Everything in the world, including you, is made of matter. What exactly is matter? **Matter** is anything that has mass and occupies space. In this section, you will learn about mass and volume.

Mass

The **mass** of an object is a measure of the amount of matter in the object. An object's mass stays constant everywhere in the universe.

Mass is used to measure many things, from food to people (**Figure 1**). For example, when you buy a bag of potato chips, you are buying a certain mass of potato chips. Small masses, such as the mass of a bag of potato chips, are often measured in grams. Larger masses, such as the mass of people or vehicles, are often measured in kilograms (*kilo* means "1000"). Very small masses, such as the amounts of some medicines, are measured in milligrams (*milli* means "one-thousandth," or "$\frac{1}{1000}$").

$$1 \text{ mg} = \frac{1}{1000} \text{ g}$$

$$1 \text{ kg} = 1000 \text{ g}$$

Figure 1
The mass of objects with different amounts of matter can be measured in different units.

Prefix	kilo		centi	milli
Multiple	1000		$\frac{1}{100}$	$\frac{1}{1000}$
Length	kilometre (km)	**metre (m)**	centimetre (cm)	millimetre (mm)
Mass	kilogram (kg)	**gram (g)**	centigram (cg)	milligram (mg)
Volume		**litre (L)**		millilitre (mL)

LEARNING TIP

The International System of Units, or metric system, is commonly referred to as SI. SI comes from the French name, *Le Système internationale d'unités*.

Measuring Mass

When you measure the mass of an object on a balance or a scale, you are measuring the mass directly. Therefore, this is an example of direct measurement.

Sometimes, you need to use a more complicated method to measure mass. For example, to find the mass of a quantity of water, you first need to find the mass of an empty, dry container. Then you pour the water into the container and find the mass of the container and the water. Finally, you subtract the mass of the empty container from the mass of the container with the water in it. The formula is

$$\text{Mass of water} = (\text{mass of container} + \text{water}) - \text{mass of container}$$

This is an example of indirect measurement.

Volume

As well as having mass, matter occupies space. **Volume** is a measure of the amount of space that is occupied by matter.

Measuring the Volume of a Liquid

You can measure a small volume of a liquid directly in a graduated cylinder. A graduated cylinder is a tall, narrow container with a scale of numbers on the side (**Figure 2**).

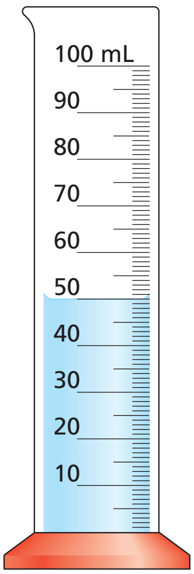


Figure 2
A graduated cylinder is marked out in steps (graduations) to enable measurement.

To measure the volume of a liquid in a graduated cylinder, you read the scale of numbers. When you look at a liquid in a graduated cylinder from the side, you will notice that the top surface has a slight curve where the liquid touches the cylinder. This curved surface is called the meniscus. For an accurate measurement, you should have your eye level with the meniscus, as shown in **Figure 3**. Then you read the volume at the bottom of the meniscus.

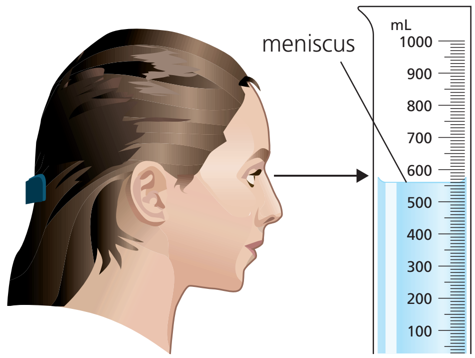


Figure 3
Read the volume of a liquid from the bottom of the meniscus.

The volume of a liquid is generally measured in litres (L) or millilitres (mL). (A millilitre is $\frac{1}{1000}$ of a litre.) You will be familiar with measurements of volume from containers of milk or soft drinks.

Calculating the Volume of a Rectangular Solid

You can measure a rectangular solid with a ruler and then calculate its volume using the following formula:

$$\text{Volume} = \text{length} \times \text{width} \times \text{height}$$

If you measure all the sides in centimetres, then the volume will be in cubic centimetres (cm^3). If you measure all the sides in metres, then the volume will be in cubic metres (m^3).

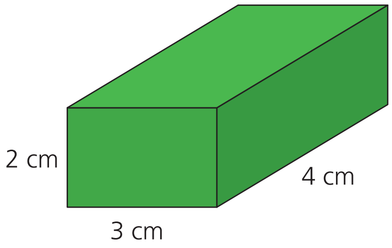


Figure 4

The volume of a rectangular solid with a length of 3 cm, a width of 4 cm, and a height of 2 cm (**Figure 4**) is calculated as follows:

$$\begin{aligned}\text{Volume} &= \text{length} \times \text{width} \times \text{height}\\ &= 3\text{ cm} \times 4\text{ cm} \times 2\text{ cm}\\ &= 24\text{ cm}^3\end{aligned}$$

The volume of a solid is usually given in cubic centimetres (cm^3). The volume of a liquid is usually given in millilitres (mL). Recipes, however, usually use millilitres for both solid and liquid volumes. This works because 1 cm^3 is the same as 1 mL, and 1000 cm^3 is the same as 1 L. Thus, in the calculation above, the volume could also be stated as 24 mL.

Measuring the Volume of an Irregular Solid

Sometimes, you cannot measure the length, width, and height of a solid because the sides are not regular. The volume of a small, irregular solid, such as a jagged rock, must be measured by displacement. To do this, choose a container (such as a graduated cylinder) that the irregular solid will fit inside. Pour water into the empty container until it is about half full. Record the volume of water in the container, and then carefully add the solid. Make sure that the solid is completely submerged in the water. Record the volume of the water plus the solid (**Figure 5**). Calculate the volume of the solid using the following formula:

$$\text{Volume of solid} = (\text{volume of water} + \text{solid}) - \text{volume of water}$$

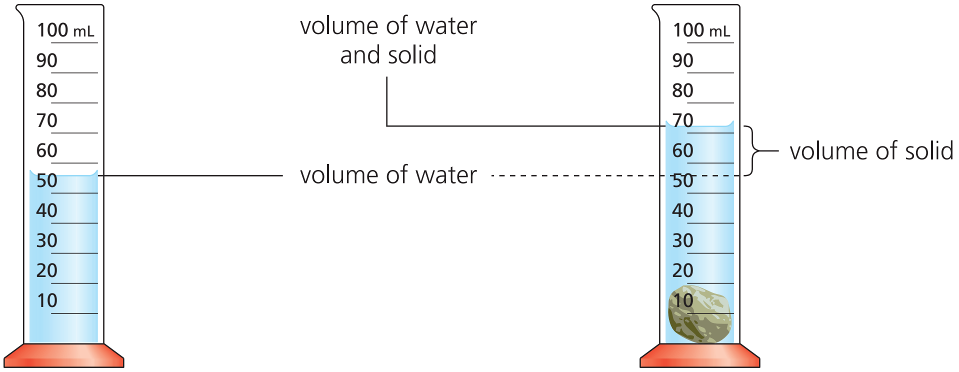


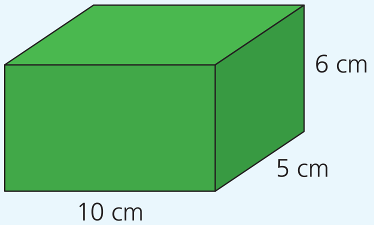
Figure 5
Measuring volume by the displacement of water

LEARNING TIP

For review in measuring mass and volume, see "Measurement and Measuring Tools" in the Skills Handbook.

CHECK YOUR UNDERSTANDING

1. Define mass and volume. State the units that are used to measure each.
2. Name two pieces of equipment that can be used to measure mass and volume. How do these pieces of equipment improve our ability to communicate with each other?
3. What is the correct way to read the volume of a liquid in a graduated cylinder?
4. Determine the volume of the following box.



4.4 Conduct an Investigation

SKILLS MENU

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

Measuring Mass and Volume

In this investigation, you will use what you learned in section 4.3 to determine the mass and volume of some common classroom objects (**Figure 1**). First you will estimate the mass and volume of these objects. Then you will check your estimates using direct measurement or the displacement of water.

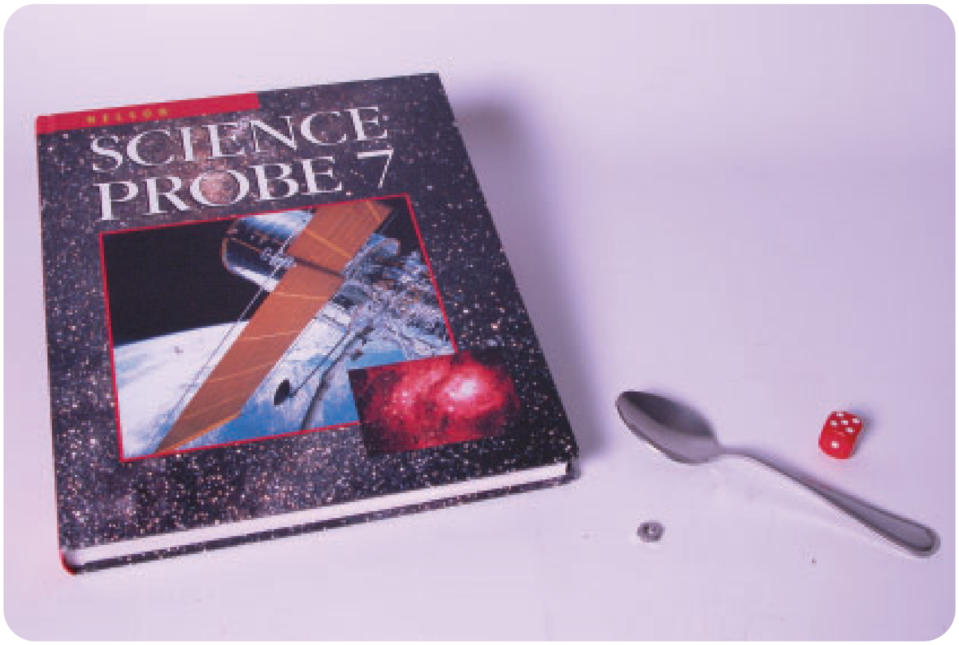


Figure 1
How would you determine the mass and volume of these objects?

Question

What is the mass and volume of common classroom objects?

Materials

- safety goggles
- variety of regular solids (for example, textbook, dice, and block of wood)
- variety of small irregular solids (for example, small rock, small spoon, and metal nut)
- balance or scale
- ruler
- 100-mL graduated cylinder or large measuring cup
- water

Procedure

1 Estimate the mass of each object in grams. Record your estimates in your notebook in a table like the one below.

Data Table for Investigation 4.4

Object	Estimated mass (g)	Actual mass (g)	Estimated volume (cm^3 or mL)	Actual volume (cm^3 or mL)
textbook				
eraser				

2 Use the balance or scale to determine the actual mass of each object in grams. Record your results in your table, under "Actual mass."

3 Estimate the volume of each object in either cm^3 or mL. Record your estimates in your table.

4 Determine the actual volume of each rectangular solid in cm^3. Record your measurements, calculations, and results on your table, under "Actual volume."

5 Determine the actual volume of each irregular solid in mL using displacement. Remember to tilt the graduated cylinder or measuring cup and gently slide the solid into the water.

Record your measurements, calculations, and results in your table, under "Actual volume."

Analyze and Evaluate

1. Which masses or volumes were you able to estimate most accurately? Why?
2. Which masses or volumes did you estimate least accurately? Why?
3. You used the displacement of water to measure the volumes of irregular solids.
   a) Explain why "displacement of water" is an appropriate name for this method.
   b) Why is this method an example of indirect measurement?

Apply and Extend

4. Describe two everyday situations in which the measurement of mass or volume is important.

5. Imagine that you are provided with a scale, a sample of modelling clay, a piece of string, a graduated cylinder, and some water (**Figure 2**). How could you use these materials to prove that you can change the shape of the clay without changing the volume of the clay?

Figure 2

CHECK YOUR UNDERSTANDING

1. Why did you slide each object into the graduated cylinder rather than dropping it in? Would your results have changed if you had not slid all the objects into the cylinder in the same way? Would you have still obtained fair measurements? Explain your answer.
2. When would the displacement of water not be a good method for finding the volume of an irregular object?

Calculating Density

4.5

Look at **Figures 1** and **2**. In both photos, the oil is floating on the water. This property of oil makes it possible to clean up an oil spill and to skim the oil from a boiling pot of eulachons [YOO-luh-kons]. Why does oil float? Oil must be lighter than water, but what does this mean? A litre of oil is certainly not lighter than a glass of water.

To compare fluids using the words "light" and "heavy," you must examine the same volume of each fluid. Thus, a litre of oil is lighter (has less mass) than a litre of water. When you compare the masses of the same volume of different substances, you are comparing their densities. **Density** is the mass per unit volume of a substance. Oil floats on water because it is less dense than water.

LEARNING TIP

Make connections to your prior knowledge. Ask yourself, "What do I already know about floating and sinking? How does this information fit with what I already know?"

Figure 1
An oil spill being contained.

Figure 2
Eulachon oil being skimmed from a pot.

TRY THIS: RANK BY DENSITY

Skills Focus: observing, predicting, measuring

1. Find six identical opaque containers, such as plastic film containers. Fill the containers with different materials, such as water, sand, tiny pebbles, syrup, shampoo, and wood chips (**Figure 3**).
2. Close the containers and mix them up so you do not know which one is which. Number the containers.
3. Rank the containers in order from highest density to lowest density. You may use any method you choose to determine your ranking, but you cannot open the containers. Record your ranking.
4. Which densities were you able to estimate quite accurately? Which were harder to estimate? Why?

Figure 3

Using Density

Density is a property of matter that can be calculated. It is the mass of a substance per unit volume of this substance. It is expressed as grams per cubic centimetre (g/cm^3) or grams per millilitre (g/mL).

Density is calculated by dividing the mass of an amount of substance by its volume. The formula is

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

Each substance has its own unique density. Water has a density of 1.0 g/mL. Liquids and solids that float on water have a density of less than 1.0 g/mL. Liquids or solids that sink in water have densities of more than 1.0 g/mL.

Table 1 lists the densities of some common substances. Notice that western red cedar has a lower density than water. Therefore, western red cedar floats in water, as do most types of wood (**Figure 4**). Crude oil also has a lower density than water, which is why oil spills stay afloat in the ocean. Copper has a higher density, however, so it sinks in water. The densities of two substances can be used to predict which will float and which will sink.

LEARNING TIP

Make connections to your prior knowledge. Ask yourself, "How does this information on density fit with what I already know?"

Table 1 Densities of Some Common Substances

Substance	Density (g/mL)
wood (western red cedar)	0.37 (approximate)
crude oil	0.86–0.88 (approximate)
pure water	1.00
copper	8.92

Figure 4
What property of wood allows forest companies to transport logs in this way?

CHECK YOUR UNDERSTANDING

1. What is density? How is it calculated?
2. Use the "Actual mass" and "Actual volume" columns of your data table for Investigation 4.4 to calculate the density of each object.
3. Calculate the density of each kind of wood.
   a) a child's block made of birch wood with a volume of 510 cm^3 and a mass of 306 g
   b) a pine log with a mass of 96 000 g and a volume of 240 000 cm^3
   c) a sculpture made of ebony with a volume of 81 cm^3 and a mass of 96 g

4.6 Conduct an Investigation

SKILLS MENU

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

Will It Float or Sink?

Will a rock float in water? Will a cork float in alcohol? Will alcohol float on glycerine? In this investigation, you will predict whether various solids will float or sink in three liquids. Then you will test your predictions. You will also predict and test what will happen when you combine the three liquids.

Question

Which materials will float or sink in rubbing alcohol, water, and glycerine?

Materials

- safety goggles
- apron
- small pieces of various solids (such as cork, wood, and rock)
- ruler
- graduated cylinder
- balance
- 3 250-mL beakers or small glass jars
- rubbing alcohol (isopropyl alcohol, density 0.8 g/mL)
- water (density 1.0 g/mL)
- glycerine (density 1.3 g/mL)
- 3 colours of food colouring

Procedure

1. Calculate the density of each solid. You may have to use indirect measurement to determine the volumes of some of the solids. Record the densities in your notebook in a table like the one below.

Data Table for Investigation 4.6

Materials tested	Mass	Volume	Density (g/cm^3)	Will it float or sink ...? in rubbing alcohol	in water	in glycerine
ice						
wax						

2 Use your densities to predict which solids will float in each liquid. Write your predictions as "yes" or "no" in your table.

3 Put on your apron and safety goggles.

Rubbing alcohol can harm your eyes. Wear safety goggles at all times.

4 Fill each beaker three-quarters full with one of the liquids. Test your predictions by placing each solid in the three liquids. Use a check mark (4) or an (8) to indicate whether or not each prediction is correct.

5 Pour half of the water out of your beaker. Use a drop of food colouring to make each liquid a different colour. In your notebook, predict what will happen if you combine the three liquids. **Gently** pour some of the alcohol and then some of the glycerine into the water. Record your observations.

Analyze and Evaluate

1. Summarize your results in a few sentences.
2. Explain how you can use density to predict whether or not one substance will float on another substance.

Apply and Extend

3. Which substance that you tested is the most dense? Which is the least dense? Give one use for each substance that relies on its density.
4. In the last step of the procedure, you combined different liquids. Describe the final appearance of the combined liquids. What can you conclude about the densities of the three liquids?

5. **Table 2** gives the densities of several metals. Mercury is the only metal that is a liquid at room temperature. Mercury is very toxic. You should never touch it or inhale its vapours. Use **Table 2** to determine which metals would float and which would sink in liquid mercury (**Figure 1**).

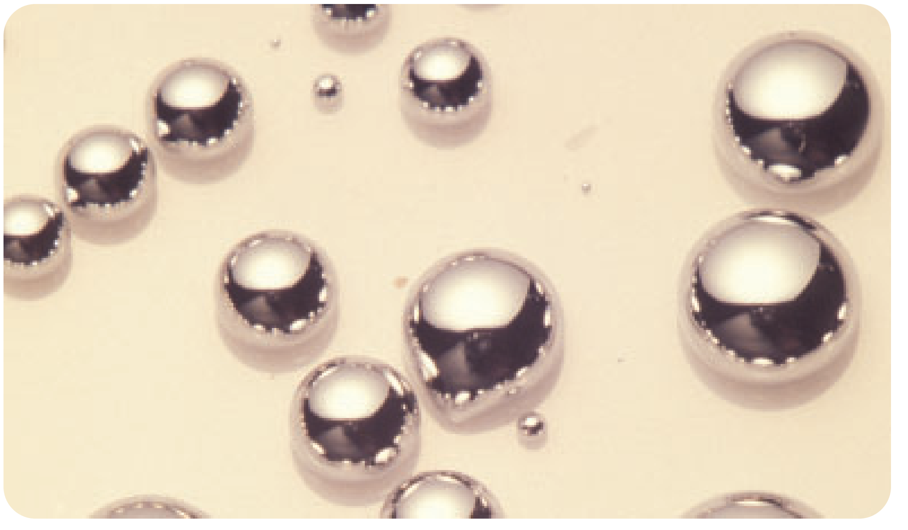


Figure 1
Mercury is a silvery-white, liquid metal.

Table 2 Densities of Some Common Metals

Metal	Density (g/mL or g/cm^3)
aluminum	2.7
chromium	7.2
copper	8.95
gold	19.3
iron	7.86
lead	11.34
mercury	13.6
silver	10.5
tin	7.31
zinc	7.13

CHECK YOUR UNDERSTANDING

1. How could mistakes in your measurements or calculations have affected the accuracy of your predictions?
2. Could the food colouring you added to the liquids in step 5 have affected the densities of the liquids? Explain.

Chapter Review 4

Matter can be described using properties.

Key Idea: Matter can be described using observable properties.

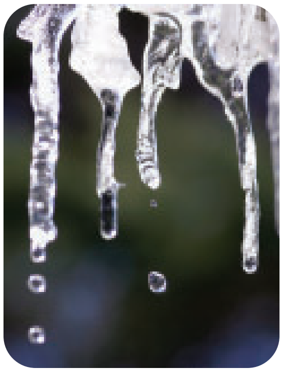
You can use your senses to describe the colour, texture, and state of this sundae.

Vocabulary

property p. 91

states p. 92

Key Idea: Matter can be described using measurable properties.



Melting point

Boiling point

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

Density

Vocabulary

melting point p. 92

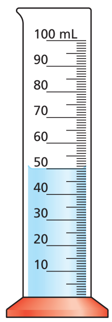
freezing point p. 93

boiling point p. 93

density p. 107

Key Idea: Matter is anything that has mass and volume.

- Mass is a measure of the amount of matter in an object.
- Volume is a measure of the amount of space that is occupied by matter.



Vocabulary

matter p. 100

mass p. 100

volume p. 101

Review Key Ideas and Vocabulary

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

1. List properties that you can observe using only your senses. Choose an object in your classroom, and describe it using these properties.
2. Name two properties that require measurements.
3. Describe both the equipment you would need and the steps you would take to measure
   a) the volume of a ring
   b) the mass of a sample of liquid
   c) the volume of a cement block
   d) the mass of a stone
   e) the volume of a sample of liquid
4. Define density. Why is density considered to be a property of matter, but length is not?

Use What You've Learned

5. Vinegar and water are both clear liquids at room temperature (**Figure 1**). What properties could you use to tell them apart?

Figure 1

6. If a substance is a solid at room temperature (20°C), what can you say about its melting point?
7. Look at the melting and boiling points of mercury and ethanol (**Table 1**). Which substance would be better to use in an outdoor thermometer in the Arctic? Why?

Table 1 Melting Points and Boiling Points of Two Substances

Substance	Melting point (°C)	Boiling point (°C)
mercury	−38.9	356.6
ethanol	−114.3	78.5

8. For each substance, state which is the larger value.
   a) 340 mL or 1 L of apple juice
   b) 100 g or 0.5 kg of laundry soap
   c) 50 L or 500 mL of water in a bathtub
   d) 2 kg or 500 g of potatoes
9. The mass of a dry, empty beaker is 250 g. The mass of the beaker and a liquid is 475 g. What is the mass of the liquid?
10. A classroom measures 11.0 m by 9.0 m by 3.0 m. What is the approximate volume of air in the classroom?
11. A graduated cylinder contains 40 mL of water. A stone is carefully slipped into the cylinder. The level of the water reaches 57 mL. What is the volume of the stone?
12. a) Suppose that you tried to use the displacement of water to find the volume of a sugar cube. What problem could you have? What could you do to solve this problem?
    b) List two other objects whose volumes you could not measure using the displacement of water. Explain why.
13. Describe a method you could use to determine the volume of your body.

14. An ice cube is placed on one balance pan of an equal-arm balance. Masses totalling 3.5 g are placed on the opposite pan to level the balance (**Figure 2**). If the ice cube is allowed to melt, do you expect the balance to stay level? Explain.

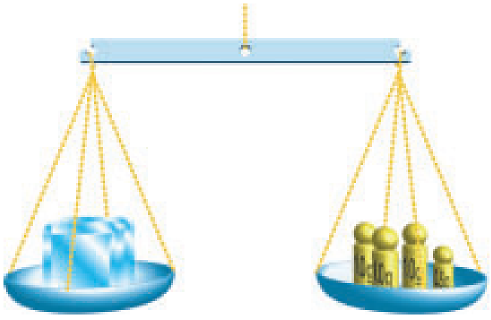


Figure 2

15. Investigate methods that are used by Aboriginal peoples to obtain the oil from eulachons (**Figure 3**). Identify the properties of oil that are used in these methods.

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Figure 3

16. A hydrometer can be used to measure density of liquids (**Figure 4**). Conduct research to find out what a hydrometer is and how it measures density.

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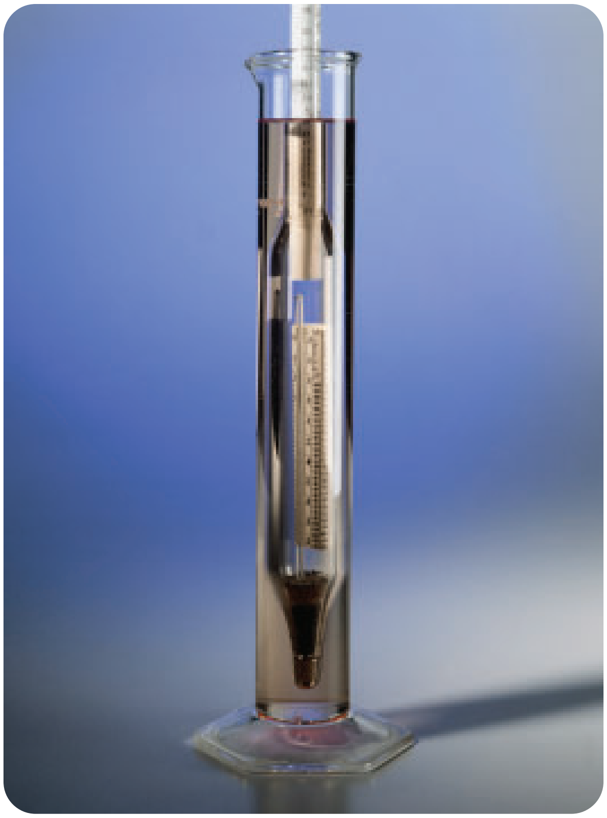


Figure 4

Think Critically

17. During a class discussion, one student states that solids are always denser than liquids. Several other students disagree with this statement. Which position would you take? Give examples to support your position.

Reflect on Your Learning

18. You have learned a lot about matter in this chapter. Think back to the beginning of this chapter. How have your ideas about matter changed?

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

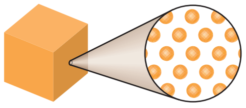
5.1

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.

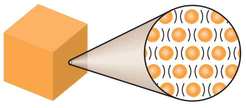
Many years later, scientists came back to Democritus' idea and added to it. The theory they developed is called the **particle model** of matter.

There are four main ideas in the particle model:

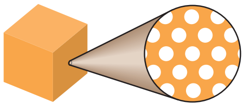
1. All matter is made up of tiny particles.



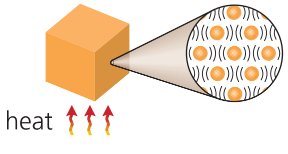
2. The particles of matter are always moving.



3. The particles have spaces between them.



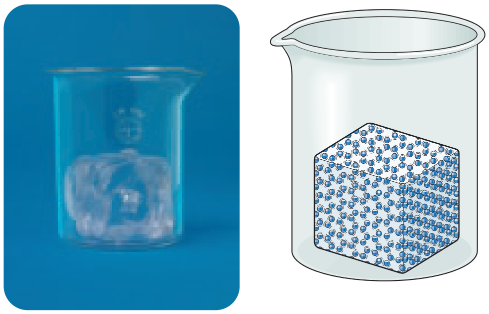
4. Adding heat to matter makes the particles move faster.



LEARNING TIP

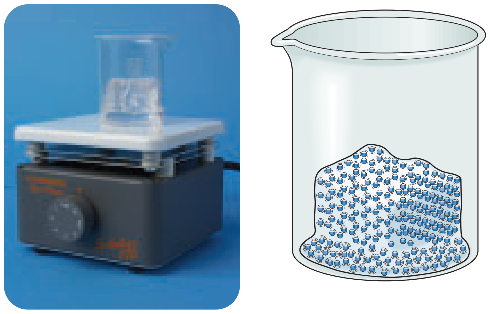
Are you able to explain the particle model of matter in your own words? If not, re-read the main ideas and examine the illustration that goes with each.

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.**

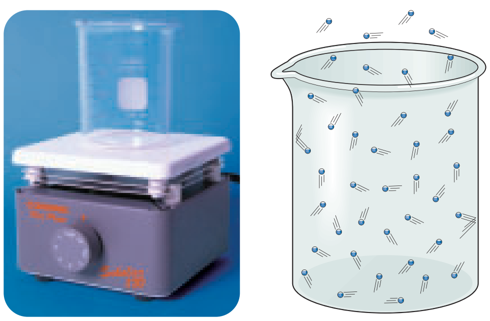
The reverse of melting is called **freezing** or solidification. This is the change from a liquid to a solid. As a liquid cools, the particles in the liquid lose energy and move more and more slowly. When they settle into fixed positions, the liquid has frozen or solidified.

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.

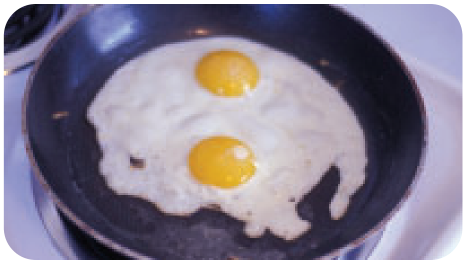


Figure 2
Chemical changes

a) Burning wood

b) Cooking eggs

The Importance of Chemical Changes

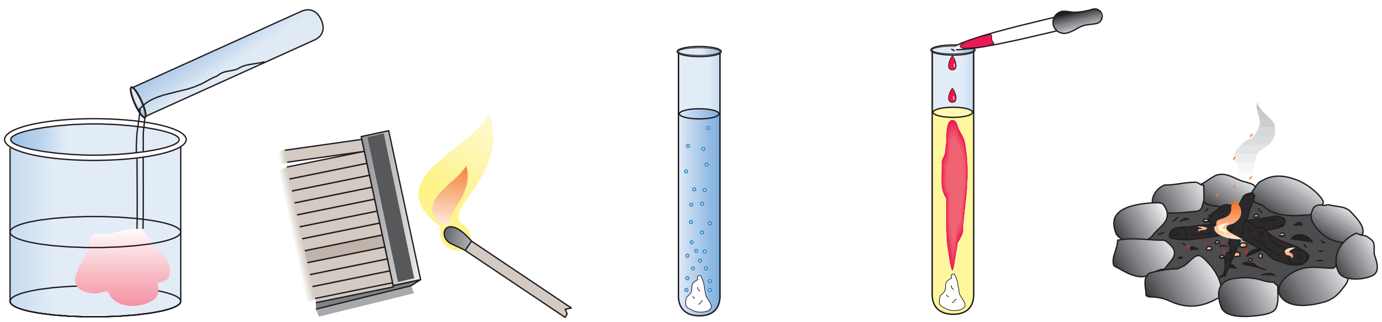
You rely on chemical changes to survive. The clothes you wear and the food you eat are the results of chemical changes. There are millions of chemical changes going on around you. Some are even happening in your body. Plants use energy from the Sun to combine water and carbon dioxide, which react to 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.

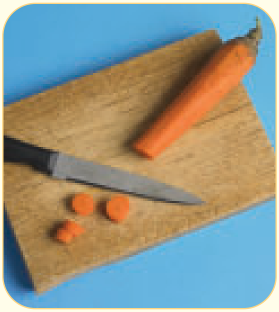
Figure 3
Evidence of a chemical change

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.

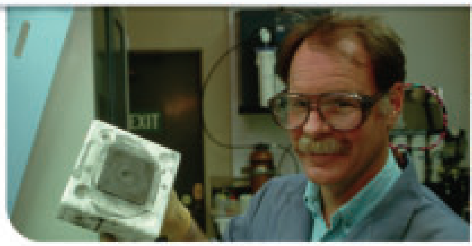


Figure 1

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.

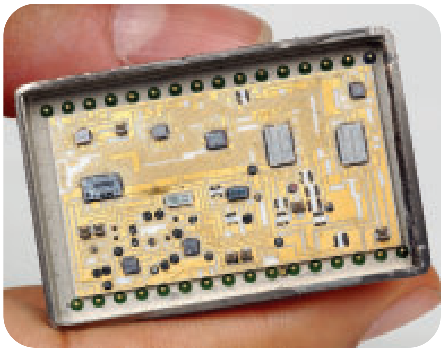


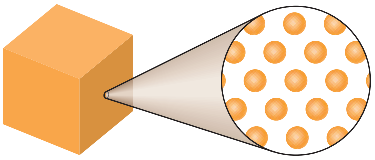
Figure 3

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

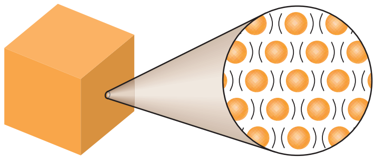
5 Chapter Review

Matter is made up of moving particles.

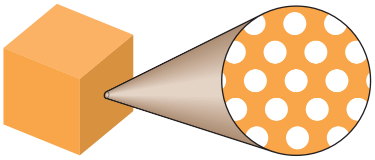
Key Idea: The behaviour of matter can be explained using the particle model.



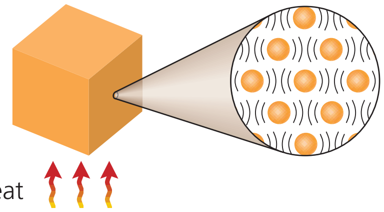
All matter is made up of tiny particles.



The particles of matter are always moving.



The particles have spaces between them.



heat

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

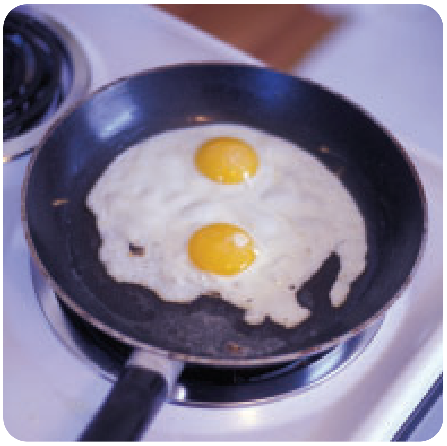
Vocabulary

physical change p. 121

chemical change p. 122

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

Reversible change



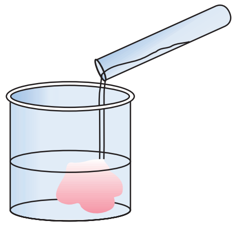
Non-reversible change

Vocabulary

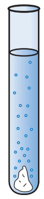
reversible changes p. 122

non-reversible changes p. 122

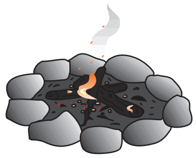
Key Idea: Chemical changes can be distinguished by observable clues.



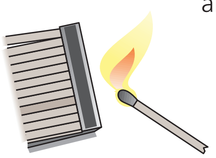
A new colour appears.



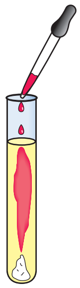
Bubbles of gas are produced.



The change is difficult or impossible to reverse.



Heat, light, or sound is produced or absorbed.



A new material is produced.

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?

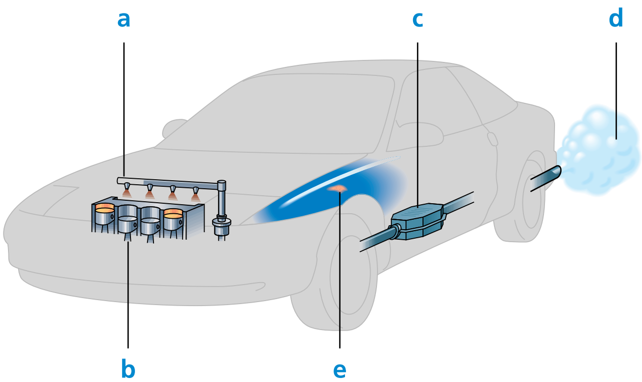


Figure 4

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?

Matter can be classified.

KEY IDEAS

- All matter can be classified as pure substances or mixtures.
- Pure substances can be classified as elements or compounds.
- Mixtures can be classified as mechanical mixtures, suspensions, or solutions.
- Mixtures can be separated by a variety of methods.
- Solutions can be measured by concentration, solubility, and acidity.

Matter is made up of many different substances. Some of these substances are similar to each other, and some are very different. You can see and feel most substances. You can also describe them, based on what you see and feel—for example, gold is solid, hard, and shiny.

The properties of matter that you studied in Chapter 4 can be used to classify matter. Classifying matter helps you predict properties of similar substances. For example, silver has many of the same properties as gold and, like gold, is used to make jewellery. Classifying matter also helps you predict how substances will behave when they are mixed with other substances. The gold that is used in jewellery is not pure gold. It is mixed with other metals to make it stronger. In this chapter, you will learn some of the ways that scientists classify matter.

Pure Substances and Mixtures

6.1

As you have already learned, all matter is made up of particles. There are many different kinds of particles. Different substances have different properties because they contain different kinds of particles.

Pure Substances

A substance that contains only one kind of particle is called a **pure substance.** There are millions of pure substances, but only a few can be found in nature. For example, water is a pure substance, but pure water is difficult to find in nature. Even the clearest spring water contains dissolved minerals. In nature, pure substances tend to mix with other substances. Diamonds are one of the few exceptions (**Figure 1**). They are formed deep within Earth, in only a very few areas.

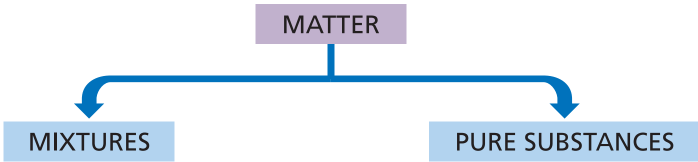
Figure 1
A diamond is an example of a pure substance. All the particles in a diamond are the same.

Most of the pure substances that you encounter in your daily life have been made pure by people through refining. Aluminum foil is a pure substance, and so is table sugar (**Figure 2**).

Figure 2
Aluminum foil and sugar are pure substances.

LEARNING TIP

Before you read this chapter, begin a graphic organizer that shows how different types of matter can be classified. The first level in your organizer will look like the diagram to the right. As you work through this chapter, add more levels to your organizer.



All samples of a pure substance have the same properties, no matter what size the samples are or where in the world the samples are found. For instance, all samples of pure gold have the same melting and boiling points and the same density. Because every sample of a pure substance has the same properties, scientists have made reference lists of pure substances and their properties. These reference lists can help you to identify an unknown substance based on its properties.

Mixtures

Almost all the natural substances and manufactured products in the world are mixtures of pure substances. A **mixture** contains two or more pure substances, as shown in **Figure 3**.

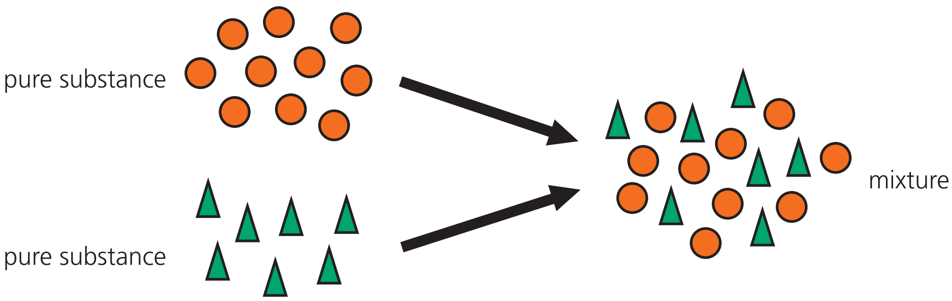


Figure 3
Most substances that you encounter are mixtures. Mixtures contain at least two pure substances.

Mixtures can be any combination of solids, liquids, and gases. For example, soft drinks are mixtures made from liquid water, solid sugar, and carbon dioxide gas (**Figure 4**).

Figure 4
Soft drinks may look like pure substances, but they are mixtures.

Breads are mixtures of yeast, flour, sugar, water, air, and other chemicals (**Figure 5**). The properties of mixtures may be different in different samples because there may be more or less of the different kinds of particles. For example, breads do not always have the same number of yeast or sugar particles in them.

Figure 5
Bread is a mixture of different substances.

TRY THIS: TEST INK

Skills Focus: observing, interpreting data

1. Cut a "tongue" in a piece of filter paper.
2. About 1 cm from the end of the tongue, draw a large dot with a black water-soluble marker.
3. Put the filter paper on top of a 250-mL beaker, with the tongue bent down into the beaker.
4. Carefully add water until it touches the filter paper tongue but does not touch the dot. Observe what happens as the water soaks into the filter paper. Is ink a pure substance or a mixture?

CHECK YOUR UNDERSTANDING

1. Explain the difference between a pure substance and a mixture, using examples of each.
2. Explain the difference between a pure substance and a mixture, using the particle model.
3. Give three examples of pure substances and three examples of mixtures.

6.2 Elements and Compounds

LEARNING TIP

The key vocabulary words on the next two pages are illustrated with both photographs and drawings that show you the particles. If you are having trouble remembering the difference between elements and compounds, use the illustrations for clarification.

There are millions of pure substances. Can anyone expect to learn about all of them? How would you start? How would you find out which ones are safe? How would you find out which ones are useful?

People have investigated pure substances for thousands of years. Ten thousand years ago, people learned how to extract copper from rocks by heating the ore. In medieval times, alchemists [AL-ku-mists] tried to break down metals, such as copper, to make gold. They dissolved and mixed various substances, filtered, and heated. None of the alchemists ever succeeded in making gold. They discovered, however, that some pure substances can be broken down into other pure substances, while others cannot. For this reason, pure substances are classified into two types: elements and compounds.

Elements

Elements are pure substances that cannot be broken down into any other pure substances. After many investigations, scientists found that there are only about 104 pure substances that are elements.

Elements are composed of only one kind of particle. For instance, aluminum foil is made of the element aluminum. It is composed of only particles of aluminum (**Figure 1**).

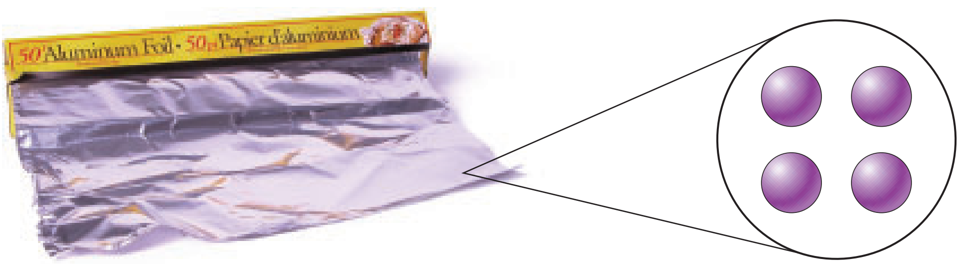


Figure 1
The element aluminum in aluminum foil is composed of aluminum particles.

Some elements, such as iron, aluminum, and oxygen, are common in nature, although they are usually found mixed with other substances. Other elements, such as krypton, are extremely rare. Some elements are considered safe. Other elements, such as sodium and chlorine, are explosive or poisonous.

Compounds

Elements can combine with other elements to form new pure substances, called compounds. **Compounds** are pure substances that are made up of two or more different elements. Compounds are related to elements in the same way that words are related to the letters of the alphabet. Thousands of words can be made from the 26 letters of the English alphabet. Similarly, millions of compounds can be made by combining the 104 elements.

Compounds can be solids, liquids, or gases. One example of a compound is water. Water is made up of the elements hydrogen and oxygen (**Figure 2**). Thus, a particle of water contains both hydrogen and oxygen. Every particle of water is the same as every other particle of water. At one time, scientists thought that water was made up of particles that could not be broken down further. Scientists now know, however, that water can be broken down into hydrogen and oxygen.

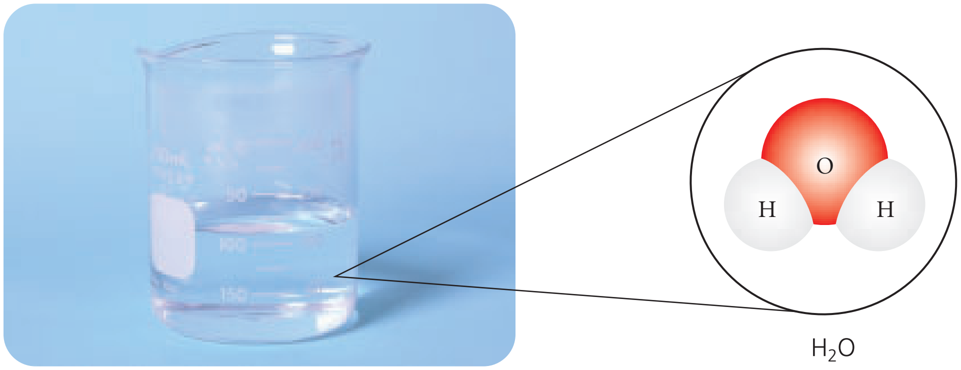


Figure 2
Water is a compound composed of hydrogen and oxygen particles.

The elements in some common compounds are listed in **Table 1**.

Table 1 Elements in Some Common Compounds

Compound	Elements combined in compound
water	hydrogen and oxygen
table salt (sodium chloride)	sodium and chlorine
carbon dioxide	carbon and oxygen
sugar (any type)	carbon, hydrogen, and oxygen
alcohol (any type)	carbon, hydrogen, and oxygen
chalk (calcium carbonate)	calcium, carbon, and oxygen
baking soda	sodium, hydrogen, carbon, and oxygen

Different elements have different properties because they have different particles. In the same way, different compounds have different properties because they have different combinations of elements. The properties of a compound can be very different from the properties of the elements that make it up. Table salt (**Figure 3**) is made of two elements, called sodium and chlorine. Sodium on its own is a soft, silvery metal that is poisonous and reacts violently with water (**Figure 4**). Chlorine is a greenish-yellow gas that is extremely poisonous (**Figure 5**). Each of these elements could be fatal if consumed on its own—for example, if you breathed in too much chlorine or swallowed a large quantity of sodium. When sodium and chlorine combine, however, they form table salt (sodium chloride), which you can safely eat and need in your diet.

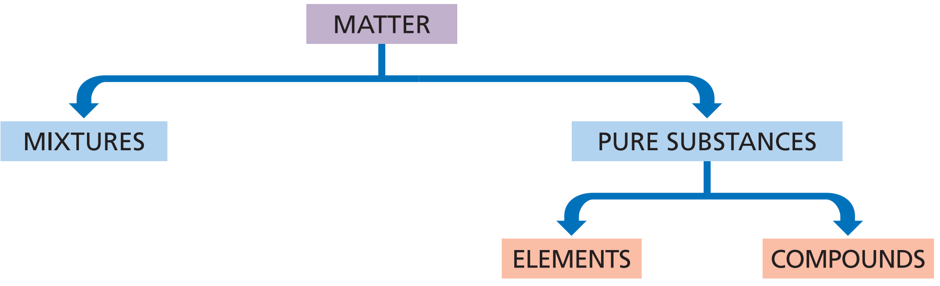
Figure 3
Table salt

Figure 4
Sodium metal

Figure 5
Chlorine gas

LEARNING TIP

Go back to the graphic organizer you started in section 6.1. Add "elements" and "compounds" under "pure substances." Your graphic organizer should now look like this:



TRY THIS: CLASSIFY MODELS OF MATTER

Skills Focus: creating models, classifying

Copy your graphic organizer onto a large piece of paper.
Your teacher will give you eight jars, containing the following items (**Figure 6**):

1. five nuts
2. five bolts, five nuts, and five washers
3. five bolts with nuts attached
4. five bolts with a nut attached and five bolts with a washer and a nut attached
5. five bolts
6. five nuts and five washers
7. five bolts with a washer and a nut attached
8. five washers

Figure 6

Each jar is a model, representing a different type of matter. Each bolt, nut, and washer represents a different type of particle. Classify the eight models of matter as elements, compounds, or mixtures by placing them in the appropriate places on your graphic organizer.

LEARNING TIP

If you are having difficulty remembering the differences between mixtures, pure substances, elements, and compounds, scan the text for the information you need and make notes on your graphic organizer before you try to classify the models.

CHECK YOUR UNDERSTANDING

1. Explain the difference between an element and a compound, using examples of each.
2. Explain the difference between an element and a compound, using the particle model.
3. State whether each pure substance is an element or a compound. Explain your reasoning.
   a) a clear, colourless liquid that can be split into two gases with different properties
   b) a yellow solid that always has the same properties and cannot be broken down
   c) a colourless gas that burns to produce carbon dioxide and water

6.3 Mixtures

Most of the substances you use in your daily life are not pure substances. For example, hand lotion, shampoo, and soap are made of many substances, such as colouring and perfumes, mixed together. Foods contain preservatives and other additives. Even fruit juice that is labelled "100% pure" is actually a mixture of water, citric acid, and other substances (**Figure 1**).

Figure 1
This "pure" apple juice is a mixture.

Classifying Mixtures

If you were asked to name some pure substances, you might think of common substances such as sugar, water, salt, and oxygen gas. Other substances you might think of may seem to be pure, even though they are not. For example, how would you classify vinegar? Is it a pure substance or a mixture? To be able to classify matter, you need to know more about mixtures. One way that scientists classify mixtures is to group them according to their appearance.

LEARNING TIP

Before you read further, look at the subheadings on the next two pages. Predict how many categories scientists use to classify mixtures.

Mechanical Mixtures

A **mechanical mixture** is a mixture in which two or more different parts can be seen with the unaided eye. Granola cereal is an example of a mechanical mixture (**Figure 2**). Concrete is another example.

Figure 2
This cereal is a mechanical mixture. What other foods can you classify as mechanical mixtures?

Suspensions

A **suspension** is a cloudy mixture in which clumps of a solid or droplets of a liquid are scattered throughout a liquid or gas. Muddy water and tomato juice are suspensions. The parts of a suspension may separate into layers if the suspension is not stirred.

Farm-fresh milk is a suspension. If the milk is left standing, the fatty part (the cream) floats to the top and the watery part sinks to the bottom (**Figure 3**). Commercially available milk does not separate. It is a special kind of suspension, called an **emulsion,** which has been treated to keep it from separating. In a process called homogenization, the milk is sprayed through very small openings. This breaks down the fat into droplets that are so tiny they stay suspended.

Figure 3
Cream floats to the top of farm-fresh milk.

Solutions

A **solution** is a mixture that appears to be only one substance. The parts of a solution are so completely mixed that they cannot be seen, even under a microscope. This is because the particles of the substance that dissolves fill in the spaces between the particles of the substance it dissolves in. Clear apple juice (a liquid) (**Figure 4**), clean air (a gas), and stainless steel (a solid mixture of metals) are all solutions.

Figure 4
Apple juice is a solution.

LEARNING TIP

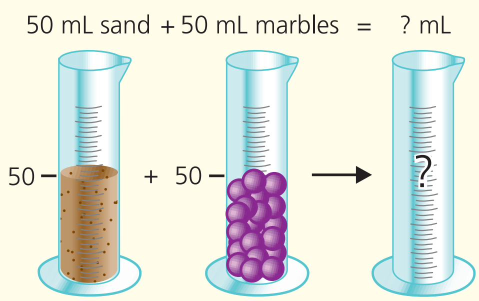
For a review on models, see "Creating Models" in the Skills Handbook.

TRY THIS: MODEL A SOLUTION

Skills Focus: modelling, predicting, observing

You can make a model to show how particles mix in a solution. The advantage of making a model is that you can observe a process you would not normally be able to see.

1. Half fill a clear plastic container with marbles. On the outside of the container, mark the level of the marbles with a marker. Then half fill a second, identical container with sand.
2. Predict the total volume that will result when you combine the marbles and the sand by marking the level you think will result.
3. Carefully pour the sand into the container with the marbles, and shake gently. How accurate was your prediction of the total volume? Explain.
4. How is the container of sand and marbles like a solution? How is it different?

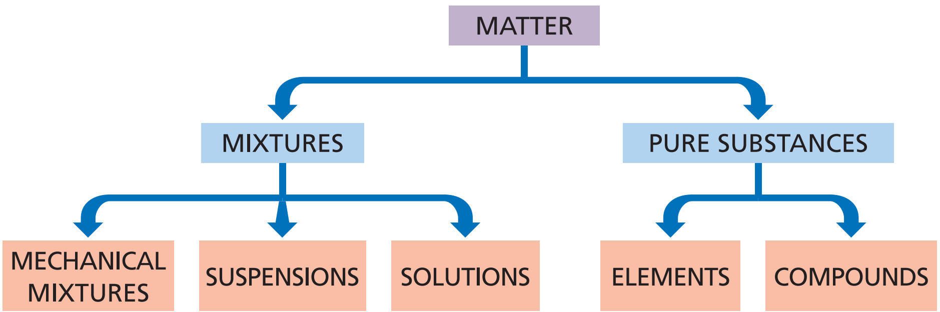


Examples of Mixtures

Table 1 gives examples of mechanical mixtures, suspensions, and solutions. Can you explain the classification of each substance listed?

Table 1 Examples of Mechanical Mixtures, Suspensions, and Solutions

Mechanical mixtures	Suspensions	Solutions
snow falling through the air	foggy air	clean air
salad	salad dressing	vinegar
cornflakes and milk	orange juice	tea
concrete (cement, sand, and gravel)	muddy water	tap water
abrasive skin cleanser	hand lotion	clear shampoo



LEARNING TIP

Go back to the graphic organizer you started in section 6.1. Complete it by adding "mechanical mixtures," "suspensions," and "solutions" under "mixtures." Your graphic organizer should now look like the one on the left.

CHECK YOUR UNDERSTANDING

1. List at least three mechanical mixtures and three solutions from your everyday life that were not mentioned in this section.
2. State whether each substance is a mechanical mixture, a suspension, or a solution. Explain your reasoning.
   a) green relish
   b) freshly squeezed orange juice
   c) soda pop in a glass
   d) bubble tea
   e) trail mix
   f) traditional Aboriginal paint, made of red ochre and grease
   g) vegetable soup
3. How are suspensions and solutions similar? How are they different?
4. Suppose that you dissolve 250 mL of drink crystals in 1000 mL of water. You get 1175 mL of drink rather than 1250 mL. How can you use the particle model of matter to explain this?

6.4 Separating Mixtures

> **LEARNING TIP**
> Before reading this section, "walk" through it, looking at the headings. What ways of separating mixtures do you think you will learn about?

Does your family have a "junk drawer" somewhere, maybe in the kitchen or near the door (Figure 1)? Have you ever tried to sort out all the items that have collected in the drawer? In everyday life, there are many situations in which people want to separate the parts of a mixture. For example, you do not want to drink water that contains algae or fish, or dissolved chemicals from factories. You prefer to have these removed from the water before it is pumped to your home. Harmful or toxic substances from factories must be removed from any waste products before the waste products can be released into the environment.

Figure 1
How could the boy separate the items in the drawer?

Depending on the mixture involved, separating the parts can be easy or difficult. In this section, you will learn about some ways to separate different types of mixtures.

Picking Apart

You would probably separate the mixture in a junk drawer by simply taking out the different items—tools, elastic bands, scrap paper, and so on. You would use observable properties, such as shape and colour, to separate the mixture. If the pieces in a mixture are smaller, you might have to use a magnifier and forceps. Picking apart works when you can easily see the different pieces (Figure 2). It only works well for small quantities of mixtures. It is too time-consuming to use for large quantities.

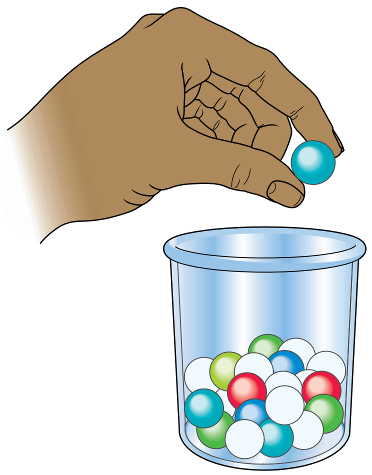


Figure 2
Picking apart a mixture

Filtering

You can remove solid pieces of matter from a liquid or gas by passing the mixture through a device that allows smaller particles to pass through but holds back larger particles. This is called filtering (**Figure 3**). Drinking water is an example of a mixture that is filtered. The water passes through a filter, which allows the liquid through but holds back larger particles. The liquid that passes through is called the filtrate and the solid material that is held back by the filter is called the residue.

There are many other examples of filtration. Air is filtered in car engines and factory smokestacks. Window screens act as filters to keep flies and mosquitoes out of homes. Workers who use spray paint wear facemasks so that they do not breathe in droplets of paint. Tea bags keep tea leaves out of tea, and coffee filters keep coffee grounds out of coffee.

Even very small pieces of substances can be removed from mixtures by filtration if the holes in the filter are small enough. Thus, filters can be used to separate solids from mechanical mixtures or suspensions. Filters cannot be used, however, to separate parts of solutions.

Figure 3
Filtering a mixture

Using Density

Density can also be used to separate mixtures. If the substances in a mechanical mixture have different densities, one substance may float and another may settle to the bottom (**Figure 4**). For example, density can be used to separate a mixture of sand and wood chips. If water is added to the mixture, the wood chips float and the sand sinks, making the mixture easy to separate.

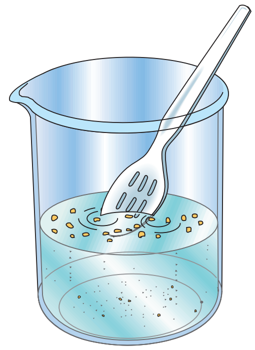


Figure 4
Using density to separate a mixture

Using Magnetism

Magnetism can be used to separate a mechanical mixture if one of the substances in the mixture is attracted to a magnet (**Figure 5**). This works well for a mixture of iron filings in sand.

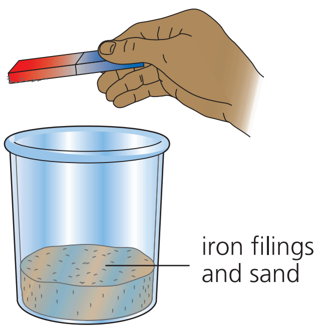


Figure 5
Using magnetism to separate a mixture

Dissolving

You can sometimes **dissolve** one of the substances in a mixture. When a substance dissolves, it mixes completely with another substance. For example, if you add water to a mixture of sand and salt, the salt dissolves. This makes the undissolved sand easier to separate out of the mixture by filtering (**Figure 6**).

Figure 6
Dissolving one of the substances in a mixture

Evaporating

You can also evaporate part of a solution to get a substance dissolved in it (**Figure 7**). For example, you can evaporate the water from a cup of tea. The solid that remains is the tea. Sometimes, the solid that remains crystallizes. For example, when the water evaporates from a salt-water solution, the salt crystallizes.

Figure 7
Evaporating one of the substances in a mixture

CHECK YOUR UNDERSTANDING

1. Describe the method you would use to separate each mixture in **Figure 8**.

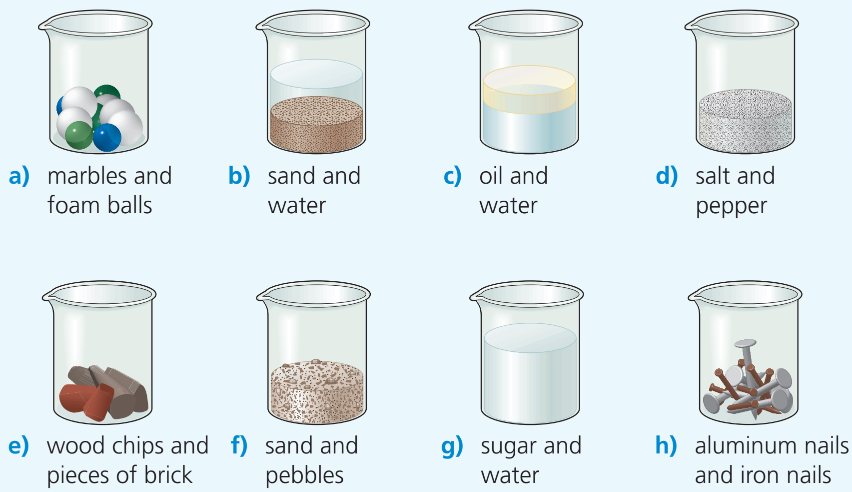


Figure 8

2. List several different filters in your home and school. What is the purpose of each filter?

Separating a Mystery Mixture

Often, scientists do not know exactly what substances are in a mixture before they try to separate it. Sometimes they have to separate something out of a mixture to use in a different test. In this activity, you will be provided with a mystery mixture. You must determine what the different substances in the mixture are.

LEARNING TIP

For more information on the steps in problem solving, see the "Solving a Problem" in the Skills Handbook.

Problem

For this activity, your teacher will give you a mystery mixture to separate.

Task

Your task is to separate the substances in the mixture using methods you learned in section 6.4. You should be able to identify six different substances.

Criteria

To be successful, your procedure must

- allow you to separate all six of the substances in the mixture
- be clear enough for someone else to follow and get the same results

Plan and Test

1. Look at your mixture. Are there any easily observable properties that give you clues about how to proceed? What separation methods can you use? In what order will you use them?
2. Design a procedure to separate your mystery mixture. Remember the different ways to separate a mixture: picking apart, filtering, using density, using magnetism, dissolving, and evaporating.
3. Decide what materials you will need. Draw a diagram to show how you will set up the equipment. Your diagram should be at least half a page in size.
4. Submit your list of materials, diagram, and procedure to your teacher for approval. Your procedure must include any safety precautions and an observation table.
5. Carry out your procedure.

Evaluate

6. Were you able to separate your mystery mixture into six separate substances? What substances did you find in your mixture?

LEARNING TIP

For more information on how to create a flow chart, see "Using Graphic Organizers" in the Skills Handbook.

Communicate

7. Draw a flow chart to show how you separated your mystery mixture. Post your flow chart, and compare it with the flow charts that your classmates have drawn.

CHECK YOUR UNDERSTANDING

1. Did any of the methods you tried fail to separate a substance from your mixture? If so, why?
2. What physical properties did you use to separate each substance from your mixture?
3. Are there any other methods you could have used to separate your mixture?
4. Do you think you recovered all of each substance in your mixture? How might you improve your procedure to recover as much as possible of each substance?

Measuring the Concentration and Solubility of Solutions

6.6

Concentration

When a solid dissolves in a liquid, the liquid that does the dissolving is called the solvent. The solid that dissolves is called the solute. For example, in a solution of orange-drink crystals and water, the water is the solvent and the orange-drink crystals are the solute (**Figure 1**).

Figure 1
The drink on the right has more solute than the drink on the left. How can you tell?

Have you ever made a drink by dissolving drink crystals in water and found that it tasted watery? This happens when you do not have the right concentration of solute in the solvent. **Concentration** [kon-suhn-TRAY-shun] is the amount of solute that is dissolved in a given quantity of solvent or solution.

Solutions that are made with the same substances may contain different amounts of each substance. A solution with a low concentration of solute is said to be **dilute** [die-LOOT]. A solution with a higher concentration of solute is said to be more concentrated. For example, lemonade with a small amount of dissolved sugar is a more dilute solution than lemonade with a lot of dissolved sugar. The lemonade with more sugar is a more concentrated solution. It tastes sweeter than the more dilute solution.

LEARNING TIP

The key vocabulary words on this page are illustrated. If you are having trouble with these vocabulary words, look at **Figure 1** for clarification.

> **LEARNING TIP**
>
> Make a web to show what you already know about substances that dissolve in water.

Solubility

You can make orange drink because the orange-drink crystals dissolve in water. Another way to say that a substance dissolves in water is to say that it is soluble in water. Can you think of some other substances that are soluble in water? If the orange-drink crystals did not dissolve in water, you would not be able to make the drink. An insoluble substance is a substance that does not dissolve. Can you think of some substances that are insoluble in water? Can a substance that is insoluble in water be dissolved in another solvent?

TRY THIS: OBSERVE DIFFERENT SOLVENTS

Skills Focus: predicting, observing, classifying

Predict whether salt, sugar, butter, and wax will dissolve in water and in ethanol. Now try to dissolve each of these solutes in the two different solvents (**Figure 2**). Record your results.

Observe Different Solvents

	Dissolves in water?	Dissolves in ethanol?
salt		
sugar		
butter		
wax		

Figure 2
Adding sugar to ethanol to see if the sugar dissolves

Saturated and Unsaturated Solutions

Even if a substance is soluble in a solvent, there is usually a limit to how concentrated the solution can become. For example, there is a limit to how many orange-drink crystals you can dissolve in a glass of water. Imagine that you add more and more drink crystals to a glass of water, stirring constantly. Eventually, the drink crystals will just stay at the bottom of your glass (**Figure 3**). The drink solution will not be able to dissolve any more drink crystals because it is saturated with them. A solution is **saturated** with a solute when no more of the solute can be dissolved in it. A solution is **unsaturated** with a solute when more of the solute can be dissolved in it.

Figure 3
How much sugar do you think can be dissolved in this lemonade?

The ability of a substance to dissolve in a solute is called **solubility.** You can measure the exact amount of solute that is required to form a saturated solution in a certain solvent at a certain temperature. Temperature is important because you can generally dissolve more solute in warm water than in cold water.

Solubility is different for each combination of solute and solvent. The amounts of different solutes that are needed to saturate a certain volume of solvent varies enormously. For example, more sugar than salt is needed to saturate 100 mL of water at room temperature (20°C) (**Table 1**).

Table 1 Solubilities of Common Substances in Water

Solute	Temperature (°C)		
	0	20	50
baking soda	6.9 g/100 mL	9.6 g/100 mL	14.5 g/100 mL
table salt	35.7 g/100 mL	36.0 g/100 mL	36.7 g/100 mL
sugar	179 g/100 mL	204 g/100 mL	260 g/100 mL

TRY THIS: DISSOLVE SOLUTES

Skill Focus: predicting, observing

1. Make a saturated solution of water and salt by stirring small amounts of salt into about 100 mL of water until no more salt will dissolve.
2. Now that the water is saturated with salt, do you think you will be able to dissolve anything else in the water? Make a prediction.
3. Test your prediction by trying to dissolve sugar in your saturated salt solution.

Supersaturation

A very few solid solutes can be used to create a solution that is more than saturated. A solution that contains more of the solute than can be found in a saturated solution is called a **supersaturated** solution.

You can make a supersaturated solution by starting with a saturated solution at high temperature and then allowing the solution to cool slowly. Normally, as a solution cools, the solute particles lose energy. Some of the solute particles draw together and form the crystal pattern of the solid. In a supersaturated solution, the solute particles are not able to get into a crystal pattern. As a result, the solution remains liquid even when it is at a temperature at which it would normally be a solid.

If the supersaturated solution is not disturbed, all the solute may remain dissolved. If you strike the container lightly with a stirring rod or a spoon, however, the resulting vibrations may cause some of the solute particles to move into a crystal pattern. Immediately, the rest of the extra solute will fall out of solution and join the crystal. You can produce a similar effect by adding a seed crystal of the solute for the excess solute particles to build on (**Figure 3**).

LEARNING TIP

Pause and think. Ask yourself, "What did I just read? What did it mean?" Try to reword the information on supersaturation in your own words.

Figure 3
Adding a seed crystal causes the rapid formation of crystals in a supersaturated solution of sodium acetate.

CHECK YOUR UNDERSTANDING

1. Identify the solute and the solvent in the photo to the right.
2. List two liquid solutions that do not contain water.
3. Suppose that you add one teaspoon of sugar to your cup of tea. A friend adds four teaspoons of sugar to his cup of tea. Whose tea is a more concentrated sugar solution?
4. Is the solubility of all solutes the same? Explain.
5. Describe how you can tell the difference between an unsaturated solution and a saturated solution.

LEARNING TIP

Locate the information needed to answer these questions by scanning the text for key words.

6.7 Design Your Own Experiment

SKILLS MENU

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

Factors That Affect the Rate of Dissolving

Imagine that you are trying to make a cold drink, such as lemonade, in a hurry. All that you have to sweeten your drink are sugar cubes, and they seem to be taking forever to dissolve. When you add sugar to a drink, several factors affect how quickly the sugar dissolves. Based on your experiences, you probably have some ideas about what these factors are. But have you ever tested your ideas?

LEARNING TIP

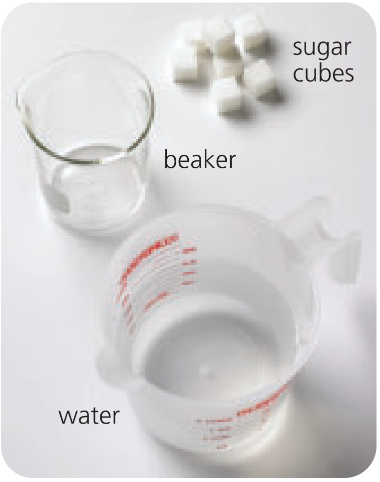
For help in writing hypotheses, controlling variables, or writing up your experiment, see the Skills Handbook sections "Hypothesizing," "Controlling Variables," and "Writing a Lab Report."

Question

What factors affect how quickly a solute dissolves in a solvent?

Hypothesis

You will be testing at least three variables in this experiment. Write a hypothesis for each variable that you plan to test. Use the form "If … then the sugar will dissolve more quickly."



Materials

- sugar cubes
- beakers
- water

List any other materials that you will need to perform this experiment.

Procedure

- This is a controlled experiment to investigate factors that affect the rate of dissolving. Design a procedure for the experiment. For each part of your procedure, determine
  - what variable(s) will change
  - what variable(s) will stay the same
- Submit your procedure, including any safety precautions, to your teacher for approval. Also submit a diagram, at least half a page in size, showing how you will set up your experiment.

Data and Observations

Create a table to record your observations. Record your observations as you carry out your experiment.

Analysis

1. Compare your results with your classmates' results. Were your results similar?
2. Use the particle model of matter to explain why each factor affected the rate of dissolving.

Conclusion

Were your hypotheses correct? Did your observations support, partly support, or not support your hypotheses? Write a conclusion for your experiment.

LEARNING TIP

For help in writing a conclusion, see the example and explanation in the "Writing a Lab Report" section of the Skills Handbook.

Applications

1. A soup recipe calls for bouillon to be added. You find both bouillon powder and bouillon cubes in your kitchen cupboard. Which form of bouillon will speed up the soup-making process? Explain your answer.
2. Most brands of soda pop are solutions of water, dissolved sugar, and dissolved carbon dioxide gas. When you remove the cap from a cold bottle of pop, you hear a faint whoosh as the gas escapes. When you remove the cap from a warm bottle, however, the whoosh is much louder. What effect do temperature and pressure have on the rate that carbon dioxide gas comes out of a pop bottle?
3. Give three examples of situations in which speeding up or slowing down the rate of dissolving might be important. How do you think this could be done in each situation?

CHECK YOUR UNDERSTANDING

1. What were the independent and dependent variables in each part of your procedure?
2. Suggest at least two factors that you think would have no effect on the rate of dissolving. Explain why you think they would have no effect.

6.8 Measuring the Acidity of Solutions

Have you ever wondered what makes lemon juice sour (**Figure 1**)? Lemon juice is a solution that contains dissolved compounds. Scientists classify some compounds by the properties of the solutions they form.

Figure 1
Lemon juice has a sour taste.

LEARNING TIP

Check your understanding of the properties of acids and bases. Work with a partner and take turns describing the properties.

Acids are compounds that form solutions with the following properties:

- have a sour taste
- react with (corrode) metals
- can cause serious burns on skin

Many acidic solutions, such as lemon juice and vinegar, are harmless. They can be used to give foods a tangy flavour. Other acidic solutions are extremely dangerous. Hydrochloric acid, for example, is used to etch concrete and would make holes in your skin or clothing.

Bases are compounds that form solutions with the following properties:

- have a bitter taste
- feel slippery
- react with (break down) fats and oils
- can cause serious burns on skin

Some basic solutions are harmless. You can drink a solution of baking soda and water to calm an upset stomach. Other basic solutions, such as drain cleaner, should be used with extreme care. They should never be allowed even to touch your skin.

You often use the properties of acidic and basic solutions in your daily life. Some common acids and bases are shown in **Figure 2**.

Figure 2
Common acids (left) and bases (right)

LEARNING TIP

Make connections between what you are learning about the properties of acids and bases in this section and what you already knew about the products in **Figure 2**. Ask yourself, "Did I already know these products had these properties?"

Identifying Acids and Bases

Because many acids and bases are not safe to taste, scientists use other properties to identify them. One property that is safe to use is their effect on a dye called litmus [LIHT-muhs]. Acidic solutions turn blue litmus paper red. Basic solutions turn red litmus paper blue. Litmus is called an indicator because it indicates whether a solution is acidic or basic (**Figure 3**).

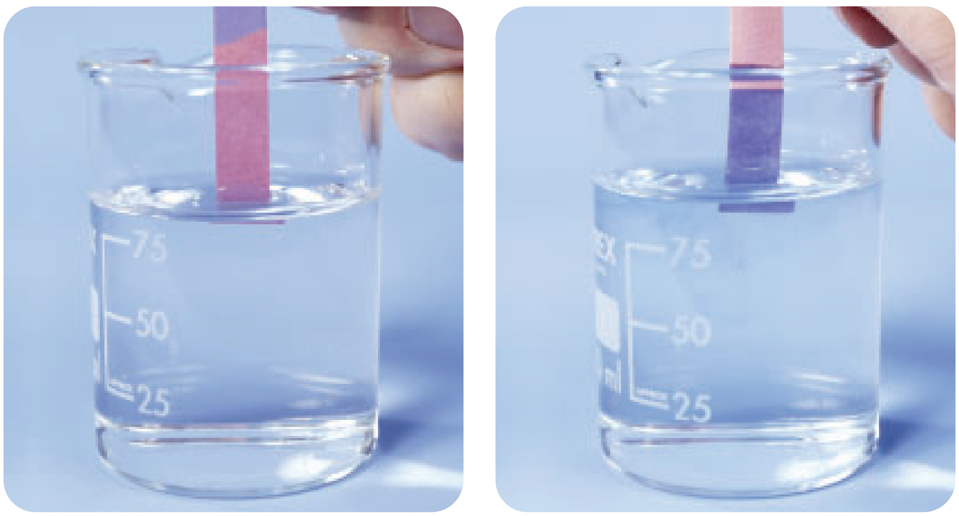


Figure 3
Blue litmus paper turns red in an acidic solution (left). Red litmus paper turns blue in a basic solution (right).

Scientists measure acidity on the **pH** scale—a scale of numbers running from 0 to 14 (**Figure 4**). If a compound is neither an acid nor a base, it is **neutral** and has a pH of 7.0. Pure water, for example, is neutral. **Acidic** solutions have pH values that are below 7. The more acidic a solution, the lower its pH value is. A solution with a pH between 0 and 3 is very acidic. **Basic** solutions have pH values that are above 7. The more basic a solution, the higher its pH value is. Very basic solutions, such as drain cleaners, have pH values that are close to 14.

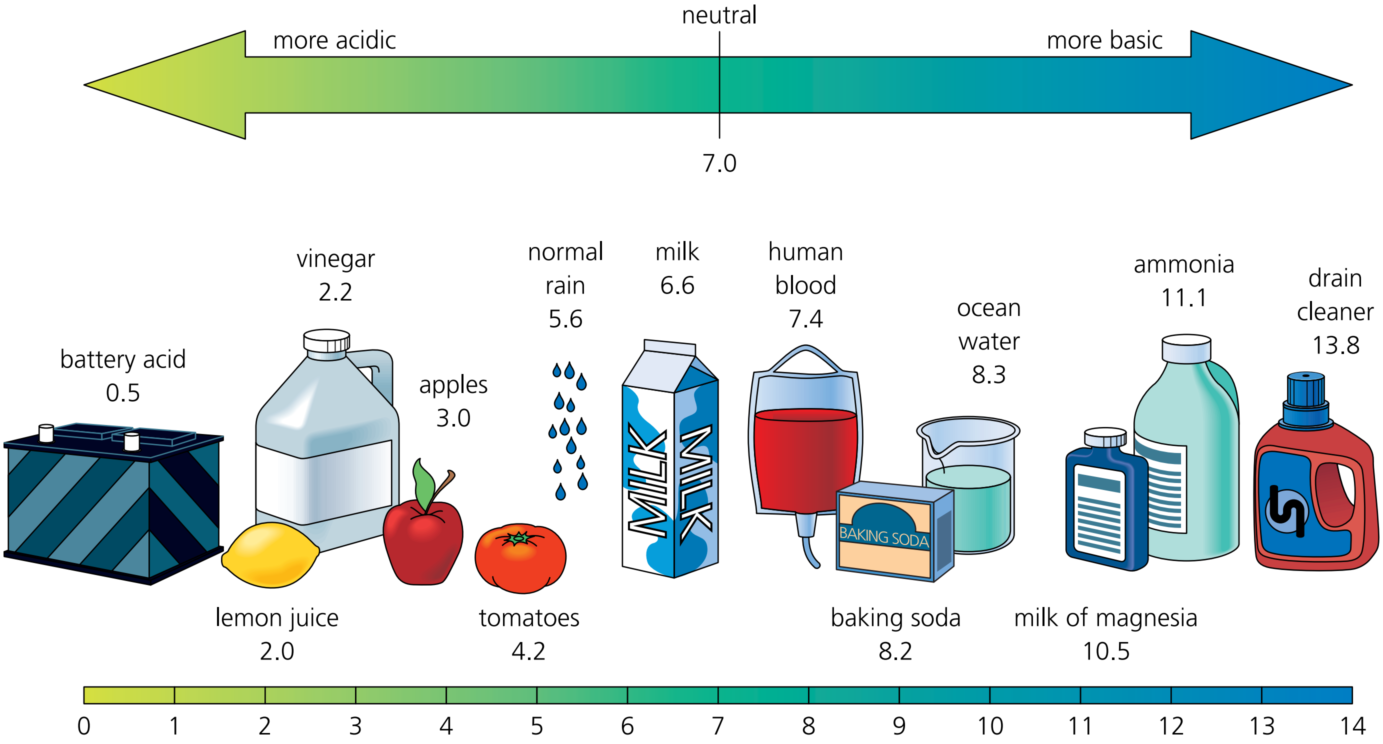


Figure 4
The pH values of some common substances

CHECK YOUR UNDERSTANDING

1. Make a Venn diagram to compare acids and bases. Include at least two examples for each.
2. When might you need to know whether a solution is acidic or basic?
3. Dishwasher detergent, oven cleaner, and drain cleaner are all basic solutions with high pH values. What property of basic solutions makes these products useful?

SKILLS MENU

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

Measuring the pH of Household Products

Acids and bases can be distinguished from one another by the colours they turn certain indicators. The pH paper you will use in this investigation is a universal indicator. It contains several indicators, which turn different colours in solutions with different pH values (**Figure 1**). You will also use an indicator that you will make yourself and develop a colour scale for this indicator.

Figure 1
pH paper turns different colours.

Question

What is the pH of some common products around your home?

Materials

- red cabbage
- 400-mL beaker
- hot plate
- apron
- safety goggles
- several clean beakers or glass jars
- several household products that are solutions, such as lemon juice, apple juice, baking-soda solution, vinegar, milk, coffee, tea, and shampoo
- samples of different types of water, such as tap water, rainwater, swimming-pool water, hot-tub water, and water from a lake or stream
- wide-range pH indicator paper
- medicine dropper

Acids and bases are harmful to eyes and skin. Always wear safety goggles and an apron.

Procedure

1 Slice the red cabbage, and put it in the 400-mL beaker. Add water to cover the cabbage. Boil the cabbage on a hot plate for about half an hour while you continue with the other steps. After half an hour, turn off the heat and let the cabbage cool.

Be careful when using the hot plate.

2 In your notebook, draw a data table like the one below.

Data Table for Investigation 6.9

Substance tested	Prediction: acid, base, or neutral?	pH
lemon juice		
baking-soda solution		

3 Before you test the solutions, predict whether each solution will be acidic, basic, or neutral. Record your predictions in the second column of your table.

4 Put on your apron and safety goggles.

5 Put about 20 mL of a different household product or different type of water in each beaker.

There is the risk that acids and bases may irritate eyes and skin. If you get any acid or base in your eyes or on your skin, immediately rinse the area with water for 15 to 20 min, and tell your teacher.

6 Test the pH of each solution by dipping a strip of pH paper into the beaker. Compare the colour that results with the colour scale on the dispenser. If the colour that results is in between two colours on the scale, estimate the pH. Record the pH for each solution in your data table.

7 Add 5 drops of red cabbage juice to each solution you tested in step 6. Record the colours. Use the information from the data table you completed in step 6 to develop a red cabbage indicator scale. Set up your indicator scale in a table like the one below.

Red Cabbage Indicator Scale

pH	Colour of red cabbage indicator
1	
2	
3	
4	
5	
6	

8 After you have completed your tests, wash your hands.

Analyze and Evaluate

1. Which solutions were acidic? Which were basic? Which were neutral?
2. Which solution was the most acidic? Which was the most basic?
3. Why do different samples of water have different pH values?

Apply and Extend

4. Samples of water are taken from two swimming pools. One sample has a pH of 4. The other sample has a pH of 5. Which is more acidic?
5. Some people like to squeeze a few drops of lemon juice into their tea (**Figure 2**). When they add the lemon juice, the tea changes colour. Use what you know about acids and bases to explain why this happens. What other substances might cause the colour of tea to change?

Figure 2
What happens to tea when lemon juice is squeezed into it?

CHECK YOUR UNDERSTANDING

1. Did you have any surprises in your predictions about acids and bases? What have you learned that would help you make more accurate predictions if you were given a new set of samples?

LEARNING TIP

For a review of what is involved in making predictions in science, see "Predicting" in the Skills Handbook.

6.10 Explore an Issue

> **LEARNING TIP**
> For more information on the steps in exploring an issue, see "Exploring an Issue" in the Skills Handbook.

Should Salt Be Used on a Walkway?

Different substances have different properties because every pure substance is made up of different kinds of particles. Each pure substance has its own melting point and boiling point. Adding a solute to a substance changes the melting point or boiling point of the substance.

In winter, snow and ice can make driving and walking dangerous (**Figure 1**). To melt the ice and reduce the danger, salt (sodium chloride) is often spread on roads and walkways. Why is this done? What does salt do to the snow and ice to help make the roads and walkways safer?

Figure 1
How could spreading salt on this road make it safer for drivers?

Salting roads and walkways makes driving and walking safer, but it also causes some serious problems. What are these problems? Are there alternatives to using salt on roads and walkways?

The Issue

It is the middle of winter and the walkway in front of your school has completely frozen over. You are worried that someone might slip on the ice. What should you do? Should you spread salt on the ice? How does this help? What are the benefits of spreading salt on the ice? What are the drawbacks? Are there alternatives to salt? What are the benefits and drawbacks of these alternatives?

Background to the Issue

Gather Information

Work in pairs to learn more about spreading salt on walkways. Where can you find more information? If you are doing an Internet search, what key words can you use?

www.science.nelson.com GO

Identify Solutions

You may wish to use the following questions to help you identify solutions:

- What does salt do to ice and snow? (*Hint*: Think in terms of chemistry—melting point, solutions, and so on.)
- What are the drawbacks of using salt on walkways?
- What are some alternatives to using salt?
- How much does each alternative cost?
- What are the benefits and drawbacks of each alternative?
- What are the environmental impacts of salt and each of the alternatives?

Make a Decision

What will you use on the walkway? What criteria did you use to decide?

Communicate Your Decision

Write a position paper about why salt should or should not be used on the walkway. If you decide that salt should not be used, explain why. Then discuss alternatives to salt. Explain which alternative(s) you would use, and why.

LEARNING TIP

For more information about how to do this research, see "Researching" in the Skills Handbook.

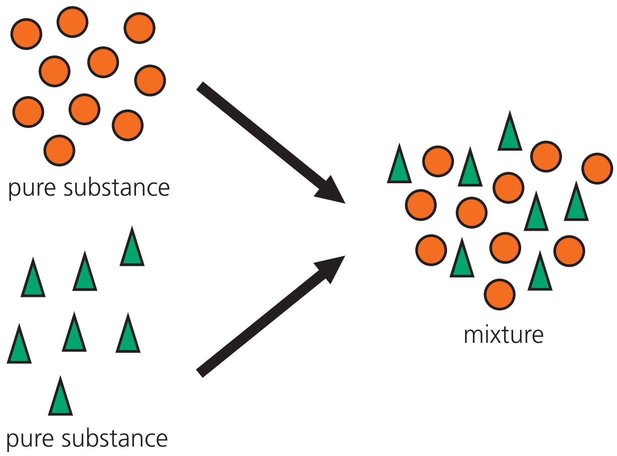
CHECK YOUR UNDERSTANDING

1. How did you come up with your position? Are there things you could have done differently? Explain.
2. Why should you always be prepared to consider alternatives?
3. Why should you always be prepared to defend your position on an issue?

6 Chapter Review

Matter can be classified.

Key Idea: All matter can be classified as pure substances or mixtures.

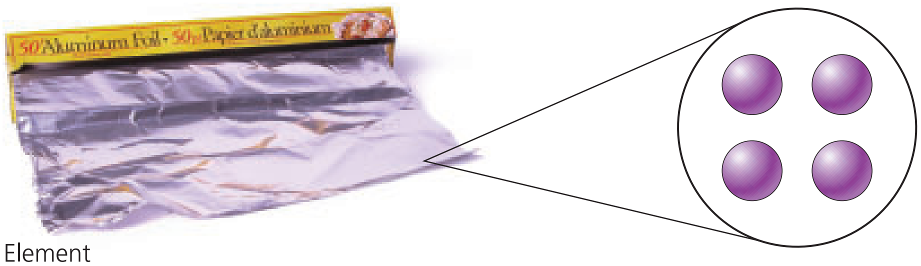


Vocabulary

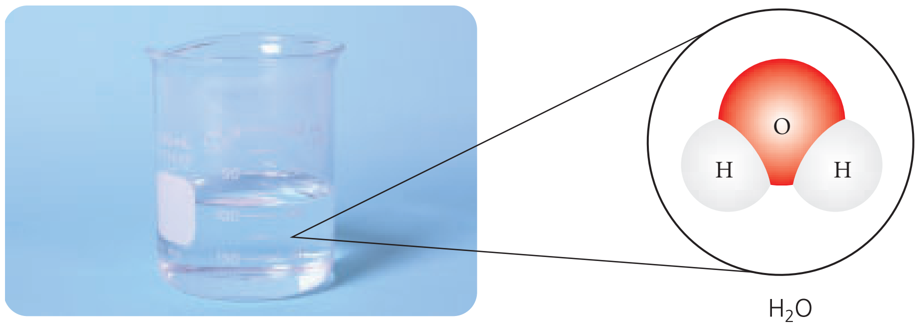
pure substance p. 137

mixture p. 138

Key Idea: Pure substances can be classified as elements or compounds.



Element



Compound

Vocabulary

elements p. 140

compounds p. 141

Key Idea: **Mixtures can be classified as mechanical mixtures, suspensions, or solutions.**

Mechanical Mixture

Suspension

Solution

Vocabulary

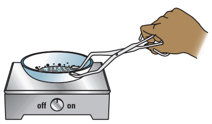
mechanical mixture p. 145

suspension p. 145

emulsion p. 145

solution p. 146

Key Idea: **Mixtures can be separated by a variety of methods:**



Evaporating

Using density

Filtering

Dissolving

Picking apart

Using magnetism

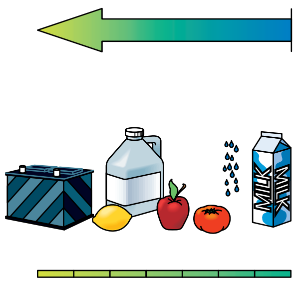
Vocabulary

dissolve p. 150

Key Idea: **Solutions can be measured by concentration, solubility, and acidity.**

Concentration

Solubility



Acidity

Vocabulary

concentration p. 153

dilute p. 153

saturated p. 155

unsaturated p. 155

solubility p. 155

supersaturated p. 156

acids p. 160

bases p. 160

pH p. 162

neutral p. 162

acidic p. 162

basic p. 162

Review Key Ideas and Vocabulary

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

1. What is the difference between a pure substance and a mixture? Give two examples of each.
2. What is the difference between an element and a compound? Give two examples of each.
3. Identify each of the following as a mechanical mixture, a suspension, or a solution. Explain your reasoning.
   a) granola
   b) orange juice
   c) tap water
   d) a toonie
   e) farm-fresh milk
   f) homogenized milk
   g) concrete
   h) clear apple juice
   i) hand lotion
   j) cereal and milk
4. Describe how you would separate the parts of each mixture. What property of matter makes the separation method work? Explain.
   a) sand and salt
   b) dust in a fluffy blanket
   c) sawdust and sand
   d) pebbles and sand
   e) flour and water
5. Read the following statements. Rewrite any statements that are incorrect so that they are correct.
   a) If a solution is saturated at 20°C, it will also be saturated at 25°C.
   b) When some solvent evaporates, a solution becomes more saturated.
   c) When a saturated solution is cooled, some crystals begin to appear in the solution. The solution is now unsaturated.
   d) A solvent is a liquid that dissolves sugar.
   e) A solute is always a solid.
   f) Oil is insoluble.
6. Five solutions have pH values of 3, 5, 7, 9, and 11. State which solution(s) is (are)
   a) acidic
   b) most acidic
   c) neutral
   d) basic
   e) sour tasting
   f) most helpful in breaking down oils and fats

Use What You've Learned

7. Mixtures and compounds both contain two or more elements. How do mixtures differ from compounds?
8. Screens and filters work in the same way. The screens on your windows and doors separate insects (such as flies and mosquitoes) from the air. Make a table like the one below. In the first column, list different types of filters and screens that can be found in your home and school, and in a car. In the second and third columns, identify what is let through and what is held back.

#8.

Screen or filter	What is let through	What is held back

9. Imagine that you have spilled a whole bottle of expensive perfumed oil into a bath. What steps could you take to recover as much of the oil as possible?

10. How could you use a flashlight to distinguish between a solution and a suspension?

11. a) Make a table that has three columns. In the first column, list 10 liquids in your home. Determine the substances in each liquid by reading the label on the container.
    b) In the second column of your table, identify the liquids that meet the definition of a solution.
    c) In the third column, list the solvent and the solute(s) in each solution.

#11.

Liquids in home	Is it a solution?	Solvent and solute

12. The label on a large bottle of liquid laundry detergent states that the bottle contains enough detergent to wash 100 loads of laundry. The label on a different brand, in a smaller bottle, also states that the bottle contains enough detergent to wash 100 loads of laundry. Both claims are true. Explain how this is possible.

13. Using what you know about solutions, predict three ways that you could shorten the time a sugar cube takes to dissolve in a drink. Explain your predictions.

14. Oil spills that occur near shorelines are often cleaned up with the help of powerful detergents. What properties of oil and a detergent solution make this work?

Think Critically

15. Is ocean water a saturated or unsaturated saltwater solution? Explain your answer.

16. “A chemical that can dissolve in water is more dangerous than a chemical that cannot.” Do you agree with this statement? Explain.

Reflect on Your Learning

17. Print the following terms on sticky notes: suspension, element, matter, mechanical mixture, compound, pure substance, solution, mixture. Arrange the sticky notes on a piece of paper. Draw lines between them to show how scientists classify matter. Check your work by comparing it with the graphic organizer you drew in section 6.3.

UNIT B

Making Connections

Comparing and Contrasting Properties of Substances

Looking Back

In this unit, you have learned how properties of matter are used to classify matter and to distinguish between different substances. You have learned how to use your senses to observe some properties and how to perform simple tests and measurements to investigate other properties.

In this activity, you will use what you have learned to compare and contrast five substances based on their properties.

Demonstrate Your Learning

Part 1: Lab Work

In this part of the activity, you will work with a partner to explore the properties of five different substances.

Materials

- safety goggles
- apron
- 5 100-mL beakers
- 50 mL of each of the following substances: corn starch, baking soda, washing soda, Epsom salts, and borax
- 7 250-mL beakers
- tap water
- set of measuring spoons
- paper towel
- 5 strips of pH paper
- vinegar
- pan
- scissors
- white glue
- food colouring

Procedure

1. Read through the procedure to find out what you will be doing. Work with your partner to design a data table for recording your observations and results. You and your partner should each make your own copy of the data table.

Wear safety goggles and an apron throughout this activity.

2. Put on your safety goggles and apron.
3. Label five 100-mL beakers "cornstarch," "baking soda," "washing soda," "Epsom salts," and "borax." Put 50 mL of each substance in the correct beaker.
4. Observe each substance. Record the observable properties of each substance in your data table.

Do not taste any of these substances. Some of them are not safe to taste.

5. Fill five 250-mL beakers with 200 mL of tap water. Label the beakers "cornstarch and water," "baking soda and water," and so on. Check whether each substance is soluble in water by trying to dissolve 5 mL (1 level teaspoon) of the substance in the correct beaker. Wipe the spoon with a paper towel between substances. Record your results.
6. Test and record the pH of each solution you made in step 4.
7. Set aside the beaker of borax and water for Part 2.

8. Put 10 mL (2 level teaspoons) of the washing soda and water solution in each of the three remaining solutions: cornstarch and water, baking soda and water, and Epsom salts and water. Record your results.
9. Set aside any beaker in which there is a change so that you can observe it again the next day.
10. Empty the remaining solutions into the sink. Remove the labels, and wash the empty 250-mL beakers.
11. The next day, observe the beakers you set aside. Record your observations.
12. Empty the beakers, except the borax/water beaker you set aside in step 7, in the sink and wash them.

13. Fill five 250-mL beakers with 100 mL of vinegar. Label the beakers "cornstarch and vinegar," "baking soda and vinegar," and so on. Check whether each substance reacts with an acid (vinegar) by adding 5 mL (1 teaspoon) of the substance to the correct 250-mL beaker. Record your results.
14. Empty all the vinegar solutions into the sink. Remove the labels and wash the beakers.
15. Return any unused portions of the solid substances (except the cornstarch) to the containers provided by your teacher. Remove the labels and wash the beakers.

Part 2: Just for Fun

You will not be assessed on this part of the activity.

1. *Oobleck*: Use your leftover cornstarch to make oobleck. Add small amounts of water to the cornstarch, stirring gently, until the mixture is the consistency of pancake batter. The mixture should "tear" if you run a finger through it and then "melt" back together. Slowly pour some of the oobleck into a pan. As you pour it, try to cut the stream with scissors. When all the oobleck is in the pan, try hitting it with your hand. Is it solid or liquid? Try putting your hand into it slowly. Is it solid or liquid? Roll some oobleck between your hands to make a ball. Does it hold its shape when you stop? Make a "worm," and pull it apart quickly. What happens? When does oobleck act like a solid? When does it act like a liquid? Clean up the materials you used with warm water.

2. *Bouncy slime balls*: Get a 250-mL beaker. Mix together 30 mL (2 level tablespoons) of white glue, 20 mL (4 level teaspoons) of water, and 3 drops of food colouring in the beaker. Add 30 mL (2 level tablespoons) of the borax and water solution you set aside earlier. Stir. Take the resulting substance out of the beaker. Divide it between you and your partner. See who can stretch it the farthest. Can you break it? Will it bounce? In what ways is it similar to oobleck? Clean up the beakers and measuring spoons with warm water.
3. Wash your hands thoroughly.

Part 3: Analysis of Results

In this part of the activity, you will work on your own. Use the information in your data table for Part 1 to answer the following questions.

1. Did you see any chemical changes in Part 1? If so, what combination(s) produced each change? What clues showed that a chemical change had occurred?
2. Do any of the five substances have a single property that distinguishes them from all the other substances? If so, which substances are they and what is the property?
3. Choose any two of the five substances. Make a Venn diagram to show which of their properties are the same and which are different. Staple your data table and Venn diagram together, and give them to your teacher.

ASSESSMENT

LAB WORK

Check to make sure that your lab work provides evidence that you are able to

- work cooperatively with a lab partner
- work safely in a lab situation
- follow procedures
- measure with precision
- record observations and measurements
- clean up lab equipment

DATA TABLE

Check to make sure that your data table provides evidence that you are able to

- design a data table
- identify observable properties
- record observations and measurements accurately
- communicate clearly

ANALYSIS OF RESULTS

Check to make sure that your analysis of results provides evidence that you are able to

- identify properties that are common to two or more substances
- identify properties that are unique to a substance
- identify chemical changes
- use appropriate science terminology
- communicate clearly