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The food you eat is a pure substance or a mixture. You are a part of ecosystems. The things you do can affect even the smallest living things, like the beetle on the cover. What would your life be like without heat and our ability to control it? You interact with different structures everyday—your home is a structure, but so are tables and MP3 players. Throughout this text you will learn about these four topics—Pure Substances and Mixtures, Interactions in the Environment, Heat in the Environment, and Form and Function—and how they apply to your everyday life.
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This textbook will be your guide to the exciting world of science and technology. On the following pages is a tour of important features that you will find inside. **GET READY** includes all the features of the introductory material that come before you begin the first chapter of each unit. Under **GET INTO IT** you will find all the features within the sections of each chapter. Finally, **WRAP IT UP** shows you the features in the Chapter Summary and Chapter Review, and the Unit Review and Unit Task. Try the **Go Discover** activity on page xix to become familiar with the features in your new textbook. 

**Get Ready**

**Unit Opener**  
Each of the four units has a letter and a title. There is also a large photo. Look at this photo and think about what you might be learning in the unit.

**Discover Science and Technology**  
Read these stories at the start of every unit to discover an interesting topic related to the learning in the unit.

**Unit Preview and Big Ideas**  
The Unit Preview introduces you to what you will learn in the unit. The Big Ideas provide a quick summary of the main topics covered.

**Chapter Titles**  
The titles of the three chapters in the unit are listed here.

**Linking to Literacy**  
Get the most out of your reading by using the strategies described in this feature.
Let's Get Started
This fun activity will help you to review what you already know (or do not know) about the topics in the unit.

Unit Task Preview
Find out about the task that you will complete at the end of each unit.

Unit Task Icon
Look for this icon throughout the unit. When you see this icon, you will know that you have just learned skills or knowledge that will help you to complete the Unit Task.

Assessment Box
This box lists some of the skills and knowledge you should be using to complete the Unit Task.

Chapter Opener
Each Chapter has a number, a title, and a Key Question.

Reading Science and Technology
Read a comic, story, photo essay, or article related to the topics covered in the chapter. Use the strategies in the Linking to Literacy box to interpret and understand your reading.

Looking Ahead
These statements outline the new concepts and skills you will learn by the end of the chapter.

Vocabulary
This is a list of the key terms you will learn in the chapter.
You will come across many new and unfamiliar terms. These key terms are in bold print and highlighted. Definitions of key terms are in the margins and in the glossary at the back of the book.

This icon lets you know that you can find more information on the Nelson Science website.

These boxes contain tips to help you understand and interpret the text, images, and other features in the textbook.

Important equations are highlighted in a red box.

This feature shows you how to solve numerical problems using the GRASS method. Make sure to complete Practice problems to check your learning.
Try This Activity
These are quick, fun activities designed to help you understand concepts and improve your science skills.

Skills Handbook Icon
The Skills Handbook Icon appears in Sample Problems and other activities. It directs you to the section of the Skills Handbook that contains helpful information and tips.

Unit Task Icon
This icon lets you know that what you have learned in the section will be helpful to you as you complete the Unit Task.

Check Your Learning
This box appears at the end of each content section. Complete these questions to make sure you understand the concepts you have learned.

Magazine Features
Look for these special feature sections in each unit to learn about exciting developments in science, cool new technology, or how science relates to your everyday life.

AWESOME SCIENCE

SCIENCE WORKS

Tech CONNECT

Discover Your Textbook xv
Perform an Activity
These are active hands-on activities that allow you to explore the science and technology you are learning.

Explore an Issue Critically
These activities allow you to examine social and environmental issues related to the topics you are learning in the unit.

Equipment and Materials
These photos help you to identify all the items you will need to complete the activity or investigation.

Conduct an Investigation
These investigations are an opportunity to apply your scientific inquiry skills.

Solve a Technological Problem
These activities require you to use technological problem-solving skills to find a solution to a human need or want.

Safety Precautions
Look for these warnings about potential safety hazards in investigations and activities. They will be in red type with a STOP icon.

Skills Menu
The Skills Menu in each activity lists the skills that you will use to solve the problem or reach a conclusion.
Wrap It Up

Chapter Summary
This is a study guide that will help you to summarize and review your learning.

Looking Back
Review the Looking Ahead statements from the beginning of the chapter. The concepts you have covered are summarized here.

Big Ideas
The Big Ideas covered in the chapter are checked off.

Achievement Icons
Review questions are tagged with icons that identify the types of knowledge and skills you must use to answer the question.

Chapter Review
Complete these questions to check your learning and apply your new knowledge.

Vocabulary
This feature lists all the key terms you have learned and the page number where the term is defined.

Self-Quiz Icon
There is an online study tool for each chapter on the Nelson Science website.
The Unit Task requires you to apply the skills and knowledge you have learned in the unit to complete a challenge.

**Unit Review**
Complete the Unit Review questions to check your learning of all the concepts and skills in the unit.

**Make a Summary**
This is a quick activity to help you summarize your learning of the entire unit.

**Assessment Box**
This feature lists the criteria that your teacher will use to evaluate your Unit Task. Read these criteria carefully before completing the task.

---

**Unit A**
**Unit Review**

**Pure Substances and Mixtures**

**Make a Summary**

1. Write a definition of pure substance.
2. Write a definition of mixture.
3. Write a definition of solution.

**Unit A Review Questions**

1. What is a pure substance?
2. What is a mixture?
3. What is a solution?
4. What is the difference between a pure substance and a mixture?
5. What is the difference between a solution and a non-solution?

**Communicate**

1. What is a pure substance composed of?
2. How can you test to determine if a substance is pure?
3. How can you determine if a substance is a mixture?

**Evaluate**

1. How well were you able to apply all the learning outcomes of the unit?
2. How well did you perform on the assessment?
3. How would you rate your overall performance in the unit?
**Glossary**
This is a list of all vocabulary terms in your book in alphabetical order.

**Pronunciation Key**
Keys are provided for words that are difficult to read or pronounce.

**Page References**
The page on which a glossary term first appears is provided at the end of each definition.

**Skills Handbook**
The Skills Handbook is your resource for useful science and technology skills and information. It is divided into numbered sections. Whenever you see a Skills icon, you can use the numbers in the icon to find the relevant section of the Skills Handbook. For example, Section 3.J.2. Researching, is found in Section 3. Scientific Research, subsection 3.J. Exploring an Issue Critically.

**GO DISCOVER**
Complete the following activity to check out the different features of your textbook.

1. What is the title of the second chapter in Unit C?
2. How many Try This activities are there in Unit B?
3. What are the five headings under which the Chapter Review questions are organized?
4. There are two Skills Handbook Icons in Section 1.6. On which pages will you find the sections of the Skills Handbook that these icons refer to?
5. Locate the glossary at the back of your textbook. What is the definition of “solubility”? In which section will you find this vocabulary term?
6. What skills will you use in Section 2.4?
7. Which Big Ideas are covered in Chapter 2?
8. What are the skills that your teacher will be assessing as you complete the Unit A Unit Task?
Chocolate chip cookies are made from many different ingredients. Some of the ingredients, such as sugar and salt, look very similar. However, each ingredient has a different purpose in the recipe. Sugar makes the cookies sweet. Butter keeps the cookies soft after they are baked.

Each ingredient in the recipe looks like just one type of material. The sugar is made up of small, white crystals. The butter is a soft, yellow solid. When you mix the ingredients, however, you get chocolate chip cookie dough. You can see some of the different ingredients in the dough, like chocolate chips and small pieces of butter. Cookie dough is a particular kind of mixture.

In this unit, you will learn about different pure substances and mixtures in the world around you. You will investigate how to separate mixtures, and what the benefits of separation might be. You will consider the choices involved in making, using, and disposing of many pure substances and mixtures. Finally, you will apply what you learn to help you solve a pollution problem.

**BIG Ideas**

- Matter can be classified according to its physical characteristics.
- The particle theory of matter helps to explain the physical characteristics of matter.
- Pure substances and mixtures have an impact on society and the environment.
- Understanding the characteristics of matter allows us to make informed choices about how we use it.
Raven and Matt like to spend time with their friends in the woodland not far from their school. They enjoy climbing the trees, lounging in the grass, watching the insects, and listening to the birds. Across the river, at the bottom of the woodland, there are factories.

One day, Raven noticed that the river looked different: it was soapy, with white bubbles floating on it. Matt found a dead fish lying on the shore. Raven and Matt were worried. Unsure what to do, they talked to their teacher at school. The teacher had a suggestion. "We can call the Ministry of the Environment. They will send an environmental scientist to test the river water for pollution. If the river is polluted, they may be able to find out where the problem is, and figure out how to fix it."
A couple of days later, the environmental scientist came to the school and asked Raven, Matt, and their teacher to come with her to the river. They pointed out the dead fish and the pipes pouring wastewater from the factories into the river. "Is the wastewater killing the fish?" Matt asked.

"Could be," replied the scientist. "Some chemicals can harm the environment. We need to make sure that the factories remove any harmful material from their wastewater before they let it flow into the river."

The scientist collected samples of water from different parts of the river, and took samples of the waste coming out of each factory pipe.

"I'll take these samples to the lab to figure out what's in each one," she explained. "We will find out if any of them contain harmful substances."

A few weeks later, the environmental scientist came back to update Matt and Raven on what had happened. "One of the factories was letting toxic substances flow out in their wastewater. We found out which factory it was and fined them. They have figured out a way to remove those substances from their waste mixture, so that they are not polluting anymore. The river is already starting to recover. I'm going to check on it for the next few months to make sure that it stays clean. Thanks for letting us know about the problem. If we work together, we can help protect the environment from pollution."
Exploring Matter

To help you remember what you already know about matter, your teacher will show you three demonstrations similar to those in Figures 1, 2, and 3. Make careful observations, and relate what you see to what you know about matter. Try to answer the questions in the captions.

Figure 1 How are the three samples of water the same? How are they different? How could they change?

Figure 2 What happens to salt when it is added to water? If material "disappears," where does it go? Has it really ceased to exist?

Figure 3 When you feel "wind" from a fan, what are you actually feeling? Why? What is air? Is it all the same, or is it made up of more than one substance?
Test a Sample of Industrial Waste

Many jobs involve separating and testing materials to find out what they contain. For example, a food scientist tests foods to find out how much fat, sugar, and fibre they contain. An environmental scientist tests soil and water to look for pollution. A mining engineer designs and tests ways to separate valuable minerals from waste rock.

Before testing a sample, a scientist determines whether it is just one kind of substance, or a mixture of substances. If a sample is a mixture, it can be separated into its different parts. Mixtures can be separated in many ways, as you will discover in this unit. An engineer may help out with the separation process. Scientists and engineers may work together to find the easiest and fastest way to separate a mixture into its different parts.

In the Unit Task, you will play the role of an environmental scientist. Your teacher has a sample collected from a river. The sample contains some factory waste. You will separate the sample into its parts and identify each part. For the Unit Task, you will need to use knowledge and skills that you develop as you work through this unit.

You will be assessed on how well you

- identify components that can be separated out of a mixture
- plan, test, and adjust your separation procedure
- communicate your separation procedure
- recommend a removal technique for any dangerous components
KEY QUESTION: What kinds of matter are around us?

Looking Ahead

- Human production, use, and disposal of pure substances and mixtures have both benefits and costs.
- The particle theory explains the behaviour of particles of matter.
- The skills of analysis can be used to apply the particle theory to changes in matter.
- A pure substance contains only one kind of particle, but a mixture contains more than one kind of particle.
- The skills of scientific inquiry can be used to classify matter as a pure substance or a mixture.
- A mechanical mixture contains different components that you can see.
- A solution is a mixture that looks like a pure substance.

VOCABULARY

- matter
- chemistry
- particle theory of matter
- solid
- volume
- liquid
- gas
- pure substance
- mixture
- mechanical mixture
- heterogeneous mixture
- solution
- homogeneous mixture
Take Our Kids to Work Day

Today was Take Our Kids to Work Day. Instead of going to school, Jiao was going to work with her mom.

Jiao's mom had already told Jiao something about her job. “I work in a lab where we design artificial flavours. Remember the strawberry yogurt you had for breakfast? It had real strawberries in it, but it also had artificial strawberry flavour. That flavour was designed by scientists in my lab!”

“How did they do it?” Jiao had wanted to know.

“Strawberries are a mixture of many different substances,” said her mom. “The scientists analyzed real strawberries to see which chemicals give the strawberry its smell and taste. Then, they figured out how to make similar chemicals in the lab. The right mixture of chemicals tastes and smells like real strawberries.”

When they arrived, Jiao and her mom went into a special room where they both tied their hair back. They put on white lab coats, eye protection, and gloves. Then, they went into the lab.

The lab smelled delicious! Jiao could smell bananas and cherries, and a yummy caramel smell that made her mouth water.

Jiao noticed rows of bottles sitting on shelves all around the room. “What’s in all those bottles?” she asked.

“The small bottles hold all the flavours we have designed. It’s not safe to taste things in the lab, but you can smell them,” said her mom.

Jiao’s mom took the lids off two small bottles. Jiao sniffed the first one carefully, wafting the air as her mom had shown her. It smelled like apples. The second smelled like pineapple. “Wow!” said Jiao.

“I like your job. Maybe I’ll design flavours, too, when I grow up.”

LINKING TO LITERACY

Gaining Meaning from Context

You can learn about new or difficult words from the story you are reading without using a dictionary. See if you can figure out what a new word means by using information from the sentence or paragraph.

1. In this story, Jiao learns about substances and chemicals. Read the information in the paragraph that begins with, “Strawberries are a mixture…” Can you tell what the word “substances” means? What might be a good synonym for this word?

2. What other new words did you learn from this story? Work with a partner to compare words you learned about by using information from the text.
What Is Matter?

You have probably seen, touched, and tasted hundreds of different things in your life. You have touched wood, steel, and ice. You use shampoo, and you drink milk. You breathe air. Have you ever wondered what all these things are made of?

The examples listed above are all made of matter. In fact, all of the objects around you are made of matter (Figure 1). **Matter** is anything that has mass and takes up space. Remember the chocolate chip cookies at the beginning of the unit? All of the ingredients are examples of matter. A mixing spoon is an example of matter. Your entire body is made of matter!

**Figure 1** What examples of matter can you see?

The Science of Matter

The study of matter and its changes is called **chemistry**. Scientists who work in chemistry are called chemists. The photograph at the beginning of this chapter shows chemists working in a lab. Knowledge of chemistry is useful in many different careers. People who work in medicine, cooking, art, photography, and solving crimes all use chemistry in some way.
Some chemists use their knowledge about matter to develop new kinds of matter. Often, scientists study matter that is found in nature, and then imitate it. These human-made chemicals are sometimes better than chemicals found in nature. For example, natural almond extract comes from wild almonds. It contains tiny amounts of a dangerous poison called cyanide. Human-made almond extract is a mixture of substances made in a chemistry lab (Figure 2). It is similar to the natural flavour, but it does not contain poisonous cyanide. Human-made chemicals are also sometimes cheaper to obtain than chemicals found in nature.

Human-made chemicals, however, are not always better than natural ones. Lemonade made with real lemons includes lots of vitamin C. Lemonade made with artificial flavour may taste almost the same, but will probably not have the same vitamin content.

The Makeup of Matter
What makes up matter? To help us think about matter, we will look at something made of just one type of matter: aluminum foil (Figure 3). Imagine using stronger and stronger microscopes to examine the foil. What would you see? With the first microscope, you would see the smooth, shiny surface of the foil, perhaps with some little scratches or marks (Figure 4). With a stronger microscope, the marks would be more visible, but you could still recognize the material as aluminum foil.

What if you used the most powerful kind of microscope available—a scanning probe microscope? You might be surprised at what you would see. Figure 5 shows what a piece of aluminum foil looks like through a scanning probe microscope. The surface is not smooth or silver-coloured. Instead, it is made of many tiny bumps. These bumps show the presence of aluminum particles.
A small piece of aluminum foil contains billions of tiny aluminum particles. All matter is made of particles that are too small to be seen, except through powerful microscopes. These particles of matter are tinier than the smallest thing you can imagine. Imagine a piece of aluminum foil that is 1 cm by 1 cm. If each particle in that piece of foil were expanded to the size of an egg, the eggs would cover the entire surface of Earth to a depth of several metres.

**The Particle Theory of Matter**

All matter is made of tiny particles. Different kinds of matter are made of different kinds of particles. The particles themselves do not look like the kind of matter they make up. For example, a single particle of aluminum does not look the same as a piece of aluminum. A single particle of water does not look or behave like the water in a lake. Only when large numbers of particles are together do aluminum particles behave like aluminum, or water particles behave like water.

The particle theory of matter (also known as “particle theory”) helps to explain what scientists have learned about these tiny particles of matter. The main ideas of the particle theory are listed in Table 1.

<table>
<thead>
<tr>
<th>Main idea</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. All matter is made up of tiny particles.</td>
<td></td>
</tr>
<tr>
<td>2. Particles have empty spaces between them.</td>
<td></td>
</tr>
<tr>
<td>3. Even though you cannot see them, particles are moving randomly all the time.</td>
<td></td>
</tr>
<tr>
<td>4. Particles move faster and spread farther apart when they are heated.</td>
<td></td>
</tr>
<tr>
<td>5. Particles attract each other, so they tend to stay together rather than fly apart.</td>
<td></td>
</tr>
</tbody>
</table>
Using the Particle Theory

You can use the particle theory to explain many of the things you observe in everyday life. The following sample problem shows how to use the particle theory to explain an observation.

SAMPLE PROBLEM: Explain an Observation Using the Particle Theory

If you placed a few drops of food colouring in a container of water without stirring, what do you think you would see (Figure 6)?

Solution: Particles of food colouring and particles of water are moving and bumping into each other all the time. This causes the food colouring particles and the water particles to mix together, even without stirring.

Figure 6

Look at the paper in this textbook. Is it hard to believe that the paper is made of billions of invisible particles? If you answered yes, you are not alone. For thousands of years, people did not know that matter is made of particles. Today, we accept the particle theory because it helps scientists to explain many puzzling observations.

TRY THIS: Explain Observations Using the Particle Theory

SKILLS MENU: performing, observing, analyzing, communicating

In this activity, you will make observations and use the particle theory to explain your observations. You may want to review the main ideas of the particle theory in Table 1.

Equipment and Materials: tablespoon; ceramic coffee mug; timing device; sugar; room-temperature water; cold water; ice; hot water

Never taste anything in the science lab. Use care when working with hot water.

1. Stir a level spoonful of sugar into a mug of water at room temperature. At the same time, start timing. Keep stirring until you can no longer see the crystals of sugar. Measure the time it takes for the sugar to completely disappear. Record your observations.

2. Empty the sugar water into the sink and rinse the mug.

3. Repeat steps 1 and 2 using cold water with a couple of ice cubes in it.

4. Repeat steps 1 and 2 using hot water.

A. What did you observe in all three mugs of water?
B. Use the particle theory to explain your observations.
C. In which mug of water did the sugar crystals disappear most quickly?
D. Use the particle theory to explain your observations in part C.

CHECK YOUR LEARNING

1. (a) In this section, you learned that matter is made of very tiny particles. Do you find this idea easy or difficult to understand? Explain why.
   (b) What can you do to help you understand this idea better?

2. (a) What is matter?
   (b) Give three examples of things that are made of matter.

3. In point form, list the five main ideas of the particle theory. You may use diagrams.
More About Matter

Have you ever seen a snowflake under a microscope? Look at the beautiful snowflake in Figure 1. Can you tell what kind of matter it is made of? If not, how could you find out?

Figure 1 If you held this snowflake in your hand, it would melt into a drop of water. The snowflake is made of the same kind of matter as a drop of water.

Three States of Matter

Snowflakes are a form of solid water. Water particles are always water particles, whether water is in solid (ice), liquid (water), or gas (water vapour) form. All forms of matter, including water, can exist in three different states: solid, liquid, and gas. The particles are exactly the same in each state. Individual particles do not freeze or melt. Instead, their movement changes. Also, the arrangement of particles is different in each state. Matter also behaves differently in each state.

Solids
A solid has a definite shape and a definite volume. Volume is the quantity of space something occupies. For example, a coin is made of metal. The metal is in the solid state. Therefore, the coin's shape and volume remain constant (if the coin's temperature does not change).

Liquids
A liquid has a definite volume, but does not have a definite shape. Instead, a liquid takes the shape of its container. Milk is an example of a liquid. If you have 250 mL of milk in a carton, the milk's volume will be 250 mL. The volume does not change if you pour the milk into a cylindrical glass, but the shape will change.
**Gases**

A gas does not have a definite volume or a definite shape. Instead, a gas takes the shape and volume of its container. When a deflated basketball is filled with air, the air particles occupy a spherical space and a volume equal to the volume of the inflated ball.

**Particles of Solids, Liquids, and Gases**

The particles of a sample of matter always stay the same, whether the matter is solid, liquid, or gas. The difference is in the movement and arrangement of the particles. Particles move differently in solids, liquids, and gases.

The particles of a solid are like students sitting in a movie theatre watching a movie (Figure 2). The students have a bit of distance between them, they can fidget in their seats, but they cannot move around very much.

The particles of a liquid are like students moving through a crowded shopping mall (Figure 3). The students can walk around, but they are still close together.

The particles of a gas are like students running out of the school building on the last day of school (Figure 4). The students can move quickly, and in all different directions.

The particles are also arranged differently in each state of matter. Particles are closer together in solids and liquids than in gases. Because of this closeness, the forces of attraction among the particles hold the particles together. This explains why the volume of a solid or a liquid does not change much. The particles of gases are farther apart, so the forces of attraction cannot hold the particles together in a fixed volume.

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**gas:** a state of matter that does not have a definite volume or a definite shape; a gas takes the shape and volume of its container.

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**LINKING TO LITERACY**

**Synthesizing Information**

When you read text that presents new information, you compare it to what you have already read or already know. Use the text on this page, the diagrams, and what you already know to help you understand particles in solids, liquids, and gases.

---

**Particles of a solid**

Figure 2  The particles of a solid are closely packed together. The particles stay in the same positions, but they vibrate all the time.

**Particles of a liquid**

Figure 3  The particles of a liquid are still close together, but they can move around each other in all directions.

**Particles of a gas**

Figure 4  The particles of a gas are very far apart. They have lots of energy and move very fast in all directions. The particles can even leave their container if it is not sealed.

---

**To learn more about the particle theory and the states of matter, Go to Nelson Science**
Changes in State

Matter can change from one state to another. A change in state can happen when a sample of matter is heated or cooled.

**TRY THIS: Changes in State**

**SKILLS MENU:** observing, analyzing, communicating

What happens when matter changes state from a solid to a liquid to a gas?

**Equipment and Materials:** microwave oven; small plastic sandwich bag; rubber band; small ice cube or ice chip

Be careful when handling items that have been heated in a microwave oven. Some parts may be much hotter than others. Do not use a metal tie to seal the sandwich bag. Do not try this investigation at home without responsible adult supervision.

1. Put a small piece of ice in a plastic sandwich bag. Squeeze all the air out and tie the top of the bag tightly shut with a rubber band.

2. Put the bag in the microwave oven for 60 s or more, until the bag appears to inflate. Observe through the door of the microwave oven. Record your observations.

3. Stop the microwave as soon as you see the bag inflate, and open the door. Take the bag out carefully and hold it in your hand. Record your observations.

A. What changes of state took place in the ice? Use the particle theory to explain what happened to the ice particles during the changes you observed.

When ice is heated, the water particles move faster, so the water changes from solid to liquid. More heating makes the particles move even faster and farther apart, so the liquid water changes to a gas. The particles of a gas are much farther apart than the particles of a solid or a liquid.

If the gas is cooled, the attractive forces pull the particles closer together, and the gas changes back into a liquid. What would happen if you cooled the liquid water even more by placing it in a freezer? The particles would slow down: the water would change from a liquid to a solid. When a sample of matter changes state, the particles themselves remain the same. The number of particles also remains the same. It is the arrangement and speed of the particles that changes. Figure 5 shows water changing state from liquid to gas. As liquid water is heated, water particles start to move faster. They leave from the surface moving very quickly. (This is shown by longer arrows.) As more and more particles leave from the surface, the liquid water becomes water vapour.

**Check Your Learning**

1. In this section, you learned that particles are moving all the time, even in the solid state. Do you find this easy or difficult to believe? Discuss this with a classmate or your teacher, and explain why or why not.

2. What are the three states of matter?

3. In your own words, use the particle theory to explain why water changes from a solid (ice) to a liquid (water) when it is heated.

4. Identify the state of each of the following materials:
   (a) a rock
   (b) grape juice
   (c) air

5. Draw a diagram that shows particles of a solid, a liquid, and a gas. Your labels should describe the motion of the particles in each state and the attraction among the particles.
Other States of Matter

You have just learned about solids, liquids, and gases. Scientists have found other states of matter that have unique properties.

A gas that is electrically charged is called plasma. Plasma is sometimes considered to be a fourth state of matter. It is found mainly in stars and nebulas in outer space.

Plasma (which is different from blood plasma) has fascinated people for thousands of years. The northern lights are an example of plasma in nature (Figure 1). Traditionally, Inuit have believed that the northern lights were the torches of spirits guiding souls to a land of happiness and plenty.

Figure 1 The northern lights (aurora borealis)

Today, you can find plasma in many manufactured items, such as fluorescent lights, neon signs (Figure 2), and plasma television screens.

Figure 2 Neon lights contain plasma.

According to the particle theory, particles move more slowly when they are cooled. Experiments have shown that this is true. Scientists have cooled particles until they almost stopped moving completely. If you drew a graph showing the movement of particles against temperature, the graph would indicate that the particles would stop moving at approximately –273 °C. This temperature is called absolute zero. Absolute zero is the coldest possible temperature that could ever exist. Scientists believe that even the coldest places in our universe are warmer than absolute zero.

In 1924, Albert Einstein predicted that if you cooled particles down to absolute zero, a new state of matter would form. In 1995, scientists Eric Cornell and Carl Wieman finally managed to cool down a sample of particles to a temperature very close to absolute zero. Einstein was right: the particles formed a new state of matter!

This exciting new state of matter is called a Bose–Einstein condensate. Scientists think that this discovery may lead to very tiny computer chips in the near future.

To read more about these strange states of matter,
Testing the Particle Theory

In this investigation, you will explore what happens to the mass of a sample of matter when it changes state. You will also explore what happens when two samples of matter are added together. You will use the particle theory to analyze your observations.

**Testable Questions**

**Part A:** What happens to the mass of a solid when it melts?

**Part B:** How does mixing a solid and a liquid together (until the solid disappears) affect the total mass of the mixture?

**Hypothesis/Prediction**

Write a hypothesis for each of the Testable Questions. Each hypothesis should include a prediction as well as a reason for your prediction based on the particle theory.

**Experimental Design**

**Part A:** You will take measurements to compare the mass of a sample of frozen water with the mass of the same sample when it is liquid.

**Part B:** You will take measurements to compare the actual mass of a salt-and-water mixture with the predicted mass.

**Equipment and Materials**

- eye protection
- apron
- beaker (100 mL)
- triple beam balance
- hot plate
- beaker tongs
- weighing papers
- stirring rod
- graduated cylinder (100 mL)
- 6 ice cubes
- water
- 20 g of salt

**Be careful when using a hot plate. Do not touch the heated surface, even when it is not plugged in; it could still be very hot. Do not unplug the hot plate by pulling on the electrical cord. Pull the plug itself. Use caution when handling glassware. Report any broken glassware to your teacher.**
Procedure

Part A: Melting Ice

1. Read the complete investigation and construct a suitable table called Table 1 for recording your observations. Ask your teacher to approve your table before you continue.

2. Put on your eye protection and apron. Measure and record the mass of an empty, dry beaker.

3. Add one piece of ice to the beaker. Measure and record the total mass.

4. Place the beaker on the hot plate, and then turn the heat to low. Allow the ice to melt completely. Do not let the water boil. Remove the beaker from the hot plate using beaker tongs. (It could still be hot.) Measure and record the total mass of the beaker and melted ice.

5. Pour the water into the sink and dry the beaker completely.

6. Repeat steps 3 and 4 using the same beaker. This time, use five pieces of ice all at once, instead of one piece. Again, record your observations.

Part B: Salt in Water

7. Read the rest of the investigation and construct a suitable table called Table 2 for recording your observations. Ask your teacher to approve your table before you continue.

8. Measure and record the mass of an empty, dry beaker.

9. Measure 50 mL of water into a graduated cylinder, and then pour the water into the beaker. Measure and record the total mass.

10. Measure and record the mass of a weighing paper. Add 5 g of salt to the weighing paper. Add the salt to the water and stir. Measure and record the total mass of the beaker, water, and salt.

11. Pour the salt water into the sink. Rinse and dry the beaker.

12. Repeat steps 8 to 11, but this time using 100 mL of water and 10 g of salt.

Analyze and Evaluate

(a) Using your measurements in steps 2 and 3, calculate the mass of the single piece of ice. Record this value in Table 1.

(b) Using your measurement in step 4, calculate the mass of the melted ice. Record this value in Table 1.

(c) Repeat (a) and (b) for the five pieces of ice.

(d) Using your measurements in steps 8 and 9, calculate the mass of 50 mL of water. Record this value in Table 2.

(e) Calculate the total mass of the beaker, the water, and the salt before mixing. Record this value in Table 2.

(f) Using your measurements in step 10, calculate the mass of the beaker, the water, and the salt after mixing. Record this value in Table 2.

(g) Repeat (d), (e), and (f) for 100 mL of water and 10 g of salt.

(h) Use your results to answer the Testable Questions. Compare your answers to your Hypothesis/Prediction. Account for any differences.

(i) Why do you think you repeated each experiment with different masses?

Apply and Extend

(j) If you froze the water in Part A and then determined its mass again, what would you observe?

(k) If you left the mixed liquid in Part B in a warm place for a long time and then measured the mass, what would you observe?
The apple juice in Figure 1 is labelled as 100 % apple juice. Does this mean that the juice is made of only one kind of matter? Does it have only one kind of particle in it?

Apple juice is actually a mixture of water particles, sugar particles, flavour particles, and vitamin particles. Apple juice may look like one kind of matter, but it contains many kinds of particles all mixed together.

**Pure Substances**

Most examples of matter in everyday life contain more than one kind of particle. Some types of matter, however, do contain only one kind of particle (Figure 2). A piece of aluminum foil contains only one kind of particle. Each aluminum particle is the same as every other aluminum particle. White table sugar is made of only sugar particles.

Aluminum and table sugar are both examples of pure substances. A **pure substance** is a type of matter that contains only one kind of particle (Figure 3(a)). Other examples of pure substances include distilled water and salt. Uranium, used in nuclear power stations to produce electricity, is another pure substance.

Water from your tap is not a pure substance. It contains water particles and a number of other kinds of particles, too. Distilled water, however, has had all of the “non-water” particles removed: it is pure water.

**Mixtures**

When you stir a spoonful of sugar into a glass of distilled water, the sugar disappears and the water tastes sweet. Now there are two kinds of particle in the glass. The sweetened water is not a pure substance anymore. It is a mixture containing sugar particles and water particles.

A **mixture** is a type of matter that contains more than one kind of particle. A mixture is made of two or more pure substances mixed together (Figure 3(b)).
Matter

SKILLS MENU: performing, observing, analyzing

You can test the ink in a black marker to determine if it is a pure substance.

Equipment and Materials: water-soluble black marker; colourless drinking glass or beaker; 10 cm strip of filter paper; tap water

1. Use the marker to draw a horizontal black line about 3 cm from the bottom of the strip of filter paper.
2. Pour water into the glass to a depth of about 1 cm.
3. Carefully stand the strip of filter paper in the glass of water. The black line should be close to the water, but not touching it (Figure 4).

A. What happens to the black line on the paper after 1 min? After 5 min?
B. Is the ink in a black marker a pure substance or a mixture? What evidence supports this?

Figure 4 Use the clip on the marker lid to hold the paper away from the side of the glass.

Mixtures can be solids, liquids, or gases, or even combinations of these. Steel, batteries, and cookies are all mixtures in the solid state. Antifreeze and milk are mixtures in the liquid state. The air you breathe is a mixture of gases.

Many mixtures that we use, such as the mixtures inside compact fluorescent light bulbs (CFLs) and batteries, include some pure substances that can be harmful if they escape into the environment. CFLs contain mercury. Some batteries contain cadmium while others contain lead. Mercury, cadmium, and lead are all pure substances that are toxic to both animals and people. We should not dispose of CFLs and batteries in the regular garbage. We should carefully collect them and deposit them at special recycling stations, where their components can be separated out and recycled.

Unit Task

Think about the Unit Task. How will this information about pure substances and mixtures be useful as you work on the task?

CHECK YOUR LEARNING

1. (a) What is a pure substance? Give three examples.
   (b) What is a mixture? Give three examples.
2. In your notebook, draw a sample of matter that is a pure substance. Make sure you show the types of particles present in the pure substance. Explain why your drawing shows a pure substance and not a mixture.
3. Is milk a pure substance or a mixture? Explain how you know.
4. (a) Why should you not place used batteries in the regular garbage?
   (b) How should you dispose of batteries?

LINKING TO LITERACY

After Reading: Summarizing

After you finish reading the section “Pure Substances and Mixtures,” work with a partner to summarize all of the key ideas. The text subheadings will help to guide your thinking. Develop one sentence for each of the subheadings in the text.

To learn more about disposing of dangerous substances, Go to Nelson Science.

NEL
Identifying and Classifying Matter

All samples of matter are either pure substances or mixtures. Sometimes, two pure substances mix so completely that the resulting mixture looks like a pure substance. In this activity, your teacher will give you six samples of matter labelled A, B, C, D, E, and F. You will use information about the different types of matter, and design your own tests to identify the six samples. Some of your tests will involve making mixtures. Using the equipment and materials listed, you will perform your tests. When you have tested and identified each sample, you will examine the mixture(s) that you made. You may discover that there are different types of mixtures.

Purpose
To plan and perform tests to identify six unknown samples of matter.

Equipment and Materials
- eye protection
- apron
- gloves
- 6 test tubes with stoppers
- test-tube rack
- spoon
- beaker (250 mL)
- magnifying glass
- 6 samples of matter (labelled A, B, C, D, E, and F)
- water

Never taste anything in the science lab. Some of the samples could be toxic. Handle glassware carefully. Report any broken or chipped glassware to your teacher. Use rubbing alcohol very carefully.
**Procedure**

**Part A: Identify the Samples**

1. Samples A to F are the six substances listed in Table 1. You will use the information in Table 1 to identify the six unknown samples. Design at least one test for each sample. (Hint: Your tests might involve mixing pairs of the samples. See Figure 1. Do not mix more than two samples together.) Write the steps of your procedure. Include any safety precautions you will need to take. Create a table in which to record your observations.

<table>
<thead>
<tr>
<th>Sample of matter</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>distilled water</td>
<td>• colourless liquid</td>
</tr>
<tr>
<td></td>
<td>• mixes completely with sugar</td>
</tr>
<tr>
<td>rubbing alcohol</td>
<td>• colourless liquid</td>
</tr>
<tr>
<td></td>
<td>• does not mix completely with sugar</td>
</tr>
<tr>
<td>glycerol</td>
<td>• thick, colourless liquid</td>
</tr>
<tr>
<td></td>
<td>• mixes completely with water</td>
</tr>
<tr>
<td>castor oil</td>
<td>• thick, pale yellow liquid</td>
</tr>
<tr>
<td></td>
<td>• does not mix completely with water</td>
</tr>
<tr>
<td>sugar</td>
<td>• white powder</td>
</tr>
<tr>
<td></td>
<td>• mixes completely with water</td>
</tr>
<tr>
<td>flour</td>
<td>• white powder</td>
</tr>
<tr>
<td></td>
<td>• does not mix completely with water</td>
</tr>
</tbody>
</table>

**Figure 1** To mix samples in a test tube, fill the tube no more than halfway. Put a stopper in the test tube, and put your thumb firmly over the stopper. Holding the test tube away from you, gently turn it upside down two or three times. Wear gloves when mixing samples this way.

2. When your teacher has approved your procedure, perform the tests. Record your observations as you go along.

3. Keep the mixtures in the test tubes. You will need them for the next part of the activity.

**Part B: Examine the Mixtures**

4. Use a magnifying glass to examine each mixture that you made in Part A. Record your observations.

**Analyze and Evaluate**

(a) Identify each sample of matter in Part A.

(b) Was any sample of matter particularly easy to identify? Why?

(c) Was any sample of matter particularly difficult to identify? Why?

(d) Using your observations in Part B, classify the mixtures into groups.

(e) How did you classify the mixtures into groups?

(f) Not all of the samples were pure substances. Explain how you can tell which ones were mixtures.

(g) Can you always tell the difference between a pure substance and a mixture? Explain why or why not.

**Apply and Extend**

(h) Imagine that you are a scientist in a forensics lab. You have a beaker with a clear, colourless liquid. Suggest a test that might help to identify the liquid. Remember: You should never taste anything in a lab.

(i) Make a list of what you have learned in this chapter about safety in the science lab. Include a description of the following:

   - wearing protective clothing
   - caution around glassware
   - checking labels for warning symbols
Mechanical Mixtures and Solutions

Mixtures are an important part of food preparation. Figure 1 shows a mixture of eggs, vegetables, and cheese cooking on a stove to make an omelette. Figure 2 shows a glass of grape juice. How are these mixtures the same? How are they different?

Scientists classify mixtures into two main groups: mechanical mixtures and solutions. Both are mixtures because both are made up of two or more different kinds of particles.

**Mechanical Mixtures**

Sometimes it is easy to tell whether something is a mixture, but at other times it is more difficult. You can tell that the soil in Figure 3 is a mixture because you can see the different parts. If you can see different kinds of matter in a mixture, it is called a mechanical mixture. Mechanical mixtures are also called heterogeneous mixtures.

**LINKING TO LITERACY**

*During Reading: Monitoring Comprehension*

As you read through this page, stop from time to time to think about what you are reading. Can you put the pieces of information together to make sense? Good readers stop to think when something does not make sense. They look for key words to help their understanding. Often they reread text and locate information from titles, pictures, captions, and tables.
You see and use mechanical mixtures almost every day. To find a mechanical mixture, you could look inside your closet at home or inside your pencil case at school. Maybe you ate a mechanical mixture for breakfast, such as cereal and milk, or a raisin bran muffin. Figure 4 shows three more examples of mechanical mixtures.

Figure 4  How can you tell that each example is a mechanical mixture?

**Solutions**

Some mixtures do not look like mechanical mixtures. They look like pure substances. Like the grape juice in Figure 2, clear shampoo looks like only one kind of matter. However, both grape juice and clear shampoo are mixtures. Grape juice contains water particles, sugar particles, and flavour particles. Shampoo contains water particles, detergent particles, colour particles, and scent particles.

Mixtures that look as though they are pure substances are called solutions. A **solution** contains more than one kind of particle, but it looks like a pure substance. Solutions are sometimes called **homogeneous mixtures**. Both steel and seawater are solutions. Think back to the black marker ink that you tested in Section 1.4. What evidence do you have that marker ink is a solution, rather than a pure substance or a mechanical mixture?

Clear apple juice is a solution. The air you breathe is also a solution. More examples of solutions are shown in Figure 5. Try to think of three solutions that you have seen today.

Figure 5  Stainless steel is made of iron, chromium, and nickel particles. Tea is made of water, caffeine, and flavour particles. Clear nail polish is made of nitrocellulose, resin, colour, and acetate particles.
You have probably realized that homogeneous mixtures, or solutions, can be in any of the three states: solid, liquid, or gas. However, in any one solution, there is only one state visible. This is not the case for heterogeneous mixtures, which can include different states in one mixture.

**TRY THIS: Explore Mixtures at Home**

**SKILLS MENU:** observing, communicating

In this activity, you will explore mixtures in your home.

1. Search your home for at least four different mixtures. Try to find a variety of mixtures, including the following:
   - a mixture of two or more solids
   - a mixture of two or more liquids
   - a mixture made by mixing a solid and a liquid
   - a mixture made by mixing a liquid and a gas

2. Copy and complete Table 1 in your notebook, adding details about the four mixtures. If you do not know the components of the mixture, look at the container or label (if there is one) to find out.

<table>
<thead>
<tr>
<th>Name of mixture</th>
<th>Name of mixture</th>
<th>Name of mixture</th>
<th>Name of mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components of the mixture</td>
<td>Components of the mixture</td>
<td>Components of the mixture</td>
<td>Components of the mixture</td>
</tr>
<tr>
<td>Safety warning (if present)</td>
<td>Safety warning (if present)</td>
<td>Safety warning (if present)</td>
<td>Safety warning (if present)</td>
</tr>
</tbody>
</table>

### Particles of Mixtures

Maybe it surprises you that clear apple juice, air, and steel are homogeneous mixtures, and not pure substances. The different kinds of matter are not visible in a solution like apple juice. Why not? Figure 6 may help you to answer this question. It compares the distribution of the particles of a solution with the distribution of the particles of a mechanical mixture.

**Figure 6** (a) The different particles of a solution are evenly mixed. (b) The different particles of a mechanical mixture are unevenly mixed.

In a solution, the different kinds of particles are mixed together evenly. Individual particles are too small to see, so when you look at a solution, it looks like just one kind of matter. You will learn more about the particles of solutions in Chapter 2.

In a mechanical mixture, the different kinds of particles are not mixed evenly. Instead, they stay together in groups and are distributed unevenly. As a result, when you look at a mechanical mixture, you can usually see the different kinds of matter.
TRY THIS: Make a Mixture

SKILLS MENU: observing, analyzing, communicating

In this activity, you will make your own mixture and observe its properties.

Equipment and Materials: apron; clear drinking glass or beaker; spoon; water; cooking oil; food colouring; liquid dish detergent

1. Put on your apron. Pour water into a glass until it is half full.
2. Add a spoonful of oil to the water and stir. Record your observations.
3. Add a few drops of food colouring to the mixture and stir. Record your observations.
4. Add a few drops of dish detergent to the mixture and stir. Record your observations.

A. In step 2, what kind of mixture did you make?
B. In step 3, did the food colouring mix with the water or the oil? What kind of mixture did the food colouring form?
C. What happens to the mixture when the dish detergent is added in step 4?

Classifying Matter

You have learned that matter can be classified as either a pure substance or a mixture. Mixtures can be further classified as mechanical mixtures or solutions. Pure substances can combine to form mixtures. Figure 7 summarizes what you have learned about classifying matter.

Figure 7  Classification of matter

Unit Task  How do you think this information about mechanical mixtures and solutions will be useful as you work on the Unit Task?

CHECK YOUR LEARNING

1. (a) Which ideas did you find easiest to understand as you learned about the arrangements of the particles of mixtures?
   (b) Which ideas did you find most difficult to understand as you learned about the arrangements of the particles of mixtures? Explain why.
   (c) Suggest a strategy to help you better understand the arrangement of the particles of mixtures.

2. Describe each of the following types of mixture:
   (a) a mechanical mixture
   (b) a solution

3. Copy Figure 7 (above) into your notebook. Add two examples of each type of mixture and two examples of a pure substance.

4. (a) What is the difference between the arrangement of the different particles of a mechanical mixture and the arrangement of the different particles of a solution?
   (b) Draw diagrams of the particles of a mechanical mixture and the particles of a solution.

5. Identify each of the following as a mechanical mixture or a solution:
   (a) stainless steel
   (b) a granola bar
   (c) clear apple juice
   (d) an omelette
   (e) soil from your backyard
Using Compact Fluorescent Light Bulbs

Pure substances and mixtures affect the world around you. Using pure substances and mixtures involves both benefits and costs. A benefit is a good or positive result. A cost is a bad or negative result. Some pure substances are harmful to the environment or to human health. Some mixtures contain pure substances that could pollute the air, soil, or water. Often, a mixture or a product containing a mixture has both benefits and costs associated with it. For example, compact fluorescent light bulbs (CFLs) use much less energy than incandescent bulbs (Figure 1). However, CFLs contain a mixture of gases and mercury—a toxic pure substance that can pollute the environment when the bulb is thrown away (Figure 2). Are the benefits of using CFLs worth the costs?

The Issue

The town council of a small Ontario town is having a meeting to discuss whether to promote the use of energy-saving CFLs and how to handle the disposal of CFLs. You are a concerned resident in the town. You and a small group of townspeople have been asked by the town council to research these issues. Your group has been asked to summarize your research and present it at the town council’s next meeting. You are also expected to recommend a position on each issue.

To prepare for the meeting, you will research the benefits and costs of using CFLs in place of incandescent light bulbs. You should also research the disposal options for CFLs.
Goal
To research CFLs, and to develop and present a cost-benefit analysis of the use and disposal of CFLs.

Gather Information
Working as a group, you will gather information on the issue. Use newspapers and books, as well as the Internet, to find information. Remember that when searching for information using the Internet, some sites will be more trustworthy than others. It is important to seek accurate information when doing research. Educational or government sites are often good places to start.

Identify Solutions
The following questions may help you to conduct your cost-benefit analysis and to find possible solutions:
• What are the benefits of using CFLs?
• How can the benefits of using CFLs be maximized?
• What are the costs, or drawbacks, of using CFLs?
• How can the costs of using CFLs be minimized?
• What are the disposal options (both safe and dangerous) for CFLs (Figure 3)?
• What are the best available alternatives?

Make a Decision
Are the benefits of using CFLs worth the costs? Is there a safe way to dispose of broken CFLs? How did you decide?

Communicate
With your group, prepare a presentation on the issues. Decide how you will make your presentation: a brochure, an audiovisual presentation, a poster, a video, or something else. Your report should include the following information:
• benefits and costs of CFLs
• information on the safe disposal of CFLs
• your opinion on what the town should do about the issue

Present your report at a town meeting. Other groups will also present their reports. Together, you will decide what the town will do about the issue.

Figure 3 If your town decides to promote CFLs, how will you dispose of used or broken bulbs?
Classifying Matter

BIG Ideas

- Matter can be classified according to its physical characteristics.
- The particle theory of matter helps to explain the physical characteristics of matter.
- Pure substances and mixtures have an impact on society and the environment.
- Understanding the characteristics of matter allows us to make informed choices about how we use it.

Looking Back

Human production, use, and disposal of pure substances and mixtures have both benefits and costs.

- We use pure substances and mixtures in everything we do.
- Some mixtures contain pure substances that are harmful to people and the environment.
- Some pure substances are beneficial but are also potentially dangerous.

The particle theory explains the behaviour of particles of matter.

- Everything that has mass and takes up space is made of matter.
- The particle theory states that all matter is made up of tiny particles that are separated by empty spaces. These particles are attracted to one another.
- The particle theory states that particles are in constant motion, and move faster and farther apart when they are heated.
- Three states of matter are solid, liquid, and gas.

The skills of analysis can be used to apply the particle theory to changes in matter.

- Changes in mass observed during investigations can be explained using the particle theory.
A pure substance contains only one kind of particle, but a mixture contains more than one kind of particle.

- Aluminum, table sugar, salt, and distilled water are all examples of pure substances.
- The particles of pure substances do not change, regardless of their state of matter.
- Mixtures can be mechanical mixtures (heterogeneous mixtures) or solutions (homogeneous mixtures).
- Chocolate chip cookies, steel, salad dressing, pop, and ketchup are examples of mixtures.

The skills of scientific inquiry can be used to classify matter as a pure substance or a mixture.

- Pure substances and mixtures can be identified using observation skills.
- Different properties of pure substances and mixtures can be determined by mixing them together.

A mechanical mixture contains different components that you can see.

- A granola bar, cooking oil with herbs, and a children’s ball room are all examples of mechanical mixtures.
- A mechanical mixture is also called a heterogeneous mixture.

A solution is a mixture that looks like a pure substance.

- Stainless steel, clear tea, and clear nail polish are all solutions.
- A solution is also called a homogeneous mixture.
What Do You Remember?

1. What is matter?

2. (a) List the five main ideas of the particle theory.
   (b) Choose one idea of the particle theory. Draw a diagram that illustrates this idea.

3. (a) List, compare, and contrast the three states of matter.
   (b) Give an example of matter in each of the three states.

4. What are the main differences between the particles of a solid and the particles of a gas?

5. (a) What is a pure substance?
   (b) What is a mixture?

6. Draw a picture to show the difference between the particles of a pure substance and the particles of a mixture.

7. Is clear apple juice (Figure 1) a pure substance or a mixture? Explain your answer.

8. Tap water contains small amounts of minerals and other chemicals. Is tap water a pure substance or a mixture?

9. (a) What is a mechanical mixture?
   (b) How is a mechanical mixture different from a solution?

10. Classify each of the following mixtures as a mechanical mixture or a solution:
    (a) a fruit salad
    (b) clear liquid hand soap
    (c) an oil-and-vinegar salad dressing

11. List two solutions that you can drink.

12. Use the particle theory to explain why you can see the different parts of a mechanical mixture, but not the different parts of a solution.

13. Draw a picture to show the difference between the arrangement of particles of a mechanical mixture and the arrangement of particles of a solution.

14. Based on what you learned in this chapter, list three things that a piece of wood, a bowl of salad, and your body all have in common.

What Do You Understand?

15. Classify the following materials into three groups: pure substances, mechanical mixtures, and solutions.
    (a) copper wire
    (b) iced tea
    (c) seawater
    (d) fruit salad
    (e) table sugar
    (f) salad dressing

16. Jonas blew up a balloon in his room. When he took the balloon outside, it got bigger. Was it hotter or colder outside than in his room? Use the particle theory to explain your answer.

17. When an ice cube melts, do the particles of the ice cube change to a different type of particle? Explain why or why not.

18. Janice says that a glass of orange juice with pulp in it is a solution. Pedro says that it is a mechanical mixture. Do you agree with Janice or Pedro? Explain why.
19. Can you tell if a liquid is a pure substance or a solution by looking at it? Explain why or why not.

20. Madur stirred together flour, oil, green peas, chopped onion, and some spices to make dough for pakoras. Is the final mixture a mechanical mixture or a solution? Explain why.

21. (a) Jing has a brand-new, unopened bottle of ginger ale. Is the pop a solution or a mechanical mixture? Explain.
(b) Jing opens the bottle, and the pop starts to fizz (Figure 2). Is the pop a solution or a mechanical mixture now? Explain why.

22. Ken added a spoonful of salt to a glass of water. He stirred until the water was clear again. What kind of mixture did Ken make? Explain your answer.

23. Tina says, "A solution can have only two different kinds of particles." Deepa says, "A solution can have many different kinds of particles." Whom do you agree with? Explain why.

24. Lakisha says, "You can have a mechanical mixture that has both solids and liquids in it." Kris says, "A mechanical mixture has to be all solids or all liquids, not both." Whom do you agree with? Give an example to explain why.

Solve a Problem!

25. Jayzee's old kettle developed a crusty white layer on the inside after years of boiling tap water (Figure 3). The white solid would not wash out, even with soap and water.

(a) What may have caused the white solid to build up on the inside of the kettle?
(b) If Jayzee buys a new kettle, what could she do to prevent the same white solid from building up in this kettle as well?

Create and Evaluate!

26. Create a rap, rhyme, or jingle describing the particle theory, then explain how well your rap, rhyme, or jingle describes the particle theory.

Reflect on Your Learning

27. In this chapter, you learned about pure substances, mechanical mixtures, and solutions.
(a) Which of these three things do you find the easiest to understand? Explain why.
(b) Which of these three things do you find the hardest to understand? Explain why.
(c) What can you do to help you understand these three things better?

28. Think back to the Key Question on the first page of this chapter.
(a) In a brief paragraph, answer the Key Question. You may use diagrams.
(b) Write one or two more questions about the topic of this unit that you would like to explore.
KEY QUESTION: What are the parts of a solution, and how do the particles of a solution behave?

Looking Ahead

- Solutions are composed of a solvent and one or more solutes.
- Water is called "the universal solvent" because it can dissolve many different kinds of matter.
- The particle theory can be used to explain how a solute dissolves in a solvent.
- "Concentration" describes a solution, and "solubility" describes a solute.
- The skills of scientific inquiry can be used to compare the solubilities of different samples of matter.
- Experimentation skills can be used to determine how to increase the rate at which matter dissolves.

VOCABULARY

- dissolve
- solvent
- solute
- dissolving
- pollution
- soluble
- insoluble
- concentrated solution
- dilute solution
- concentration
- saturated solution
- unsaturated solution
- solubility
A Canadian Tradition

Maple syrup is a traditional Canadian topping for pancakes and French toast. Maple syrup comes from the sap of sugar maple trees. People collect the sap and boil off most of the water. As the water evaporates, the sap becomes thicker, darker, and very sweet.

The First Nations peoples of North America have many stories about maple syrup.

Story 1: Glooskap and the Lazy People
Long ago, the Creator made sugar maple trees. At that time, the sap of the trees was thick and sweet. All you had to do was cut the bark, and syrup dripped out.

One day, the great lord Glooskap walked into a village. To his surprise, it was empty! Glooskap found all the people of the village lying under sugar maple trees, drinking the sweet sap.

"Get up!" said Glooskap. "You need to work!" But everyone ignored him. So Glooskap got water from the river and poured it over the sugar maple trees. The water made the sap thin and not very sweet.

"You are too lazy," Glooskap told the people. "Now you have to work to get maple syrup. You must boil the sap to make it good to eat."

Story 2: The Discovery of Maple Syrup
Many years ago, a man came home from hunting. He threw his hunting axe into a maple tree nearby and went to sleep. While he slept, thin, watery sap dripped into a cooking bowl that was sitting on the ground. The next day, the man's wife began to make stew for dinner. She saw the bowl of sap and added it to her stew. She cooked her stew for a long time.

When the man and woman ate the stew, they were amazed! The stew was sweet and delicious. From that day on, the woman collected the sap from the sugar maple tree and used it in her cooking.

LINKING TO LITERACY

Making Connections
To gain deeper meaning from your reading, make connections to what you have read before and to your own experiences.

1. Read the introductory paragraph and then describe the process that is used to make maple syrup.

2. What connections can you make between the process used for making maple syrup and each of the myths?

3. What connections can you make to your own experiences? Describe meals or desserts you have tried that were made with maple syrup.
**Solute and Solvents**

Have you ever made iced tea by mixing a powder and water (Figure 1)? If so, did you use more powder or more water to make the drink? You probably mixed a lot of water with a small amount of powder. What kind of mixture is iced tea? It looks like a pure substance, but you know that it contains at least two components (water and tea). It is a homogeneous mixture, or solution. The powder mixes evenly, or **dissolves**, into the water to make the solution.

Most solutions are made by dissolving a small quantity of one type of matter into a much larger quantity of another type of matter. The part that is present in the larger quantity is called the **solvent**. The part that is present in the smaller quantity is called the **solute**. The solutes are the parts of the solution that dissolve. Solutions are generally made by **dissolving** one or more solutes in a solvent.

**Liquid Solutions**

You are probably most familiar with solutions that are liquids. These all have liquid solvents. In food preparation, the solvents are usually liquids like water or vegetable oil. In iced tea, water is the solvent. Water is the most common solvent on Earth.

Other solvents, besides water, are also useful. Ethanol is the solvent in perfume. Turpentine is a solvent that is used with paints. Ethyl acetate is one of the solvents in nail polish (Figure 2).

The solutes that dissolve in liquids may be solids, liquids, or gases. Salt and sugar are common solid solutes. Acetic acid is a liquid solute that can be added to water to form vinegar. Gases such as carbon dioxide and nitrogen dissolve in our blood and are carried around our bodies. Can you think of other solids, liquids, and gases (solutes) that dissolve in liquids to form solutions?
Water: The Universal Solvent

The water from your tap probably looks and tastes like pure water. Tap water is a solution that contains many solutes. These solutes include iron, aluminum, salt, fluorine, calcium, magnesium, and chlorine. How did they get into your tap water? As water flows in rivers and lakes and underground, it comes into contact with many types of matter (Figure 3). Gases from the air and minerals from the rocks and soil dissolve in the water. Pollutants may also dissolve in the water.

Before water reaches your tap, it is cleaned to make it safe for drinking. Chlorine and fluorine are sometimes added to the water. Chlorine kills bacteria, and fluorine may help keep your teeth healthy.

Water probably dissolves more different substances than any other solvent. For this reason, water is sometimes called “the universal solvent.” Water is the solvent in many important solutions.

Water in Your Body

Your body is about 70% water. All this water dissolves many different solutes, making a variety of solutions. The solutes include salt, oxygen, sugars, and mineral components such as calcium and potassium. These solutes are able to travel around your body because they are dissolved in water. Blood plasma, sweat, urine, and tears are common solutions produced by your body. Water is the solvent in all of these solutions.

Water around Earth

About 70% of Earth’s surface is covered by water. There is always about the same amount of water on Earth. Water from rivers and oceans evaporates into the air and then condenses to form clouds and precipitation (rain and snow). As water moves around Earth, it dissolves many different solutes. These solutes are transported to almost every part of the world. Figure 4 shows that solutes in water can be absorbed by living things.
Solid Solutions

Not all solutions are liquids. Solutions can also be solids. In a solid solution, both the solvent and the solute are solids. The gold used to make jewellery is often called “14-karat gold.” Pure gold is 24-karat gold, so 14-karat gold is made up of 14 parts of gold to 10 parts of other metals—generally silver, copper, nickel, or palladium (Figure 5). In this case, gold is the solvent and the other metals are the solutes.

Solid solutions are called “alloys” when they contain two or more metals. To make alloys, the metals are heated until they melt, and then they are mixed together and allowed to cool. Brass is an alloy of copper and zinc (Figure 6). Bronze is an alloy of copper and tin. In both brass and bronze, copper is the solvent. What are the solutes?

Gas Solutions

The air you breathe is about 78 % nitrogen gas, 21 % oxygen gas, and 1 % argon gas, along with smaller amounts of other gases like carbon dioxide. Air is therefore a solution that is a gas. What is the solvent of this solution? What are the solutes?

In all gas solutions, both the solvent and the solutes are gases. Other gas solutions include the gasoline-air mixture in a car engine, and the perfume that you may smell in the air as someone walks by you.

During Reading: Comparisons

You have now read about three different types of solutions: liquid, solid, and gas. How are these similar? How are they different? How does making comparisons help you to deepen your understanding of solutions?

Figure 5 Yellow gold is a solid solution of solutes (silver and copper) in a solvent (gold).

Figure 6 Brass is an alloy (a solid solution) of copper and zinc.

TRY THIS: Identify Solutions at Home

SKILLS MENU: observing, analyzing, communicating

A. Try to identify the solvent and the solute for each solution. If they are not listed on a label, use the Internet to help you find out. Remember that the solvent is always the largest ingredient in a solution. To learn more about the contents of household products,

Go to Nelson Science

B. Present your discoveries in a table.

To smell any substance, hold it away from you and, using your hand, waft the scent toward your nose. Never directly inhale an unknown substance.

There are many household products that you use everyday. Can you tell which ones are solutions?

1. Search at home for two liquid solutions, two solid solutions, and two gas solutions. Examples might include clear shampoo, cleaning products, medicines, clear juices, gold jewellery, objects made of brass, bronze, or steel, and anything that you can smell!
Water Pollution

Plants and animals get some of the nutrients they need from water. However, water can dissolve pollutants, too. Pollution includes any pure substance or mixture that contaminates the natural environment. Polluted water is a mixture of pure water and pollutants. Figure 7 shows how pollutants can enter water from various sources.

It is very important to keep the water in our lakes, rivers, and oceans clean, so that organisms can grow and live there normally. We all have to be careful not to let contaminants get into our water.

Figure 7 Sources of water pollution

Unit Task  How will you use the information about solutes and solvents in this section when you start to work on the Unit Task?

CHECK YOUR LEARNING

1. In your own words, define solute and solvent.
2. Ocean water is a solution. It contains about 96 % water, 4 % salt, and very small amounts of other salts and minerals.
   (a) What is the solvent in ocean water?
   (b) What are the solutes in ocean water?
3. (a) List one solution that is a solid, one solution that is a liquid, and one solution that is a gas.
   (b) For each solution, describe the solvent and the solute(s).
4. A sealed bottle of soda water contains carbon dioxide gas dissolved in water. When you open the bottle, the gas bubbles out of the solution.
   (a) What is the solvent in soda water? How do you know?
   (b) What is the solute?
5. How is water an important solvent in the body?
6. (a) What is pollution?
   (b) Name four ways that pollutants enter water.
Dissolving and the Particle Theory

Here is a demonstration you can try at home. Fill a glass with milk. Next, slowly add popped corn to the milk, one piece at a time. How much popcorn can you add before the milk overflows? Figure 1 shows that you can add a lot! Why is the volume almost the same even though you are adding more matter to the glass?

TRY THIS: Where Does the Sugar Go?

**SKILLS MENU:** performing, observing, analyzing, evaluating

In this activity, you will observe what happens to the volume of mixtures when two substances are combined together.

**Equipment and Materials:** graduated cylinder (100 mL); 50 mL measuring cup; plastic graduated cylinder (250 mL); stirring rod; sugar; water; sand; marbles

1. Predict the total volume of a mixture of 50 mL of sugar with 100 mL of water.
2. Measure 50 mL of sugar into a 250 mL graduated cylinder. Measure 100 mL of water in the smaller graduated cylinder.
3. Add the water to the sugar. Stir for 1 to 2 min. What is the total volume?
4. Repeat this activity using sand to represent water particles and marbles to represent sugar particles.

A. Explain what you think happened to the water and sugar particles when they were mixed.
B. How does the sand and marble model help you explain what happened to the sugar and water particles?

You can use the particle theory to help explain what happens when solutes dissolve. Go back and reread the particle theory in Table 1 in Section 1.1. The particle theory states that there are spaces between all particles. This means that, in a sample of water, there are many water particles, but also many empty spaces. The same is true in a sample of sugar. When you look at sugar, you can see many grains, or crystals, of sugar. Each sugar crystal contains enormous numbers of invisible sugar particles. When sugar dissolves, the sugar particles separate and mix with the water particles.

Figure 2 shows a model of sugar particles dissolving in water particles. As the sugar particles separate, the smaller water particles fit into the spaces between the larger sugar particles. The water and sugar particles are attracted to each other, so they move closer together when they are mixed. This is why the total volume is often slightly less than the volumes of the two separate components.
Sugar particles are attracted to water particles, but what happens if the particles of one pure substance are not attracted to the particles of another pure substance? For example, will sugar dissolve in other solvents as easily as it dissolves in water (Figure 3)? You can explore this question in the following activity.

**TRY THIS: Compare Different Solvents**

**SKILLS MENU:** performing, observing, analyzing, evaluating, communicating

In this activity, you will compare how sugar dissolves in three different liquids: water, rubbing alcohol, and oil. If a solid dissolves in a liquid, then you have a solute and a solvent. This tells you that the solute and solvent particles are strongly attracted to each other—even more strongly than the particles of the solute are attracted to each other. What will happen if the particles are not strongly attracted to each other?

**Equipment and Materials:** apron; small clear glass; small spoon; 3 liquids (water, rubbing alcohol, oil); sugar

Rubbing alcohol is poisonous and flammable. Do not sniff or taste it! Make sure there is no open flame in the room.

1. Put on your apron. Pour water into a clear glass to a depth of about 3 cm. Add about half a spoonful of sugar to the water. Stir the mixture. Record your observations.

2. Rinse out the glass. Repeat step 1 using rubbing alcohol instead of water.

3. Rinse out the glass. Repeat step 1 using oil instead of water.

A. Did all of the sugar dissolve in each of the three liquids? How were you able to tell?

B. Which solute and solvent particles are most strongly attracted to each other? How do you know?

C. Which solute and solvent particles are not very strongly attracted to each other? How do you know?

In the Try This activity, you discovered that sugar dissolves better in some solvents than in others. If a solute dissolves in a particular solvent, we say that it is **soluble** in that solvent. If a solute does not dissolve, it is **insoluble**. Sugar, for example, is soluble in water but insoluble in vegetable oil. Think of one solute that is insoluble in water. What does this tell you about the particles of this solute in water?

**Unit Task**

How will you use your new knowledge of how solutes dissolve in the

**CHECK YOUR LEARNING**

1. Use the particle theory to explain what happens when solutes dissolve. Use a diagram in your explanation.

2. Sundeep mixed 300 mL of water with 100 mL of sugar. She says, “The total volume is 300 mL + 100 mL = 400 mL.” Do you agree with Sundeep? Explain why or why not.

3. Define the terms “soluble” and “insoluble.” Give one example of each.

4. Drink crystals are a mixture of sugar, flavour particles, and colouring particles. The crystals dissolve in water.
   (a) What is the solute in this solution? What is the solvent?
   (b) What happens to the different particles as the crystals dissolve in water particles?
Concentration and Solubility

When you eat an apple, do you eat the seeds? Apple seeds contain a very tiny amount of cyanide (Figure 1). Cyanide is a poisonous chemical. Do not worry about being poisoned if you occasionally swallow some apple seeds. The cyanide is present in such tiny amounts that it will not harm you.

Pure substances can be good or bad for you depending on how much of the substance you consume. For example, digitalis is a chemical found in foxglove plants. Doctors sometimes prescribe small amounts of digitalis as a medicine for heart disease.

People used to drink “foxglove tea”—a solution made by soaking parts of the foxglove plant in hot water—to cure some illnesses. But they had to be careful! Drinking foxglove tea with a small amount of digitalis in it could help a person with a weak heart. Drinking foxglove tea with a lot of digitalis in it, however, could harm or even kill a person by making the heart beat too fast. As this example shows, it is important to know how much of a substance there is in a solution. In this section, you will learn how to describe and calculate the quantity of solute in a solution.

Concentrated and Dilute Solutions

The words “concentrated” and “dilute” are used to describe how much solute is in a certain volume of solution. A **concentrated solution** has a large amount of solute in a volume of solution. A **dilute solution** has a small amount of solute in a similar volume of solution. Figure 2 compares a model of the particles of a concentrated solution to a model of the particles of a dilute solution.

![Figure 2](image-url) A concentrated solution contains many more solute particles (shown in green) than the same volume of a dilute solution.
Suppose you and a friend are making fruit punch (Figure 3). You add one spoonful of drink powder to a glass of water. Your friend adds six spoonfuls of drink powder to an identical glass of water. Which solution will be concentrated? Which solution will be dilute?

**Calculating Concentration**

The **concentration** of a solution is the quantity of solute in a certain volume of solution. The more solute dissolved, the greater the concentration. Suppose 100 mL of solution contains 5.0 g of sugar. The concentration of sugar in that solution is 5.0 g/100 mL.

One way to express the concentration of liquids is as the mass of solute (in grams) per 100 mL of solution. The equation for this is

\[
\text{concentration} = \frac{\text{mass of solute in grams}}{100 \text{ mL of solution}}
\]

The following Sample Problem shows how to calculate the concentration of a solution.

**SAMPLE PROBLEM: Calculate Concentration**

Suppose a solution contains 6.0 g of sugar in 200 mL of sugar-and-water solution. What is the concentration of the sugar-and-water solution?

*Given:* mass of solute = 6.0 g
volume of solution = 200 mL

*Required:* concentration of the solution

*Analysis:* concentration = \( \frac{\text{mass of solute in grams}}{100 \text{ mL of solution}} \)

*Solution:* concentration = \( \frac{6.0 \text{ g}}{200 \text{ mL}} \)
Remember to divide both the numerator and the denominator by 2 to get concentration per 100 mL.
concentration = \( \frac{3.0 \text{ g}}{100 \text{ mL}} \)

*Statement:* The concentration of the sugar-and-water solution is 3.0 g/100 mL.

*Practice:* Calculate the concentration of a solution made by mixing 4.5 g of baking soda in enough water to form 50.0 mL of solution. (Remember that the formula calculates the concentration of 100 mL of solution, so you may have to change the volume in your calculation.)

**Saturated and Unsaturated Solutions**

What would happen if your friend continued to add drink powder to the glass of fruit punch? Eventually, no more powder would dissolve. The solution would be saturated. A **saturated solution** is a solution in which the maximum amount of solute has been dissolved. An **unsaturated solution** is a solution that still has room for more solute to dissolve.

---

**saturated solution:** a solution in which no more solute can dissolve

**unsaturated solution:** a solution in which more solute can be dissolved
TRY THIS: Make a Saturated Solution

SKILLS MENU: performing, observing, analyzing

How much drink powder does it take to make a saturated solution?

**Equipment and Materials:** apron; graduated cylinder (100 mL) or measuring cup; clear glass; 5 mL measuring spoon; water at room temperature; drink crystals

1. Put on your apron. Measure 100 mL of water into the glass. Add exactly 1 spoonful of drink crystals (5 mL), and stir.
2. Continue adding spoonfuls of crystals, stirring after each one. Count the number of spoonfuls you add. Stop adding crystals when no more will dissolve.

**A.** How many spoonfuls of drink crystals dissolved in the water?

**B.** One spoonful of drink crystals has a mass of about 4 g. Calculate the mass of the crystals that dissolved in 100 mL of water to form a saturated solution.

**C.** If you had 200 mL of water, what mass of drink crystals would you need to make a saturated solution?

---

**Solubility**

You now know that there is a limit to the amount of solute that can dissolve in a solvent. Chemists call this amount the **solubility** of a solute: the maximum amount of solute that will dissolve in a given volume of solvent at a particular temperature. When this amount of solute has dissolved, a saturated solution has been formed. Solubility can be measured in grams of solute per 100 mL of solvent at room temperature. The mathematical equation is

\[
\text{solubility} = \frac{\text{maximum mass of solute that will dissolve, in grams}}{100 \text{ mL solvent at a certain temperature}}
\]

Remember the distinction between concentration and solubility. Concentration is measured in grams of solute per 100 mL of solution (g/100 mL solution), but solubility is measured in grams of solute per 100 mL of solvent (g/100 mL solvent). Different solutes have different solubilities, as Table 1 shows. The solubility of a solute changes depending on different factors. In the next section, you will investigate some of the factors that affect solubility.

**Table 1 Solubility Table**

<table>
<thead>
<tr>
<th>Solute</th>
<th>Solubility in water at 20 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>sugar</td>
<td>204 g/100 mL of water</td>
</tr>
<tr>
<td>salt</td>
<td>36 g/100 mL of water</td>
</tr>
</tbody>
</table>

**CHECK YOUR LEARNING**

1. You learned several new terms in this section.
   (a) Which term was the easiest for you to remember? Why?
   (b) Which term was the hardest for you to remember? Why?
   (c) How can you make the term (your answer to (b)) easier to remember? Share your strategy with a classmate.

2. Define each of the following terms in your own words:
   (a) concentrated solution
   (b) dilute solution
   (c) saturated solution
   (d) unsaturated solution
   (e) solubility

3. How are the terms “solubility” and “saturated” similar? How are they different?

4. What is the important difference between how concentration and solubility are measured?

5. Which solute is more soluble: sugar or salt? (Refer to Table 1.)

6. Kai has 200 mL of water at room temperature. How much salt can she dissolve in the water? (Refer to Table 1.)
Pharmaceuticals

Have you taken any medicine recently? A spoonful of cough syrup, some antacid for an upset stomach, or a traditional herbal infusion? All liquid medicines are solutions. Usually, the active ingredient in the medicine is the solute. The solvent is just there to keep the medicine well mixed, easy to measure, and easy to swallow (Figure 1).

**Figure 1** Children often find it easier to swallow medicine as a liquid than as a pill.

Until the early twentieth century, most medicines were made by pharmacists in their own shops. Now, big drug companies have taken over this role. These companies employ teams of doctors, pharmacists, chemical engineers, and lab technicians to develop and manufacture the medicines (Figure 2).

**Figure 2** The development team makes sure that it is easy to take the correct dose.

Many liquid medicines contain water as the solvent. Sometimes, however, an active ingredient does not dissolve well in water. In that case, a different solvent has to be used, such as ethanol. The pharmaceutical industry selects solvents very carefully. They must dissolve the active ingredient without changing it, and the solvent must not be harmful to the person taking the medicine.

Besides medicines that you take by mouth, you might have seen pharmaceuticals in liquid form that can be administered in other ways: by injection, as topical applications, in eye drops or ear drops, or through nasal sprays or inhalers. For example, creams and ointments like sunscreen are often made with oily solvents. These solvents help the active ingredients to stay on your skin longer than they would if the solvent were water.

The pharmaceutical industry and Health Canada closely monitor the components and concentrations of most pharmaceutical solutions. This assures us that the medicines are safe and effective.

To learn more about pharmaceuticals and careers in this field,
Solubility

In this activity, you will compare the solubility of Epsom salts and table salt in both cold and hot water by preparing saturated solutions and taking careful measurements.

**Purpose**
To explore the relationship between solubility and temperature.

**Equipment and Materials**
- apron
- eye protection
- large beaker
- glass stirring rod
- thermometer
- graduated cylinder (50 mL)
- beaker (100 mL)
- balance
- 5 mL measuring spoon
- weighing papers
- electric kettle
- water
- ice cubes
- Epsom salts
- table salt
- 5 mL measuring spoon
- weighing papers
- electric kettle
- water
- ice cubes
- Epsom salts
- table salt
- 5 mL measuring spoon
- weighing papers
- electric kettle
- water
- ice cubes
- Epsom salts
- table salt

**Procedure**
1. In your notebook, draw a table similar to Table 1.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Analysis of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Epsom salts</td>
</tr>
<tr>
<td>Before adding</td>
<td>Volume of</td>
</tr>
<tr>
<td>to water</td>
<td>beaker with water added (g)</td>
</tr>
<tr>
<td>After adding</td>
<td>Mass of beaker with water added (g)</td>
</tr>
<tr>
<td>to water to</td>
<td>form saturated solution (g)</td>
</tr>
<tr>
<td>added salt</td>
<td>Mass of salt added to water (g)</td>
</tr>
<tr>
<td>Temperature of solution (°C)</td>
<td></td>
</tr>
<tr>
<td>Solubility of salt in water at recorded temperature</td>
<td></td>
</tr>
</tbody>
</table>

2. Put on your apron and eye protection.
3. Prepare cold water by placing some ice cubes in a glass or beaker of cold tap water and stirring until the water temperature is close to 0 °C.
4. Use a graduated cylinder to pour 50 mL of the ice-cold water into a 100 mL beaker.
5. Measure the mass of the beaker and water on a balance and record the mass in Table 1.
6. Scoop approximately 20 mL of Epsom salts onto a weighing paper.
7. Place a small amount of the Epsom salts (enough to fit on the end of a spoon) in the water. Stir until all the crystals have dissolved.
8. Repeat step 7 until some crystals remain at the bottom of the beaker, no matter how thoroughly you stir. The solution is now saturated.

9. Measure the temperature of the saturated solution. Record your observation in Table 1.

10. Measure the mass of the beaker, water, and dissolved Epsom salts using the balance and record in Table 1.

11. Dispose of the solution according to your teacher’s instructions. Return any unused Epsom salts to your teacher. Rinse and dry the beaker.

12. Use a graduated cylinder to obtain 50 mL of hot water from the kettle. Pour the hot water into the dry beaker.

**(d)** Compare the solubility that you calculated for table salt in cold water and in hot water. What can you conclude?

**(e)** Compare the solubility of Epsom salts with the solubility of table salt in cold water and in hot water.

**(f)** What kind of mixture was in the beaker just before you emptied it? Name the components of the mixture.

**(g)** How could you improve the accuracy of your measurements in this activity?

**(h)** When you compare the solubility of table salt in water with the solubility of Epsom salts in water, the one variable that you are changing is the type of salt. You must control all other variables. Which variables were not controlled very well? How could you control these variables better?

### Apply and Extend

**(i)** Apply the particle theory to your observations in this activity. Can the particle theory help you to predict the differences that you observed between the solubilities of table salt and Epsom salts? What do you think are some of the problems in using the particle theory to explain solubility?

**(j)** Think about the results of your investigations for the solubility of table salt and Epsom salts. Suppose you made a saturated solution of table salt in hot water and then cooled the water down. What do you think might happen? Suppose you made a saturated solution of Epsom salts in hot water and then cooled it. What do you think might happen?
Disso ving
Solutes
Faster

Can you change the speed with which sugar dissolves? What can you do to make a sugar cube dissolve faster in water?

**Testable Question**
Write two testable questions that investigate how quickly sugar cubes dissolve in water.

**Hypothesis/Prediction**
For each testable question, make a hypothesis. Your hypothesis should include both a prediction and reasons for your prediction. Use the particle theory to provide a reason for each prediction.

**Experimental Design**
Think about how you will design your experiment. To conduct a fair test, you should only change one variable at a time. For each question, write the one variable that you will change, and the other variables that you will keep constant.

**Equipment and Materials**
You will use sugar cubes and water. Make a list describing what else you will need to test the hypothesis for each of your questions. Figure 1 and Figure 2 might give you some ideas.
Understanding Text Patterns: Procedure
An investigation is written in a way that explains, step by step, how the investigation should be done. Every investigation is designed to test a hypothesis or prediction and to answer a testable question. You then follow a procedure to reach these goals. A procedure is written as a series of steps, much like a recipe. Becoming familiar with this text pattern will help you to understand what you are asked to do when conducting an investigation.

Procedure
1. With your partner, brainstorm how you will investigate each of your testable questions. Write the steps of your procedure.
2. Add to your procedure any necessary safety precautions.
3. Create a table in which to record your observations.
4. Ask your teacher to check and approve your procedure before you continue, and then perform your procedure. Record your observations.

Analyze and Evaluate
(a) Analyze your results and answer your testable questions.
(b) Did your observations support your hypotheses? What happened in each experiment?
(c) Use the particle theory to explain what you observed in each experiment.
(d) Evaluate your experimental design. What would you change if you were going to repeat the experiment?
(e) Suggest another testable question to investigate, relating to speed of dissolving.

Apply and Extend
(f) In this investigation, you found ways to make solutes dissolve faster. Describe how you use one of these ways in your everyday life.
(g) Think of one way in which your discovery could be used by an industry making products.
(h) You may sometimes want a solute to dissolve slowly instead of quickly (Figure 3). For example, when you take a pill, you may want it to dissolve in your stomach and not in your mouth. Think about the last time you took medicine in the form of a pill. What did the pill manufacturer do to keep the pill from dissolving too quickly?

Figure 3 Some pills dissolve quickly. What would you do if you wanted the pill to dissolve slowly?

Unit Task
You have now learned about the speed at which solutes dissolve, and what factors change this speed. How might this be useful when you start to work on the Unit Task?
Solutions

Looking Back

Solutions are composed of a solvent and one or more solutes.

- Solutions may be solids, liquids, or gases.
- Examples of common solvents include water, ethanol, copper, and nitrogen gas.
- Examples of common solutes include sugar, salt, tin, and oxygen gas.

Water is called “the universal solvent” because it can dissolve many different kinds of matter.

- Water is the solvent in many solutions produced by the body, including blood plasma, tears, and urine.
- Water dissolves minerals and nutrients, making them available to plants and animals.
The particle theory can be used to explain how a solute dissolves in a solvent.

- The particle theory states that matter is made up of tiny, invisible particles, and that particles have empty spaces between them.
- When a solute dissolves in a solvent, the particles of the solute separate from each other and become evenly mixed with the particles of solvent.
- The particle theory states that particles attract each other. The attraction between solute and solvent particles explains why solutes dissolve.

“Concentration” describes a solution, and “solubility” describes a solute.

- Concentration is a measure of the quantity of solute in a given volume of solution, often expressed as

\[
\frac{\text{mass of solute (g)}}{100 \text{ mL of solution}}
\]

- Solubility is a measure of the quantity of solute that can be dissolved in a given volume of solvent at a certain temperature, often expressed as

\[
\frac{\text{mass of solute (g)}}{100 \text{ mL of solvent}}
\]

- A concentrated solution contains more solute than does the same volume of a dilute solution.
- Solubility is different for different pure substances and at different temperatures.

The skills of scientific inquiry can be used to compare the solubilities of different samples of matter.

- Solubility can be determined by creating saturated solutions and taking careful measurements.
- Solubility can be affected by changing the temperature of the solvent.

Experimentation skills can be used to determine how to increase the rate at which matter dissolves.

- The rate at which matter dissolves can be investigated by changing one variable (such as temperature or speed of stirring), while keeping all other variables constant.
What Do You Remember?

1. Use each of the following terms appropriately in a sentence. (Write one sentence for each term.)
   (a) dissolve  
   (b) solute  
   (c) solvent  
   (d) concentrated  
   (e) dilute  
   (f) solubility

2. (a) List three examples of common solvents.  
    (b) List three examples of common solutes.

3. Which of the solutions in Figure 1 is concentrated? Which solution is dilute? Explain.

4. Hassan dissolved a spoonful of salt in a glass of water.
   (a) Draw a labelled diagram showing the particles in Hassan’s solution.
   (b) Explain your picture.
   (c) What is in the space between the particles?

5. Figure 2 shows a green solid in a glass of water. After a while, the green solute dissolves in the water.
   (a) Draw a picture of the final solution.  
   (b) Explain your drawing.

6. Ling is dissolving some sugar cubes in water. List three things Ling can do to dissolve the sugar cubes faster.

What Do You Understand?

7. Look back at the information about maple syrup in the chapter opening.
   (a) Why is maple syrup an example of a solution?  
   (b) What is the solvent in maple syrup?  
   (c) What are some of the solutes in maple syrup?  
   (d) Is maple syrup more or less concentrated than maple sap? Explain why.

8. Jordan's iced tea contains 96 % water, 3 % sugar, and 1 % caffeine and other tea flavours.
   (a) What is the solvent of this solution?  
   (b) What are the solutes in this solution?

9. Why is water “the universal solvent”?

10. Malcolm dissolves 50 mL of drink powder in 150 mL of water. He is surprised that the final volume is only 170 mL.
    (a) Why do you think Malcolm is surprised at the final volume?  
    (b) Use the particle theory to explain Malcolm’s observation.

11. Your teacher gives you a solution of salt in water. How can you find out if it is a saturated solution?

12. Raven is vigorously stirring a mixture of sand and water. She says, “As long as I keep stirring, the sand stays dissolved in the water.” Do you agree with Raven? Explain why or why not.
13. Mohan dissolved a lot of sugar in a glass of water until no more sugar would dissolve. Mohan says, “This is a saturated solution.” Raven says, “It is a concentrated solution.” Are both correct? Explain your answer.

14. Matt thought of a model to help explain concentrated and dilute solutions. He said, “A concentrated solution is like a swimming pool full of people. A dilute solution is like the same swimming pool with only a few people in it.”
(a) What part of Matt’s model represents the solute particles?
(b) What part of Matt’s model represents the solvent?
(c) Do you think Matt’s model does a good job of explaining concentrated and dilute solutions? Explain why or why not.

Solve a Problem!
15. The solubility of sugar in water at room temperature is 204 g/100 mL.
(a) How much sugar will dissolve in 100 mL of water at room temperature?
(b) How much sugar will dissolve in 2000 mL of water at room temperature?

16. A coffee shop attendant added instant coffee powder to hot water until no more would dissolve. He added 30 g of powder to 100 mL of water. What is the solubility of the instant coffee powder in hot water?

17. Malcolm added table salt to water until no more would dissolve. He added 108 g of salt to 300 mL of water. What is the solubility of the table salt in water at that temperature?

18. Calculate the concentration (in g/100 mL) of each of the following solutions:
(a) 3 g of sugar in 100 mL of solution
(b) 10 g of sugar in 50 mL of solution
(c) 54 g of sugar in 200 mL of solution

Create and Evaluate!
19. A vegetable soup recipe requires one teaspoonful of salt. A chef accidentally puts in one tablespoonful. Now the soup is much too salty.
(a) What can the chef do to reduce the salty taste of the soup?
(b) What effects would your suggestion in (a) have on the soup?

20. Think back to Matt’s models of solutions in question 14.
(a) Create your own model to help explain concentrated and dilute solutions. Here are a few ideas you could use:
- cereal flakes in milk
- people in a park
- leaves on a tree
(b) Evaluate your model.

Reflect on Your Learning
21. In this chapter, you learned a lot about solutions.
(a) Create a t-chart with the headings “Easy to Understand” and “Hard to Understand.”
(b) Which of the ideas in this chapter were the easiest to understand? List these in your t-chart.
(c) Which of the ideas were the hardest to understand? List these in your t-chart.
(d) Draw pictures of one idea that you found easy to understand, and one idea that you found difficult to understand. Share your drawings with the class.

22. Think back to the Key Question on the first page of this chapter.
(a) In a brief paragraph, answer the Key Question. You may use diagrams.
(b) Write one or two more questions about the topic of this unit that you would like to explore.