8.0 Mixtures and solutions can be analyzed through concentration, solubility, and separation.

Chemists can use colour as an indicator to help determine the solubility and concentration of solutions.

What You Will Learn

In this chapter, you will:

- identify the components of a solution
- describe the concentration of a solution in qualitative and quantitative terms
- describe the difference between saturated and unsaturated solutions
- describe the processes used to separate mixtures or solutions into their components

Skills You Will Use

In this chapter, you will:

- use scientific inquiry/experimentation skills to investigate factors that affect the solubility of a substance and the rate at which substances dissolve
- use scientific inquiry/experimentation skills to investigate the properties of mixtures and solutions

Why This Is Important

Preparing your favourite meal involves understanding the properties of the mixture. Concentration and solubility can affect the taste and quality of the meal.

Before Reading

Thinking Literacy

Monitoring Comprehension

A **KTW** chart is used to identify what you already **K**now about a topic, what you **T**hink you know, and what you **W**ant to know. Complete a KTW chart for the properties of mixtures and modify it as you read the chapter to monitor your comprehension.

Key Terms

- concentration
- distillation
- filtration
- saturation
- solubility
- solute
- solvent
- supersaturated

8.0 Getting Started

Figure 8.1 Unsafe drinking water in Walkerton caused the deaths of seven people.

When you take a drink of water, you assume that it will not make you sick. The people of Walkerton, Ontario, thought their water was safe (Figure 8.1). But between May and July 2000, seven people in the town died because they drank contaminated water. More than 2000 people became ill. The government of Ontario made safe drinking water a priority because of the tragic events that took place in Walkerton.

To purify drinking water, various components of the mixture that make up untreated water must be separated and removed. The separation process is complex and involves many stages, including treatments that sort particles by size. The process eventually requires mixing the water with chemicals to kill bacteria and other harmful living components (Figure 8.2 on the next page).

Through research involving separation of mixtures, water purification experts have improved the processes for purifying drinking water. Many industrial processes also rely on an understanding of mixtures and solutions. Examples include separating metals and minerals from mined rocks and separating oils and oil products from crude oil. Many common household products and items that you use every day, such as dishwashing detergent, hair gel, and snack foods, have come about as a result of industrial uses of mixtures.

Wise use of consumer products is enhanced by understanding key ideas about mixtures and solutions. In this chapter, you will learn about different aspects of, and methods of separating, mechanical mixtures and solutions.

Figure 8.2 The components of the mixture that make up untreated water must be separated and removed.

C14 *Quick Lab*

Making a Solution

Many solutions involve mixing a substance in a liquid until the substance is completely dissolved. For example, you can mix powdered drink crystals with water to make a refreshing drink.

Purpose

To see what is involved in making a solution

Materials & Equipment

- 50-mL or 100-mL graduated cylinder
- water (room temperature)
- beaker
- 5-mL measuring spoon
- powdered drink crystals
- stir stick

CAUTION: Do not taste anything during this activity.

Procedure

1. Use the graduated cylinder to measure 50 mL of water into the beaker.
2. Use the measuring spoon to measure 5 mL of the powdered drink crystals. Add the drink crystals to the water.
3. Stir the mixture until the substance has dissolved. Record your observations in a table similar to the one below.

Table 8.1 Making a Solution

Amount Added	Observations
5 mL	

4. Keep adding the drink crystals, 5 mL at a time, until they will not dissolve in the water.

Questions

With a classmate or as a whole class, discuss the following questions.

5. How did you know that you could not dissolve more drink crystals in the water?
6. How did stirring the water affect the dissolving of the drink crystals in the water?

8.1 Solutions: Concentration and Solubility

Here is a summary of what you will learn in this section:

- The concentration of a solution can be described in qualitative and quantitative terms.
- Solutes and solvents can be identified in various kinds of solutions.
- Water is sometimes referred to as the universal solvent.

Figure 8.3 Common ingredients used in baking can form solutions with water.

Cooks and chefs prepare and follow recipes for meals that call for specific amounts of ingredients (Figure 8.3). When those ingredients are properly mixed together, they produce great-tasting foods. For example, experienced cooks understand that just the right amount of salt dissolved in water will produce a desired taste. Too much salt may not completely dissolve in the amount of water necessary, or it may produce a flavour that is too salty. An understanding of concentration and solubility is necessary to prepare foods properly.

C15 *Starting Point* Skills P C

Dissolving Common Kitchen Ingredients in Water

Salt, baking soda, and sugar are common ingredients used in baking. However, they dissolve in water at different rates.

Work with a partner. One person will perform the experiment, while the other will measure time and record the data in a notebook. Obtain a beaker or glass with 50 mL of water at room temperature. Measure 5 mL of one of the ingredients listed above. After the substance is added to the water, measure the amount of time required for it to dissolve in the water.

Record the colour and clarity of the solution. Repeat your procedure for the other ingredients, and then answer the following questions.

1. Which ingredient took the least amount of time to dissolve in water?
2. Which ingredient took the most time to dissolve in water?
3. Were all solutions identical in appearance? If not, what was the difference?

C16 During Reading

Thinking Literacy

Pause and Check

Readers can do many things when they realize their understanding of a concept is breaking down. On this page, you are reading about the two components of solutions: the solute and the solvent. Can you distinguish between these two things? Focus on the solute and create a two-column chart to record "What It Is" and "What It Is Not." Add information from the text to your chart. What do you notice about the column entitled "What it is not"? What is it describing?

Solutions

As you learned in the previous chapter, a solution is a homogeneous mixture because it has the same appearance throughout. Solutions can occur as solids, liquids, or gases. Solid solutions are called **alloys** (Figure 8.4). Liquid and gaseous solutions are simply called **solutions**.

Figure 8.4 The brass door knocker is a mixture of copper and zinc.

Solutions consist of solutes and solvents. A **solute** is the substance that dissolves. A **solvent** is the substance into which the solute dissolves. The solvent is usually the substance present in the greatest amount. For example, in the air you breathe, nitrogen is found in the greatest amount. It is the solvent into which solutes such as oxygen, argon, and carbon dioxide dissolve. In seawater, salt and other substances (solutes) dissolve in water (solvent). Examples of common solutions are shown in Table 8.2.

Table 8.2 Examples of Common Solutions

Solute	Solvent	Solution
zinc (solid)	copper (solid)	brass
salt, minerals (solid)	water (liquid)	seawater
benzene (liquid)	rubber (solid)	rubber cement
ethylene glycol (liquid)	water (liquid)	antifreeze
carbon dioxide (gas)	water (liquid)	soft drink
oxygen, argon (gas)	nitrogen (gas)	air

Water — The Universal Solvent

Water is often referred to as the universal solvent because many different solids, liquids, and gases dissolve in it to form solutions. For example, seawater is a solution of water with many dissolved solids, such as salt and magnesium, and gases, such as oxygen and carbon dioxide.

Not all substances are soluble in water. For example, many oils and fats do not dissolve in water. However, you can remove fats and oils from clothes and dishes by using a solution of soap or detergent in water. These cleansers break up the fats and oils so they can be washed away.

C17 Learning Checkpoint

Components of Solutions

1. Name three types of solutions — one solid, one liquid, and one gas.
2. Identify three common solutions used in the kitchen. List the solutes and solvents found in each solution.
3. Name a substance that dissolves in water. How can you prove that it is water soluble?
4. Make a list of three substances that cannot dissolve in water. For each substance, identify a solvent in which it will dissolve.

Suggested Activity
C18 Quick Lab on page 218

Take It Further

Most clothing is washed in water using laundry detergent. Most detergents work best in hot water. Some fabrics (e.g., wool) can be damaged by the heat from hot water (and hot air in dryers). Dry cleaners use different solvents to clean clothing. Find out more about these solvents. Begin your search at ScienceSource.

Solubility

Solubility is the relative ability of a solute to form a solution when added to a certain solvent. It is also defined as the maximum amount of solute you can dissolve in a fixed amount of solvent at a given temperature. To form a solution, the solute particles must be attracted to the solvent particles, which allows the particles to spread evenly throughout the solution. For example, salt dissolves in water because the salt particles are attracted to the water particles (Figure 8.5, left). This forms a saltwater solution.

However, salt does not dissolve in olive oil because the salt particles are not attracted to the oil particles (Figure 8.5, right). When a substance does not dissolve in a solvent, that substance is **insoluble** in that solvent. A solution is not formed by the combination of the two substances when one of the substances is insoluble in the other other.

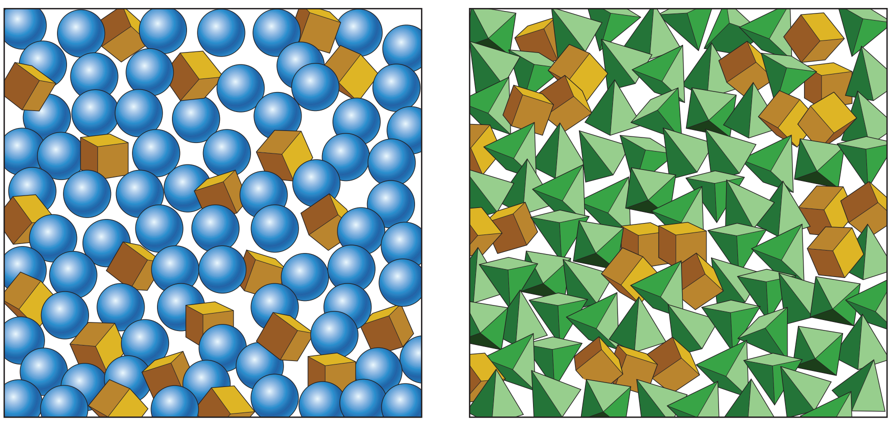


Figure 8.5 (Left) Salt (brown) dissolves in water (blue) because the particles are attracted to one another. (Right) Salt particles (brown) form clumps and do not dissolve in olive oil (green) because the particles are not attracted to one another.

Concentration — Qualitative

The amount of solute in a solvent can be expressed in qualitative terms. A **concentrated solution** is a solution that contains a large amount of dissolved solute and very little solvent. For example, frozen juice concentrate is a concentrated solution of orange juice solids (solute) and a small amount of water (solvent). A **dilute solution** has very little solute dissolved in the solvent. By adding water (solvent) to the frozen juice concentrate (solute), you would be diluting the frozen orange juice. This would create a diluted solution of orange juice (Figure 8.6).

Figure 8.6 Frozen orange juice is diluted with water to form an orange juice solution.

Concentration — Quantitative

The **concentration** of a solution is the amount of solute dissolved in a specific amount of solvent. For example, if 5 g of salt are dissolved in 500 mL of water, the concentration of the solution is 5 g/500 mL (or 1 g/100 mL). This can be read as "five grams per five hundred millilitres" or "one gram per one hundred millilitres." We could also call this a 1 percent solution. For example, a concentration of 1 g/100 mL means that 100 mL of the solvent has 1 g of solute dissolved in it.

Saturation

In all solutions, there is a maximum amount of solute that can be dissolved in a given amount of solvent at a given temperature. This is called **saturation**. A **saturated solution** is one that has been formed from the maximum amount of solute for a given amount of solvent at a certain temperature. Every solution has a **saturation point** at a given temperature, which means that no more solute can be dissolved in a fixed volume of solvent at that temperature.

If more solute can be dissolved in a solvent at a given temperature, then the solution is unsaturated. You can dissolve more solute in an **unsaturated solution**. Under certain circumstances, a saturated solution can be cooled below a critical temperature to form a **supersaturated solution**, which contains more solute than would normally be dissolved in the solution.

WORDS MATTER

The prefix "un" means "not." The prefix "super" means "above, beyond or over."

C18 Quick Lab

Soluble or Insoluble

Although they are similar in appearance, salt and sugar do not necessarily share similar characteristics when it comes to solubility. In this activity, you will investigate if salt and sugar are soluble or insoluble in two different solvents — water and vegetable oil.

Purpose

To determine whether salt and sugar have similar characteristics of solubility in different solvents

Materials & Equipment

- 4 transparent plastic cups or beakers
- pen or marker
- 4 labels
- measuring spoons
- water
- vegetable oil
- salt
- sugar
- 4 stir sticks

Procedure

1. Make a table for your observations similar to the one shown below.

Table 8.3 Solvents, Solutes, and Solubility

Container	Solvent	Solute	Observations
A			
B			
C			
D			

2. Label the 4 containers (i.e., plastic cups or beakers) A, B, C, and D.
3. Use a measuring spoon to pour 5 mL of water into containers A and B.
4. Dry the measuring spoon, and then pour the same amount (5 mL) of vegetable oil into containers C and D.
5. Predict whether each of the solutes will dissolve in one, both, or neither of the solvents. Record your predictions in your notebook.
6. Use a measuring spoon to add 2 mL of salt to containers A and C, and then add 2 mL of sugar to containers B and D.
7. Using separate stir sticks, stir each mixture and carefully observe the contents of each container to determine if some of each of the solutes has dissolved. Record your observations in the table.
8. Once you are done, clean up the materials as directed by your teacher and wash your hands thoroughly.

Questions

9. Which solutes were soluble in which solvents?
10. Were your predictions about the solubility of each combination of solute and solvent correct?
11. Which solvent appeared to be best able to dissolve when the solutes were tested?
12. Use the particle theory of matter to determine why the solutes dissolved as observed.
13. Use the particle theory of matter to explain why water is a very good solvent for many different solutes.

8.1 CHECK and REFLECT

Key Concept Review

1. Explain how a metal alloy is a solution. Provide one example of a metal alloy.
2. Explain how to change a dilute solution to a concentrated solution.
3. Explain the meaning of the terms "saturated," "unsaturated," and "supersaturated" with reference to the amount of solute and solvent in solutions.
4. What is the concentration of a solution, expressed in g/100 mL, if 25 g of solute is dissolved in 40 mL of water?
5. Why is water referred to as the universal solvent? Is this description of water accurate?

Connect Your Understanding

6. Use your understanding of the terms "soluble" and "insoluble" to explain why you must shake a bottle of salad dressing made with oil and vinegar before you use it.
7. Use your understanding of solutes and solvents to explain why a supersaturated solution tends to be unstable and likely to have the solute come rapidly out of solution when shaken or disturbed.

Practise Your Skills

8. In a classroom experiment, 5 g of sugar are added to 50 mL of water. Calculate the concentration of the sugar solution and express your answer in units of g/100 mL.

For more questions, go to ScienceSource.

C19 *Thinking about Science and the Environment*

Solutes and Solvents

Chocolate and peanut butter are solutes that do not dissolve well in water. They are difficult to remove from kitchen cutlery and clothing. Solvents like oil and turpentine stain clothing.

In your notebook, make a list of two solutes and two solvents that might be difficult to clean up or dispose of safely. Identify at least two ways to minimize the impact on the environment of clean-up or disposal of these substances.

8.2 Factors Affecting Solubility

Here is a summary of what you will learn in this section:

- The particle theory of matter explains how solutes dissolve in solvents.
- Solubility is affected by temperature, type of solute or solvent, particle size, and stirring.

Salt has many different uses, and it also comes in different forms. Rock salt is used in water softeners to help remove unwanted particles of dissolved minerals from water (Figure 8.7, top). Table salt is used to add flavour to foods (Figure 8.7, bottom). They both dissolve in water, since salt particles are attracted to water particles, but table salt dissolves more quickly than rock salt.

Solubility is an interesting property of solute particles and their interaction with solvent particles. For example, when you paint with water-based paints, it is easy to clean up and remove the paint from your brush with water. However, oil-based paints do not dissolve in water. Cleaning up is made more difficult because only certain solvents, such as turpentine, will dissolve oil-based paints.

Figure 8.7 Rock salt (top) takes longer to dissolve than table salt (bottom).

C20 *Starting Point*

Skills P C

One Lump or Two Teaspoons

If you have ever eaten at a restaurant or shopped in a grocery store, you may have seen that sugar comes in different forms. You can buy granular (loose) sugar by the bag or packet, and you can also buy sugar cubes. In this activity, you will determine which dissolves more quickly in water: one sugar cube or two teaspoons of granular sugar.

Work with a partner. Measure 50 mL of water into each of two colourless, transparent containers. Then add one sugar cube to one container while your partner adds two teaspoons of sugar to the other container. Do not shake either container or touch them in any way. Determine which sample finishes dissolving first: one sugar cube or two teaspoons of granular sugar.

Solubility and the Particle Theory

In Chapter 7, you learned that all matter is made up of particles. According to the particle theory of matter, those particles are in constant motion. Particles are constantly rotating, vibrating, and moving about from one place to another. In a solution, this means that solute particles are always bumping against other solute particles as well as solvent particles.

Figure 8.8 shows that dissolving a salt crystal begins with water particles bumping into salt particles at the edge of the crystal. The water particles are attracted to the individual salt particles. With constant motion, they are able to free individual salt particles from the larger crystal. Individual salt particles are then carried away by bumping into water particles. This leaves room for other water particles to bump into and carry off other salt particles at the edge of the crystal. The process continues until all the salt particles are surrounded by water particles and are evenly distributed throughout the water.

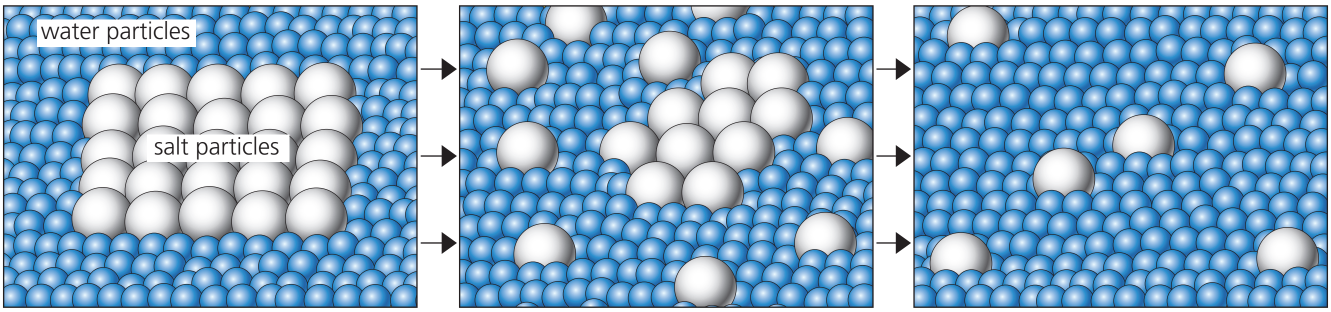


Figure 8.8 The constant motion of particles and the attraction of water particles to salt particles cause salt to dissolve in water.

Rate of Dissolving

How quickly a substance dissolves in a solvent is variable. A teaspoon of table sugar will dissolve rapidly in a hot drink (Figure 8.9). The same amount of sugar will take much more time to dissolve in a glass of ice water. Similarly, table salt dissolves rapidly in water at room temperature. Large pieces of salt, like those used in home water softeners, dissolve much more slowly, which makes this type of salt ideal for use over long periods. The rate of dissolving is affected by stirring, temperature, and particle size.

Figure 8.9 A teaspoon of sugar dissolves quickly in a hot drink.

Suggested Activity
C24 Inquiry Activity on page 225

Stirring

Stirring a solution increases the rate at which a solute dissolves in a solvent. For example, you may have tried to make a soft drink by dissolving flavour crystals in a pitcher of water (Figure 8.10). The flavour crystals are the solute and water is the solvent. If the package of flavour crystals is poured into the water, dissolving begins, but clumps of powder may remain. To speed up the process, you probably used a spoon to stir the water with the flavour crystals. This results in a more uniform arrangement of flavour crystals and water particles and makes dissolving occur more quickly. You can actually see the flavour crystals being stirred until they dissolve in the water. The end result is a solution, as all parts of the soft drink mixture look the same.

Figure 8.11 is a particle diagram of water particles surrounding salt particles. It illustrates how salt particles dissolve more quickly in water that is stirred compared to salt particles in water that is not stirred. As shown in the left part of the diagram, the water particles at the edge of a salt crystal tend to remain near the edge of the crystal. This limits the number of water particles that can interact with individual salt particles and it limits the amount of dissolving that can occur. As shown in the right part of the diagram, stirring the water pushes some of the salt particles surrounded by water particles away from the edge of the crystal and increases the number of water particles that are able to interact with salt particles. Thus, more salt particles are exposed to and come in contact with more water particles. This speeds up the dissolving process.

Figure 8.10 Stirring makes the flavour crystals dissolve more quickly.

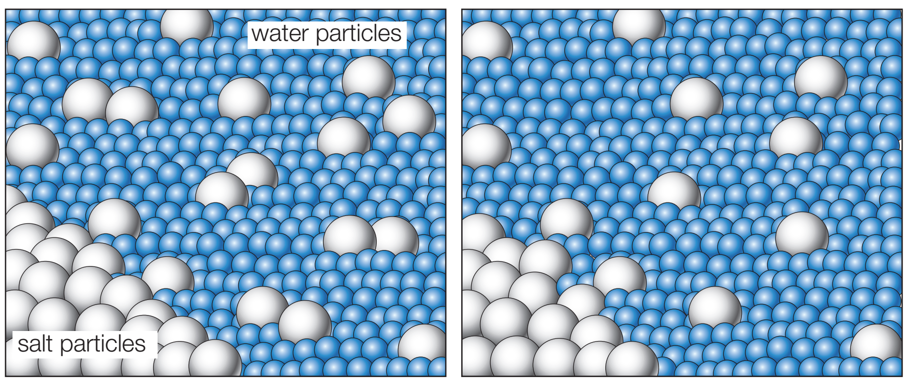


Figure 8.11 (Left) Water particles surround salt particles at the edge of a salt crystal and tend to remain near the edge. (Right) When the water is stirred, more water particles are free to bump into salt particles and surround them.

C21 Learning Checkpoint

Using a Particle Diagram to Explain Rate of Dissolving

John Dalton (1766–1844) was a chemist, meteorologist, and physicist. He is best known for developing ideas about particles. His early records contain particle diagrams, which he used to represent the chemicals he was studying.

In your notebook, make a particle diagram to show why stirring the water and sugar cubes in this glass tends to increase the rate of dissolving of the sugar cubes (Figure 8.12).

Figure 8.12 A particle diagram can help you explain how stirring affects the rate of dissolving of the sugar cubes in the water.

Temperature

As you learned in the previous chapter, temperature affects the speed at which particles move. Particles move more rapidly at higher temperatures, as heat is transferred by the movement of the particles. Since the rate of dissolving depends on solute particles bumping into solvent particles, when the particles move more rapidly, more solvent and solute particles will bump into one another. In addition, the solvent particles at the edge of a piece of solute will more rapidly carry away the solute particles that they meet. This will quickly spread the solute particles throughout the solvent. With increasing temperature, most solutes dissolve more rapidly in most solvents. This explains, for example, why a teaspoon of sugar dissolves more quickly in a cup of hot tea than in a glass of iced tea.

Particle Size

Particle size also affects the rate of dissolving. Large particles take longer to dissolve than smaller particles of the same substance. For example, sugar cubes dissolve more slowly than granular sugar. Similarly, rock salt, which is lumpy, dissolves more slowly than table salt, which is made of tiny crystals. You learned that solvent particles must bump into solute particles for dissolving to occur. Particles of a solvent will contact solute particles at the surface of a clump or crystal of solute particles. Therefore, large pieces of a solute must be broken apart to enable solvent particles to come in contact with solute particles.

Take It ***Further***

To survive, fish need oxygen, which they obtain from oxygen dissolved in the water. Temperature affects the amount of gas that dissolves in liquids. At higher temperatures, the content of oxygen dissolved in water decreases. With climate change and global warming, water temperatures in rivers and lakes are expected to increase. Determine how the increased temperature will affect fish in Ontario and around the world. Begin your search at ScienceSource.

C22 Design a Lab

Toolkit 2

SKILLS YOU WILL USE
- Designing an experimental procedure
- Recording and organizing data

Growing Crystals

Crystals can be grown from solutions made from common solutes with water as the solvent. This is a slow process involving the growth, particle by particle, of a solute on a seed crystal suspended in a supersaturated solution. The resulting crystals are often quite beautiful in colour and demonstrate some of the characteristic shapes of the solute particles from which they are made.

Question

How can you grow crystals from a solution?

Design and Conduct Your Investigation

1. Form a research team with a partner.
2. Decide what type of solute you will select from the following list:
   - sugar
   - salt
   - alum
   - copper sulfate
   - Rochelle salt
3. Determine where you will conduct the investigation.
4. Decide on what apparatus will be needed for you to complete that activity.
5. Make a plan that clearly identifies how you will conduct your investigation, including how much time you intend to spend on the investigation to monitor progress each day.
6. Discuss your plan with your teacher. Once the plan has been approved, conduct the investigation.
7. When your work is finished, be prepared to bring your crystal to class for comparison with others.

C23 Quick Lab

Particle Size and Rate of Dissolving

Purpose

To investigate the effect of particle size on the rate of dissolving

Materials & Equipment

- 5 mL granular sugar
- 5 mL icing sugar
- 50-mL beaker or small jar
- tablespoon
- teaspoon
- water
- stopwatch

CAUTION: Do not taste anything during this activity.

Procedure

1. Use a teaspoon to obtain 5 mL of granular sugar.
2. Place the granular sugar in a small jar or beaker.
3. Add 3 tablespoons of water and determine the time required for granular sugar to dissolve.
4. Repeat steps 1 to 3 with icing sugar.

Questions

5. Which type of sugar dissolved in the shortest time?
6. Were your findings the same as the rest of your class?
7. Use a particle diagram to explain how particle size affects the rate of dissolving.

C24 *Inquiry Activity*

Toolkit 2

SKILLS YOU WILL USE
- Measuring
- Recording and organizing data

Factors Affecting Rate of Dissolving

Question

How do temperature, stirring, and size of particles affect the rate of dissolving?

Materials & Equipment

- rock salt
- 8 small beakers or glasses
- masking tape
- small but sturdy plastic bag
- cold tap water
- warm tap water
- stir sticks

Procedure

1. Read through the procedure. Write your predictions in your notebook about the effect that temperature, stirring, and size of particles will have on the rate of dissolving of the rock salt samples. Use the particle theory to guide your prediction.

2. In your notebook, prepare a table similar to the one shown below.

Table 8.4 Factors affecting rate of dissolving

	Time to Dissolve (s)			
	Cold Water		Hot Water	
Treatment	Stirred	Not Stirred	Stirred	Not Stirred
clumped				
crushed				

3. Obtain eight small beakers or glasses and use masking tape to label four of them Cold Water and the other four Hot Water.

4. Obtain eight clumps of rock salt. Place one clump each in two beakers labelled Cold Water and one each in two beakers labelled Hot Water.

5. Place two clumps of rock salt in a plastic bag and step on it to crush them. Divide the contents of the bag into two empty beakers labelled Cold Water. Crush the last two clumps of rock salt as above and divide the bag's content between two empty beakers labelled Hot Water.

6. Fill one Cold Water beaker with 50 mL of cold tap water. Fill one Hot Water beaker with 50 mL of hot tap water.

7. Without stirring, record the time each sample of rock salt takes to dissolve.

8. Repeat steps 5 and 6 with the other beakers, but this time, stir the water with the stir sticks.

Analyzing and Interpreting

9. Was your prediction for the effect of temperature correct? Explain how you used the particle theory of matter to help with your prediction.

10. Was your prediction for the effect of particle size correct? Explain how you used the particle theory of matter to help with your prediction.

11. Was your prediction for the effect of stirring correct? Explain how you used the particle theory of matter to help with your prediction.

Skill Builder

12. What did you use to measure time for the experiment? Do you feel confident that you were accurate in your measurement of time?

Forming Conclusions

13. Suggest three ways to speed the dissolving of a lump of road salt in water. Use the particle theory to explain how each one works.

8.2 CHECK and REFLECT

Key Concept Review

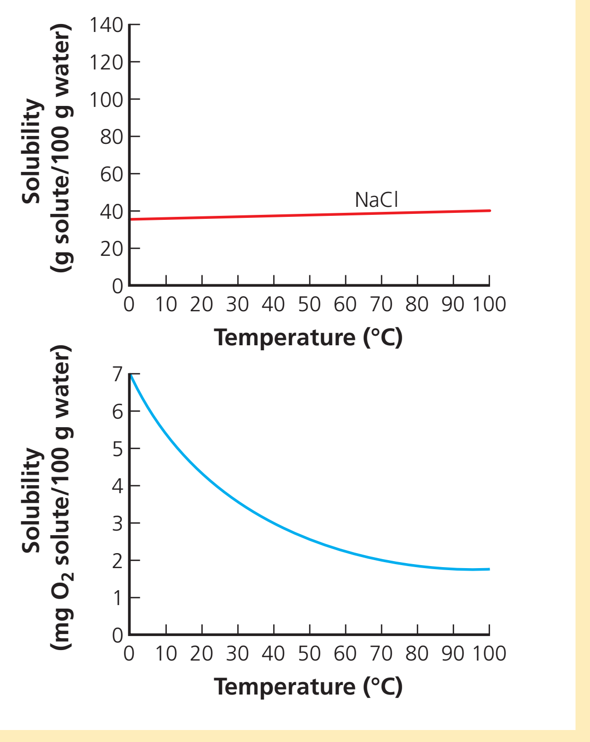
1. Identify two factors about particles that enable them to form solutions.
2. List three factors that influence the rate at which dissolving occurs.
3. Use the particle theory of matter to explain why table salt dissolves more rapidly than rock salt.
4. Use the particle theory of matter to explain why hot chocolate powder dissolves more rapidly in hot water than in cold water.

Connect Your Understanding

5. Use the particle theory of matter to explain why laundry detergents tend to work better in hot water than in cold water.
6. Use the particle theory of matter to explain why icing sugar dissolves more rapidly than granular sugar.

Practise Your Skills

7. Use the particle theory of matter and the information in the graphs below to explain the solubility of solids and gases in liquids.



For more questions, go to ScienceSource.

C25 *Thinking about Science and the Environment*

Winter Safety and Salt on Roads

During periods of cold weather, salt is spread on roads to melt ice and snow and make driving safer. Later, the salt is still present to dissolve in rainwater and flows into wetlands, rivers, streams, and lakes.

1. With a partner, brainstorm some possible environmental problems and record them in your notebook.
2. With a partner, brainstorm possible ways of solving these problems and record them in your notebook.

8.3 Separating Solutions and Mechanical Mixtures

Here is a summary of what you will learn in this section:

- Solutions can be separated by filtration, paper chromatography, evaporation, or distillation.
- Mechanical mixtures can be separated by sorting, sifting, or magnetism.

The manufacturing of cheese involves a process of separating the solid and liquid parts from milk, which is a mechanical mixture. Certain chemicals can be added to milk to cause solid globs called curds to appear and drop away from the liquid part called whey. This process is known as curdling. After this process takes place, the cheese solids can be treated in different ways, usually involving removal of additional water to make many different varieties of cheese (Figure 8.13).

Figure 8.13 Cheese is made by separating milk into different substances.

C26 *Starting Point*

Skills A C

Coffee Filter Chromatography

Obtain a 10-cm strip of coffee filter from your teacher. Draw a line in pencil with a ruler 2 cm from one end. Place a dot of ink from a black marker on the middle of the line. Fill a small container with water to a depth of 1 cm. Place the filter strip in the water with the dot about 1 cm above the water, and tape the strip to a pencil (Figure 8.14).

1. Which colour was carried the farthest? Which colour travelled the least distance?
2. Why did the different colours of ink separate and travel different distances? Use the particle theory of matter to explain your answers.

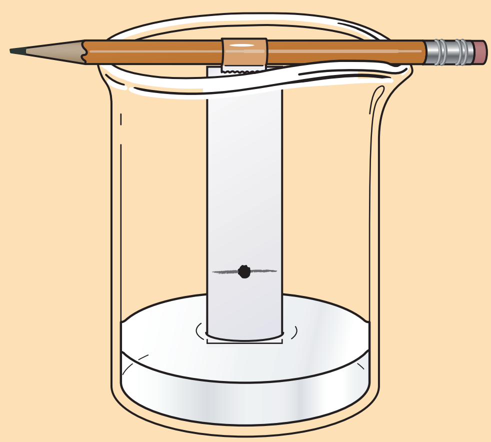


Figure 8.14 Determine which colours of ink move the farthest.

C27 During Reading

Checking the Meaning of Key Words

Slowing the pace of reading, rereading, or pausing to think are effective strategies to monitor comprehension. Checking the meaning of key words is another.

While reading this section, write down a list of terms that you do not understand. You can make vocabulary cards to help you understand their meaning (Figure 8.15). To get you started, here are a few terms from the first part of the section:

- chromatography
- filtration
- distillation
- evaporation

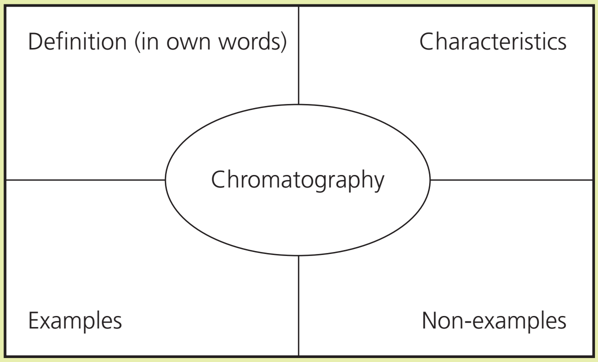


Figure 8.15 Vocabulary cards are useful for helping you to understand terms.

Separating Solutions

The components of a solution have very similar properties and characteristics, which makes them difficult to separate. The most common strategy involves making either the solute or the solvent change state (e.g., changing the solute from solid to liquid) so that it can be removed from the solution.

Paper Chromatography

In **paper chromatography**, a highly concentrated solution is placed on a single spot and is absorbed by the paper. The paper is dipped in a solvent, such as water, so that the spot is above the solvent. The solvent moves through the paper because the solvent particles are attracted to the paper particles and to one another (Figure 8.16). Different substances within the mixture dissolve and are carried by the solvent through the paper. The distance that a substance moves depends on its solubility in the solvent and its attraction to the paper. Different compounds travel different distances from the starting point and become separated.

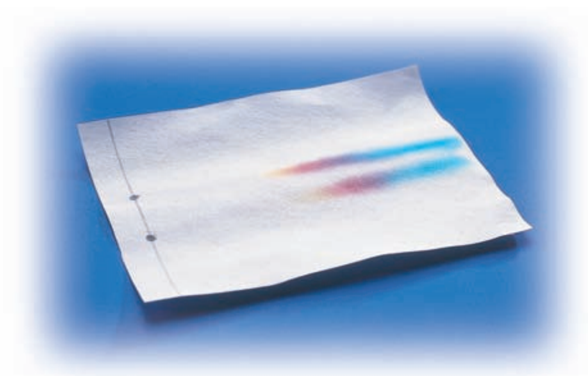


Figure 8.16 In paper chromatography, colours separate based on solubility and attraction to paper.

Evaporation

During the process of evaporation, water particles in a container leave the liquid (as vapour) and mix with surrounding air particles. Figure 8.17 shows that the escaping water particles have more energy and are moving faster than the remaining particles. They have enough energy to escape from the surface of the liquid. If the liquid is a solution, then the concentration of solute will increase because the number of solute particles remains constant while the number of water particles decreases. Over time, if all of the water particles leave the solution, then only the solute particles will be left behind, as they have been separated from the water. Thus, evaporation allows the solute to remain but not the solvent.

You already learned that maple syrup is made by boiling maple sap. This process causes the water in the maple sap to evaporate, which leaves behind a concentrated solution of maple syrup.

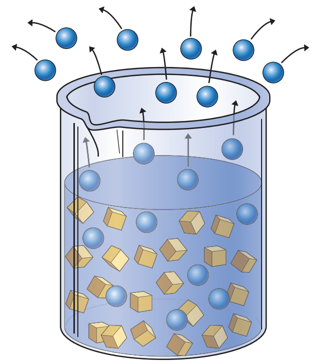


Figure 8.17 Evaporating solvent particles leave solution, while solute particles remain in greater concentration.

Distillation

Distillation enables you to retain both the solute and the solvent from a solution. During the distillation process, the solution is boiled. This vaporizes the solvent (turning it into a gas) and separates it from the solute (Figure 8.18). The solute remains in the original container. Then the solvent gas condenses on a relatively cool surface and is collected. This separation technique is useful for substances with large differences in boiling points.

Some types of bottled water are created by distillation. This process is common when creating drinking water from salt water. Distillation removes the salt from the water, which makes it drinkable.

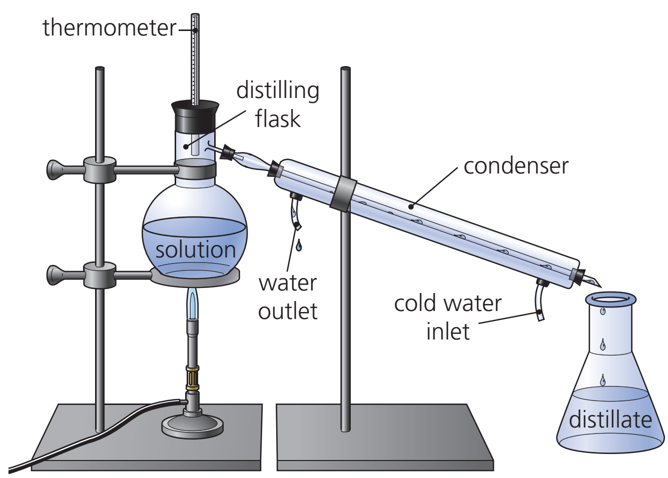


Figure 8.18 Distillation separates substances using boiling and condensation. In this apparatus, cold water is used to cool the vapour in the condenser.

Separating Mechanical Mixtures

Generally speaking, separating mechanical mixtures is easier than separating solutions because the components of the mechanical mixture are usually quite different from each other.

Figure 8.19 Water passes through the filter, but larger particles of dirt are trapped by the filter.

Filtration

Filtration is the mechanical process of separating solids from liquids or gases using a porous article or mass, such as paper or sand. Figure 8.19 shows how a paper filter can be used to separate the solid bits from a mixture of dirt and water. When the mixture is poured into the filter, the solid parts become trapped in the filter, while the water passes through the filter. Salt or other minerals dissolved in the water will pass through the filter and remain in the water.

Automatic coffee makers use a filter to make coffee. The water passes through the coffee grounds, which creates the coffee solution, leaving the coffee grounds in the filter.

Sorting

In some cases, the components of mechanical mixtures are easy to see and are easily identifiable. **Sorting** is a technique that involves separating substances on the basis of appearance, which may involve colour, size, texture, or composition.

Figure 8.20 shows a blue box with a number of recyclable items. Some curbside recycling programs require the driver of the recycling truck to place the contents of the blue box into appropriate bins. Metal objects are separated from glass items, and plastic containers are separated from paper products. These separate groups of objects are then recycled. For example, aluminum cans are melted down and recycled as new aluminum cans. Some paper products are recycled for use in printing newspapers.

Figure 8.20 You can sort recyclable materials into different bins for easier recycling.

Sifting

Sifting is a means of separating solids by component size. It involves shaking or agitating a solid material while it passes through a screen or mesh. For example, bakers sift flour to remove larger clumps, which helps to make the pastries light and fluffy (Figure 8.21). Components of the solid materials that are small enough to pass through openings in the sifting device are separated from larger components that cannot fit through the same openings.

Although it seems like they are similar techniques, sifting is different from filtration. Filters tend to have much smaller holes than screens used for sifting. As a result, a solid that would pass through a screen would not pass through a filter. Also, filtration is used to separate solids from liquids or gases, whereas sifting separates solids from other solids.

Figure 8.21 Pastry chefs sift flour to keep cakes and pastries light and fluffy.

Magnetism

Some metals are **magnetic** because their component particles are attracted to the particles within magnets. Iron, steel, nickel, and some compounds are highly attracted to magnets, whereas most other substances are not. Therefore, a magnet can be used to separate magnetic materials, such as automobile parts made with iron, from those materials that are not magnetic, such as plastic dashboards, foam insulation, and the rubber tires of cars (Figure 8.22).

Figure 8.22 A magnet will pick up some types of metal but not others.

Take It ***Further***

Recycling programs are in place throughout Canada and around the world. These programs successfully divert waste items from disposal in solid waste landfills. Many products that you use everyday have been made from recycled materials. Find out more about the sources of recycled materials. Begin your search at ScienceSource.

C28 *Problem-Solving Activity* Toolkit 3

SKILLS YOU WILL USE
- Designing, building, and testing
- Recording results

Designing a Method to Separate a Mixture

Recognize a Need

Many industrial and manufacturing applications involve the need to separate components of a mixture of different substances. This may involve removing precious stones, minerals, or metals from rocky raw material, making cheese by separating clumped material called curd from raw milk, or some other application. In this activity, you will work with a team to design a method to separate the components of a mixture determined by your teacher.

Problem

How can you separate this mixture into each of its component parts?

Materials & Equipment

- as determined by the teacher

Criteria for Success

- A method of separation for each component part is approved by the teacher.
- The mixture is sorted into each component part.

Brainstorm Ideas

1. Classify each of the substances known to be in the mixture using the following criteria:
   - pure substances or mixtures
   - water soluble or water insoluble
   - magnetic or non-magnetic
   - large particle size or small particle size
2. Determine which separation methods will be allowed by your teacher.

Make a Drawing

3. Show on your flowchart when and how each substance is separated from the mixture.
4. Ask your teacher to approve your process.
5. Revise your process as necessary, and repeat steps 3 and 4 until your flowchart is approved by your teacher.

Test and Evaluate

6. Using the flowchart you prepared as your guide, conduct the separation as you have planned.
7. Be prepared to demonstrate your separation technique by modelling the procedure for your class. As much as is possible, use real examples and include the thinking process you used to design your technique.
8. When finished, clean up your work station and wash your hands thoroughly.

Communicate

9. Prepare a brief presentation (2 min) of your separation technique and deliver this to your class. Be sure that all team members contribute to the presentation.
10. Use simple examples to get your point across. Try to include extensions that would enable other students, groups, or industries to use your technique for other mixtures.

C29 *Inquiry Activity* Toolkit 2

SKILLS YOU WILL USE
- Evaluating procedures
- Drawing conclusions

Separating a Mixture of Nails, Salt, Sand, Oil, and Water

Question

What methods are necessary to separate and retain all components of a mechanical mixture?

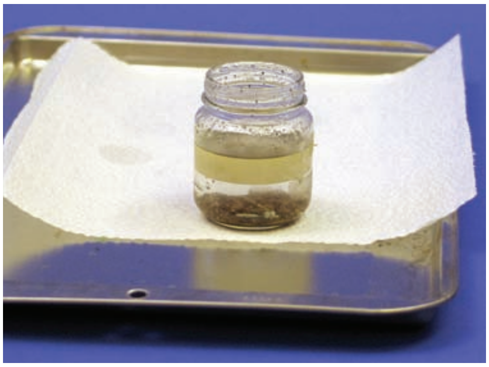


Figure 8.23 You will devise a method to separate this mixture of nails, salt, sand, oil, and water.

Materials & Equipment

- small jar with lid
- 5–10 small nails
- 5 mL table salt
- 5 mL fine sand
- 50 mL tap water
- 50 mL vegetable oil
- 2 small beakers
- bar magnet
- paper towel
- metal tray

Procedure

1. Work with a partner. Combine the nails, table salt, sand, water, and oil in the small jar.
2. Firmly secure the lid to the jar and shake the contents vigorously to dissolve and thoroughly mix the components of the mixture.
3. As a team, discuss and determine how to separate **and retain** all of the components of the mixture.
4. Discuss your procedure with your teacher, and get approval before you proceed with the method.

Analyzing and Interpreting

5. What component did you separate from the mixture first?
6. How did your choice in question 5 affect what you separated next?
7. How did you ensure that the maximum amount of each component of the mixture was retained?
8. Check with other students in your class. Did all students follow the same sequence to separate components from the mixture?
9. Use your understanding of the particle theory of matter to explain why your procedure worked to separate and retain the components of your mixture.
10. Wash your hands thoroughly after completing this investigation.

Skill Builder

11. How did you and your partner decide on the method you eventually used to complete this activity?

Forming Conclusions

12. What property of solutions was most useful to enable separation of the mixture?
13. What property of solids was most useful to enable separation of the mixture?

8.3 CHECK and REFLECT

Key Concept Review

1. Use the terms "dilute" and "concentrated" to explain the difference between maple sap and maple syrup.
2. Explain the difference between evaporation and distillation. Provide an example of each method of separating solutions.
3. Explain why separating a solid mixture is often easier than separating components of a solution.
4. Most types of commercial flour are sifted before they are packaged and sold in the store. What effect do you think this has on the quality of the flour?
5. Explain how paper chromatography could be used to separate a mixture of different-coloured inks.

Connect Your Understanding

6. Explain what steps you could take to purify water for drinking if you were not sure about the water quality.
7. Explain why landscapers might sift soil that they use to construct gardens.

Practise Your Skills

8. You are given a mixture of chalk dust, larger pieces of blackboard chalk, paper clips, and salt. Draw a well-labelled flowchart to explain how you would separate each substance in the mixture.

For more questions, go to ScienceSource.

C30 *Thinking about Science and the Environment*

STSE

Carbon Removal and the Environment

In Ontario, four generating stations burn coal to produce electricity. The resulting mixture of waste gases includes a great deal of carbon dioxide. In the future, it may be possible to separate carbon dioxide from the waste gases and store it underground, perhaps in abandoned mines.

Work with a partner. Think about some of the benefits that might come from carbon dioxide removal. Additionally, think about some of the negative consequences that could result. Write your ideas in your notebook, and be prepared to discuss your thoughts in a small group or with the rest of the class.

Careers in Consumer Products Safety

Figure 8.24 Careers in consumer products safety may involve testing different products to ensure that they are safe to use by consumers.

Every year, hundreds of people are injured or killed by the improper and unsafe use of consumer products. The Canadian government has established a branch of Health Canada called Consumer Products Safety to help protect Canadians from poorly manufactured products (Figure 8.24).

Safety Services

On its website, Health Canada lists a number of ways in which the Consumer Products Safety Branch works to serve Canadians. These include:

- supporting the development of safety standards and guidelines
- enforcing legislation by conducting investigations, inspections, seizures, recalls, and prosecutions
- testing and conducting research on consumer products

Educational Requirements

Each one of the identified roles requires well-trained people to ensure that the job is done thoroughly and correctly. Generally speaking, to begin a career in consumer products safety will require that you complete a secondary school graduation diploma and that you take math and science courses each year.

Additional requirements include the completion of a two- to three-year college, hospital, or university degree program in biology, chemistry, physics, or the health sciences. It may also require additional qualifications, including clinical training. Supervisors and instructors in this area require considerable experience in their respective fields.

Questions

1. Identify the branch of government responsible for maintaining the safety of consumer products in Canada. Explain why this work is necessary.
2. List three roles performed by this branch of government. Identify how knowledge of pure substances and mixtures would help in performing this role.
3. A career in consumer products safety will involve considerable interaction with people. Consider the types of people skills and qualities you will need to display in this career.

8.0 Chapter Review

Assess Your Learning

After Reading — Thinking Literacy

Reflect and Evaluate

You will work in pairs or small groups to respond to the statements that follow these instructions. Use the marker colour assigned to your group to write a response to the first statement you are given. At your teacher's signal, move to the next statement. Read what has already been written, changing or adding as necessary to monitor the class's comprehension of each concept. What strategies did you use to monitor the comprehension of others during this activity?

- All solutions contain water and a solute.
- A concentrated solution is a saturated solution.
- Distillation is the same thing as evaporation.
- Hand sorting is a large part of all recycling programs.

Key Concept Review

1. What is the difference between a solute and a solvent in a solution? Give an example of each. (k)
2. Describe the components of an air solution using the terms "solute" and "solvent." (k)
3. (a) Why is water called the universal solvent? (k)
   (b) List two examples of substances that dissolve in water. (t)
   (c) List two examples of substances that do not dissolve in water. Is it good that they do not dissolve in water? Explain why or why not. (t)
4. Create a Venn diagram to identify and explain two factors that affect the rate at which a solute dissolves in a solvent. (k)
5. Compare and contrast the properties of dilute and concentrated solutions. (k)

Connect Your Understanding

6. A solution is made when 50 g of sugar is dissolved in 500 mL of water. What is the concentration of the solution in units of: (a)
   (a) g/mL?
   (b) g/1000 mL?
7. Use the particle theory of matter to explain the effect of particle size on rate of dissolving. Draw a particle diagram to illustrate your explanation. (t)
8. Salt dissolves more rapidly in hot water when compared to cold water. Why is this so? Use the particle theory of matter to explain your answer. (t)
9. Many fish species prefer cold water and some cannot survive in water above 20°C. Use your understanding of solubility of solids and gases to explain why these fish cannot survive in warm water. (t)

ACHIEVEMENT CHART CATEGORIES
(k) Knowledge and understanding (t) Thinking and investigation (c) Communication (a) Application

10. While you are adding salt to a garden salad, the top of the shaker comes off. A large amount of salt falls into a salad bowl which already contains lettuce, pepper, and vinegar. Explain how you could separate the salt from this salad mixture using your understanding of solutions and mixtures. a

Practise Your Skills

11. Look at Figure 8.19 on page 230 that shows the filtration of dirty water. Draw a sketch of the filtration and show the particles of water and dirt in the dirty water. Also show the particles in the liquid at the bottom of the container. Explain why this is a separation of a mechanical mixture and not a separation of solutions. t

Unit Task Link

In your unit task, you will investigate water samples taken from a number of sources. What properties of mixtures will enable you to understand how some pure substances and mixtures may enter and contaminate water supplies? Be sure to include key ideas like solubility and the effect of temperature on mixtures when you continue work on your unit task.

C31 *Thinking about Science and Technology*

STSE

What Colour Is Your Food?

All foods are mixtures. Some mixtures are more complex than others. You may have noticed that some food labels include the common ingredient "artificial colour." The dyes used in these foods are approved for use by the Canadian government. Red dyes are extracted from the shell of a type of beetle or from coal tar, a product of coal. From canned cherries to ketchup to some breakfast cereals to red meat, red dyes are added to make foods look fresh, good quality, or interesting. What is the impact on society of the use of these kinds of mixtures in our food?

What to Do

1. Find food labels for products that may contain red dyes. Look for "artificial colour," allura red, food red, E129, carmine, or cochineal extract. Your teacher may give you labels to examine.

Consider This

With a classmate or as a whole class, discuss the following questions.

1. Make two lists: one of the foods you were most surprised to find out had been treated with red dyes, and the other of foods you were least surprised to find out contained red dyes.
2. Are there any products that are actually improved simply by adding colour?
3. Do you think that the use of government-approved dyes to add colour to food is acceptable if it is just to satisfy consumers? Or do you think there are larger issues for society regarding the use of these dyes? If you think there are, suggest what the impacts might be.