CHAPTER 2

Solutions

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	concentrated solution
solvent	dilute solution
solute	concentration
dissolving	saturated solution
pollution	unsaturated solution
soluble	solubility
insoluble	

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.

2.1 Solutes 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.

Figure 1 This iced tea was made by dissolving iced tea powder in water.

dissolve: to mix one type of matter into another type of matter to form a solution

solvent: the larger part of a solution; the part of a solution into which the solutes dissolve

solute: the smaller part of a solution; the part of a solution that dissolves in the solvent

dissolving: mixing completely with a solvent to form a solution

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).

Figure 2 Ethanol, turpentine, and ethyl acetate are useful solvents for matter that does not dissolve in water.

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?

LINKING TO LITERACY

During Reading: Comparisons

Comparisons are used to make clear what is the same and what is different about two or more items. As you read this section, compare characteristics of solvents and solutes. How are they similar? How are they different? How does making comparisons help you to better understand solvents and solutes?

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.

Figure 3 As water flows in a stream, it dissolves many substances.

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.

To learn more about "the universal solvent,"
Go to Nelson Science

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.

Figure 4 Plants absorb the minerals and nutrients dissolved in water through their roots.

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?

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.

LINKING TO LITERACY

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?

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.

TRY THIS: Identify Solutions at Home

SKILLS MENU: observing, analyzing, communicating

SKILLS HANDBOOK 5.F., 6.D.1.

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!

   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.

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.

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.

pollution: contaminants in the environment that could harm living things

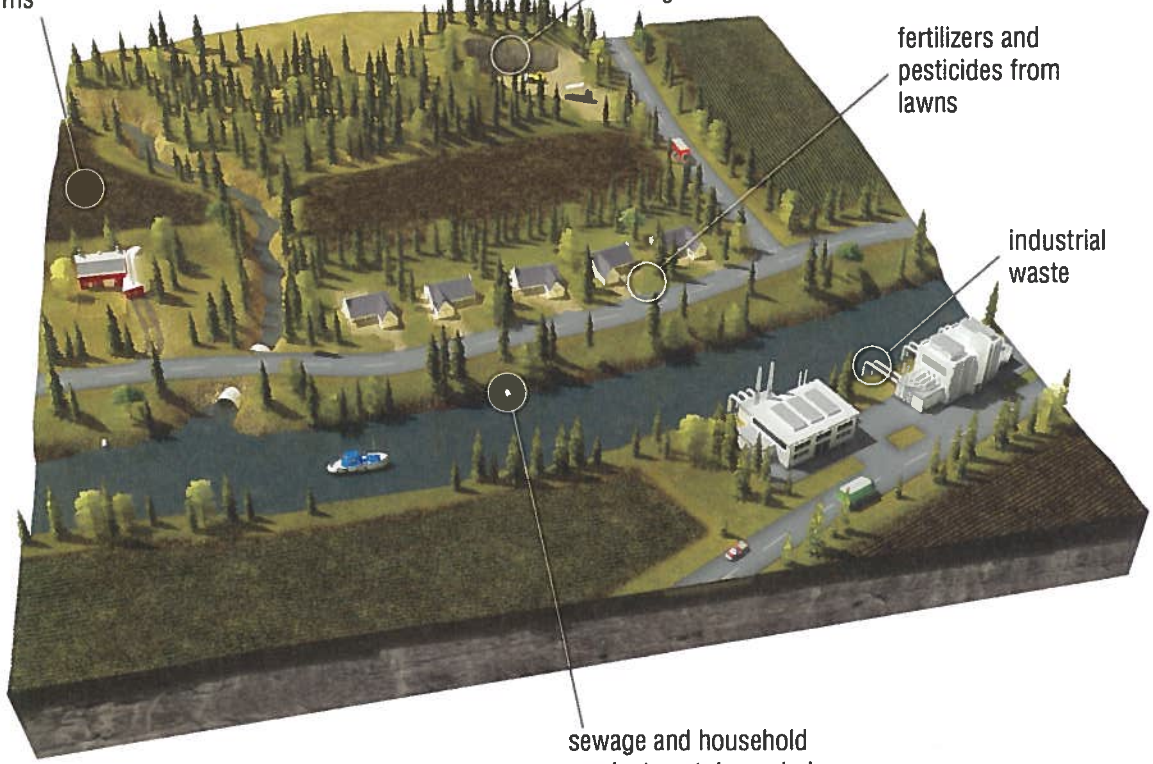


Figure 7 Sources of water pollution

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.

2.2 Dissolving and the Particle Theory

Figure 1 You can add a lot of popcorn to a full glass of milk.

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

SKILLS HANDBOOK 2.B.7., 6.A.2.

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); 25 mL measuring spoon; 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.

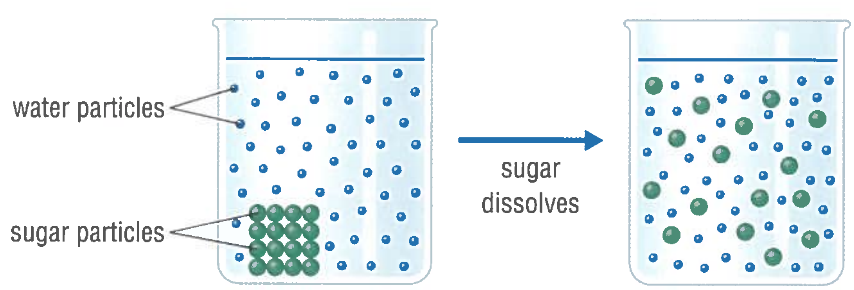


Figure 2 The sugar particles are attracted to the water particles, so the sugar particles separate and mix with the water particles. There is less space between the particles when sugar and water are mixed.

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.

Figure 3 Does sugar dissolve equally well in all solvents?

TRY THIS: Compare Different Solvents

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

SKILLS HANDBOOK 2.B.5., 2.B.7.

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?

soluble: able to dissolve in a specified solvent

insoluble: unable to dissolve in a specified solvent

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

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?

2.3 Concentration and Solubility

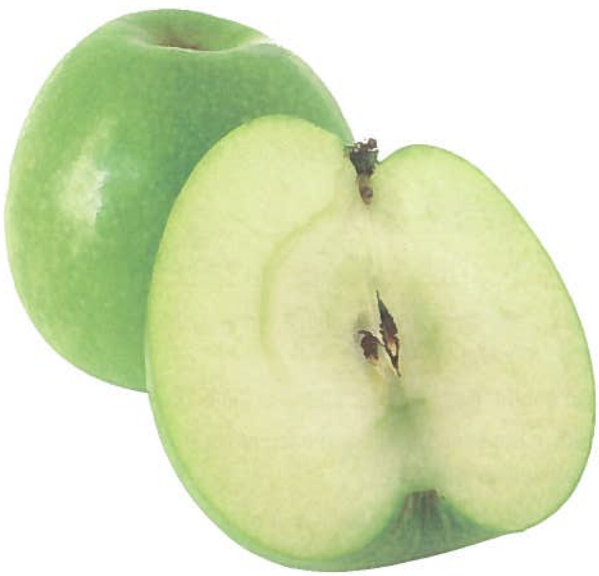


Figure 1 Apple seeds contain tiny amounts of a toxic chemical called cyanide.

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.

To learn more about foxglove and digitalis, Go to Nelson Science

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.

concentrated solution: a solution with a large number of solute particles in a given volume of solution

dilute solution: a solution with a small number of solute particles in a given volume of solution

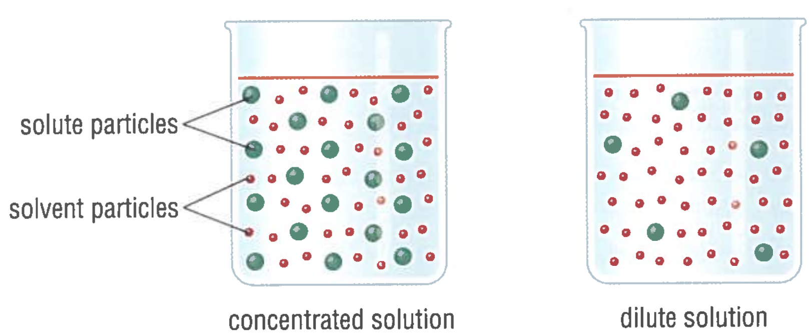


Figure 2 A concentrated solution contains many more solute particles (shown in green) than the same volume of a dilute solution.

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?

Figure 3 Which solution has had a lot of drink powder added to it?

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

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

concentration: the amount of solute present in an amount 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: $\text{concentration} = \frac{\text{mass of solute in grams}}{\text{100 mL of solution}}$

Solution: $\text{concentration} = \frac{6.0\text{ g}}{200\text{ mL}}$

Remember to divide both the numerator and the denominator by 2 to get concentration per 100 mL.

$\text{concentration} = \frac{3.0\text{ g}}{100\text{ mL}}$

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.)

LINKING TO LITERACY

Questioning to Check Your Understanding

As you read about concentration and solubility, stop after every few sentences. Ask yourself questions to check your understanding. Can you explain what you have just read in your own words? If your answer is "No," then reread, look for key words, or look at the pictures and captions for more information.

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

SKILLS HANDBOOK 6.A.2.

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

solubility: a measure of how much solute can dissolve in a certain solvent to form a saturated solution at a particular temperature and volume

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

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

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

Solute	Solubility in water at 20 °C
sugar	204 g/100 mL of water
salt	36 g/100 mL of water

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.)

SCIENCE WORKS

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,
Go to Nelson Science

2.4 PERFORM AN ACTIVITY

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.

SKILLS MENU

- ☐ Questioning
- ☐ Hypothesizing
- ☐ Predicting
- ☐ Planning
- ■ Controlling Variables
- ■ Performing
- ■ Observing
- ■ Analyzing
- ■ Evaluating
- ■ Communicating

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


apron


eye protection

large beaker


glass stirring rod


thermometer


graduated cylinder (50 mL)

beaker (100 mL)


balance


measuring spoon


weighing papers


electric kettle


water


ice cubes


Epsom salts


table salt

Procedure

SKILLS HANDBOOK 6.A.3., 6.A.4.

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

Table 1 Analysis of Observations

		Epsom salts in cold water	Epsom salts in hot water	Table salt in cold water	Table salt in hot water
Before adding salt to water	Volume of water (mL)				
	Mass of beaker with water added (g)				
After adding salt to water to form a saturated solution	Mass of beaker with saturated solution (g)				
	Mass of salt added to water (g)				
	Temperature of solution (°C)				
	Solubility of salt in water at recorded temperature				

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.

Use care when handling containers with hot water.

13. Repeat steps 5 to 11 using the beaker of hot water instead of ice-cold water, and record your observations in Table 1.
14. Repeat steps 3 to 13 using table salt instead of Epsom salts. Record your data in Table 1.

Analyze and Evaluate

SKILLS HANDBOOK 2.B.7., 2.B.8.

(a) Complete your observations by calculating the mass of Epsom salts and table salt in each case. Record the masses in Table 1. Calculate the solubility of Epsom salts and table salt in cold and hot water.

(b) How did you find the mass of the salt that dissolved in the water, without measuring the mass of the salt on the balance? What assumption did you make in finding the mass of the salt in this way?

(c) Compare the solubility that you calculated for Epsom salts in cold water and in hot water. What do you conclude about how the solubility of Epsom salts changes with temperature?

(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?

Dissolving Solutes Faster

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

SKILLS MENU

- Questioning
- Hypothesizing
- Predicting
- Planning
- Controlling Variables
- Performing
- Observing
- Analyzing
- Evaluating
- Communicating

Testable Question

SKILLS HANDBOOK 2.B.1.

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

Hypothesis/Prediction

SKILLS HANDBOOK 2.B.3.

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.

Figure 1 Change one variable at a time to see how it affects the dissolving rate of sugar.

Figure 2 Useful equipment and materials for testing the dissolving rate of sugar

LINKING TO LITERACY

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

SKILLS HANDBOOK 2.B.4., 5.

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

SKILLS HANDBOOK 2.B.7., 2.B.8.

(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?

CHAPTER 2

SUMMARY

Solutions

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

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

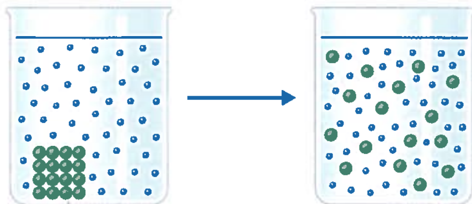
- Solutions may be solids, liquids, or gases.
- Examples of common solvents include water, ethanol, copper, and nitrogen gas.
- Examples of common solutes include sugar, salt, tin, and oxygen gas.

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

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

- 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

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

- 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.

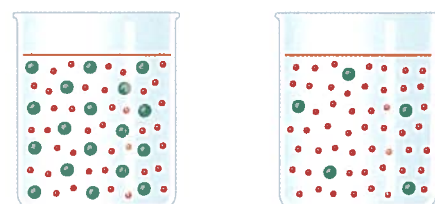
- Solubility can be determined by creating saturated solutions and taking careful measurements.
- Solubility can be affected by changing the temperature of the solvent.

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.

VOCABULARY

dissolve, p. 36
solvent, p. 36
solute, p. 36
dissolving, p. 36
pollution, p. 39
soluble, p. 41
insoluble, p. 41
concentrated solution, p. 42
dilute solution, p. 42
concentration, p. 43
saturated solution, p. 43
unsaturated solution, p. 43
solubility, p. 44



CHAPTER 2 REVIEW

The following icons indicate the Achievement Chart categories: K/U Knowledge/Understanding T/I Thinking/Investigation C Communication A Application

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 K/U C
2. (a) List three examples of common solvents.
   (b) List three examples of common solutes. K/U
3. Which of the solutions in Figure 1 is concentrated? Which solution is dilute? Explain. K/U

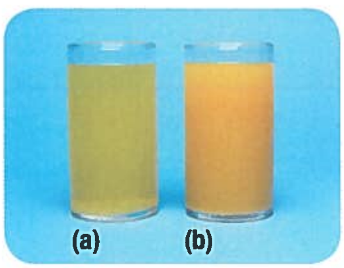


Figure 1

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? K/U C
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. C
   (b) Explain your drawing. K/U

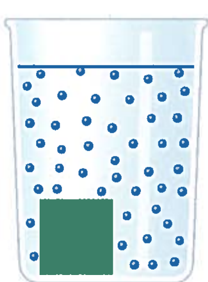


Figure 2

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

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. K/U A
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? K/U
9. Why is water "the universal solvent"? K/U
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? K/U
    (b) Use the particle theory to explain Malcolm's observation. A
11. Your teacher gives you a solution of salt in water. How can you find out if it is a saturated solution? T/I
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. K/U

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. K/U

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. T/I

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? K/U T/I

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? K/U T/I

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? K/U T/I

18. Calculate the concentration (in g/100 mL) of each of the following solutions: K/U T/I
   (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? T/I A

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. T/I

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.