Chapter 8

Some substances dissolve to form solutions faster and more easily than others.

Did you notice in Chapter 5 that water was called "pure water" when it was identified as a pure substance? Why was it necessary to call it "pure water?" In what way is "pure water" different from "ordinary water?" The water that flows out of a tap or that falls from the sky as rain or that empties into the ocean from a river is not a pure substance. It's actually a solution. There are very small amounts of dissolved solids such as sodium chloride and dissolved gases such as carbon dioxide and oxygen. In fact, you would be hard-pressed to find totally pure water anywhere in nature. Water is so good at dissolving things that it cannot stay pure for very long at all.

You will find out how pure water, called distilled water, is made when you explore how to separate solutions and other mixtures in the next chapter. In this chapter, you will first learn more about how solutions are made and the factors that affect making them.

What You Will Learn

In this chapter, you will
- **identify** the solute and the solvent in a variety of solutions
- **distinguish** between soluble and insoluble substances
- **describe** the concentration and solubility of substances qualitatively and quantitatively

Why It Is Important

You make or make use of solutions each day. Learning how to describe the solutions that you make and use lets you communicate with others more effectively. This is especially important for solutions that require safe handling, such as pesticides.

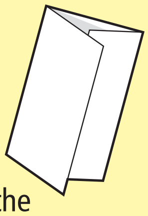
Skills You Will Use

In this chapter, you will
- **express** the concentration of a solution and the solubility of a solute
- **predict** and graph the effect of temperature on solubility
- **investigate** factors that affect the rate of dissolving

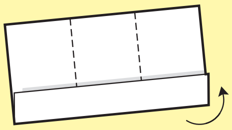
FOLDABLES™ Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 8.

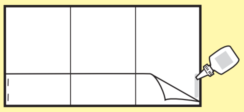
STEP 1 **Fold** a horizontal sheet of 11 × 17″ paper into thirds by folding first the right, then the left sides inward.



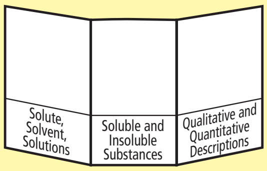
STEP 2 Unfold the paper and fold the bottom quarter of the page upward to create a pocket.



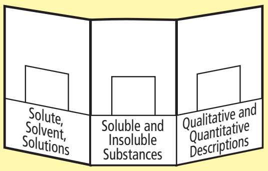
STEP 3 **Glue** or **staple** the outer edges of the pocket closed.



STEP 4 **Label** the pockets with the following titles: *Solute, Solvent, Solutions; Soluble and Insoluble Substances;* and *Qualitative and Quantitative Descriptions.*



STEP 5 **Cut** small pieces of paper to fit in each pocket. These will be used as note cards.



Organize Use the note cards to record main ideas, supporting facts, new terms, and definitions from the chapter. Use half-sheets of grid paper to predict and graph the effect of temperature on solubility. Store these sheets in the appropriate pockets of the Foldable.

8.1 Making Solutions: Solutes and Solvents

When one substance dissolves in another, the substance that dissolves is the solute and the substance in which it dissolves is the solvent. A substance is soluble in a solvent when it dissolves in the solvent. A substance is insoluble in a solvent when it does not dissolve in this solvent. The particle theory of matter can explain why soluble substances dissolve in a solvent.

Key Terms

dissolves
insoluble
soluble
solute
solvent

Figure 8.1 shows the only type of hummingbird that is found in eastern Canada. Many people like to put out special feeders to attract the quick, colourful bird to their homes. Hummingbird feeders hold a solution that is made by mixing sugar with water. You may recall from Chapter 7 that a solution is a homogeneous mixture. When you mix two substances and they form a solution, you say that one substance **dissolves** in the other substance. As you can see in Figure 8.2:

- The **solute** is the substance that dissolves.
- The **solvent** is the substance in which the solute dissolves.

When you mix sugar and water, the sugar is the solute and the water is the solvent. The sugar dissolves in the water.

Figure 8.1 The ruby-throated hummingbird feeds on insects as well as the nectar (sugary sap) of plants. The birds willingly dine on the sugar-water solution that people make for them, too.

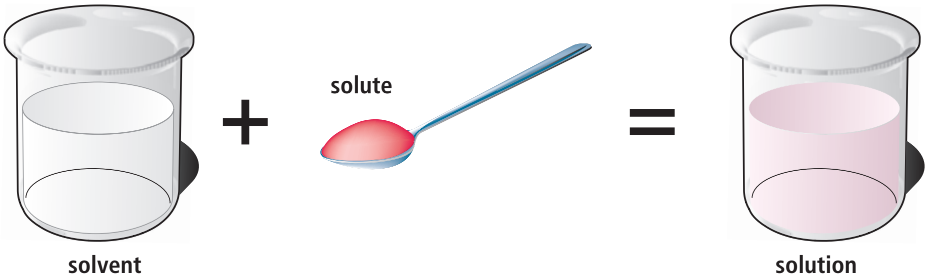


Figure 8.2 To make a solution, a solute dissolves in a solvent.

Different States of Solutes and Solvents

If you read the labels on liquid products around your home, you will notice that water is the solvent for many different solutes. But water is not the only type of solvent. In fact, solvents can be solids and gases, too! The same is true of solutes. Table 8.1 gives some examples of solutions with their solutes and solvents. In most solutions, there is usually less solute than solvent.

Table 8.1 States of Solvents and Solutes for Various Solutions

Solution	Solute	Solvent	State of Solute	State of Solvent
air	oxygen, carbon dioxide, and other gases	nitrogen	gas	gas
soda water	carbon dioxide	water	gas	liquid
vinegar	acetic acid	water	liquid	liquid
filtered ocean water	sodium chloride (salt) and other minerals	water	solid	liquid
brass	zinc	copper	solid	solid

Did You Know?

The ruby-throated hummingbird grows no larger than 9 cm long. But don't judge it by its size alone. Each fall, fueled by their nectar-feeding, these small birds leave Canada and migrate to their winter destination: Mexico!

8-1A Name That Solute and Solvent

Think About It

In this activity, you will identify the solute and the solvent in a variety of solutions.

What to Do

1. Read the four statements about solutions carefully. The way that each statement is written gives you clues to help you tell which part of the solution is the solute and which part is the solvent.
2. For each statement, do the following:
   (a) Identify the state of the solution that is described. Refer to Table 8.1 if you need help.
   (b) Identify the solute.
   (c) Identify the solvent.

Statement 1

Brass is a metal that is used to make musical instruments and doorknobs. Brass is a solution of zinc metal in copper metal.

Statement 2

Hydrogen peroxide is used to disinfect cuts and wounds. Hydrogen peroxide is a solution made of 3% hydrogen peroxide and 97% water.

Statement 3

Dental amalgam is a metal that is used to fill cavities. Dental amalgam is a solution of mercury in tin. (Mercury is a metal that is liquid at room temperature.)

Statement 4

Deicing fluid is a powerful liquid that is used to clean car and truck windshields. One kind of less-toxic deicing fluid is a solution of propylene glycol in water.

What Did You Find Out?

1. Explain how you decided which part of the solutions was the solute and which part was the solvent.

Soluble and Insoluble

As you know, when you mix a solute like sugar with a solvent like water, the sugar dissolves in the water. Another way of saying "the sugar dissolves in the water" is to say "the sugar is soluble in the water." A substance that is **soluble** is able to dissolve in a certain solvent.

What about things that do not dissolve? For instance, sand does not dissolve in water. Another way of saying "sand does not dissolve in water" is to say "sand is insoluble in water." A substance that is **insoluble** is not able to dissolve in a certain solvent.

8-1B Eggshell Shocked

Find Out ACTIVITY

Eggshells are mostly calcium carbonate. In this activity, you will see what happens when an egg is left floating in water and another egg is left floating in vinegar.

Safety

- Raw eggshells can sometimes be a source of food poisoning. Wash your hands after you handle the eggs.

Materials

- 2 large beakers (400 mL or 500 mL) or large jam jars
- 2 raw eggs
- water
- white vinegar

Connection

Remind yourself of what calcium carbonate is in section 7.1.

What to Do

1. Add water to one beaker or jar until it is about half-full. Add vinegar to the other beaker or jar until it is about half-full.
2. Gently place a raw egg in each jar.
3. In your science notebook, write the date and describe the appearance of the egg in each jar. Also, describe the appearance of the water and the vinegar.
4. Observe the two jars each day for a few days. Describe the eggs, the water, and the vinegar each day. Remember to write the date each day.
5. When the activity is over, clean up and put away the equipment you have used.

What Did You Find Out?

1. What, if any, changes to the egg did you observe in the water?
2. What, if any, changes to the egg did you observe in the vinegar?
3. Is eggshell (calcium carbonate) soluble or insoluble in water? Is it soluble or insoluble in vinegar? Give evidence to support your answers.

Insoluble in Some Solvents, Soluble in Others

As you can see in Figure 8.3, motor oil does not dissolve in water. In other words, motor oil is insoluble in water. As you can see in Figure 8.4, though, motor oil is soluble in other substances. For instance, motor oil dissolves in gasoline.

Figure 8.3 Motor oil is one type of petroleum product. Petroleum products do not dissolve in water.

Figure 8.4 Small engines, like those in some lawnmowers and chainsaws, run on a solution of motor oil and gasoline. A certain volume of the oil is dissolved in a larger volume of gasoline. So, the oil is the solute and the gasoline is the solvent.

Figure 8.5 shows another example of a substance that is insoluble in one solvent but is soluble in another. Grass stains are caused by a green-coloured chemical called chlorophyll. Grass stains are hard to wash out of clothing because chlorophyll is insoluble in water. It is also insoluble in laundry detergent. A different solvent, such as rubbing alcohol, is needed to dissolve grass stains. Chlorophyll is soluble in rubbing alcohol.

Figure 8.5 Chlorophyll is a green-coloured chemical that is found in the leaves of green plants. Water cannot dissolve chlorophyll, but rubbing alcohol can.

Explore More

If a Styrofoam cup comes in contact with nail polish remover, the cup material will dissolve. And yet nail polish remover does not harm fingernails. How can this be? Why are people cautioned to use nail polish remover carefully? Begin your research at **www.discoveringscience.ca**

Reading Check

1. What does the term *soluble* mean?
2. What does the term *insoluble* mean?
3. Vinegar is insoluble in vegetable oil. Does this mean that vinegar is a totally insoluble substance? Explain why or why not.

Suggested Activity

Conduct an Investigation 8-1C on page 259.

Connection

Section 5.1 has information to help you review the particle theory of matter.

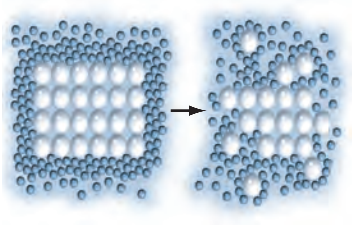


Figure 8.6 The water particles pull one sugar particle away from the other sugar particles in the crystal. Then the motion of the water particles carries the sugar particle away. This makes room for more water particles to move in and pull other sugar particles away.

internet connect

Find out how nanotechnology and other methods are helping people dissolve dirt and other impurities that have invaded great works of art. Start your search at **www.discoveringscience.ca.**

Why Some Substances Dissolve

The particles of a substance stay together because they are attracted to each other. What happens to the attraction among sugar particles when you put sugar in water? Why does each sugar crystal break up and dissolve? There must be other attractions. The sugar particles are also attracted to the water particles, so they mix with the water particles.

A group of water particles can attract a sugar particle more strongly than the other sugar particles around it. Figure 8.6 shows what happens to sugar particles on the edge of a sugar crystal. The process in Figure 8.6 continues until all of the sugar is dissolved. Particles of sugar gradually move around and mix evenly amongst the particles of the water. A solution is formed.

A solution can also form when oil is mixed with gasoline. In this case, the attractions between the oil particles and the attractions between the gasoline particles are alike. They are both very weak. Do not forget, the particles in each are always moving. When these two substances mix, the weak attractions are broken by the motion of the particles and a solution is formed.

Why Some Substances Do Not Dissolve

Just mixing two substances together does not always make a solution. Why are some substances insoluble? Think about the attraction of fat particles and the attraction of water particles in a glass of milk. For the particles of fat to dissolve in the water, they would have to be more attracted to the water particles than to the other particles of milk fat. But fat particles are not more attracted to the water particles. So the fat particles stay together and form insoluble globules in the liquid.

This idea of particle attraction applies to many other combinations of substances. For instance, it can help to explain why grass stains are tough to get out of clothing. The particles of chlorophyll in the grass stains are more attracted to each other than they are to water particles. To get out the grass stains, you need to use a different solvent—one whose particles attract the particles of chlorophyll. As you learned on the previous page, rubbing alcohol is such a solvent.

Reading Check

1. Why are some substances insoluble in a certain solvent?
2. When sugar is added to water, which is stronger: the attraction of water particles for sugar particles or the attraction of sugar particles for sugar particles?

8-1C Does It Dissolve?

Find Out ACTIVITY

In this activity, you will test two solutes to see how well they dissolve in different solvents.

Safety

- Do not taste, eat, or drink any of the substances in this activity.

Materials

- 4 small transparent containers (such as small beakers or plastic cups)
- 4 labels
- 4 stir sticks
- water
- vegetable oil
- salt
- flour
- measuring spoons

What to Do

1. Copy the table of observations below into your science notebook. Give your table a title.
2. Label the four cups 1, 2, 3, and 4.
3. Use a measuring spoon to pour about 2 mL of water (about half a teaspoon) into cups 1 and 2. Pour about 2 ml of vegetable oil into cups 3 and 4.
4. Record the solvent in your table.
5. Predict whether each of the two solutes (salt and flour) will dissolve in one, both, or neither of the solvents. Record your predictions.
6. Using the stir sticks, add a little salt to cups 1 and 3 and a little flour to cups 2 and 4. Record the names of the solutes in your table.
7. Stir each mixture. Observe the contents of each container to see if the solutes have dissolved. Record your observations in your table.
8. Clean up and put away the equipment you have used.

Container	Name of Solvent	Name of Solute	Observations
1			
2			
3			
4			

What Did You Find Out?

1. Write a summary of your results.
2. Were your predictions accurate? Explain why you think they were or were not.
3. Predict what would happen if you did this activity again using ethanol (a type of alcohol) as a third solute. Give reasons to explain your prediction. If there is time, test it. (Make sure you observe all safety rules when handling the ethanol.)

Wild, Weird, Wonderful

www Science

The Strange Case of the Water That Wasn't

In 1966, a Russian scientist who was giving a talk in England told the scientists of a new discovery. He said that Russian scientists had discovered a new form of liquid water. The particles of this new form of water were held together in a way that made the water thicker and denser than ordinary water. This new water, called polywater, could stay a liquid at temperatures as low as –55°C and at temperatures as high as 260°C. It was made in the lab by heating and condensing water in very narrow glass tubes. But the process was so painstaking that only a few drops could be made at a time.

The difficulty of making polywater didn't stop other scientists from studying it. During the late 1960s and the early 1970s, hundreds of scientists from around the world published their thoughts and experiments with polywater. Some proclaimed dire consequences if polywater ever got out of the lab and into nature. It would, the scientists predicted, change all normal water into polywater.

It took about seven years for the truth about polywater to emerge. And the truth was: There was no such thing!

"Polywater", it turned out, was just a solution. Small amounts of silicon and a few other impurities had dissolved from the thin glass tubing into water. Polywater, it turned out, was water that was polluted with impurities.

The polywater event happened for a simple reason. Scientists forgot, for a period of time, about water's abilities as a solvent.

Check Your Understanding

Checking Concepts

1. Give two examples of substances that are soluble in water.
2. Give two examples of substances that are insoluble in water.
3. Give one example of a substance that is insoluble in water but is soluble in a different solvent.
4. Identify the solute and the solvent in these examples.
   (a) Your friend makes lemonade by mixing lemon-flavoured drink crystals with water.
   (b) Vinegar is a solution that is made up of 5% acetic acid and 95% water.
   (c) Humid air is a solution of water vapour in air.
   (d) Home-made window cleaner can be made by dissolving vinegar in water.
   (e) One way to make apple juice is by mixing water with frozen concentrated apple juice.
   (f) A small outboard motor on a boat is fuelled with a mixture of motor oil and gasoline.
   (g) Some people prefer to drink tea with lemon juice.
   (h) Therapeutic massage oil is a solution that contains the oil of a medicinal plant such as sage mixed with almond oil.
5. In Chapter 7, you learned that a stainless steel frying pan is a solution called an alloy.
   (a) Name the solvent in stainless steel.
   (b) Name one solute in stainless steel.

Understanding Key Ideas

6. Use the particle theory of matter to explain why glass is insoluble in water. Use diagrams as well as words to answer this question.
7. Some people suggest using hairspray to remove ink stains. Use the terms "soluble," "solvent," and "insoluble" to explain this suggestion.
8. (a) List six substances (two solids, two liquids, and two gases) that dissolve in water.
   (b) List six substances that do not dissolve in water.
   (c) Water is often called "the universal solvent." How do you know that this statement is incorrect?
   (d) Even though it is incorrect to call water a universal solvent, the statement is still useful and accurate. Explain why.

Pause and Reflect

What is the difference between a substance that is soluble and a substance is insoluble? Imagine that you have to explain this difference to a class of grade 5 students. Devise an analogy that will make this difference simple and understandable to the students. (An analogy is a type of comparison in which you use something that is familiar to explain something that is or might be unfamiliar.)

8.2 Concentration and Solubility

A concentrated solution has a larger mass of solute for a certain volume of solvent. A dilute solution has a smaller mass of solute for a certain volume of solvent. The concentration of a solution may be expressed quantitatively in units of grams of solute per litre of solvent (g/L). When a solution is unsaturated, more solute can dissolve in the solvent at the same temperature. When a solution is saturated, no more solute can dissolve at the same temperature. Different solutes have different solubilities. The solubility of most solids in a liquid can be increased by increasing the temperature. Stirring a solution increases the rate of dissolving, but not the solubility of a solute. The solubility of gases in a liquid can be increased by decreasing the temperature.

Key Terms

concentrated solution
concentration
dilute solution
saturated solution
solubility
unsaturated solution

Figure 8.7 The darker-coloured tea on the left is a concentrated solution. The lighter-coloured tea on the right is a dilute solution.

Figure 8.7 shows two cups of tea. Both cups have the same volume of tea. And both tea bags are the same size. You can see, though, that the tea on the right is lighter in colour than the tea on the left. How can you explain this difference?

Look at the light-coloured tea on the right. Because of its light colour, you might guess that the tea bag has not been sitting in the water for very long. Only small quantities of the substances in the tea bag have dissolved in the water.

Now look at the dark-coloured tea on the left. The tea bag likely has been sitting in the water for several minutes or longer. The substances in the tea bag have had more time to dissolve in the water. The dark-coloured tea contains more dissolved substances than the light-coloured tea.

The darker tea is a concentrated solution of tea and water. A **concentrated solution** has a large mass of dissolved solute for a certain quantity of solvent.

In comparison, the lighter tea is a dilute solution of tea and water. A **dilute solution** has a small mass of dissolved solute for a certain quantity of solvent.

Suppose that you make a fruit drink with drink crystals. If you find that the taste is too sweet, you can add water to make the solution more dilute. If you find that the taste is not sweet enough, you can add more drink crystals to make the solution more concentrated.

Concentration

The quantity of solute that is dissolved in a certain quantity of solvent is the **concentration** of the solution. You can describe concentration *qualitatively* (with words) if you use the terms "concentrated" and "dilute." You can also express concentration *quantitatively* (with numbers). This is especially important when safety is an issue. For instance, manufacturers include the concentration of the solution on the label of many products. That way, people know how to use the product safely.

One of the most common ways to show concentration is in units of grams per litres (g/L). This tells you the mass of solute that is dissolved in 1 L of solution. For example, the product shown in Figure 8.8 is a herbicide (a plant-killing chemical) commonly used to kill weeds before a crop is planted. Roundup™ is a solution of a chemical called glyphosate and water. The label shows that this product contains 7 g/L of glyphosate. This means that there are 7 g of glyphosate in 1 L of the product.

Figure 8.8 The active ingredient in this herbicide is glyphosate. According to the label, what is the concentration of glyphosate? What other information does the label show? Why?

Reading Check

1. You put three teaspoons of sugar in jug with half a litre of water. You put two teaspoons of sugar in a second jug with half a litre of water. Which jug is more concentrated?
2. How is the qualitative definition of concentration different from the quantitative definition?
3. Explain what g/L means.

Suggested Activity

Find Out Activity 8-2B on page 270
Find Out Activity 8-2C on page 271

Figure 8.9 When 316 g of bluestone are dissolved in 1 L of water at 0°C, the bluestone solution is saturated. No more bluestone will dissolve in the solution at this temperature.

A Limit to Concentration

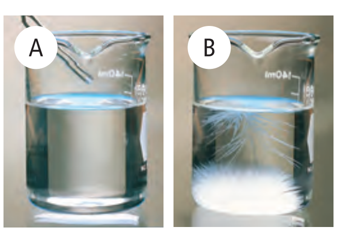
If you put a spoonful of salt in a glass of water, the salt will dissolve. You can add a second spoonful and a third and a fourth. With each spoonful, the solution becomes more and more concentrated. Can you continue to add salt to the same volume of water forever? No. Eventually, you reach a point at which the salt will not dissolve in this volume of water any more. At this point, the solution is said to be saturated.

A **saturated solution** forms when no more solute will dissolve in a specific amount of solvent at a certain temperature. For example, a saturated solution of salt and water is formed when 357 g of salt are dissolved in 1 L of water at 0°C. If more salt is added to this solution at this temperature, the salt will not dissolve. Figure 8.9 shows a saturated solution of water and a substance called bluestone. Notice the lump of undissolved solid that is left on the spoon.

An **unsaturated solution** is a solution that is not yet saturated. Thus, more solute can dissolve in it.

Did You Know?

A supersaturated solution is one that has more solute than would normally dissolve at a given temperature. Only some solutes can be used, and the solute can come out of solution very easily. You start with a saturated solution and then cool it without disturbing it. If you disturb the solution by adding a small crystal of solute (as in photo A), the extra solute quickly becomes solid (photo B).



Solubility

Solubility refers to the mass of a solute that can dissolve in a certain amount of solvent at a certain temperature. For example, you read earlier that 357 g of salt will dissolve in 1 L of water at 0°C. In other words, the solubility of salt in water at 0°C is 357 g/L.

Table 8.2 lists the solubility of several common substances in water. Notice that the solubilities are given as mass of solute (in grams) that will dissolve in 1 L of water at 0°C to form a saturated solution.

Table 8.2 Solubilities of Some Common Substances at 0°C

Substance	State (of Solute)	Solubility in Water (g/L)
baking soda	solid	69
bluestone	solid	316
calcium hydroxide	solid	1.9
carbon dioxide	gas	3.4
Epsom salts	solid	700
ethanol	liquid	unlimited
limestone	solid	0.007
nitrogen	gas	0.03
oxygen	gas	0.07
salt	solid	357
sugar	solid	1792

Rate of Dissolving

You know from your daily life that it takes a while to dissolve sugar in water. But you may also know from your daily life that you can make sugar dissolve faster. For instance, sugar will dissolve faster if the water is at a higher temperature. What factors do you think affect *how fast* something will dissolve?

When you investigate a question like this, you are talking about the *rate of dissolving*. The rate of dissolving refers to how quickly a solute dissolves in a solvent.

You probably already know another way of making a solute dissolve more quickly: stirring. For example, if you make a fruit drink with drink crystals, you likely do what the student in Figure 8.10 is doing. You stir the mixture to increase the rate of dissolving. Figure 8.11 explains why.

Word Connect

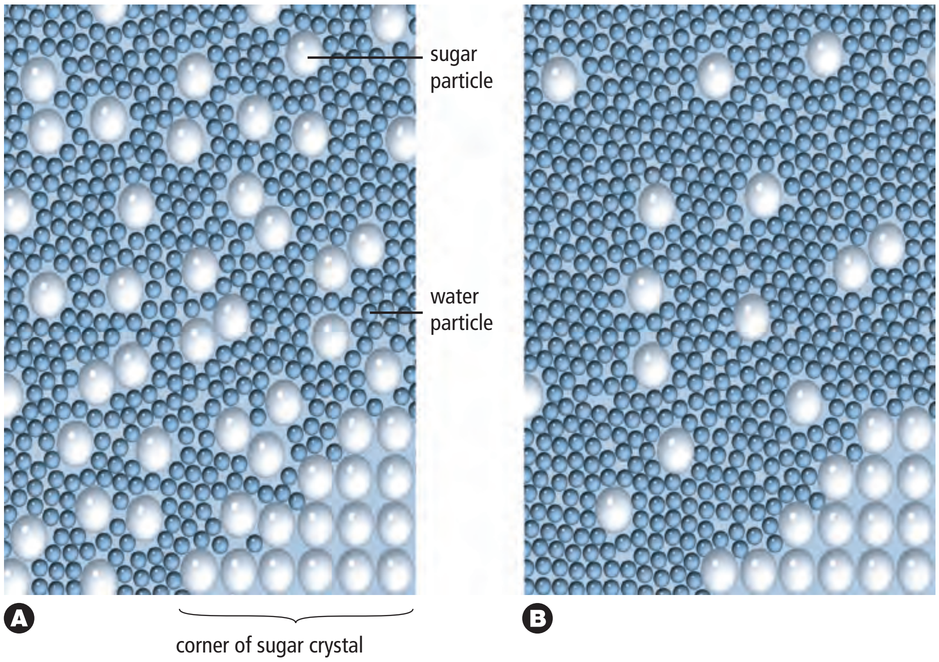
In Table 8.2, the solubility of ethanol in water is listed as unlimited. This means that any amount of ethanol will dissolve in *any* amount of water. Liquids such as these, which can dissolve in any amount in each other, are said to be *miscible*. Miscible comes from a Latin word that means "to mix."

Figure 8.10 Why might stirring or shaking a mixture make a solute dissolve faster?

Suggested Activity

Conduct an Investigation 8-2A on page 268

Figure 8.11 The particle theory of matter can be used to explain how stirring increases the rate of dissolving.



(A) Before the mixture is stirred, the sugar particles move into the solution at a rate that depends only on the natural movement of the nearby water particles. The solution close to the crystal is more concentrated, and the solution farther from the crystal is more dilute.

(B) When you stir the mixture, you cause the solute and the solvent to interact more quickly. Stirring pushes some of the concentrated solution away from the crystal. At the same time, stirring also pushes dilute solution closer to the crystal. Because there is more interaction between the solute and the solvent when you stir, the rate of dissolving increases.

Did You Know?

Some candies are made with confectioner's sugar. It is the same as table sugar, but it has smaller grains. If you put a grain of each type of sugar on your tongue, the confectioner's sugar will taste sweeter. That's because more of it can dissolve in the same time. (You can only taste sugar when it is dissolved on your tongue.)

Size of Solute and Rate of Dissolving

You probably know from experience that smaller pieces of solute will dissolve more quickly than larger pieces. For instance, smaller grains of sugar dissolve faster than larger grains of sugar. (You can try this yourself to verify it.) Why does the size of sugar or any other solid solute affect the rate of dissolving? Dissolving a solid in a liquid takes place at the surface of the solid. By breaking a large solid into smaller pieces, you expose more surfaces. Now there are more surfaces for the solvent to interact with. Because there is more interaction between the solute and the solvent, the solute dissolves faster—the rate of dissolving increases.

You can see how this idea works in Figure 8.12. The photo shows a whole sugar cube and a sugar cube that has been broken into smaller pieces. Both sugar cubes have the same mass. The surfaces of both cubes were coloured red with a felt pen before one cube was broken.

Breaking the cube has made more surfaces, which are white in the photo. So, now the total surface area of the pieces of sugar is greater than the surface area of the whole cube. Now there can be more interaction between the cube pieces and a solvent. So, the broken cube will dissolve faster than the whole cube.

Figure 8.12 These two sugar cubes are identical in size and in mass. But the broken sugar cube has more surfaces (many red and white surfaces) that can interact with a solvent than the whole sugar cube (just six red surfaces).

Pressure and the Solubility of Gases in Liquids

A sealed bottle of pop like the one in Figure 8.13 has a lot in common with a deep-sea diver like the one in Figure 8.14. Both are under pressure, and both contain concentrated solutions of gases in liquids.

In a bottle of pop, carbon dioxide gas is pumped under pressure into the water in the bottle. Gases are more soluble in liquids when the pressure is higher. The higher pressure forces extra gas particles into the spaces between the water particles. But the extra gas particles dissolve only because they are forced into the solution under pressure. When the cap is removed, the pressure inside the bottle lowers very quickly. This causes the gas to be less soluble. As a result, the gas comes out of solution. That's why you see lots of small bubbles when you open a bottle of pop such as the one in Figure 8.13.

This is similar to what happens inside a diver's blood. The diver's body is under pressure caused by the deep water, so the blood contains more gas particles than normal. These gases stay dissolved only as long as the pressure remains. As the diver rises to the surface, the pressure on the diver's body (and blood) becomes less. If the diver rises too quickly, the gases in the blood come out of solution very quickly. They form bubbles in the diver's blood, just like the bubbles in a bottle of pop. These gas bubbles are released from the blood into body tissues with painful, and possibly fatal, results.

This condition is often called "the bends." To avoid it, a diver must ascend gradually from any depth greater than 9 m. This helps the nitrogen gas to come out of solution slowly and into the lungs so that it can be exhaled safely.

Figure 8.13 When the pressure of the carbon dioxide gas in a pop bottle decreases, the solubility of the gas in the liquid pop decreases. Bubbles of gas quickly come out of solution.

Figure 8.14 The blood of all deep-sea divers develops a life-threatening solution of a gas dissolved in a liquid. That's why it's important for all divers to learn how to descend into the water and ascend from the water properly.

Reading Check

1. What is the difference between a saturated solution and an unsaturated solution?
2. The solubility of salt is 357 g/L at 0°C. Explain what this statement means.
3. How does the size of the solute affect the rate of dissolving?
4. What happens to carbon dioxide gas when the pressure on a solution of pop is reduced?

Explore More

Soda water and pop are used for enjoyment today, but they began as medicines! Find out about the history of pop—and why it's called pop in the first place. Begin your research at **www.discoveringscience.ca.**

Suggested Activity

Find Out Activity 8-2D on page 271

8-2A How Does Temperature Affect Solubility?

Skill Check
- Predicting
- Measuring
- Controlling variables
- Graphing

Safety

- It is not safe to taste any substances in the science classroom, even if you think they are safe. Containers or substances that look clean may still contain invisible traces of harmful chemicals left over from a previous activity

Materials

- balance
- graduated cylinder
- thermometer
- small beakers or test tubes with stoppers
- stirring rod
- measuring spoon
- solute of your choice (for instance: table salt, Epsom salts, flavoured drink powder, baking soda)
- clock or stopwatch

Do you think heating a solvent will affect the amount of solute that will dissolve in it? The data table below shows the solubility of three different solutes in water at various temperatures. In this activity, you will examine these data to develop a hypothesis about how temperature affects solubility. Then, you will design an experiment to test your hypothesis.

Question

How does temperature affect the solubility of a solid solute in a liquid solvent?

Procedure

Part 1—Analyzing Solubility

1. Draw the axes for a graph. Label the *y*-axis Solubility (g/L). Label the *x*-axis Temperature (°C). Mark the scale for the *x*-axis to go from 0 to 100.
2. Plot the data in the table below. Use a different colour for each solute. Include a legend to show the solute that each colour represents.

Temperature versus Solubility for Three Solutes

Temperature (°C)	Solubility in Water (g/L)*		
	Sugar (Sucrose)	Potassium Chlorate	Ammonium Chloride
10	1910	50	320
20	2040	70	370
30	2200	110	410
40	2390	150	460
50	2610	210	500
60	2870	270	550
70	3200	340	600

* Values have been rounded to the nearest 10.

3. Connect the points for each solute by drawing a line of best fit.
4. Use dashes to extend (extrapolate) the line for each solute so that it crosses 100°C.
5. Give your graph a title.
6. Answer Analyze questions 1, 2, and 3, and answer Conclude and Apply question 1.

Core Lab

Conduct an INVESTIGATION

Inquiry Focus

Part 2—Design Your Own Solubility Study

1. Based on the evidence from Part 1, how does temperature affect solubility for a solid solute that is mixed with a liquid solvent? Write a hypothesis.
2. Design an investigation to test your hypothesis. Here are some other tips and reminders that you might find useful.
   - There is more than one safe way to increase the temperature of a liquid.
   - Heating a liquid is not the only way to investigate the effect of temperature on solubility.
   - Which variables will you control? Which variable will you change (independent variable), and which variable do you expect will change in response (dependent variable)?
   - How will you guarantee safety for yourself and everyone else in the class?
   - How will you record your data?
3. Write the procedure for your investigation. Get your teacher's approval. Then, carry it out.
4. Clean up and put away the equipment you have used.
5. Answer Analyze question 4, and answer Conclude and Apply question 2.

Analyze

1. Describe the shape of the lines on your graph.
2. What happens to the lines as temperature increases?
3. Predict the solubility of each solute at 90°C. (Use your dashed line to help you make your prediction.)
4. How did the solubility in warmer water of the substance you tested compare with its solubility in colder water?

Science Skills

Go to Science Skill 1 for tips on drawing graphs. Go to Science Skill 2 for tips on how to work with variables.

Conclude and Apply

1. What happened to the solubility of each solid solute as the temperature of the water increased?
2. How well did your results support your hypothesis?

8-2B How Much Is Too Much?

Find Out ACTIVITY

Is there a limit to the amount of solute that can dissolve? In other words, can a solution be made more and more concentrated, with no limit? Does it matter what the solute is? You will explore these questions in this activity.

Safety

Materials

- graduated cylinder
- 250 mL beaker
- measuring spoon
- about 40 g of salt
- Petri dish (or piece of paper)
- water
- stirring rod
- balance
- additional substance provided for testing (for example, sugar, bluestone, calcium hydroxide)

What To Do

1. Use the graduated cylinder to measure 100 mL of cold tap water. Pour the water into the beaker.
2. Pour the salt into the Petri dish. Place the Petri dish on the balance. Measure and record the mass of the salt and dish. Use a table like the one below to record your measurements. Remember to include the units of mass. Then remove the Petri dish from the balance.

Measurements for Determining the Amount of Salt that Dissolves in 100 mL of Water

A. Mass of salt and Petri dish before mixing with water	
B. Mass of salt and Petri dish when salt no longer dissolves in the water	
C. Mass of salt that dissolved in 100 mL of water (Hint: A – B = C)	

3. Use the measuring spoon to add a small amount (about 2.5 mL—half a teaspoon) of salt to the water. Stir the mixture until all the salt is dissolved.
4. Repeat step 3. After each stirring, check to see if there is any salt that does not dissolve. Keep repeating step 3 until you see that some of the salt will no longer dissolve.
5. When you reach the point at which no more will dissolve, place the Petri dish with its remaining salt on the balance. Measure and record the mass in your table.
6. Find the mass of salt that dissolved in the water. Record this mass in your table.
7. Your teacher will provide you with one more substance. Follow all safety guidelines for this substance provided by your teacher. Test this substance in the same way that you did with salt. Prepare a table like the one you used for salt to record your observations.

What Did You Find Out?

1. (a) What was the volume of water that you used to dissolve the salt?

   (b) What was the total mass of salt that you were able to dissolve in this volume of water?
2. (a) What was the volume of water that you used to dissolve the second substance?

   (b) What was the total mass of this substance that you were able to dissolve in this volume of water?
3. Did different students get different results? If so, suggest reasons for the different results.

8-2C Concentrations of Consumer Products

Find Out ACTIVITY

In this activity, you will look for concentrations on consumer products that are solutions.

Safety

Handle each product carefully as you observe its label. As a precaution, have an adult with you while you do this activity.

What to Do

1. In your home, look for five products that show their concentration on the label. The chart below shows some ways to recognize how concentration may be expressed on a label.
2. Use a table with the following headings to record information about each product.

Name of Product	Solute	Solvent	Concentration

What Did You Find Out?

1. In the products you listed, what is the most common solvent?
2. Why do you think the manufacturer provided concentration information on the label?

Unit of Concentration	What It Tells about the Solution
g/L	tells how many grams of solute per litre of solution
ppm (parts per million)	tells the ratio, 1:1 000 000, of the mass of solute in the mass of solution
%	tells the percentage of solute in the solution by volume (in other words, the volume of the solute divided by the total volume of the solution)
%	tells the percentage of solute in the solution by mass (in other words, the mass of solute divided by the total mass of the solution)

8-2D Dissolved Carbon Dioxide

Find Out ACTIVITY

Soda water is water with dissolved carbon dioxide gas. In this activity, you will make observations about solubility with your ears and eyes.

Safety

- Use sealed, plastic bottles of pop.
- Compare cold and warm (not hot) bottles.

What to Do

Design an experiment to compare the solubility of carbon dioxide gas in cold water with its solubility in warm water. You will not be able to measure the solubility in grams of solute per litre of solvent. You will need to find another way to compare the two solutions. (Hint: What do you hear when you open a can or bottle of pop? What causes the noise?)

What Did You Find Out?

1. If you wanted to have a very bubbly bottle of pop when you open it, would you store it in a cold fridge or in a cupboard? Explain answer.
2. The ocean waters around the North Pole and the South Pole have more sea life than the ocean waters near the equator. Infer a reason why. (Hint: All ocean life depends on oxygen that is dissolved in the water.)

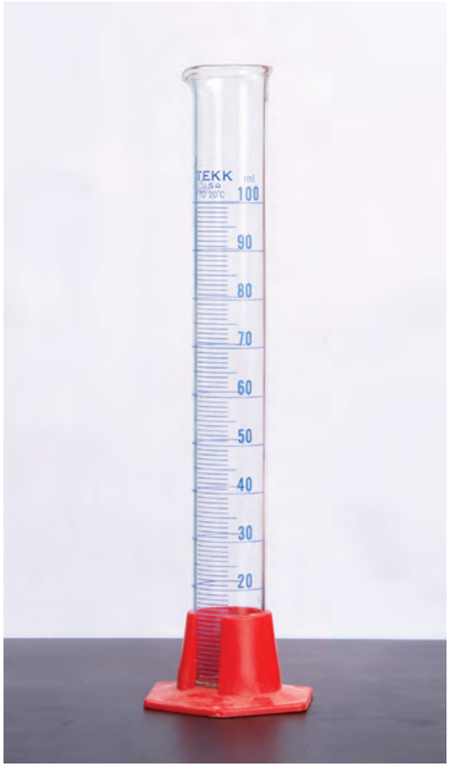
Science Math connect

Working with Concentration Units

Look again at Table 8.2 on page 264. Notice that the concentrations are expressed as grams of solute per litre of water (g/L). In the Find Out Activity on page 270, notice that the mass of solute being investigated is dissolved in 100 mL of water. How can you convert units of g/mL to g/L? How can you convert units of g/L to g/mL?

To answer these questions, start by thinking about how millilitres (mL) and litres (L) are related to each other. For instance, how many millilitres are there in one litre? If you are not sure, look at the scale on a graduated cylinder or on a beaker. You also might find it helpful to review Science Skill 4, Measurement.

Verify to yourself that there are one thousand millitres in one litre (1000 mL = 1 L). Use this information to help you solve the Practice Problems that follow.



Practice Problems

1. Devise a method to convert from mL to L. Test your method by converting the six units below. Check your answers with the class before going to step 3.
   (a) 1000 mL = ? L
   (b) 500 mL = ? L
   (c) 100 mL = ? L
   (d) 10 mL = ? L
   (e) 5 mL = ? L
   (f) 1 mL = ? L
2. Now devise a method to convert from g/mL to g/L. Check your answers with the class to make sure that everyone understands how to convert the units.
   (a) 10 g/100 mL = ? g/? L
   (b) 52 g/100 mL = ? g/? L
   (c) 65 g/100 mL = ? g/? L
   (d) 100 g/100 mL = ? g/? L
   (e) 137 g/100 mL = ? g/? L
   (f) 0.15 g/100 mL = ? g/? L
3. Review your methods closely. Then, convert all the solubilities in Table 8.2 from g/L to g/mL.

Check Your Understanding

Checking Concepts

1. Which is the most soluble substance listed in Table 8.2 on page 264?
2. (a) Which is the least soluble substance listed in Table 8.2?
   (b) How might the low solubility of this substance explain why it is a good choice for a building material?
3. Suppose that you add some solid detergent to the water in a washing machine. Then, you decide that your clothes are really dirty, so you add more detergent. Is the solution of detergent and water now more concentrated or more dilute? Explain how you know.
4. (a) The solution for a hummingbird feeder is made by dissolving 30 g of sugar in 100 mL of water at 0°C. Is the solution saturated or unsaturated? If it is unsaturated, how much more sugar could you dissolve in it before it becomes saturated?
   (b) You decide to boil the 100 mL of water for the hummingbird feeder in question (a) before adding the sugar. How much sugar, in total, can you add to the boiled water before it is saturated? (Hint: What is the temperature of boiling water?)
5. Refer to the Temperature versus Solubility table on page 268. Which solute has the highest solubility at each of the following temperatures?
   (a) 20°C
   (b) 60°C
   (c) 90°C

Understanding Key Ideas

6. Imagine that you are conducting a test for saturation. You add a small amount of solute to three different solutions, labelled A, B, and C. Based on the observations given, is each solution saturated or unsaturated?
   - Solution A: The added solute dissolves.
   - Solution B: The added solute does not dissolve.
   - Solution C: The added solute does not dissolve at first, but after some stirring the solute dissolves.
7. To keep roads safer in winter, road crews often spread salt on the roads to melt ice and snow. Which form of salt would you expect to stay on the road longer: rock salt (larger crystals) or table salt (smaller crystals)? Give reasons for your answer.
8. Suppose that you are dissolving a solute into 500 mL of water at 0°C. You find that no more than 495 g of solute will dissolve. Calculate the solubility of the solute.

Pause and Reflect

Your teacher asks you to help prepare some solutions for another class. Use the information in Table 8.2 to create a spreadsheet or a hand-drawn table that shows the number of grams of solute that are needed to make 10 mL, 50 mL, 100 mL, 500 mL, and 1000 mL of the following saturated solutions at 0°C: bluestone, Epsom salts, salt, sugar. Explain how you came up with the data for your table.

Chapter 8

Chapter Review

Prepare Your Own Summary

Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Solutes and Solvents
2. Concentration
3. Solubility
4. Rate of Dissolving

Checking Concepts

1. Identify the solute and the solvent in each of the following statements about solutions. Explain your reasoning.
   (a) A dentist prescribes a sodium fluoride solution to a patient who has severe tooth decay. The solution is 1.1% sodium fluoride in water.
   (b) Bronze is an alloy (a solid solution) of copper in tin.
   (c) There are 30 g of sugars in 1 L of Gatorade™. (Hint: The solvent for Gatorade™ is water.)
   (d) Bubbly soda water comes from underground springs such as those found in the town of Spa, in Belgium. Soda water is a solution of carbon dioxide gas in water.
   (e) Stainless steel may be made by dissolving carbon in iron.
   (f) One brand of apple juice, made from concentrate, has 100 g/L of sodium.
2. Describe the difference between:
   (a) a saturated solution and an unsaturated solution
   (b) a dilute solution and a concentrated solution
   (c) a substance that is soluble in water and a substance that is insoluble in water
   (d) a substance that has a high solubility in water and a substance that has a low solubility in water
3. Why must you include information about temperature when you state the solubility of a substance?
4. Neatly sketch a line graph or a bar graph that shows what happens to the concentration of a solution (y-axis) as you add solute to it (x-axis).
5. Ringer's solution is a fluid that doctors use for people and animals when they have lost too much water (are dehydrated). The solution contains some key salts in the same concentrations as they are in blood. These salts are sodium chloride (table salt), potassium chloride, and calcium chloride. Each 100 mL of Ringer's solution contains the following masses of these salts:
   - sodium chloride: 0.86 g
   - calcium chloride: 0.033 g
   - potassium chloride: 0.03 g

   Convert these values to concentration in units of g/L.

6. You mix 65 g of Epsom salts with 100 mL of water at 0°C.
   (a) Is the solution saturated or unsaturated? Explain how you know.
   (b) If the solution is saturated, how much solute is undissolved? If the solution is unsaturated, how much more solute could you dissolve in it?
7. You put some sugar in a jar of water, put a lid on the jar, and shake it. Why does shaking the jar increase the rate of dissolving?
8. Neatly sketch a line graph that shows what happens to the solubility of a substance (y-axis) as the solvent in which it is dissolved increases in temperature (x-axis).
9. Describe how pressure affects the solubility of a gas that is dissolved in a liquid.

Understanding Key Ideas

10. The solubility of ammonium chloride (a solid) at 60°C is 550 g/L.
    (a) If the temperature of the solution is reduced to 40°C, would you expect more solute to dissolve or less? Explain why.
    (b) If you want to dissolve 580 g of solute, would you have to raise the temperature of the solution or lower it? Explain why.
    (c) If the solution of ammonium chloride is heated to 75°C, is the solution now saturated or unsaturated? Explain why.
11. Which is more dilute: a solution with a concentration of 25 g/100 mL or a solution with a concentration of 20 g/80 mL? (Hint: Look at the concentrations very carefully.)
12. Your friend tells you that she is able to dissolve 39 g of salt in 100 mL of water. She says that there is no undissolved solute at the bottom of the container. However, the solubility of salt in water is 35.7 g/100 mL. Could your friend be telling the truth? Explain why or why not.
13. Compare the terms solubility and rate of dissolving. In what ways are they similar? In what ways are they different?

Pause and Reflect

The top rock layer of Niagara Falls is made of limestone. The solubility of limestone is 0.007 g/L at 0°C. With 200 000 000 t of water going over the falls each day, 1400 t of limestone could be dissolved. Only a tiny fraction of this amount actually dissolves, though. Give a reason to explain why.