Chapter 9

Many useful products depend on technology for separating mixtures and solutions.

The smaller photo shows three forms of solid sugar: white, yellow, and brown. You or a member of your family has probably used sugar products like these directly or in baking. The dark liquid in the fourth spoon is another sugar product: molasses. Would you believe that all four of these sugar products come from the same source? The source may be either the roots of sugar beets or the stalks of sugar cane grass. During the sugar-making process, different methods are used to purify or remove the sugar products from the original mixture of sugar-containing materials. Filtering is one of these methods. Evaporation is another. You will learn about these and other methods of separating mixtures in this chapter.

What You Will Learn

In this chapter, you will
- **identify** separation techniques that are used in and around the home
- **describe** how to use different methods to separate a variety of mixtures
- **identify** examples of how science related to mixtures and solutions affects our lives

Why It Is Important

Most of the products that people use to eat, to clean themselves, to run machines, and to build homes and shelters are made by processing and separating mixtures and solutions. Learning about mixture-related technologies may lead to a future career. It also may help you appreciate the role of mixtures and solutions in your life.

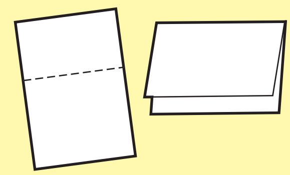
Skills You Will Use

In this chapter, you will
- **separate** the components of a variety of mixtures
- **choose** and **use** an appropriate separation technique when given a known mixture
- **choose** and **use** an appropriate separation technique when given an unknown mixture

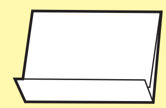
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 9.

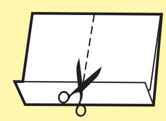
STEP 1 **Fold** an 8.5 × 11″ sheet of paper lengthwise, leaving a 2 cm tab along the bottom.



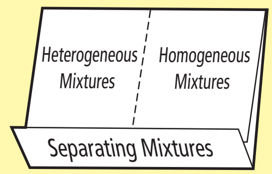
STEP 2 **Fold** the bottom tab up to cover the front flap.



STEP 3 **Cut** the front flap in half to create two flaps that open upwards.



STEP 4 **Label** the Foldable as shown.



Organize Describe methods for separating mixtures under each flap, and write down any questions that arise as you read the chapter.

9.1 Separating Mixtures and Solutions

You use a variety of techniques to separate mixtures in your daily life. Common methods that are used to separate heterogeneous mixtures into their parts include sorting by hand, mechanical sorting (such as using flotation and magnetism), and filtration. Common methods that are used to separate homogeneous mixtures (solutions) into their parts include evaporation, distillation, and paper chromatography.

Key Terms

evaporation
filtration
mechanical sorting
paper chromatography
simple distillation

You separate mixtures all the time—probably without even thinking about it. For instance, do you have a box or jar at home for pennies, nickels, and other loose change? You are separating a mixture when you sort the coins in order to spend them or to put them into coin rolls as in Figure 9.1. Figure 9.2 shows some other ways that people separate common mixtures.

Figure 9.1 Sorting coins is one example of separating a mixture.

Figure 9.2 Photos (A) to (E) show some familiar examples of mixtures being separated in and around the home.
(A) A colander is a handy device for separating pasta from a mixture of water and pasta.
(B) A screen window or door separates insects from the air that comes into a building.
(C) The spin cycle of a washing machine separates clothes from a mixture of clothes and water.
(D) A salad spinner lets you remove water from damp lettuce after it has been washed.
(E) Wearing a mask helps protect a carpenter from breathing in sawdust and other particles.

Word Connect

A colander is a type of filter that is used to strain water from washed and cooked foods. The device gets it name from a Latin word that means "to strain."

9-1A Strategies for Separation

What methods could you use to separate different mixtures? Your teacher will give your group containers with at least three mixtures. Decide how you would recover all the substances from each mixture, in their original form.

Safety

- Do not open the containers unless requested by your teacher.

Materials

- containers of different mixtures such as: salt water, muddy water, nuts and bolts, iron filings and sand, vegetable oil and sand, vegetable oil and water, salt and pepper
- additional materials, if you are asked to test your ideas

Procedure

1. Copy the table below. Leave enough lines for all the mixtures your group is assigned. Give your table a title.
2. Observe each mixture. With your group, brainstorm possible methods that you could use to separate it.
3. In the table, record the two methods your group thinks would work best for each mixture. Give reasons why the methods would work. (You might find it helpful to refer to properties of matter.)

What Did You Find Out?

1. Which properties of matter did you refer to most often?
2. Which methods of separation did you refer to most often?
3. (a) Which mixtures would be easiest to separate? Why?
   (b) Which would be the most difficult to separate? Why?
4. Name the method or methods you would use to separate this mixture: marbles, sand, iron filings? Explain why each method would work.

Mixture	Separation Method	Reasons
		1. 2.
		1. 2.
		1. 2.
		1. 2.
		1. 2.
		1. 2.
		1. 2.

Connection
Review section 7.1 to remind yourself about heterogeneous mixtures.

Separating Heterogeneous Mixtures

You can easily see the parts in a heterogeneous mixture such as raisin-flakes cereal. Figure 9.3 shows that separating the parts of this mixture is easy to do by hand or with tweezers. It will just take a long time this way!

With a heterogeneous mixture of sand and iron filings, the parts of the mixture are too small to see easily. Even if you could see them, imagine trying to pick out each grain of sand or each bit of iron one by one! Figure 9.4 shows a different property that you can use to separate the parts of the mixture. Since iron is magnetic, you can use a magnet to attract the iron filings away from the sand grains.

Figure 9.3 With a mixture such as raisin-flakes cereal, you can use properties of parts of the mixture, such as size and shape, to separate the mixture.

Figure 9.4 When you separate a mixture such as sand mixed with iron filings, you can use the property of magnetism to separate one substance (the iron filings) from another substance in the mixture. Why is the magnet inside a plastic bag?

Mechanical Sorting

The separation methods shown in Figures 9.3 and 9.4 are examples of mechanical sorting. **Mechanical sorting** is a way to separate the parts of a mixture based on properties such as particle size (Figure 9.3) and magnetism (Figure 9.4). Flotation is another type of mechanical sorting. It depends on the density of the parts. Some parts of a mixture will float while others may sink. For example, you use flotation to help you skim the fat off soup (Figure 9.5).

Figure 9.5 The density of fat is lower than the density of soup liquid, so the fat floats. When it cools and hardens, fat is easy to remove from the surface of the soup.

Filtration

Filtration is one of the most common ways to remove solid particles from a mixture. Filters like those shown in Figure 9.6 are devices that have holes in them. The holes can be large enough that you can see them easily. For instance, you can see the filtering holes in a colander or a window screen. Or the holes may be so small that you need a magnifying glass to see them. For instance, you can just barely see the holes in a tea bag. But the holes in a coffee filter are too small to see.

Filtration works like mechanical sorting, because it depends on the size of the particles in a mixture. How well a filter works depends on the size of its holes. If the holes are smaller than the size of the particles, the particles will not pass through. So, they will be separated from the mixture. This is why filters do not separate the parts of a solution. The solute particles are smaller than the filtering holes, so they pass right through the filter along with the solvent.

Explore More

The mining industry uses a separation method called froth flotation to remove bits of desired substances from the rock in which they are found. But density is not the only property on which this method depends. What is the other property? Start your research at **www.discoveringscience.ca.**

Figure 9.6 Which of these types of filters have you seen or used? What other types of filters are there? How do the sizes of their holes match their function?

Reading Check

1. Describe mechanical sorting, using magnetism as an example.
2. Why is it easier to separate the parts of a heterogeneous mixture than the parts of a homogeneous mixture (a solution)?
3. Why is the size of the holes in a filter important for filtration?

Suggested Activity

Conduct an Investigation 9-1B on page 285.

Separating Homogeneous Mixtures

Recall that homogeneous mixtures are solutions. Two common methods that are used to separate solutions are evaporation and distillation. Another method, called chromatography, is a more specialized way to separate solutions. You will learn about these methods as you read on.

Separating a Solution by Evaporation

In Unit 2, you learned that adding heat to a liquid causes it to change state to become a gas. That is, the liquid evaporates. **Evaporation** is one common way to recover the solid solute from a solution. As the liquid (solvent) evaporates, the solute is left behind. Figure 9.7 shows how this happens naturally in some areas.

Figure 9.7 The plentiful heat from the Sun evaporates the water from this basin in California. Solid crystals of salt (the white parts of the shoreline) are left behind.

Figure 9.8 Buckets hanging on maple trees is a common spring-time sight in North America. About 30 L to 40 L of sap are needed to make 1 L of maple syrup.

You may have eaten a product that is made by the evaporation method: maple syrup. The sap that flows under the bark of eastern maple trees is a dilute solution of sugar, water, and small amounts of other substances. Long ago, Aboriginal peoples learned how to make syrup from this sap. In the spring, the sap is collected by driving a small tube into the trunk of each maple tree. The sap flows out of the tube and into a bucket that is hung below it, as you can see in Figure 9.8. Buckets of collected sap are poured into large vessels and then boiled for several hours. Most of the water evaporates (boils away). What is left behind is a more concentrated solution of syrup.

Connection

You can review evaporation and other changes of state of matter in Chapter 5.

Separating a Solution by Distillation

Suppose that you are lost in a desert and the only liquid that you have is a salt solution. You need to separate the salt from the water so that you have something to drink. If you let the water evaporate, it will be lost to the air as water vapour. You will be left with only the salt. How can you recover the solvent from this solution? **Simple distillation** is a method that you can use to separate and recover a single solute *and* a single solvent from a solution.

During simple distillation, the solution is heated until the solvent changes state to become a gas. Then the gas changes back to a liquid by cooling it. The solute does not change state, so it is left behind. Figure 9.9 shows some equipment that is often used for distillation in a lab. Figure 9.10 shows a setup that you could use to collect drinkable water from salt water in a desert or other place with lots of sunlight.

Suggested Activity

Find Out Activity 9-1C on page 286.
Conduct an Investigation 9-1C on page 287.

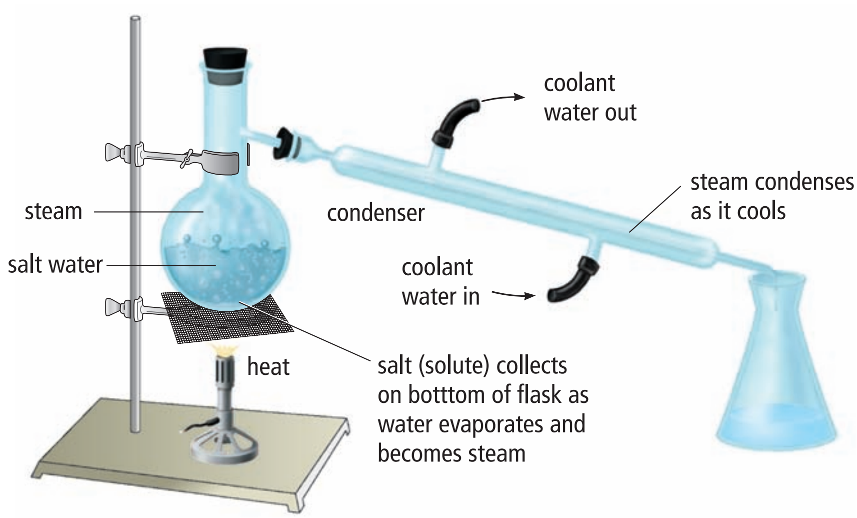


Figure 9.9 Simple distillation equipment. During what parts of this process is the solvent in the gas state? In what parts is it in the liquid state?

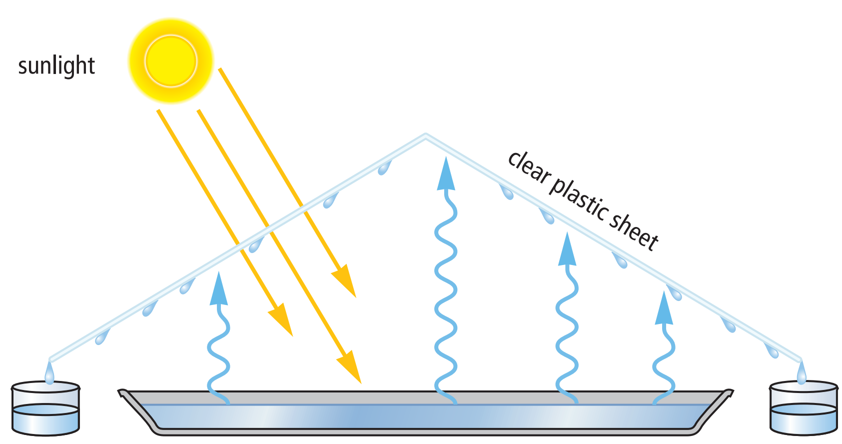


Figure 9.10 This method for distilling drinkable water from salt water requires simple materials and plentiful heat from the Sun.

internet connect

Earthquakes, floods, and other natural disasters often destroy the pipes that bring drinking water to a community. One of the risks to survivors is drinking contaminated water. How could you purify water in an emergency, using only energy from the Sun? Start your search at **www.discoveringscience.ca.**

Did You Know?

Chromatography was invented in 1903 by a Russian scientist who was studying the pigments (coloured chemicals) in the leaves of green plants. He discovered that green leaves have not only green pigments, but also orange, yellow, and red pigments. You see these pigments in the fall when leaves change colour.

Suggested Activity

Conduct an Investigation 9-1C on page 289.

Separating a Solution by Paper Chromatography

The patient was barely conscious when the paramedics wheeled him into the emergency room. As the attending doctor examined the patient, she suspected that he had been exposed to a toxic chemical. Among the tests she ordered was a "tox screen" of his blood. In the lab, chromatography would be used separate the components of the patient's blood. If a toxic chemical was present, it would show up in the test results.

Chromatography is a method that doctors, police detectives, and chemists use to separate and identify the solvents in a mixture. One type of chromatography that may be done with simple materials is called paper chromatography.

Paper chromatography is often used to separate the coloured substances in a mixture such as ink. It works by seeing how fast a dissolved substance is carried by a solvent through a material, such as filter paper, that absorbs the solutes. Figure 9.11 shows that different substances move with a particular speed to form a specific pattern. You can use the speed and pattern of the various substances in a test sample to identify them.

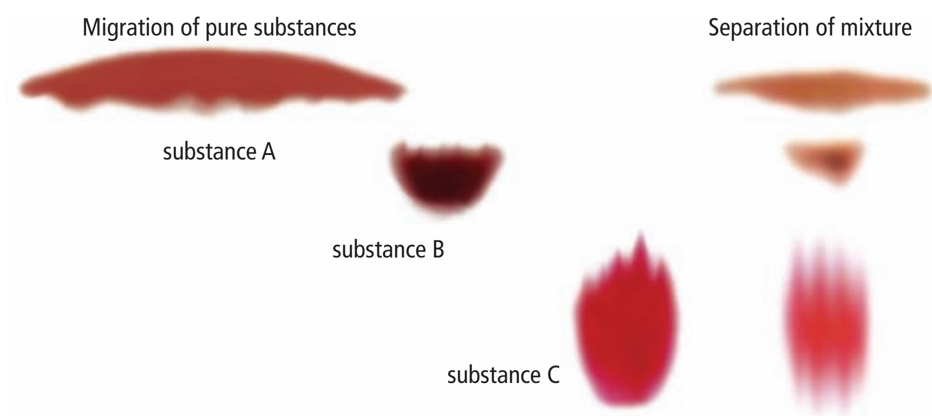


Figure 9.11 This picture shows how substance A, substance B, and substance C look after paper chromatography was done with each one separately. Then the three substances were mixed together in water, and paper chromatography was done with this solution. What do you notice?

Reading Check

1. Which part or parts of a solution does evaporation recover: the solute, the solvent, or both?
2. Which part or parts of a solution does distillation recover: the solute, the solvent, or both?
3. What is chromatography?
4. How does paper chromatography work?

9-1B Making Dirty Water Clear

Conduct an INVESTIGATION

Problem Solving Focus

SkillCheck

- Communicating
- Modelling
- Explaining systems
- Working co-operatively

Safety

- Do not taste, smell, or drink the water in this activity. It is not safe for these purposes.
- Handle the pop bottle carefully so that you do not accidentally cut yourself on the cut-off end.

Materials

- 2 L pop bottle with bottom cut off
- ring clamp
- ring stand
- stopwatch or other timer
- sand
- gravel
- cotton cloth
- 500 mL dirty water
- bucket or large beaker (to collect the filtered water)

Problem

Imagine that you run out of drinking water on a camping trip. There is a pond close by. You can see insects and leaves floating in the water. You can smell the mud and rotting leaves. How can you make 500 mL of this water clear as a first step in making the water safe to drink?

Criteria

- Design a filter that will clarify (make clear) 500 mL of dirty water.
- Use only the materials provided.
- This activity must be completed in one class period.

Design and Construct

1. With your partners, discuss which materials you will use and how you will use them.
2. Draw a diagram to show how you will set up your filtration method.
3. Get your teacher's approval before doing any tests.
4. Build your filter. Then test it with the dirty water. Use a stopwatch or other timer to time how long it takes to filter the water.
5. Clean up and put away the equipment you have used.

Evaluate

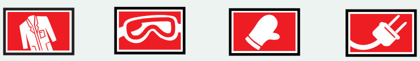
1. How did the water going into your filter compare with the water coming out of it? Describe any differences.
2. Compare the design of your filter to other designs in the class. Which design seems to work best? Explain why?
3. What could you do to make your filter produce clearer water?
4. How could you improve your design? For instance, how could you prevent the filter from clogging or make it work faster?

9-1C Separating Homogeneous Mixtures

Part 1: Evaporation

Solutions can be harder to separate than heterogeneous mixtures. You cannot use a filter or a magnet to get salt from salt water. In this activity, you will use a change of state to help you separate a solution.

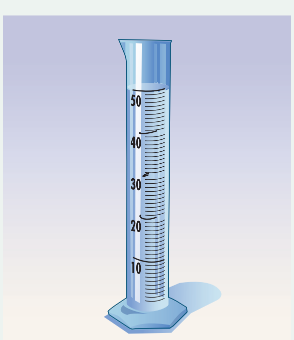
Safety

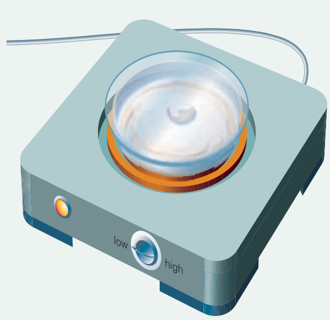


- Use heat resistant gloves to handle hot glassware.
- Be sure you are wearing your safety goggles when you are near the evaporating dish as it is heating.
- Unplug the hot plate after you turn it off. Let it cool before putting it away.

Materials

- evaporating dish
- 50 mL graduated cylinder
- hot pad
- hot plate
- stirring rod
- tongs
- watch glass
- salt water





Procedure

1. Pour 50 mL of salt water into the empty evaporating dish. Cover the dish with the watch glass.
2. Put the evaporating dish on the hot plate. Very gently heat the solution. Observe the solution as it heats, and record your observations in your notebook.
3. When all the water has evaporated, remove the evaporating dish from the hot plate. Place the evaporating dish on the hot pad to cool.
4. When the evaporating dish has cooled, remove the watch glass. Observe the material that remains in the evaporating dish. Record your observations.
5. Clean up and put away the equipment you have used.

What Did You Find Out?

1. Describe the appearance of the solution in step 1.
2. Describe the material that remained in the evaporating dish in step 4.
3. What happened to the water in the solution? (Be sure to identify the change of state.)
4. (a) What substance likely remained in the evaporating dish?

   (b) Explain why it would be unsafe to use taste to be sure of what substance it is.
5. Suggest one way that you could collect the water that evaporated.

Inquiry Focus

Part 2: Distillation

Safety

- You will be working with a hot plate, boiling water, and hot steam, all of which can cause painful burns. Work carefully around hot objects, especially steam.

Materials

- 2 mL to 3 mL distilled water
- salt
- microscope slide
- marker
- 2 beakers (250 mL)
- graduated cylinder
- medicine dropper
- hot plate
- 500 mL Erlenmeyer flask
- stopper with glass tubing already inserted
- 50 cm rubber or plastic tubing
- tongs to handle beaker or flask
- 5 mL measuring spoon

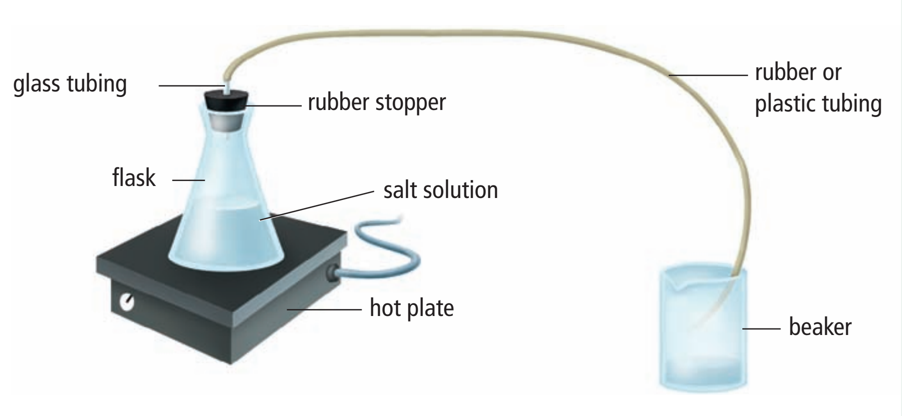
In this investigation, you will experiment with the distillation process as you separate the solvent (water) from a solution of salt water.

Question

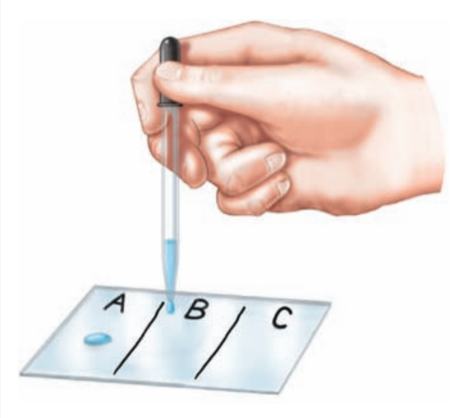
How can the parts of a salt water solution be separated and recovered?

Procedure

1. Measure 100 mL of tap water in a graduated cylinder. Pour the water into a 250 mL beaker.
2. Add 10 mL of salt, and stir until the mixture is dissolved.
3. Pour almost all of this solution into a 500 mL flask. (Save a few drops to use for testing in step 5.)
4. Using the other beaker, set up the equipment shown in the diagram below.
   (a) Make sure your hands are dry. Plug in the hot plate, and turn it on. Heat the mixture until about half of the liquid has boiled away.
   Caution: Turn off the hot plate when *half* of the liquid is gone. Then carefully remove the end of the tubing from the beaker. (Be sure to wear gloves. The tubing will be hot.)
   (b) Let the apparatus cool completely before taking it apart.



5. In this step, you will test for the presence of dissolved salt by letting three samples of liquid evaporate. Be sure to use the same amount of liquid for all three samples.
   (a) With the marker, divide the microscope slide into three parts. Label them A, B, and C as shown in the diagram on the next page.
   (b) Use the dropper to put three drops of the solution you saved in step 3 on the part of the microscope slide marked A.



(c) Clean the dropper, and rinse it a few times with some of the liquid that you collected in step 4. Then use the dropper to collect a small amount of the liquid that you collected in step 4. Put three drops on the part of the microscope slide marked B.

(d) Clean the dropper, and rinse it a few times with some of the distilled water. Then use it to put three drops of distilled water on the part of the slide marked C.

(e) Set the microscope slide in a place where it will not be disturbed. When the liquid has evaporated, observe the slide to see what material, if any, is left on it. Make a sketch to record your observations.

6. Clean up and put away the equipment you have used.

Analyze

1. (a) What did you see in the top half of the flask after the water started to boil?
   (b) What change of state must have occurred inside the flask? Explain how you know.
2. (a) Describe what you saw at the end of the rubber tubing in the beaker (step 4).
   (b) What change of state must have occurred inside the tubing?
3. After the drops of liquid evaporated from the microscope slide, what (if any) material remained on the slide for
   (a) the salt solution?
   (b) the liquid collected in step 4?
   (c) the distilled water?
4. In steps 4(c) and (d), you rinsed the eye dropper with the liquid that you were going to collect and then put on the microscope slide. What do you think was the purpose of this rinsing process?

Conclude and Apply

1. In step 4, which substance collected in the beaker: the solute or the solvent? Explain how you know.
2. What happened to the substance that was not collected in this beaker?
3. Which of the three samples in step 5 were probably pure water? Explain your answer.
4. In your opinion, would distillation be a suitable method for producing large amounts of pure water, for a large city? Give reasons to justify your opinion.

Part 3: Paper Chromatography

Safety

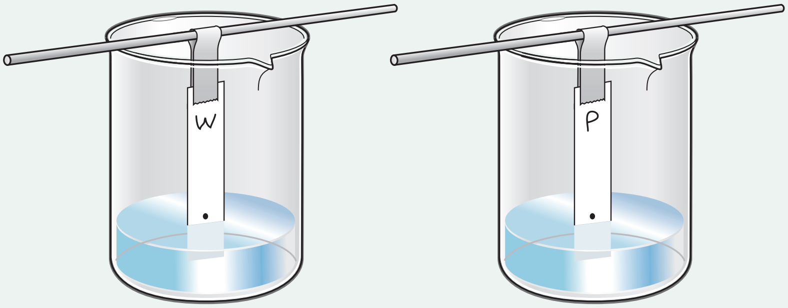
- Do not sniff the markers. Their fumes can irritate and damage the lining of the nose, throat, and lungs.
- Handle the scissors carefully.
- Dispose of all waste materials as directed by your teacher.

Materials

- 2 beakers (250 mL)
- filter paper
- black marker pen (water-soluble)
- black marker pen (permanent)
- water
- 2 plastic straws
- scissors
- ruler
- tape
- waxed paper

Procedure

1. Cut the filter paper into a narrow strip, about 2 cm wide. Make the strip long enough to fit inside the whole height of the beaker. Then make a second paper strip the same way.
2. Add water to each beaker until it reaches a depth of about 1 cm.
3. Use the water-soluble marker to make a dot of ink that is about 1.5 cm from the end of one paper strip. The dot of marker ink should be about 3 mm in diameter. At the other end of the strip, use a pencil to write the letter W (for water-soluble).
4. Repeat step 3 with the permanent marker and the other paper strip, but write the letter P (for permanent).
5. Tape the end of each strip to the centre of each straw so that the strips form a T-shape with the straws.
6. Place each straw across the top of a beaker so that the bottom of each strip hangs in the water and the ink dot is a few millimetres above the water. You might have to adjust the length of the paper strips so that the end with the ink dot is above water level.
7. Leave the beakers undisturbed until the colours have moved a few centimetres up the paper strips. Then remove them and leave them to dry on some waxed paper.
8. Clean up and put away the equipment you have used.



Analyze

1. Sketch and describe what you observed on each paper strip.
2. If you had forgotten to label the paper strips, how could you know which marker you had used to make the ink dots?

Conclude and Apply

1. Is ink a mixture of different substances? Justify your answer.
2. Do you think you could put the separated colours together again? Describe what you would do and explain why you think it would work.

Wild, Weird, Wonderful

www Science

Cleaning Up for Peat's Sake

In the early 1930s, politicians assessed and debated the state of the Newfoundland and Labrador economy. One very large component of the landscape was dismissed as being of little value. Bog lands, according to the Newfoundland Royal Commission of 1933, "extend over a large part of the Island, and their occurrence may be observed in every district of the country.... These soils are not suitable for the production of crops."

It is true that bogs are not suited for growing food crops such as fruits, vegetables, and grains. But there is a crop that forms naturally in bogs, and one company in the interior of the island of Newfoundland has learned how to harvest it with great success. That crop is peat.

Peat is a compacted mass of slightly or partly decomposed moss and other plant material that grows in the high-moisture, low-oxygen environment of bogs. Many gardeners use peat to condition their soil. One way that peat helps garden soil is by absorbing and holding onto moisture. At Hi-Point Industries in Bishop's Falls, this same property of absorption is used for other purposes as well.

Hi-Point makes and sells peat products for gardeners. But the company's main claim to fame is a range of products that help international oil companies clean up water and land that has been polluted by oil spills. More than 24 countries on nearly every continent benefit from Hi-Point's high-absorbency home-grown material.

Hi-Point's oil-absorbing peat is good for more than just the environment. It also benefits the province's economy. In 2006, Newfoundland and Labrador's Minister of Innovation, Trade and Rural Development announced that Hi-Point Industries Ltd was the winner of the Exporter of the Year Award.

Check Your Understanding

Checking Concepts

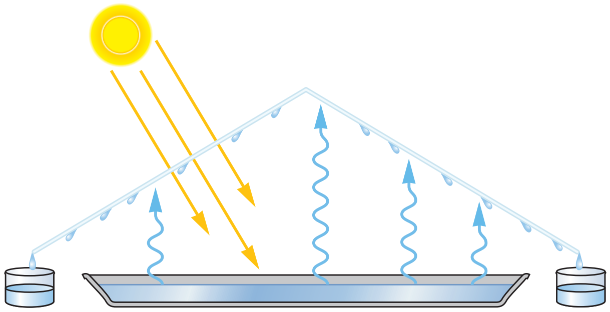
1. What types of mixtures is the colander shown in the photo designed to separate? Name three other ways that you separate mixtures in your daily life.

2. A mixture contains marbles of three different sizes. How could you use two different types of filter to separate this mixture? Draw sketches to show your method.
3. Explain how you could separate each of these mixtures.
   (a) wood chips and pieces of granite rock
   (b) iron filings and wood sawdust
   (c) salt and pepper
4. Explain how evaporation and distillation are similar and how they are different.

Understanding Key Ideas

5. The small pitcher shown in the photo is used to separate fat from gravy juices.

   (a) What property of fat and gravy juices lets you separate them?
   (b) The pitcher is designed so that gravy juices, not fat, pour out of the spout. Gravy juices are mostly water. Why does the spout come from the bottom of the pitcher?
   If you did not have a gravy pitcher, suggest two methods that you could use to separate the fat from the gravy juices. Assume that you have plenty of time. (Hint: If you are having trouble coming up with one method, think about how liquids behave during paper chromatography.)
6. The diagram shows how you could get clean drinking water from salt water. What separation method is used to collect pure water from salt water?
   (a) Describe *how* this method works.
   (b) Use the particle theory to explain *why* this method works.



Pause and Reflect

In 2001, a group of scientists who specialize in studying fog met in St. John's. One of the scientists was Canadian atmosphere specialist, Dr. Bob Schemenaur. He has designed a method to help people who live in dry regions collect water from the air by hanging large nets. When fog blows into a net, tiny water droplets in the fog catch on the fine plastic mesh of the net. These droplets then trickle down the net into a collecting vessel. What separation method is used to separate drinkable water from fog? Give reasons to justify your answer.

9.2 Separating Mixtures from Underground

Petroleum is a mixture that is made up of many solid, liquid, and gas substances. Valuable substances in petroleum can be separated by fractional distillation, which is based on their boiling points. The separated parts of petroleum may be processed further to make hundreds of thousands of other products. Gold ore is a mixture of solid substances. Gold nuggets that are mixed with sand, gravel, and mud may be separated by panning, which is a filtering-like method.

Key Terms

fractional distillation
ore
petroleum

Earth is rich in natural mixtures. Over thousands of years, we have developed technologies to process these mixtures to make useful products. This section will focus on two natural mixtures and the products we derive from them. One of these mixtures is a liquid: petroleum. The other is a solid: gold ore.

A Liquid Mixture from Underground

Petroleum, also called crude oil, is a complex mixture of liquid, solid, and gaseous substances. Petroleum is the source of most of the fuels and lubricants that run the machines we depend on.

Oil exploration companies spend many millions of dollars to find deposits of petroleum. In Canada, some of these deposits are found underground mainly in Alberta and Ontario. Other deposits are found under the ocean bottom off the east and west coasts. Figure 9.12 shows an oil rig pumping oil from beneath the ocean floor off the coast of the island of Newfoundland.

Pumping petroleum to the surface is just the first step in making use of this valuable mixture. To make useful products, the petroleum must be processed to separate and refine its components.

Figure 9.12 This oil rig is extracting crude oil from the Hibernia oil field, which is the fifth-largest source of petroleum ever found in Canada.

Fractional Distillation

You know that simple distillation is a way to separate a single solute and a single solvent from a solution. The solution is heated so that at least one part starts to change state to become a gas when it reaches its boiling point. Meanwhile, the other part stays liquid because its temperature is below its boiling point. Look again at Figure 9.9 on page 283. Notice that the gas travels up and away from the mixture and from the source of heat. In a separate chamber, the gas is cooled, and it changes state back into a liquid. The condensed liquid is then collected.

Petroleum is a much more complex mixture than salt water. Petroleum contains hundreds of different substances. Each of these substances has its own boiling point. This is the key to separating petroleum into its parts. **Fractional distillation** is a process that uses the boiling points of substances to separate a complex mixture into its parts. The process is done in a two-tower structure like the one shown in Figure 9.13. In the shorter tower, the petroleum is heated strongly enough to change it into a mixture of gases. Then this gas mixture is pumped into the bottom of the taller tower.

Inside the tall tower, the hot gases rise. As they rise, they cool. As the temperature of each part cools to just below its boiling point, it condenses. That is, it becomes a liquid. The parts of the gas mixture that have a high boiling point will condense near the bottom of the tower, because they are still very hot. Different gases condense at different levels, depending on their boiling points. Near the top (the coolest part of the tower), a few parts of the original mixture remain in the gas state. (Why would these parts of the mixture stay in the gas state?)

Each part (or fraction) of the mixture is collected in pipes at its own level and is sent to a different part of the oil refinery to be processed further. All the products that are made from the original petroleum are known as petrochemicals.

Word Connect

The "fractional" part of the term fractional distillation comes from the same root word as "fracture", meaning "break up." The fractional distillation of petroleum "breaks up" the mixture in separate parts, or "fractions."

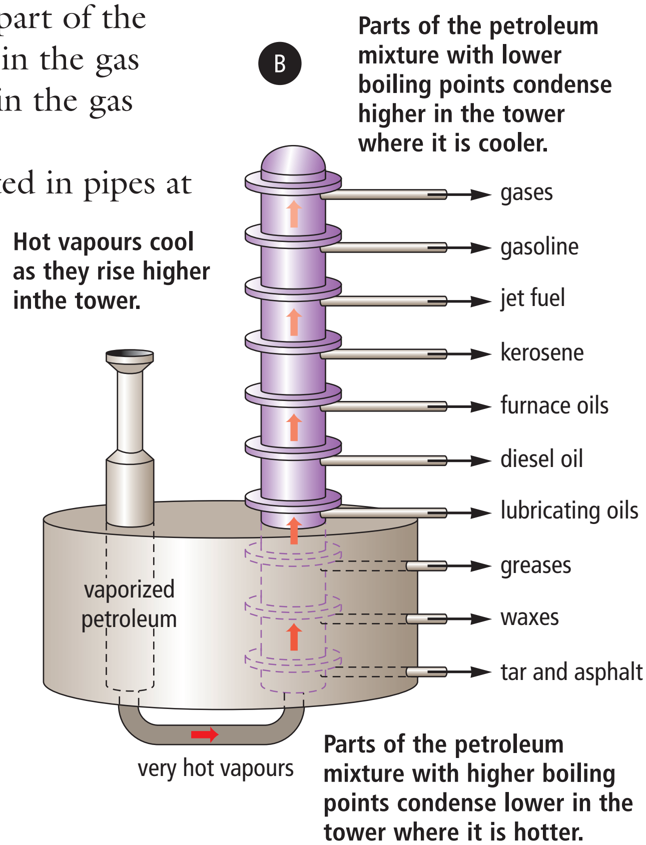


Figure 9.13 Fractional distillation towers (A) are common sights in the oil-producing regions of North America. The diagram (B) shows some of the products that are made from each separated part of the original petroleum mixture.

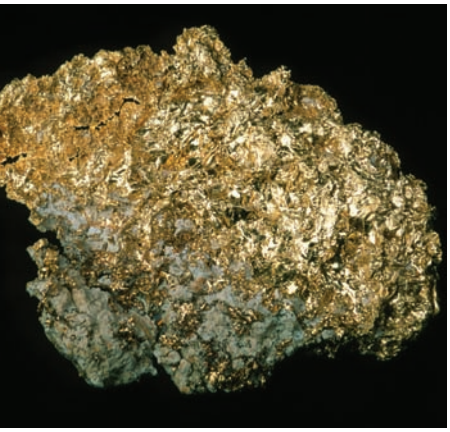


Figure 9.14 Gold is one of the few metallic pure substances that may be found in its pure form in nature. Most metals are combined with other metals in ways that require a lot of processing to separate them out in their pure form.

A Solid Mixture from Underground

Most underground materials are solids—solid rocks. Rocks are mixtures. For example, the rock shown in Figure 9.14 is a mixture that contains a highly desirable substance: gold. Rock that contains gold is called gold ore because it can be processed to get pure gold. An **ore** is a rock mixture that contains one or more valuable substances. Another example of an ore is iron ore—a rock that contains iron.

Gold is valuable because it is beautiful and rare. It is also valuable because of its properties. Gold resists wear and corrosion. It is also fairly soft, so it can be made into jewelry easily.

Gold is so valuable that some people are willing to spend a lot of time, energy, and money to get it. In the nineteenth century, reports of newly discovered gold deposits led to gold rushes. A gold rush is a situation in which many people "rush" to an area that has gold so they can claim some for themselves. The first gold rush in North America started in 1848 in California. There was another famous gold rush in the Yukon Territory in 1897. Nova Scotia had a smaller-scale gold rush in the mid-1800s.

During the gold rushes, miners did not have to dig to find gold. They looked in and around streams. The simplest way to find gold in streams was by panning. A miner dug out material from the stream bed and swirled it in a pan with lots of water. Gold is very dense. Even tiny pieces of gold have more mass than pieces of sand or gravel. As the miner swirled the mixture from the stream bed, sand, gravel, and mud were washed away. If the miner was lucky, a nugget or two of pure gold would be left at the bottom of the pan.

internet connect

Aspirin™, basketballs, chewing gum, duct tape, eyeglass lenses, and fertilizer are some of the products that are made from petrochemicals. Can you keep this alphabetical list going? Find a petrochemical product for each letter of the alphabet. Start your search at **www.discoveringscience.ca**.

Reading Check

1. Is petroleum a mixture or a pure substance? How do you know?
2. What is fractional distillation?
3. Why is fractional distillation used to process petroleum?
4. Is gold ore a mixture or a pure substance? How do you know?

9-2A Panning for "Gold"

Find Out ACTIVITY

Make a working model to show how panning for gold works.

Safety

- Turn off the hair dryer when you are not using it.

Materials

- about 1 L Styrofoam packing chips
- about 1 L marbles
- large paper bag
- large basin
- hair dryer

What to Do

1. Pour the foam chips and marbles into the large paper bag. Mix them thoroughly.
2. Place the mixture in a large basin. Use a circular motion to swish and swirl the basin steadily. Have a partner aim a hair dryer across the top of the basin. Your partner should aim away from you, for safety.

What Did You Find Out?

1. Identify the part of your model that represents:
   (a) gold nuggets
   (b) gravel
   (c) running water
2. How is your model similar to the method that was used to pan for gold? How is it different?

internet connect

The hydromet (hydrometallurgical) process is used to separate desired substances such as nickel and copper from their ores at mining operations such as the Voisey's Bay Project. How does this process work? You can start to find out by going to **www.discoveringscience.ca**.

Explore More

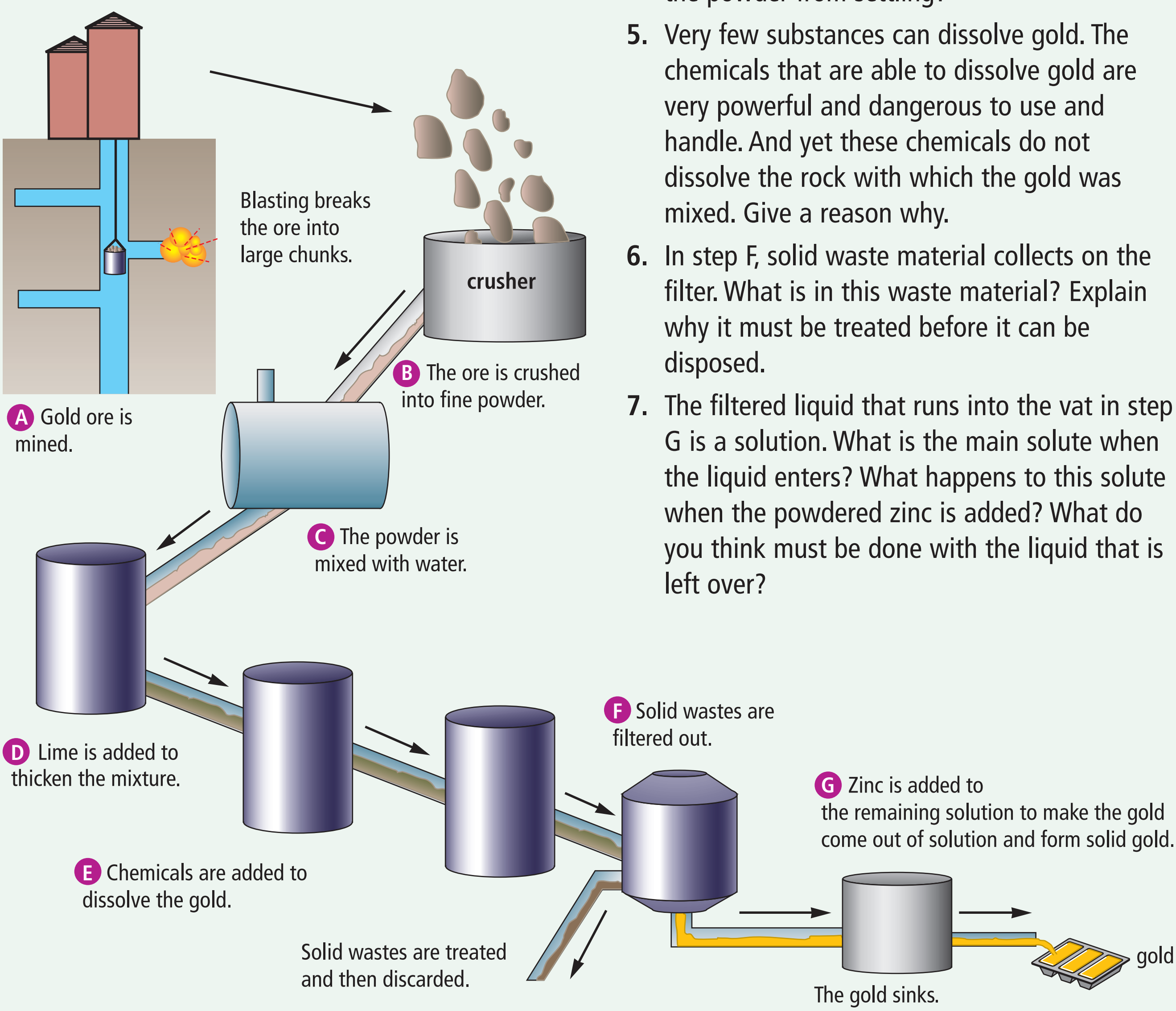
Is there gold in your province? Make a poster or write a report to outline the history of gold mining in Newfoundland and Labrador. Is gold still mined today? Start your search at **www.discoveringscience.ca.**

Mining for Gold

Gold panning was so easy to do, even for amateurs, that most stream-bed deposits have now been exhausted. Very little gold is found this way any more. Instead, gold ore must be brought up from underground and then processed to extract the gold from the rock.

What to Do

Study the diagram. Use it to answer the What Did You Find Out questions.



What Did You Find Out?

1. Is the gold still part of a mixture after step A? How do you know?
2. What do you think is the purpose of step B?
3. How does step C make it easier to pump the ore through the system?
4. The liquid mixture in step C is very runny. The powdered ore will settle out quickly unless something is done. How does step D prevent the powder from settling?
5. Very few substances can dissolve gold. The chemicals that are able to dissolve gold are very powerful and dangerous to use and handle. And yet these chemicals do not dissolve the rock with which the gold was mixed. Give a reason why.
6. In step F, solid waste material collects on the filter. What is in this waste material? Explain why it must be treated before it can be disposed.
7. The filtered liquid that runs into the vat in step G is a solution. What is the main solute when the liquid enters? What happens to this solute when the powdered zinc is added? What do you think must be done with the liquid that is left over?

Check Your Understanding

Checking Concepts

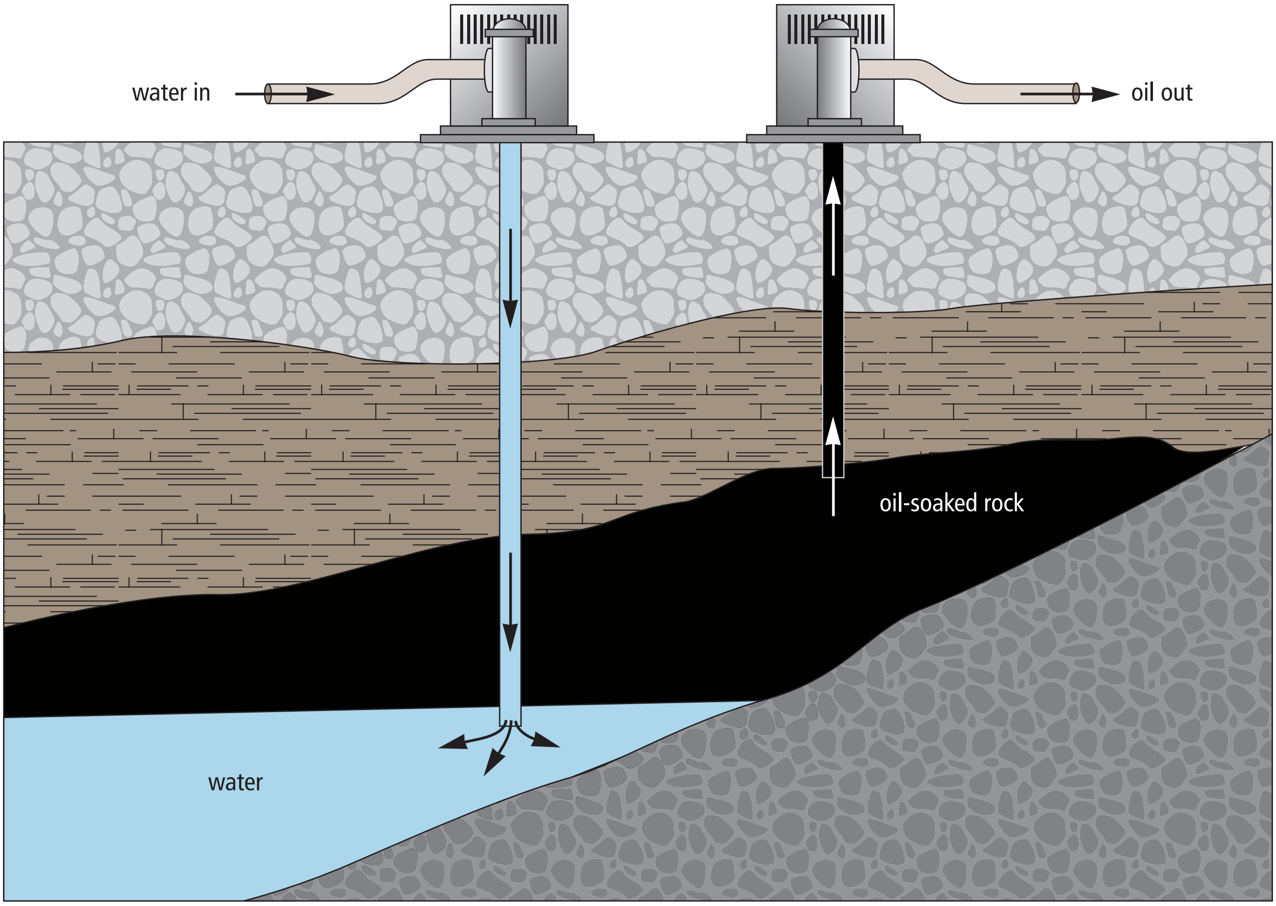
1. Petroleum is a mixture. Describe this mixture.
2. Name two places in Canada where deposits of petroleum may be found.
3. What happens to petroleum after it has been pumped to the surface?
4. How is fractional distillation of petroleum similar to the distillation of a salt water mixture? How is it different?
5. What is a petrochemical?

Understanding Key Ideas

6. Design a flowchart to describe the changes that occur to petroleum as it enters and leaves a distillation tower at an oil refinery.
7. Explain why an ore is a mixture.
8. Explain why panning was a useful method for separating gold nuggets from the rock material of stream beds.

Pause and Reflect

Like water wells, oil wells use pumps to bring petroleum deposits to the surface. Pumping petroleum is not as easy as pumping water because the oil often is a very thick liquid. It is found in small, sponge-like pores of underground rock. The diagram shows how petroleum is brought up to the surface. Which of the two pumps is lifting oil up to the surface? What is the other pump doing? How do you think it helps to separate the oil from the rock?



Career Connect

Oil Spill Adviser

The words "chocolate mousse" and "blowout" may make you think of a decadent dessert and a terrific electronics sale. These terms are also used to describe oil spills. Hesham Nabih knows all about oil spills. He runs a company that helps government agencies and oil companies prevent, manage, and contain them.

Q. How did you get interested in cleaning up oil spills?

A. I started my career as an oceanographer. An oceanographer measures water currents and studies the chemistry and ecology of bodies of water. Twenty years ago, while at a Red Sea resort in Egypt, I stepped on a ball of tar on the beach. After that, I decided to focus my efforts on fighting oil pollution. Now I develop computer software that is used to train people on how to clean up oil spills.

Q. What is an offshore blowout?

A. An offshore blowout occurs at sea when gas or oil, under high pressure, bursts out of an underwater reservoir during oil drilling or production. Oil rigs have control valves known as "blowout preventers" to stop the flow of oil if problems occur during drilling. Blowouts still happen, though.

Q. How do oil spills affect the environment?

A. Oil spills can have a serious impact on ecosystems. Oil can contaminate and smother both plants and animals. The chemical parts of oil are toxic and can cause birth defects. The environment can also be physically damaged by the methods used to clean up a spill.

Q. Cleaning up oil spills, especially cleaning up oil after it has been spilled in the water, is an example of separating a mixture. What are some of the methods used to clean up oil spills?

A. You can divide cleanup techniques into two general categories: mechanical and chemical. Mechanical devices include pressure washers, used on land, and skimmers, used on water. Skimmers remove oil from the water's surface. The two major types of skimmers are suction skimmers and adhesion skimmers. Suction skimmers float on the surface of the water and use a vacuum to suck up the oil. Adhesion skimmers soak up the oil using drums, belts, or ropes.

Q. What about chemical cleanup?

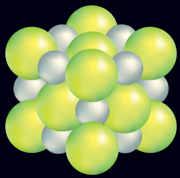
A. With chemical cleanup, chemicals are applied to the oil to break it up into tiny droplets. Micro-organisms such as bacteria can more easily convert the tiny droplets of oil into less harmful substances. Breaking up the oil into droplets also prevents the oil and water from forming "chocolate mousse", the term given to mixtures of oil and water that look like oily, reddish-brown pudding.

VISUALIZING SALT

The salt you use every day comes from both the land and the sea. Some salt can be mined from the ground in much the same way as coal, or salt can be obtained by the process of evaporation in crystallizing ponds.

MINING SALT Underground salt deposits are found where there was once a sea. Salt mines can be located deep underground or near Earth's surface in salt domes. Salt domes form when pressure from Earth pushes buried salt deposits close to the surface, where they are easily mined.

EVAPORATION PROCESS Workers fill evaporation ponds, like these near San Francisco Bay, California, with salt water, or brine. They move the brine from pond to pond as it becomes saltier through evaporation. (Red-tinted ponds have a higher salt content.) The saltiest water is then pumped from evaporation ponds into crystallizing ponds, where the remaining water is drained off. In the five years it takes to produce a crop of salt, brine may move through as many as 23 different ponds.



Unit cell of sodium chloride (NaCl)

TABLE SALT Raw sodium chloride is washed in chemicals and water to remove impurities before it appears on your dining-room table as salt. Iodine is added to table salt to ensure against iodine deficiency in the diet.

SALT MOUNDS When the crystallizing ponds are drained, the result is huge piles of salt, like these on the Caribbean island of Bonaire.

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated methods that may be used to separate the parts of heterogeneous and homogeneous mixtures. 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. Separating Heterogeneous Mixtures
2. Separating Homogeneous Mixtures
3. Separating a Liquid Mixture from Underground
4. Separating a Solid Mixture from Underground

Checking Concepts

1. What is the function of the filter used in each of the following situations?
   (a) A nurse wears a surgical mask while examining a patient's mouth.
   (b) The air filter in a vacuum cleaner has to be changed every so often.
   (c) An auto mechanic changes the gasoline filter during a maintenance checkup.
   (d) An archeologist passes soil through a sieve while looking for ancient pottery fragments.
   (e) A hanging basket for plants has small holes in the bottom through which water can pass.
   (f) Some people wear a mask made of mesh that covers their whole head when they walk through an area with lots of mosquitoes.
2. Could you use mechanical sorting to separate and recover all the parts of a homogeneous mixture? Explain why or why not.
3. Could you use evaporation to separate and recover all the parts of a heterogeneous mixture. Explain why or why not.
4. The membrane (skin-like covering) of a cell prevents most substances from entering the cell and most substances from leaving it. Only water particles and particles of some salts are able to pass unassisted through the cell membrane. Is the cell membrane a type of specialized filter? Give reasons to justify your answer.
5. Explain why (a) magnetism and (b) sorting by hand are examples of mechanical sorting.
6. In a restaurant, several kilograms of dried rice are poured into a large pot filled with water. Soon, small specks of dust and dirt are visible on the surface of the water. The rice is on the bottom of the pot, below the water's surface.
   (a) Identify the type of mechanical sorting that is described in this case.
   (b) Identify the property on which this separating technique depends, and explain why it works.
7. Use the particle theory of matter to explain why distillation can separate pure water from a sample of tap water.

Understanding Key Ideas

8. People who get lots of unwanted e-mail, called spam, may install a computer program called a spam filter. Compare a spam filter to another type of filter of your own choosing, and explain how the two filters are similar and different.
9. You have a mixture of clean sand and pure table sugar. How can you get pure sugar from this mixture? Describe your method in detail and list the equipment you would need.
10. The term “volatile” is used to describe a substance that changes state to become a gas at a low temperature. The list below shows products of fractional distillation of petroleum. Refer to Figure 9.19. Sort these products in order of their volatility, from lowest to highest.
    - diesel oil
    - gasoline
    - kerosene
    - propane
    - aviation fuels
    - asphalt and tar
    - greases
    - lubricating oils
11. You are thirsty and ask for a glass of apple juice. You are given two glasses of apple juice. One appears to be homogeneous. The other is heterogeneous, because you can see bits of sediment-like material at the bottom of the glass.
    (a) Which of the glasses of apple juice is a solution?
    (b) Describe what you could do to make the other mixture into a solution.
12. Imagine that you place the following materials into a large container: 100 mL of water, 100 mL of vegetable oil, a handful of marbles, a tablespoon of gravel, a handful of puffed wheat, a tablespoon of iron filings. Describe the methods that you would use to remove as many of the parts of this mixture as you can.
13. Describe how you might separate the sugar from a solution of vinegar and sugar.
14. "Campfire" coffee is made by boiling ground coffee beans in water over a campfire or a special butane burner. Then the coffee mixture may be poured through a strainer. Other methods of making fresh coffee at home also involve filtering.
    (a) Describe the role of filtration in making coffee.
    (b) What enables the coffee filter to do its job?

Pause and Reflect

You are refilling a pepper shaker when it overflows into a sugar bowl. How can you recover the pepper from the sugar? If you did not have access to water or any other solvent, would you be unable to recover the pepper from the sugar? Explain why or why not.

Unit Summary

7 Matter can be classified as mixtures and pure substances.

- Matter can be either mixtures or pure substances.
- Mixtures may be either heterogeneous or homogeneous.
- Homogeneous mixtures (solutions) have the same properties throughout.
- Heterogeneous mixtures have different visible parts with different properties.
- Matter is either a mixture or a pure substance based on the types of particles that make it up.
- Each pure substance has its own type of particle, which is different from the kinds of particles that make up all other pure substances.

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

- In a solution, the substance that dissolves is the solute, and the substance in which the solute dissolves is the solvent.
- A substance is soluble in a solvent if it dissolves in the solvent. A substance is insoluble in a solvent if it does not dissolve in the solvent.
- A concentrated solution has a larger mass of solute for certain volume of solvent. A dilute solution has a smaller mass of solute for a certain volume of solvent.
- Solution concentration may be expressed in units of grams of solute per litre of solvent (g/L).
- A solution is saturated when as much solute has dissolved in a solvent as it can, at a certain temperature.
- Different solutes have different solubilities, which may be increased by increasing the temperature.
- Stirring a solution increases the rate of dissolving but not the solubility of the solute.

9 Many useful products depend on technology for separating mixtures and solutions.

- Heterogeneous mixtures may be separated by methods that include sorting by hand, mechanical sorting, and filtration.
- Mechanical sorting of a mixture is based on properties such as particle size and magnetism.
- Homogeneous mixtures may be separated by methods that include evaporation, distillation, and paper chromatography.
- Petroleum is a complex mixture that can be separated by fractional distillation.
- An ore is a rock mixture that has one or more valuable substances.

Key Terms

- alloy
- mixture
- heterogeneous mixture
- homogeneous mixture
- pure substance
- solution

Key Terms

- concentrated solution
- concentration
- dilute solution
- dissolves
- insoluble
- saturated solution
- solubility
- soluble
- solute
- solvent
- unsaturated solution

Key Terms

- evaporation
- filtration
- fractional distillation
- mechanical sorting
- ore
- paper chromatography
- petroleum
- simple distillation

Purifying Mixtures

Each step of a separation may cost a company a great deal of money. This is why materials and products that are pure or nearly pure can be costly to buy. As companies develop methods that can separate a mixture more effectively, the cost can come down.

Problem

In this project, you will find the most effective manner to separate a mixture.

Saftey

- Be careful if you use a hot plate. Unplug it when it is not in use.
- Wipe up any spills as soon as they occur.

Materials

- variety of mixtures prepared by your teacher
- cups or beakers of various sizes
- magnet
- plastic wrap
- variety of filters
- funnels
- hot plate
- evaporating dishes
- water
- paper
- labels or grease pencil

Criteria

- In small groups, separate a mixture into its parts.
- Include the fewest number of separation steps as is needed to produce purified parts.
- Design a flowchart to show the steps and methods that you used in your final separation procedure.

Procedure

1. Obtain a dry mixture from your teacher. With your group, identify as many substances in the mixture as you can. Record these in a list. Be alert to substances that might be present but not clearly visible. (For instance, salt and white sand can look alike.)
2. Brainstorm the types of methods you could use to separate your mixture. As a group, decide on which methods you will use and in which order.
3. Outline the steps in each method of separation and the substance that you plan to isolate at each step. You may need to revise your outline a few times before you come up with the best sequence of steps.
4. Separate your mixture. Collect each part in a separate, labelled container. Note: If any parts are contaminated (sand stuck to larger pieces of gravel, for instance), you must purify them further.
5. Do several trials to come up with the procedure that will give you the best results in the fewest steps. Make a flowchart to record your final method.

Report

1. How well did you obtain purified parts of the mixture? How did the order of steps affect how completely you were able to separate them?
2. Which methods did you use to separate parts that were not clearly visible? How did you know that each method worked?
3. How could you improve your methods of separation? What other equipment or methods might have helped you improve the quality and effectiveness of your separations?

Integrated Research Investigation

Safe, Clean Water for Everyone

If you live in a large city or town, you may not realize that the water running down your sink or toilet eventually ends up in a river, a lake, or the ocean. What about the rain and snow that fall to the ground? On the ground, rain and snow carry oil from the roads and dissolved salt from melted slush in winter. Look along the gutters on every city street. Where does the run-off water go after it trickles down storm sewers and out of sight? What other substances might be carried in this water? In rural areas, were does the wastewater go?

Background

Water is one of the most plentiful mixtures on Earth. It is also the most essential for all living things. Many different natural and human activities add substances to water that require us to treat it so that it is safe to drink and wash with. Many of these treatments involve separation methods that you have been studying.

Find Out More

Unless you get your water from a well and this source has been tested to prove its safety, all the water in your community is treated in some way to make it safe. Use the Internet (start at **www.discoveringscience.ca**), books, magazines, and newspapers to find out the methods that are used to make water safe to drink and wash with in your community.

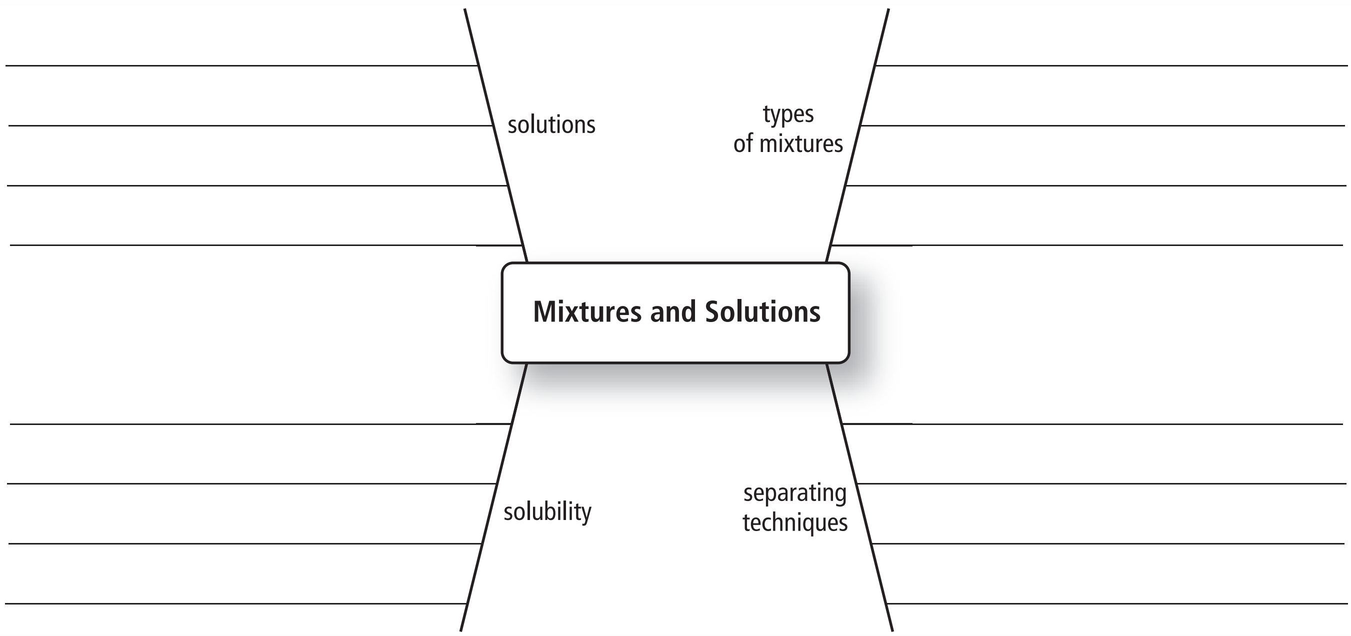
Report

1. Create a poster to display the results of your research.
2. Design an Internet page (such as a FAQ) that has additional information and links to sources for more information about water treatment.

In what ways do the process shown in these photos contribute to pollution of water resources such as wells, rivers, lakes, and the ocean?

Visualizing Key Ideas

Copy the following spider map into your notebook. Beside each topic, fill in as many words as you can that are related to that topic. Do not look at your textbook. When you have completed the map, go back through this unit and look for other words that you could include. Add these words to your spider map in a different colour of pen.



Using Key Terms

2. In your notebook, say whether the following statements are true or false. If a statement is false, rewrite it to make it true.
   (a) A solution is a heterogeneous mixture.
   (b) The particles that make up a pure substance are the same types of particles that make up all other pure substances.
   (c) Mechanical sorting may be done to separate the parts of a heterogeneous mixture.
   (d) The concentration of a solution may be expressed as the volume of solvent that can dissolve in a certain mass of solute (g/L).
   (e) A saturated solution cannot allow more solute to dissolve at a certain temperature.
   (f) An unsaturated solution cannot allow more solute to dissolve at a certain temperature.
   (g) All matter can be classified as either a mixture or a pure substance.
   (h) Filtration is one method that can be used to separate a solution.
   (i) Units of ppm tell you the concentration of a solution in grams per millimetre.
   (j) There are very few examples of mixtures in the world around you.
   (k) In a solution, the solute is the substance that does the dissolving and the solvent is the substance that dissolves.
   (l) A solution of salt and water is a homogeneous solution because the salt will settle if it is left undisturbed.

Checking Concepts

7

3. Explain the difference between a mixture and a pure substance.
4. What is a heterogeneous mixture? How is it different from a homogeneous mixture?
5. Describe a homogeneous mixture using the particle theory of matter.
6. What is an alloy?
7. Is a solution a heterogeneous or a homogeneous mixture? How do you know?

8

8. Contrast a solute with a solvent.
9. What is the difference between a saturated solution and an unsaturated solution?
10. Use an example to explain what the term "solubility" means.
11. Explain the difference between a dilute solution and a concentrated solution.
12. What happens to the solubility of a gas in a liquid as temperature increases?

9

13. Why are magnetism and flotation examples of mechanical sorting?
14. Why is a fishing net a type of filter?
15. What is the name of the method that is used to separate the parts that make up petroleum?
16. Is separating gold nuggets from stream-bed gravel a type of mechanical sorting? Why or why not?

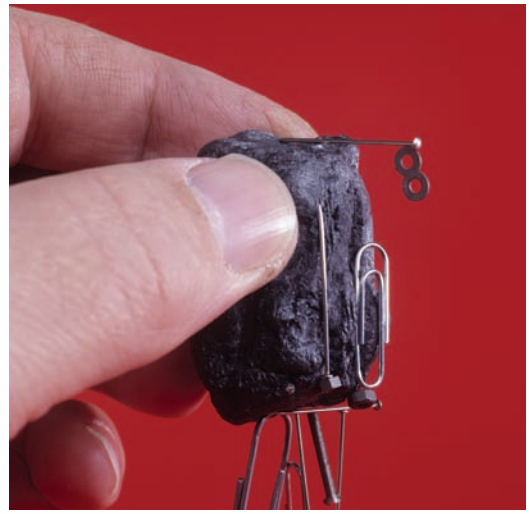
Understanding Key Ideas

17. Identify the following as a mixture or a pure substance, and give a reason to explain your choice.
    (a) oatmeal-and-raisin cookie
    (b) gold
    (c) petroleum
    (d) carbon dioxide gas
    (e) ink
    (f) tomato juice
18. Classify each of the mixtures you identified in question 17 as heterogeneous or homogeneous. Explain your decisions.
19. Explain how the particle theory of matter distinguishes between a mixture and pure substance.
20. Agree or disagree with the following statement, and justify your answer: "Many mixtures are neither clearly heterogeneous nor clearly homogeneous. Instead, they are mixtures of mixtures."
21. Explain why pizza is a heterogeneous mixture, while clean air is a homogeneous mixture.
22. Identify the solute and the solvent in each of the following solutions. (Note: There may be more than one solute in one or more of the solutions.)
    (a) soda water
    (b) vinegar
    (c) brass
    (d) ice tea
    (e) instant coffee
    (f) lemonade
23. Draw sketches to show how the particle theory of matter could explain the difference between a concentrated solution of sugar and water and a dilute solution of sugar and water.

24. Is there a limit to the concentration of a solution? Explain your answer.
25. It takes longer to dissolve 5 g of granulated sugar in water at 25°C than to dissolve 5 g of powdered sugar in water at the same temperature. Explain why.
26. How does pressure affect the solubility of a gas such as carbon dioxide in a liquid such as water?
27. Give three examples of mechanical sorting being used to separate a mixture.
28. You want to separate a solution and collect both the solute and the solvent. Explain why distillation will let you do this but evaporation will not.
29. (a) Explain how a filter works.
    (b) Give five examples of filtration being used to separate mixtures.
30. Use the terms *dilute* and *concentrated* to describe how the sap from maple trees becomes maple syrup.

Thinking Critically

31. (a) Identify three substances that are soluble in water.
    (b) Identify three substances that are insoluble in water.
    (c) If a substance is insoluble in water, could it be soluble in another solvent? Use an example to support your answer.
32. Explain how you could tell if a solution of salt and water is saturated or not.
33. One type of iron ore is composed of rock and a pure substance called magnetite. Magnetite is made up of iron particles and oxygen particles.
    (a) Magnetite is a magnetic substance, as you can see in the photo. How could you separate magnetite from the rock it is mixed with?
    (b) Magnetite and iron share the property of magnetism. How are they different?
    (c) How is iron ore different from gold ore? Explain your answer.

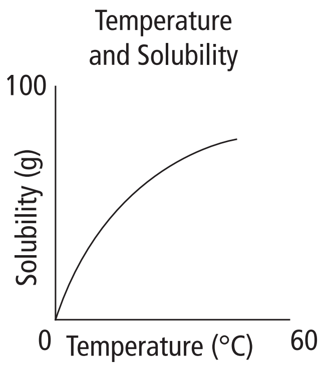


34. You are given two samples of water—one from Lake Ontario and one from the Atlantic Ocean. The labels have fallen off the sample bottles. Outline a procedure you could use to determine which sample is which. (Note: Tasting is not allowed.)

Developing Skills

35. Use drawings to model the difference between the following:
    (a) a dilute solution and a concentrated solution
    (b) a saturated solution and an unsaturated solution
    (c) a substance in water that is soluble and a substance in water that is not soluble

36. Which graph shows the relationship between increasing temperature and solubility?

A


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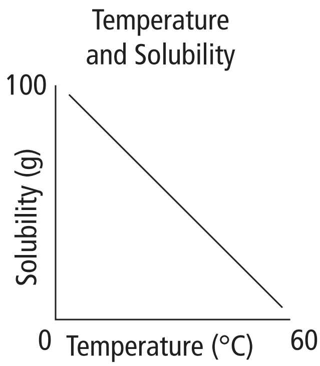

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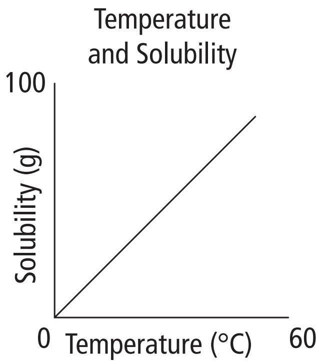
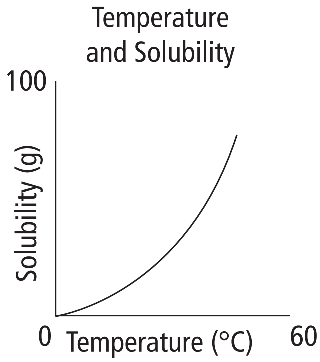


D


37. Convert the following concentrations to units of grams per litre.
(a) 15 mg/L
(b) 20 g/100 mL
(c) 159 mg/L
(d) 0.14 g/100 mL

38. The intensity of colour can be used to compare the concentration of two or more solutions. The illustration below shows three cups of tea. Which cup holds the most concentrated tea solution? Which cup holds the most dilute tea solution? Explain your reasoning.

Pause and Reflect

Which of the main points of the particle theory of matter are most useful for explaining each of the following?
(a) why water is different from sugar
(b) why nail polish is insoluble in water
(c) why water evaporates
(d) why fractional distillation of petroleum works