TOPIC
2.3

How can we describe and explain the states of matter?

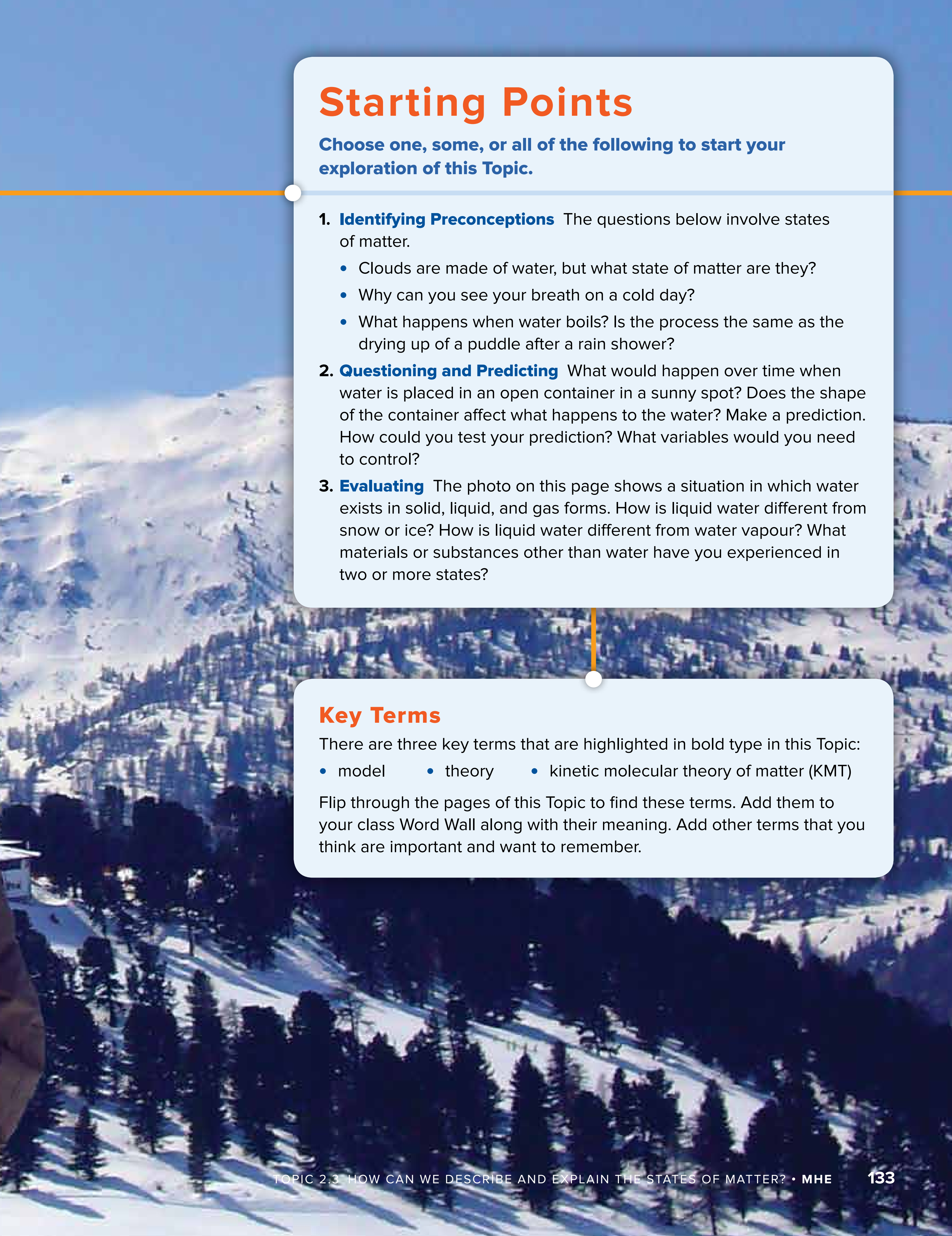
A skier pauses to take a drink of spring water, and then he breathes deeply. When he exhales, he will see small white puffs forming, similar to the clouds drifting above. Soon he will grab his poles and race down the hill, gliding along and carving into the snow and ice. The skier is experiencing water in all its forms: as a drinkable liquid, as a skiable solid, and as an invisible gas that he breathes in and out as part of the mixture we call air. Why does water in its different states—solid, liquid, and gas—have such different properties?

Key Concepts

- Matter can be solid, liquid, or gas.
- Matter is made of particles in constant motion.
- Changes in state result from changes in particle motion.
- The kinetic molecular theory explains physical changes and properties.

Curricular Competencies

- Make observations aimed at identifying your own questions about the natural world.
- Use scientific understandings to identify relationships and draw conclusions.
- Demonstrate an awareness of assumptions and identify bias in your own work and secondary sources.
- Communicate ideas using scientific language and representations.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The questions below involve states of matter.
   - Clouds are made of water, but what state of matter are they?
   - Why can you see your breath on a cold day?
   - What happens when water boils? Is the process the same as the drying up of a puddle after a rain shower?
2. **Questioning and Predicting** What would happen over time when water is placed in an open container in a sunny spot? Does the shape of the container affect what happens to the water? Make a prediction. How could you test your prediction? What variables would you need to control?
3. **Evaluating** The photo on this page shows a situation in which water exists in solid, liquid, and gas forms. How is liquid water different from snow or ice? How is liquid water different from water vapour? What materials or substances other than water have you experienced in two or more states?

Key Terms

There are three key terms that are highlighted in bold type in this Topic:

- model
- theory
- kinetic molecular theory of matter (KMT)

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Matter can be solid, liquid, or gas.

Activity

What Is It?

Working in groups, add 250 mL of cornstarch into a large bowl. Feel the cornstarch with your hand. Then slowly add 85 mL of water and mix the cornstarch as you add the water. Mix the cornstarch with your hands so that you can feel the texture and consistency. Add some food colouring if you wish. Then experiment with the mixture. What happens when you grab a handful of the mixture and try to form a ball with it? Now open up your hand. What happens to the ball? Slap the cornstarch mixture quickly. Now try squeezing it. Is it a liquid? Is it a solid? How do you know?

Matter can exist as a solid, liquid, or gas. What are some examples of liquids and solids in your everyday life? Just this morning, you may have taken a shower in water and used some shampoo and conditioner on your hair: that's three liquids. Perhaps you had a glass of juice or poured some milk on some cereal in a bowl and ate it with a metal spoon. That's two more liquids and four solids. It can be hard to think of gases as matter because many gases are invisible. Although you cannot see them, gases surround us—you can feel gases filling your lungs every time you take a breath. Figure 2.12 describes examples of solids, liquids, and gases.

Figure 2.12 Kiteboarders depend on the different properties of solids, liquids, and gases to enjoy their sport. **List three solids shown but not mentioned here and describe their physical properties.**

Properties of the States of Matter

Solids, liquids, and gases have distinct characteristics that can be used to classify them. These characteristics are summarized below in **Table 2.2**.

Table 2.2 States of Matter

State	Common Characteristics	Examples
solid	• holds its own shape • has a constant volume	 • wood • silver • stone • plastic
liquid	• takes the shape of its container • has a constant volume	 • oil • juice • antifreeze • gasoline
gas	• takes the shape and volume of its container • can be compressed	 • air • helium • hydrogen

The Fourth State

Solids, liquids, and gases are the most familiar states of matter. But most matter in the universe actually exists as a fourth state of matter called plasma. A plasma is similar to a gas in that it does not have a defined shape and volume, but plasmas have different electrical properties than gases. Some examples of plasmas are shown in **Figure 2.13**.

Figure 2.13 The fourth state of matter, plasma, is found on Earth and throughout the universe. **A** All stars, including our Sun, are made up of plasma. **B** The visible fork of a lightning bolt is plasma formed in the air by an electrical current. **C** The glowing gas of a neon sign is actually plasma.

Before you leave this page . . .

1. Give two examples of solids, liquids, and gases.
2. Which state of matter does plasma most resemble and why?

CONCEPT 2

Matter is made of particles in constant motion.

Activity

Musing on Models

What does the term “model” mean to you? Write a brief definition. What are some different examples of models in everyday life? How do you think models are used in science?

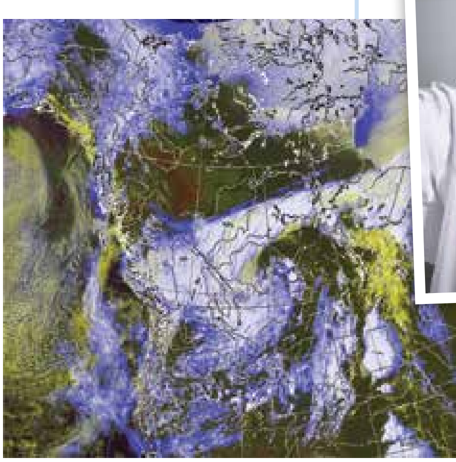
model a verbal, mathematical, or visual representation of a scientific structure or process

theory a scientific explanation that has been supported by consistent, repeated experimental results and is therefore accepted by most scientists

The terms “model” and “theory” have a variety of different meanings in different contexts. In science, however, they have very specific meanings.

A **model** consists of words, pictures, physical objects, or mathematical equations that are used to represent and explain complex objects, living things, or events in nature. Models help people analyze and communicate what they observe in the natural world. They also help us visualize processes that cannot be seen with the unaided eye. Some examples of models are shown in **Figure 2.14.**

A scientific **theory** is an explanation of a phenomenon in the natural world based on many observations and investigations. Theories can be, and often are, modified or discarded if new experimental data arise that contradict the theory or that the



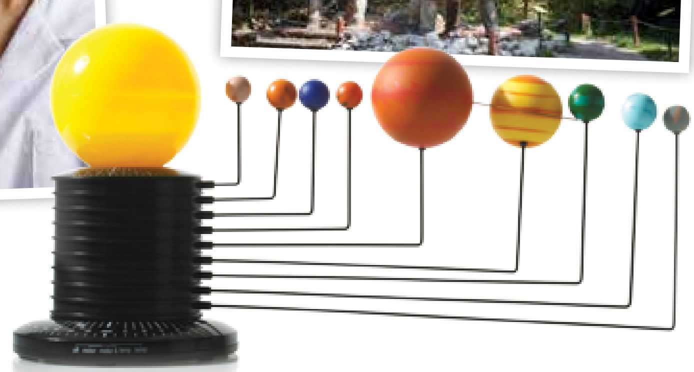


Figure 2.14 These models were made to help people understand or analyze complex systems, organisms, or events. **Do any of these models simplify or distort the organism, item, or system they are representing? If so, how and why?**

theory cannot explain. Theories often lead to new conclusions. A theory is considered successful if it both explains experimental observations and can be used to make accurate predictions. A theory is never considered to be proven, no matter how successful it is. Future experiments may lead to further changes.

Explaining Properties of the States of Matter

The *particle model of matter* is a model that enables people to visualize and understand the structure of matter, even though we cannot see it. According to the particle model of matter, all matter is made up of very small particles. These particles are so small that they cannot be seen even with the help of a light microscope.

Using the particle model of matter, scientists developed a theory to explain the behaviour of gases. This scientific theory, when extended to explain the behaviour of all states of matter, is called the **kinetic molecular theory of matter (KMT)**. An important part of the kinetic molecular theory of matter is the notion of *kinetic energy*—the energy of motion. According to the theory, all particles are constantly moving and therefore have kinetic energy. The kinetic molecular theory successfully explains many observations about matter, including the different properties of the states of matter, as well as the ways in which matter changes state.

kinetic molecular theory of matter (KMT) a scientific explanation of the behaviour of matter based on all matter being made of particles that possess kinetic energy

The Kinetic Molecular Theory of Matter

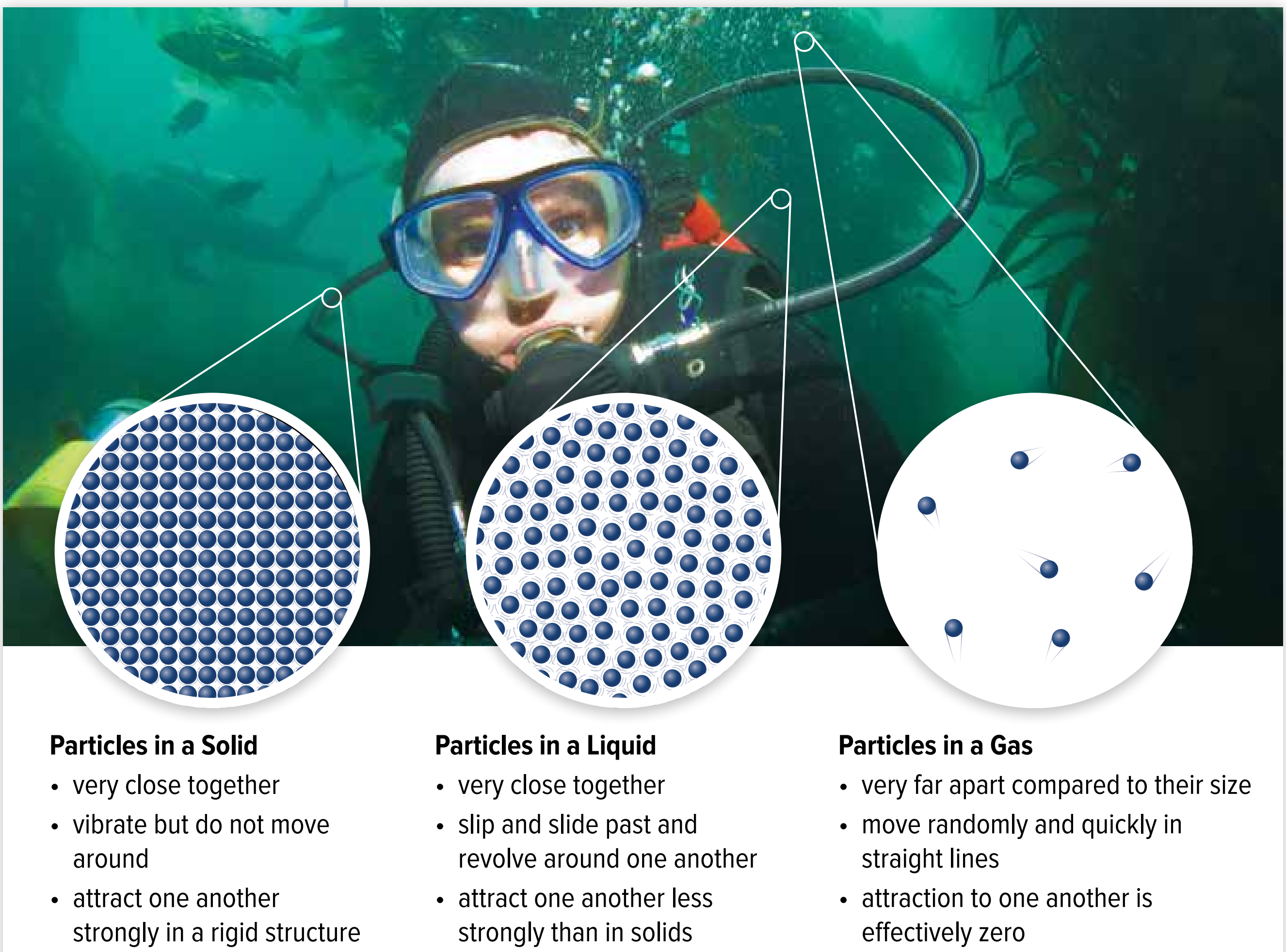
The key points of the kinetic molecular theory of matter are:

1. All matter is made up of very small particles.
2. The particles exist in empty space.
   - **(a)** In solids, particles are closely packed and held rigidly in place.
   - **(b)** In liquids, particles are also closely packed but can move around.
   - **(c)** In gases, particles have large amounts of empty space between them and are not attracted to one another.
3. Particles are constantly moving.
   - **(a)** The particles in solids vibrate but cannot move around.
   - **(b)** The particles in liquids slip and slide past and revolve around each other but stay close together. They collide with each other and the walls of their container.
   - **(c)** The particles in gases move freely in straight lines, colliding with each other and with the walls of their container.
4. Energy makes particles move. The more energy the particles have, the faster they can move and the farther apart they can get.

States of Matter and the Kinetic Molecular Theory

To use the kinetic molecular theory as a tool for explaining observations about the states of matter, it can help to visualize the particles for each state, as shown in **Figure 2.15**. Note that the particles in a gas are actually much farther apart than is suggested by the diagram.

Figure 2.15 The kinetic molecular theory explains the properties of solids, liquids, and gases based on how their particles are arranged and how they move.



Before you leave this page . . .

1. In what ways does a model differ from a theory?
2. Summarize the kinetic molecular theory of matter.
3. Describe the particles of the three states of matter in terms of how they move and the spaces between them.
4. It is easy to compress (reduce the volume of) a gas, but solids and liquids cannot be compressed very much. Use the KMT to explain why.

CONCEPT 3

Changes in state result from changes in particle motion.

Activity

The Cold Can

Dry the outside of a metal can with paper towel. Obtain 50 g (about 45 mL) of salt. Divide it into three approximately equal portions. Add the first portion of salt to the can, then half-fill the can with crushed ice. Add the second portion of salt and fill the can with ice. Top with the rest of the salt. Mix the contents well, being careful not to spill the contents of the can. Wait 5 minutes and observe the outside and inside of the can. How do you explain what you observe?

Changes of state (also referred to as phase changes) occur when matter transforms from one state to another. Most pure substances can exist in all three states depending on the temperature and pressure. A few substances, such as water, exist in all three states under ordinary conditions on Earth. Scientists use specific terms to refer to the different state changes that are possible among solids, liquids, and gases, as shown in **Figure 2.16**.

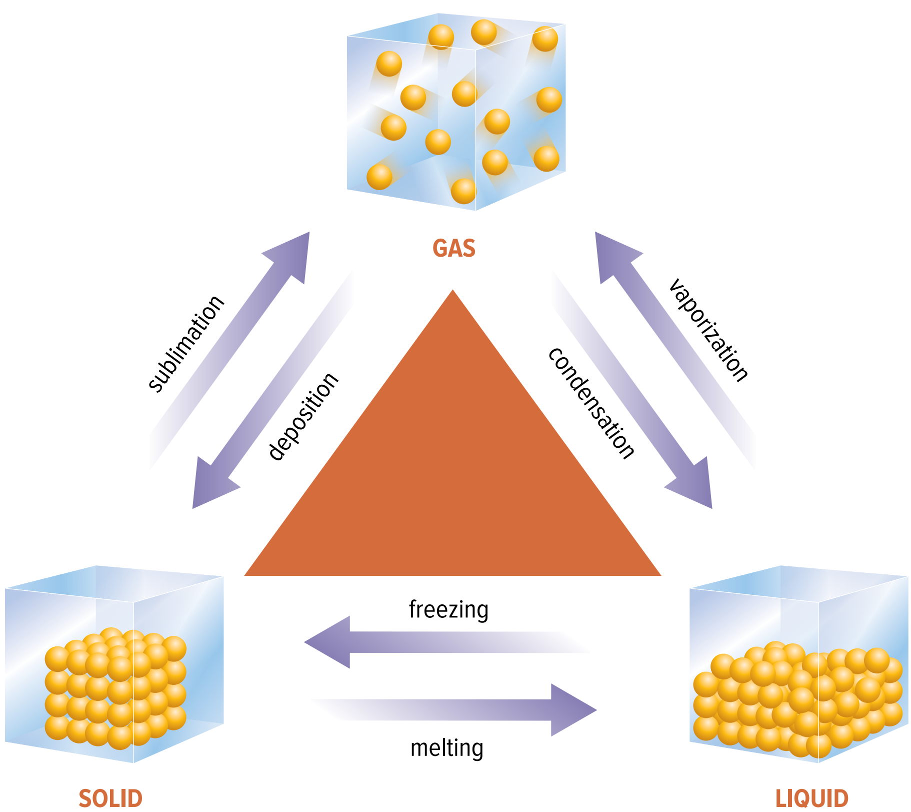


Figure 2.16 Specific terms such as melting and evaporation are used to describe how the state of matter can change.

Changes of State and Temperature

What causes matter to change from one state to another? Consider what is the same about the following examples. You put a scoop of solid butter in a hot frying pan and it melts into a liquid. A kettle full of water begins to "sing" as the heating element inside causes the water to boil. You drop some ice cubes into your orange juice and they begin to melt. You fill the empty ice cube tray with water and pop it in the freezer to make more ice. All of these examples involve adding or removing kinetic energy.

Adding energy to matter or removing energy from matter changes the temperature of the matter. What does that mean? *Temperature* is a measure of the average kinetic energy of the particles in a substance. Increasing the temperature of matter means the particles of the matter are gaining energy. Once the matter reaches a certain temperature, the particles have gained enough energy to change state.

The temperature at which a substance melts is called its *melting point*. The temperature at which a substance boils is called its *boiling point*. The melting and boiling points of pure substances are physical properties that can be used to identify them. A few examples are shown in Table 2.3.

Table 2.3 Melting and Boiling Points

Substance	Melting Point (°C)	Boiling Point (°C)
nitrogen, N_2	–210.0	–195.8
mercury, Hg	–38.8	356.7
water, H_2O	0.00	100.0
iron, Fe	1538	2862

The Kinetic Molecular Theory and Changes of State

The difference between the properties of solids, liquids, and gases can be explained by the difference in the kinetic energy of the particles of substances in those states. For any given substance, the average kinetic energy of the particles in the solid will be lower than that of the particles in the liquid. The particles in the gas will have the greatest average kinetic energy.

But why do substances change from one state to another when they are heated or cooled? Why does a heated solid melt instead of just becoming a very hot solid? Figure 2.17 shows how the KMT explains changes of state.

Connect to Investigation 2-F on pages 148–149

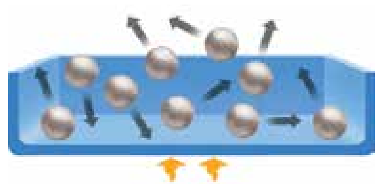
Adding Energy to Mercury

1. Solid mercury
Particles are very close to one another, are fixed in position, and vibrate. They strongly attract one another.

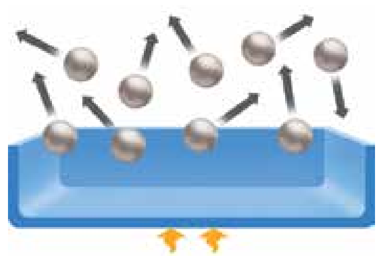
2. Melting mercury
As the temperature of the solid mercury increases, the kinetic energy of the particles increases. Eventually, the increased kinetic energy of the particles allows them to partially overcome their attraction to one another, and they break free of their rigid formation. They now begin to revolve around and slide past one another. The solid is melting.

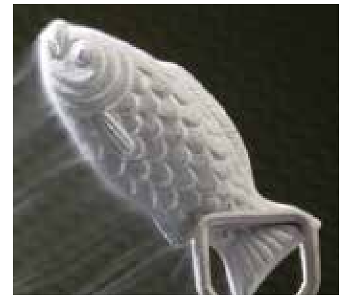
3. Liquid mercury
The particles move freely around one another, but are still close together and strongly attracted. They have taken the shape of their container.

4. Boiling mercury
As the temperature continues to increase, the kinetic energy increases and the particles move more vigorously. Some particles gain enough energy to completely overcome the attractive forces between them and other particles in the liquid. They escape into the surrounding air.



5. Gaseous mercury
All particles are highly energetic and move freely to fill their container. Further heating will increase the speed of the gas particles, which increases their kinetic energy. If in a sealed container, particles will collide with each other and with the walls of the container more forcefully and more often. This increases the pressure of the gas.





This piece of solid mercury was formed by cooling it to below –38.8°C, the melting point of mercury.

Mercury is the only metal that is a liquid at room temperature.

Figure 2.17 As a sample of solid mercury absorbs energy (shown by the orange arrows), it undergoes two changes of state.

Extending the Connections

Applying Deposition

The metallic colours of modern electronics such as phones are due to specialized materials applied using physical vapour deposition (PVD). Research PVD and choose one specific application to explore.

Before you leave this page . . .

1. Define temperature.
2. What is the melting point of a substance?
3. Use the KMT to explain how a liquid changes into a solid.

AT ISSUE What are the dangers of using mercury?

What's the Issue?

Hard-rock gold mining produces most of the world's gold. Because the gold is encased in rock, known as ore, miners must dig out large quantities of ore and then extract the gold from the rock. Some processing companies use mercury to help with this. During the extraction process, workers add liquid mercury to the ore. It forms an amalgam—a mercury-containing mixture—with the gold and helps to separate the gold from the rock.

Although this process is effective, the use of mercury in mining is banned in Canada. Why? Mercury can be highly toxic to people and the environment. For example, in order to remove the mercury from the gold-mercury amalgam, workers heat it, turning the mercury into a vapour. However this process can put workers at risk of breathing in the mercury. Also, the mercury can settle on their clothing and workers can inadvertently transport it into their homes and community, putting others at risk.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Find examples of small- or large-scale mercury contamination. Describe why and how they occurred. Do you think similar events could occur now? Explain why or why not. What properties of mercury make it so hazardous?
2. Research to find past and current applications of mercury. For past applications, find out why mercury is no longer used and what is used instead.
3. Despite its dangers, small-scale mining operations in developing countries continue to use mercury in the gold extraction process. Why do you think this might be? Discuss whether this is an equity issue and whether all countries have a responsibility to find and promote solutions. Research tools miners could use to help protect themselves from mercury poisoning during the extraction process, and explain how they work.
4. Low levels of mercury may not cause problems for animals or the environment, but mercury builds up over time—and high concentrations are toxic. Find out why mercury "builds up over time." Why does this adversely affect the environment?

CONCEPT 4

The kinetic molecular theory explains physical changes and properties.

Activity

Dye-ing to Dissolve

Work in groups. Your teacher will give you two dye tablets of the same colour. Fill one beaker with 250 mL of cold tap water and a second beaker with 250 mL of hot tap water. Place one tablet in each beaker. Record your observations using words and diagrams or photos. Do not stir the mixtures. In your group, come up with a way of communicating your findings. Share and discuss your results as a class.

The kinetic molecular theory explains states of matter and changes of state, but it can also be used to explain other physical changes as well as physical properties. For example, think about what happens when a solid dissolves in a liquid. If you place a sugar cube in water, it will appear to get smaller and smaller as time passes. Soon it will seem to disappear. If you tasted the water, however, it would taste sweet. This is evidence that the sugar has not disappeared but is still present in the liquid. A solution of water and sugar has formed. As shown in **Figure 2.18**, the kinetic molecular theory can help explain what happened.

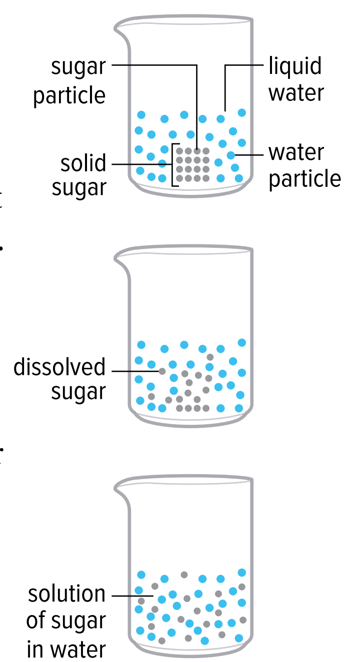


Figure 2.18 Kinetic molecular theory can help you visualize and explain what is happening to a sugar cube as it dissolves. **Why does sugar dissolve faster in hot water?**

Explaining Diffusion

Have you ever come home and instantly known what was for dinner just by the smell? The spreading of smells is an example of *diffusion*—the movement of one material through another. Why and how does the smell of fried onions or toasted bread travel from their sources to your nose? Odours come from gases that have characteristic smells. During cooking, those gases are released. Because gas particles move freely and quickly, those particles spread throughout the room.

Connect to Investigation 2-G on pages 150–151

Explaining Thermal Expansion

Solids, liquids, and gases normally expand when they are heated, and contract when they are cooled. This means that the hotter most substances get, the more their volume increases. The colder they get, the smaller their volume. The expansion of heated materials is called *thermal expansion*.

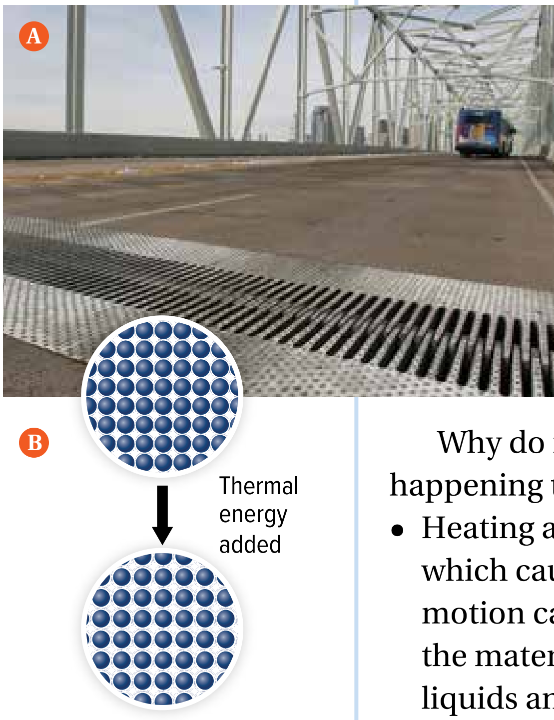


Figure 2.19 A This expansion joint prevents damage by allowing the material in this bridge to expand and contract freely with changes in temperature. B When a solid is heated, its particles gain energy and vibrate faster. They move farther apart and the solid expands as a result.

In places such as British Columbia, where temperatures can range from very cold to very hot, engineers must consider thermal expansion when building bridges and other structures. Repeated expansion and contraction can weaken building materials such as concrete, which can cause buckling, cracks, and breaks. Expansion joints such as the one shown in **Figure 2.19** allow materials to expand and contract as the temperature changes without damaging the overall structure.

Why do materials expand when they get hotter? What is happening to the particles of those materials?

- Heating a solid increases the kinetic energy of its particles, which causes them to vibrate faster. This increase in vibrational motion causes the particles to move slightly farther apart, and the material as a whole expands. The same thing happens in liquids and gases. Added energy increases their motion, and the particles move farther apart.
- Liquids expand more than solids, because their particles move more freely and can move farther apart from one another.
- Gases can expand indefinitely, but gases heated in rigid containers cannot expand more than the walls of their containers allow. The particles collide with greater and greater force with the container walls, which means that the pressure on the inside of the container increases. If the pressure becomes great enough, the container will explode.

Before you leave this page . . .

1. Use KMT to explain why a balloon in a hot car will expand and may eventually pop.
2. Use the KMT to explain what happens when salt dissolves in water.
3. The thermometers you use in the lab likely contain a narrow column of red-dyed alcohol. Use the KMT to explain how this type of thermometer works.
4. What might happen if a bridge were built in B.C. without an expansion joint? Explain.

Check Your Understanding of Topic 2.3

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. List the three main states of matter on Earth and describe the physical properties associated with each state. PA C
2. Identify a scientific model not mentioned or depicted in Topic 2.3 and briefly describe its purpose. E C
3. A liquid conforms to the shape of its container but does not expand to fill the container. Use kinetic molecular theory to explain why. PA C
4. A student sets a glass filled with ice water on a table. He notes that the outside of the glass is dry. The photograph below shows what the student observed after a short time had passed. Use the kinetic molecular theory to explain this observation. PA C

5. Use kinetic molecular theory to explain what happens when an ice cube is placed in a glass of warm water.
6. Some people use air fresheners in their cars with scents such as lemon, leather, or even "new car smell." One type of freshener consists of an ornament that has been infused with scented oil. Use the kinetic molecular theory to describe what happens when this type of air freshener is first removed from its package and hung from the rearview mirror of the car. PA C

Connecting Ideas

7. Use kinetic molecular theory to explain why puddles will eventually evaporate, even when the water never reaches the boiling point of water (100°C). Include diagrams in your explanation. AI C
8. A student freezes water in one ice cube tray and olive oil in another. She finds that the ice cubes float in liquid water while the olive oil cubes sink in liquid olive oil.
   - a) Compare the densities of the liquid and frozen water and the liquid and frozen olive oil.
   - b) Compare the two solids and liquids in terms of the differences in the spaces between their particles.
   - c) Most liquids behave like the olive oil when frozen. However, it is fortunate for life on Earth that water is an exception. Suggest one reason why.
   - d) List at least two science-related questions that you have based on this information.
   - e) Choose one question from part d) and describe how you would investigate to find an answer. QP PA E AI C

Making New Connections

9. The Mpemba effect is the name for a surprising observation: hot water freezes faster than cold water.
   - a) Why is this observation surprising?
   - b) Describe an experiment you could carry out to test this observation.
   - c) Conduct online research to find out how this effect got its name. PC AI C

TAKE a Stand

Make a Difference

Should perfume be banned in public places?

Freshly mown grass, window cleaner, wet dog, stinky socks, microwaved popcorn, wood smoke, perfume—these smells result from particles that enter the air from their sources and quickly diffuse outward. You smell them when the particles trigger the special sensors called olfactory receptors in your nose.

Take perfume as an example. Perfumes are scented oils dissolved in a mixture of alcohol and water. When you spray some perfume on your skin the alcohol and water evaporate quickly, leaving the scented oils behind. These evaporate too, but much more slowly. As the oils evaporate, their particles leave your skin and mix with the gases in the air. The particles diffuse quickly, and when some of them reach your nose, you smell the perfume.

Of course, you don't notice all the particles that reach your nose. Human olfactory receptors are not tuned to notice gases that we call "odourless," such as oxygen, nitrogen, carbon dioxide, or water vapour. But most people *do* notice and can identify a wide variety of smelly gases, including the many substances that make up a given fragrance. Some smells we like, others we don't. That's just life. But what happens when people complain that smells are affecting their health? Is that even possible?

Sweet or sickening?

The scent that one person loves to wear may, in fact, give another person a terrible headache.

The substances used in fragrances can be irritants and trigger allergy-like symptoms. In some people, fragrance sensitivity or intolerance may cause headaches, nausea, shortness of breath, muscle pain, or an itchy nose. People with asthma, bronchitis, emphysema, or allergies may be more sensitive to fragrances. Their symptoms can get worse when they smell fragrances. They may get a runny nose, muscle pain, shortness of breath, or nausea. If they are in direct contact with fragrances, they may get a bad skin rash.

In fact, according to one Canadian study, about 16 percent of the population are sensitive to environmental triggers such as strong odours. About 5 percent report that the triggers make them physically ill.

As well, some psychologists suggest that many people react to scents for psychological reasons rather than physiological ones. For these people, certain scents trigger anxiety, a psychological state that can cause physical symptoms, such as rapid breathing, higher heart rate, and even hyperventilation.

Ban or not?

Nowadays many people see signs in the offices of their family doctor or dentist, in some classrooms, or in workplaces that ask them—or tell them—not to wear certain scents or fragrances. Currently there are no laws in Canada banning fragrances in the workplace. But scent sensitivity is becoming a human rights issue. Legal experts are advising employers to take complaints seriously and put in place fragrance-free policies. They suggest employers explain to employees that the banned fragrances are not simply unpleasant to others but can trigger serious medical problems.

Some people agree that it is fair and respectful to ban fragrances in certain places, such as workplaces, public libraries, places of worship, or hospitals. Others feel these bans are valid in workplaces where people have physiological reactions to scents but not if their reactions are psychological. What do you think?

Analyze and Evaluate

1. Should the health of people with scent sensitivities be protected by laws? What are the pros and cons of banning fragrances? If so, where should these laws apply? Support your ideas.
2. Should makers of common products (such as shampoos, body washes, air fresheners, cleaning products) for home and workplace use be forced to limit the use of fragrances in their products, or should consumers be allowed to choose whether or not to buy and use fragrance-free products? Support your ideas.
3. Should people's psychological reactions to smells be treated just as seriously as physiological reactions? Research the difference, and then explain your views.
4. What kind of effect can fragrances in products such as synthetic musk have on the environment?

Communicate

5. Decide how you could help increase public awareness about this situation. Conduct any research you need to decide on a plan. Write out your plan and, with your teacher's approval, carry it out.

INVESTIGATION

2-F

GUIDED INQUIRY

Safety

- To be identified by each student group as part of planning stage

What You Need

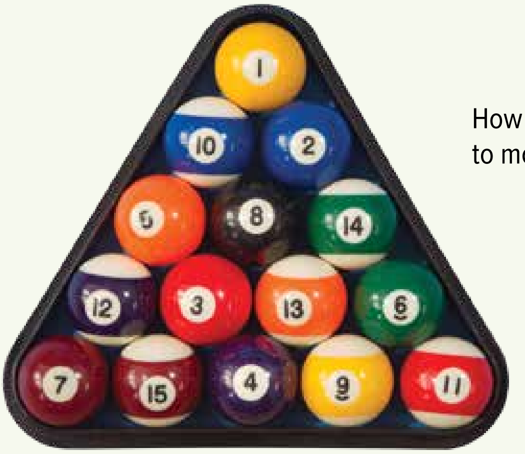
- To be identified by each student group as part of planning stage

Modelling Changes of State

The first two pages in this unit compared a marathon race with the changes that take place as a solid melts, forming a liquid, which then vapourizes. Analogies and models help us visualize and analyze processes we cannot see, such as what happens to the particles of matter when it changes state.

Question

How can you model changes of state as explained by the kinetic molecular theory of matter?



How could you use billiard balls to model changes of state?

Procedure

1. Work in groups. Your challenge is to create a model that can be used to demonstrate what happens during the changes of state, according to the kinetic molecular theory of matter. As a group, list the criteria that your model should satisfy. For example, the model should...
   - clearly demonstrate all of the possible changes of state among solids, liquids, and gases
   - show the main types of movement of the particles in each state
   - show the structure of matter in each state

2. Brainstorm some possible ways to make your model. For example, you could...
   - make a series of labelled illustrations on a poster
   - use software to make a series of simple animations
   - make a stop-action video using coins to represent particles
   - make a live-action video with people acting as particles
   - plan a game that has people acting as particles in various states
   - set up an interactive museum exhibit using marbles and various containers to represent the states and changes of state
3. Decide on what kind of model you want to make and come up with a detailed plan to make it. Your plan should include…
   - a list of materials you will need
   - safety precautions you will follow
   - steps you will take to make your model
   - sketches to illustrate how your finished model will work
4. With your teacher's approval, carry out your plan.

Process and Analyze

1. Test your model. Does it satisfy the criteria you outlined in step 1 of the procedure? If not, how can you improve the model so it does?
2. Repeat step 1 above until you are satisfied with your model.
3. Do any problems or limitations remain with your model that you were not able to address? Explain.

Evaluate, Apply, and Communicate

4. Present your model to the class. Allow time for questions and suggestions.
5. Based on the feedback you received, what modifications would you make to improve your model?

INVESTIGATION
2-G

Skills and Strategies

- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Never eat or drink anything in the laboratory.
- Clean up any spills immediately and inform your teacher.
- Dyes may stain clothing or skin.
- Have your procedure approved by your teacher before you begin.

What You Need

(Suggested)

- a variety of clear containers
- graduated cylinders
- dyes of various colours
- thermometer
- stopwatch

OPEN INQUIRY

Diffusion and the KMT

Planning and performing a controlled experiment lets you investigate your own question about diffusion.

Question

You will determine your own question to investigate. See step 1 of the Procedure.

Procedure

1. Your teacher will provide a collection of materials and equipment for you to examine. Think of a question about diffusion that you can investigate using some of the materials provided. Choose one of the questions below or come up with your own:
    - How is the rate of diffusion in water affected by the temperature of the water?
    - How long does it take for dye to diffuse completely in different volumes of water?
    - Do different colours of dye diffuse at different rates in water?
2. Write a procedure to describe how you will carry out an experiment to answer your question. Be sure to consider and include the following details in your procedure:
    - What materials will you need?
    - What safety precautions will you need to take?
    - What variables are involved? How will you control all but one variable?
    - What steps will you take as you carry out your experiment?
    - How many times will you repeat your experiment?

- How will you record your observations? For example, you might fill out a table, take point-form notes, make sketches, take photographs, take a video, or do some combination of these.
- How will you analyze and communicate your results?

3. Write a hypothesis for your experiment. A hypothesis states what you think will happen and why. You can phrase your hypothesis using an "If... then..." format. Use the kinetic molecular theory to help you frame your hypothesis.
4. With your teacher's permission, carry out your procedure. Clean up as directed.

Process and Analyze

1. Compile your data into an organized form such as a table or graph.
2. Are you able to answer your question based on the results of your experiment? Explain why or why not.
3. Discuss whether and why your hypothesis was correct or not. Does the kinetic molecular theory of matter help you explain your results? Discuss why or why not.

Evaluate and Communicate

4. Write a lab report to communicate your findings based on the template provided by your teacher or using these headings: Title, Introduction, Question, Hypothesis or Prediction, Materials, Safety, Procedure, Results, Analysis, Conclusion. Be sure to incorporate images as appropriate, and include links to any videos you took if possible.
5. If you were to repeat your experiment, what changes would you make? Explain why you would make those changes.