Category V Physical Science Examples

Guiding student interpretation and reasoning

Material B
Most explorations included in the material are followed by questions intended to help students think about the exploration. Questions often ask students to relate their observations to the particle model but rarely help students to make connections between their own ideas and what they observe (pp. **103-104s**). Most importantly, questions are rarely structured in a way that leads students gradually from observations to inferences. Rather, students are asked to make huge leaps from observations to inferences (pp. **88-89s**, **100s**). Teachers are not provided with any help when students do not respond in the way that they were supposed to, nor are they urged to facilitate discussion among students about different interpretations of the same observation.

In some cases, the teacher notes do not provide the correct interpretation of the observation being made. For example, students observe that a syringe filled with air is easy to compress whereas a syringe filled with water is hard to compress. They are then asked to imagine what would happen if they tried to compress a syringe filled with a solid (p. **103s**). From this, students are asked to infer what differences there are between the particles of a solid and those of a liquid or a gas. The expected inference is that the particles of a solid are locked in place, while the particles of liquids and gases can move about (p. **103t**). This is not a valid inference. The differences in compressibility between solids, liquids, and gases do not give credence to the idea that solids are locked in place while the particles of liquids and gases can move about. A more reasonable inference from this observation (and one which students are asked to make next) would be about the distance between particles of liquids and gases. But even then, the argument requires that students make too big a leap. Furthermore, it is unreasonable to expect students to infer the spacing of particles from observing a single instance of macroscopic behavior of substances.

LESSON 4

Particles of Solids, Liquids, and Gases

From circumstantial evidence, you have developed a model of the structure of matter. So far, your model includes the following ideas:

1. All matter consists of particles.
2. Particles are different sizes, although all are small.
3. Elements are made up of particles called *atoms*, and compounds are made up of particles called *molecules*.

In the Explorations that follow, you will discover more ideas about the structure of matter to add to these three.

Compressed air in this rocket forces water through the opening at the bottom. As the water is forced downward, the rocket is propelled upward. Why do you think both air and water are needed to make this rocket work? B

EXPLORATION 5

Compressing Gases, Liquids, and Solids

Fill a plastic syringe (without the needle) with air. Then, with your finger over the end, push down on the plunger as hard as you can. What does this experiment tell you about the particles that make up a gas?

Now fill the syringe with water, and again try to push down on the piston. What is the difference between the particles that make up a gas and those that make up a liquid?

Finally, consider this: If you could get a solid (such as a piece of chalk) into the syringe, could you compress it? What differences are there between the particles of a solid and those of a liquid or a gas?

To conclude this Exploration, add a fourth statement to the particle model of matter. (See the list of ideas in the first column on this page.)

EXPLORATION 6

Particles on the Move

Your model of matter is becoming more and more useful because it can explain more observations. Now you will make a few more observations of the behavior of matter. In each instance, explain your observations in terms of what the particles in the solid, liquid, or gas are doing.

You Will Need

- food coloring
- an eyedropper
- ice water
- hot water
- a balloon
- a plastic soft-drink bottle
- an ice chest with ice
- rubbing alcohol
- 2 microscope slides
- matches
- test-tube tongs
- a beaker
- cotton balls
- a metal lid from a jar
- perfume
- a candle

STATION 1

Place a drop of food coloring into very cold water and another drop into very hot water. Explain the difference in behavior.

Exploration 6 continued ►

LESSON 4

Particles of Solids, Liquids, and Gases

FOCUS

Getting Started

Ask students what the solid, liquid, and gaseous forms of water are. *(Ice, water, water vapor)* Explain to students that the particles that make up these three states of water are the same. Then invite them to speculate about what causes these three forms of water to be different.

Main Ideas

1. Particles of matter are constantly in motion.
2. Particles are farther apart in gases than in liquids and solids.
3. Heating causes particles in a substance to move faster and farther apart.

TEACHING STRATEGIES

Answers to *Exploration 5*

The particles of a gas can be compressed. The particles that make up a liquid cannot be noticeably compressed. A piece of chalk could not be compressed in the syringe. The particles of a solid are locked in place, while the particles of liquids and gases can move about.

Sample answer: Gas particles are farther apart than are the particles that make up liquids or solids.

Answer to *Caption*

B Air can be compressed, but water cannot be. Once the compressed air is free to expand, this forces the water to shoot out of the rocket and the rocket to move skyward.

★ **An Exploration Worksheet is available to accompany Exploration 6 (Teaching Resources, page 23).**

Exploration 6 begins on the next page. ►

LESSON 4 ORGANIZER

Time Required 2 to 3 class periods

Process Skills analyzing, inferring, comparing, contrasting

New Terms none

Materials (per student group) **Exploration 5:** plastic disposable syringe without a needle; 20 mL of water; 100 mL graduated cylinder **Exploration 6, Station 1:** 2 drops of food coloring; 2 small beakers; about 250 mL of cold water; about 250 mL of very hot tap water; lab aprons (additional teacher materials: ice chest with ice); **Station 2:** balloon; 2 L or 3 L plastic soft-drink bottle; 2 large containers or buckets; 5 L of ice water; 5 L of very hot tap water; watch or clock; **Station 3:** 2 drops of rubbing alcohol; eyedropper; 2 microscope slides; a few matches; safety goggles; **Station 4:** 250 mL of ice water; 250 mL beaker; **Station 5:** a cotton ball; metal jar lid; eyedropper; a few drops of perfume; **Station 6:** candle; a few matches; materials to prop up candle, such as a metal jar lid; safety goggles

Teaching Resources
Exploration Worksheet, p. 23

EXPLORATION 6, pp. 103–104

Set up five stations in the classroom.

SAFETY ALERT Water above 55°C is scalding. Make sure no open containers of alcohol are in the room while students are lighting their matches. You may also wish to apply the drops of alcohol yourself or have a beaker of water available for disposing of the hot matches.

Answer to Station 1, *page 103*

The food coloring diffuses more quickly in the hot water because the heated particles are moving faster.

Answer to Station 2

When the bottle is placed in hot water, the air particles inside speed up and move farther apart, causing the balloon to expand. When the bottle is placed in the ice water, the air particles slow down and move closer together, causing the balloon to deflate.

Answer to Station 3

The alcohol evaporates faster on the heated glass because the heated particles of alcohol move faster.

Answers to Station 4

Water condenses on the beaker. The beaker's cool surface causes particles of water vapor in the breath to slow down and gather in droplets.

Answers to Station 5

Eventually, the perfume will be smelled from across the room. The particles of perfume are moving farther apart as they change into a gas and diffuse throughout the air.

Answers to Station 6

The heat causes the wax particles to move freely as a liquid, so the wax melts. When the candle is extinguished and the wax cools, the particles slow down, and the liquid solidifies.

EXPLORATION 6, *continued*

STATION 2

Place a balloon over the mouth of a 2 L or 3 L plastic soft-drink bottle. Place the bottle into a container of hot water for a few

into a container of ice water. Use the particle model to explain what happens.

STATION 3

Heat a microscope slide with a match. Then, after extinguishing the flame, place one drop of alco-

drop on an unheated slide. Using the particle model, explain the differences you observe.

STATION 4

Pour ice water into a beaker. Now

What do you observe? Explain this observation in terms of what you think the water molecules in your breath are doing.

STATION 5

Place a cotton ball on a metal lid. Add a few drops of perfume to

can you smell the perfume? What do you think the liquid particles that make up the perfume are doing?

STATION 6

Observe a burning candle. What forms at the top of the candle (not the top of the flame)? What

out? Explain these observations in terms of what the particles of wax are doing.

Analysis, Please!

1. Now add at least one more statement to the three given on page 103.
2. Here are six words that help describe the processes you observed in Stations 1–6: condensation, expansion, diffusion, evaporation, melting, and solidification. Which word(s) would you associate with each station?

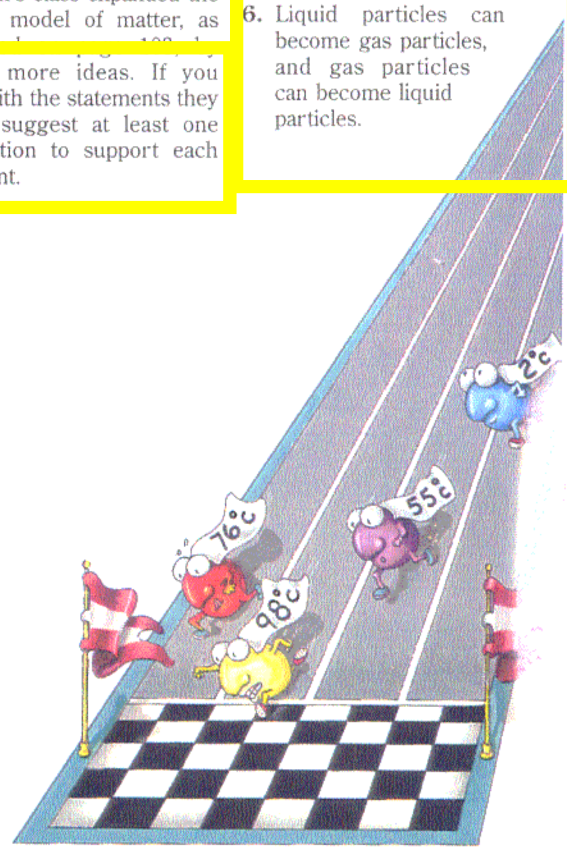
Expanding the Model

Mr. Chin's class expanded the particle model of matter, as

adding more ideas. If you agree with the statements they added, suggest at least one observation to support each statement.

More Ideas

1. Particles in gases are far apart.
2. Particles that make up liquids and solids must be as close together as possible.
3. Particles move.
4. Particles in a hot substance move faster than particles in a cold substance.
5. The faster gas particles move, the more pressure they exert on the sides of a balloon.
6. Liquid particles can become gas particles, and gas particles can become liquid particles.



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Answers to *Analysis, Please!*

1. Sample statement: Heating causes the particles of the substance to move faster and farther apart.
2. Condensation—Station 4; expansion—2; diffusion—1 and 5; evaporation—3 and 5; melting—6; solidification—6

Answers to *Expanding the Model*

1. Gases can be compressed.
2. We cannot easily compress liquids or solids.
3. Gases diffuse.
4. Raising the temperature of a liquid increases the rate of evaporation.
5. Warming the air inside a balloon causes it to expand, suggesting that the particles exert more pressure on the sides of the balloon.
6. Several changes of state were observed, such as water vapor condensing and liquid perfume evaporating.

The Follow-Up for Lesson 4 is on the next page. ►

LESSON 1

Building the Case

FOCUS

Getting Started

Have students discuss what the diagram on page 88 shows. *(It shows the relationship between observations and inferences. Observations based on measuring and information from the senses raise questions and lead to inferences, explanations, and models that can be tested.)* Point out that in this lesson students will examine some of the evidence that matter is made of particles.

Main Ideas

1. A particle model of matter can be used to explain observations of dissolving, pouring, and mixing substances.
2. A case favoring the particle nature of matter can be made based on observation and inference.

TEACHING STRATEGIES

EXPLORATION 1

PART 1

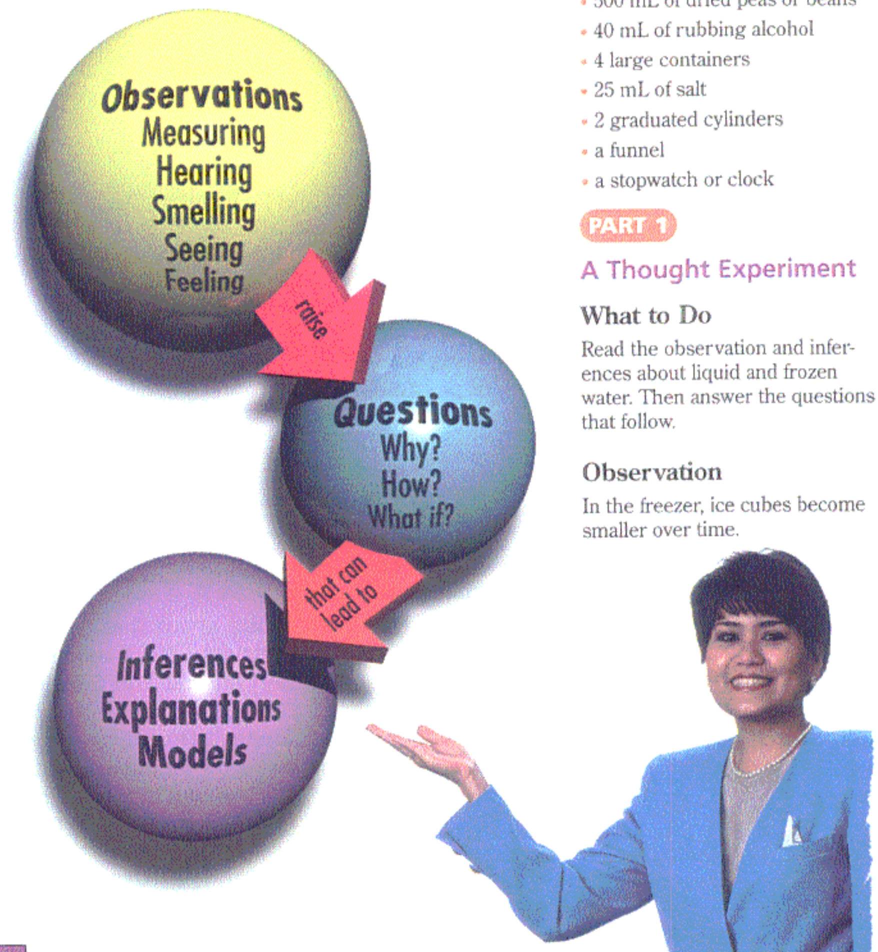
Ask students if they have ever noticed that ice cubes seem to shrink if they are left in the freezer for too long. Have them discuss what might have happened to the ice. *(Accept all reasonable responses. Some students may know that the ice has undergone sublimation.* Sublimation *is the process by which a substance changes directly from a solid to a gas without first becoming a liquid. Point out that they will study such changes of state in Chapter 6.)* Ask students the following questions:

- What is the gaseous state of water called? *(Water vapor)*
- Can you see water vapor? *(No)*
- Is water vapor a part of the air? *(Yes)*
- How do you know? *(Water often condenses out of the air, such as when moisture forms on the outside of a soft-drink can.)*

LESSON 1

Building the Case

You are the judge, jury, and attorney in a landmark case—a case that will determine whether all matter is composed of particles. This case may raise as many questions about matter and its behavior as it answers. The following experiments will provide the observations and information you will need to make some important inferences as you prepare your case in favor of the particle theory of matter—or against it.



EXPLORATION 1

Making the Case

You Will Need

- red food coloring
- an eyedropper
- a stirring rod
- a 100 mL beaker
- 500 mL of sand
- water
- 500 mL of dried peas or beans
- 40 mL of rubbing alcohol
- 4 large containers
- 25 mL of salt
- 2 graduated cylinders
- a funnel
- a stopwatch or clock

PART 1

A Thought Experiment

What to Do

Read the observation and inferences about liquid and frozen water. Then answer the questions that follow.

Observation

In the freezer, ice cubes become smaller over time.

LESSON 1 ORGANIZER

Time Required
1 to 2 class periods

Process Skills
observing, analyzing, inferring

Theme Connection
Structures

New Terms
none

Materials (per student group)
Exploration 1, Part 2: drop of red food coloring; stirring rod; 500 mL of water; 100 mL graduated cylinder; 100 mL beaker; lab aprons; **Part 3:** 4 large containers; about 500 mL of sand; about 500 mL of water; about 500 mL of dried peas or beans; **Part 4:** 50 mL of sand; 25 mL of salt; two 100 mL graduated cylinders; 200 mL of water; watch or clock with second hand; 40 mL of rubbing alcohol; stirring rod; funnel; safety goggles

Teaching Resources
Exploration Worksheet, p. 11
Discrepant Event Worksheet, p. 16

Questions

- Where does the ice go?
- How does it disappear?
- Can ice be prevented from disappearing?

Inference and Possible Explanation

- Perhaps ice (water) is made up of particles.
- Maybe some of these particles escaped from the solid state to form a gas, which floated away.

Follow-Up

1. Name another substance that changes directly from a solid into a gas.
2. Could a gas change directly into a solid? If so, think of some examples.
3. Do these observations and explanations support the idea that water is made up of particles? Why or why not?

PART 2

Seeing Red

What is the largest amount of water in which you could dissolve a drop of red food coloring and still detect its color? Here is a way to find out.

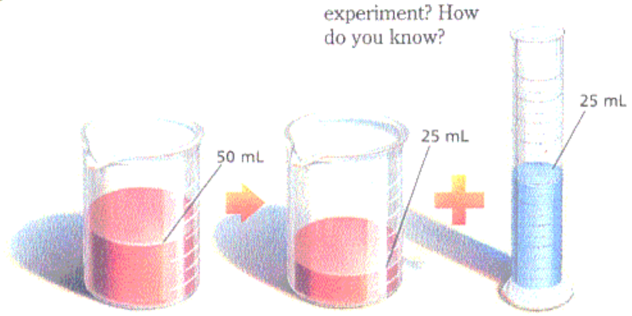
What to Do

Thoroughly dissolve a drop of food coloring in 50 mL of water. Now divide this solution into twc equal parts. Wash 25 mL down the sink, and add 25 mL of watei to what remains. Once again the total volume of the solution is 50 mL. Is the solution still colored red?

The concentration of the food coloring has been diluted to one-half of the original amount. Repeat the dilution process once more. Can you still see the red coloring in the water? Your beaker now contains one-quarter of the original drop of food coloring. Repeat the procedure—keeping accurate records—until you no longer see the red color.

Before going on to Part 3, discuss the following questions with a partner:

1. Is the color spread evenly throughout the solution, or are bits of food coloring clumped together?
2. Do you think there may be some food coloring left in the solution at the end, even though you cannot see any? How much of the food coloring do you have in the beaker of water at the end of the experiment? How do you know?
3. If matter is made up of particles, what can you infer about the size of the food-coloring particles?
4. Does the experiment support the particle theory of matter? Why or why not?



PART 3

Pour Judgment

What to Do

Fill three large containers with the substances listed below. Do not mix the substances.

- dried peas or beans
- sand
- water

Now pour each substance into an empty container. Did either of the first two substances resemble water in the way they poured?

What might you infer about matter from this experiment?

Exploration 1 continued

★ **An Exploration Worksheet is available to accompany Exploration 1 (Teaching Resources, page 11). In addition, a teacher demonstration that can be used once students have finished Exploration 1 is described in a Discrepant Event Worksheet (Teaching Resources, page 16).**

Answers to *Questions*

Students will probably not be able to provide answers at this point, although you may wish to discuss the answers with the class.

- The ice evaporates into the air in the freezer.
- The ice changes into water vapor through the process of *sublimation*. Sublimation occurs when a material changes directly from a solid to a gas.
- Ice can be prevented from disappearing by storing it under high pressure.

Answers to *Follow-Up*

1. Substances may include iodine crystals, solid room deodorizers, mothballs, dry ice, or camphor.
2. Yes, but rarely. Iodine vapor can change directly into iodine crystals, and water vapor changes directly into frost when the temperature is at or below the freezing point.
3. Yes; if part of a solid such as ice can disappear, then the solid may be made of smaller particles that can separate from each other and spread out.

Answers to *Part 2*

The solution is still colored red after the first two dilutions.

1. The color is spread evenly throughout the water.
2. Students should conclude that there will still be some food coloring left in the solution. The amount of food coloring in the beaker at the end of the experiment will depend on how many times the water has been diluted. After the first dilution, one-half of the food coloring is left. After the second dilution, one-quarter of the food coloring is left. A third dilution will leave one-eighth of the food coloring.
3. Since the food coloring spreads evenly throughout the water, students should infer that the molecules of food coloring are smaller than the spaces between the water particles.
4. Because the food coloring spreads throughout the water and can be divided into smaller and smaller quantities, the experiment supports the particle theory of matter.

Answers to *Part 3*

Students will probably agree that the sand and peas or beans all pour like water, but that the sand resembles water the most. They may conclude that the reason the sand pours more like water is because it is made up of very small particles. From this observation, students may infer that water is composed of particles just as sand is, but much, much smaller.

EXPLORATION 2, *continued*

-WASTE DISPOSAL ALERT To dispose of the Benedict's solution, pour all of the blue solution and red and greenish yellow solution into a labeled container. While stirring, add 0.1 M nitric acid solution until all of the red and greenish yellow is gone; the solution will be blue. While continuing to stir, add a 4% sodium hydroxide solution. You will notice a precipitate (solid material) forming in the solution. Continue to add sodium hydroxide until no more precipitate forms. Use a 0.1 M or weaker acid or base to ensure that the resulting mixture has a pH of between 6 and 8. Strain the solid out of the liquid. Pour the liquid down the drain. Wrap the solid in old newspaper and place it in the trash.

Pour the iodine-treated mixture into a labeled container. While stirring, slowly add a 0.1 M sodium thiosulfate solution until the mixture turns white. Pour the resulting mixture down the drain.

At the end of the activity, students should recognize that the differences in the properties of sugar and starch include the following:

- Sugar molecules are smaller than starch molecules.
- Starch turns blue-black in the presence of iodine, while sugar does not.
- Sugar turns yellow or red in the presence of Benedict's solution, while starch does not.

Answers to *Exploration 2, page 99*

6. Starch molecules did not pass through the membrane.
7. Sugar molecules did pass through the membrane.

Something to Think About

1. As a conclusion to the experiment, which of the following statements do you think is most correct? Which statement is an inference?
   a. Sugar molecules have properties that are different from those of starch molecules.
   b. The experiment showed that some molecules pass through an egg membrane.
   c. Since sugar molecules passed through the membranes and starch molecules did not, sugar molecules may be smaller in size.
   d. Iodine solution is a test for starch, while Benedict's solution is a test for sugar.
2. What is the function of the air-sac membrane? What molecules do you think pass through the membrane as the egg develops into a chicken, and why?

Flashback!

You observed the passing of water through a membrane in Chapter 2. As you may recall, this process is called osmosis. Osmosis is an important process in every living organism. Water is transferred by osmosis from cell to cell. Review and explain the observations you made in Exploration 2 of Chapter 2, using the particle model of matter in your explanation. Can you define *osmosis* using the particle model? Ⓐ

EXPLORATION 3

A Mini-Experiment—Locking in the Smell

Wrap a clove of garlic in a piece of plastic wrap. Now crush the garlic between your thumb and forefinger. Can you still smell the garlic? How many layers of plastic wrap are needed to seal in the smell? What can you conclude from this mini-experiment?

Answers to *Something to Think About*

1. Statement (c) is an inference, and it is the best conclusion to the experiment. All of the others are observations.
2. The air-sac membrane allows molecules of air to enter and leave the egg while preventing the fluids inside the egg from escaping. Obtaining oxygen from the air is essential for the growing embryo, as is eliminating excess carbon dioxide. If the liquids inside the egg were able to escape, the egg would dry out, and the developing embryo would die.

Answer to *In-Text Question*

Ⓐ Students should recall from Exploration 4 on page 43 that openings in the cell membranes of the potato slices were just the right size to allow water molecules to pass through while blocking larger particles, such as those of starch and salt. Students' definitions of osmosis will vary but should reflect an understanding that in osmosis, molecules of a certain size are permitted to pass through the openings in a membrane, while other molecules that are too large to pass through are blocked.

LESSON 4

Particles of Solids, Liquids, and Gases

From circumstantial evidence, you have developed a model of the structure of matter. So far, your model includes the following ideas:

1. All matter consists of particles.
2. Particles are different sizes, although all are small.
3. Elements are made up of particles called *atoms*, and compounds are made up of particles called *molecules*.

In the Explorations that follow, you will discover more ideas about the structure of matter to add to these three.

Compressed air in this rocket forces water through the opening at the bottom. As the water is forced downward, the rocket is propelled upward. Why do you think both air and water are needed to make this rocket work? B

EXPLORATION 5

Compressing Gases, Liquids, and Solids

Fill a plastic syringe (without the needle) with air. Then, with your finger over the end, push down on the plunger as hard as you can. What does this experiment tell you about the particles that make up a gas?

Now fill the syringe with water and again try to push down on the piston. What is the difference between the particles that make up a gas and those that make up a liquid?

Finally, consider this: If you could get a solid (such as a piece of chalk) into the syringe, could you compress it? What differences are there between the particles of a solid and those of a liquid or a gas?

To conclude this Exploration, add a fourth statement to the particle model of matter. (See the list of ideas in the first column on this page.)

EXPLORATION 6

Particles on the Move

Your model of matter is becoming more and more useful because it can explain more observations. Now you will make a few more observations of the behavior of matter. In each instance, explain your observations in terms of what the particles in the solid, liquid, or gas are doing.

You Will Need

- food coloring
- an eyedropper
- ice water
- hot water
- a balloon
- a plastic soft-drink bottle
- an ice chest with ice
- rubbing alcohol
- 2 microscope slides
- matches
- test-tube tongs
- a beaker
- cotton balls
- a metal lid from a jar
- perfume
- a candle

STATION 1

Place a drop of food coloring into very cold water and another drop into very hot water. Explain the difference in behavior.

Exploration 6 continued ►

LESSON 4 ORGANIZER

Time Required 2 to 3 class periods

Process Skills analyzing, inferring, comparing, contrasting

New Terms none

Materials (per student group) **Exploration 5:** plastic disposable syringe without a needle; 20 mL of water; 100 mL graduated cylinder **Exploration 6, Station 1:** 2 drops of food coloring; 2 small beakers; about 250 mL of cold water; about 250 mL of very hot tap water; lab aprons (additional teacher materials: ice chest with ice); **Station 2:** balloon; 2 L or 3 L plastic soft-drink bottle; 2 large containers or buckets; 5 L of ice water; 5 L of very hot tap water; watch or clock; **Station 3:** 2 drops of rubbing alcohol; eyedropper; 2 microscope slides; a few matches; safety goggles; **Station 4:** 250 mL of ice water; 250 mL beaker; **Station 5:** a cotton ball; metal jar lid; eyedropper; a few drops of perfume; **Station 6:** candle; a few matches; materials to prop up candle, such as a metal jar lid; safety goggles

Teaching Resources
Exploration Worksheet, p. 23

LESSON 4

Particles of Solids, Liquids, and Gases

FOCUS

Getting Started

Ask students what the solid, liquid, and gaseous forms of water are. *(Ice, water, water vapor)* Explain to students that the particles that make up these three states of water are the same. Then invite them to speculate about what causes these three forms of water to be different.

Main Ideas

1. Particles of matter are constantly in motion.
2. Particles are farther apart in gases than in liquids and solids.
3. Heating causes particles in a substance to move faster and farther apart.

TEACHING STRATEGIES

Answers to *Exploration 5*

The particles of a gas can be compressed. The particles that make up a liquid cannot be noticeably compressed. A piece of chalk could not be compressed in the syringe. The particles of a solid are locked in place, while the particles of liquids and gases can move about.

Sample answer: Gas particles are farther apart than are the particles that make up liquids or solids.

Answer to *Caption*

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Teaching Resources
Exploration Worksheet, p. 23