

7.2

The Particle Theory of Matter

Here is a summary of what you will learn in this section:

- The particle theory of matter describes the characteristics of matter.
- The spaces between particles are small in solids, larger in liquids, and largest in gases.
- Energy changes accompany changes of state.

Everything that you can see (e.g., cereal, milk), as well as everything that you cannot see (e.g., air, carbon dioxide), is made up of particles. **Particles** are very small portions of matter. These particles are so small that you cannot see them with your eyes alone. For example, a balloon is made up of particles (Figure 7.10). So is the air in the balloon. As the balloon fills with air, it expands. Air particles bump into each other and the balloon particles, which causes the balloon to inflate. If the balloon is filled with too many air particles, it will burst.



Figure 7.10 You cannot see the air particles in a balloon, but this student might feel their effects.

C8 Starting Point

Skills **P** **C**



Sugar Cubes and Particles

Because particles are so small, you cannot see them. A sugar cube can give you a better understanding of particles. You can see the granules that make up the sugar cube.

Work with a partner. Obtain a sugar cube and a small piece of plastic wrap from your teacher. Use the plastic to wrap the sugar cube securely. Place the wrapped sugar cube on a desk, and then gently tap the sugar cube until it breaks apart. Observe what happens.

Discuss the following questions with your partner, and be prepared to share your ideas with the class.

Consider This

1. What are the similarities between the granules of sugar and particles?
2. When you hit the sugar cube, you must have done something to break it apart. What do you think you did to the sugar granules when you hit the sugar cube?
3. If all of the sugar granules were present after you hit the sugar cube, do you think they take up the same amount of space, less space, or more space than when the granules were arranged in the cube?

The Particle Theory of Matter

The **particle theory of matter** is a theory that describes matter. It explains the behaviour of solids, liquids, and gases.

1. All matter is made up of particles.
2. All particles of one substance are identical.
3. The particles of matter are in constant motion.
4. Temperature affects the speed at which particles move.
5. Particles have forces of attraction between them.
6. There are spaces between particles.

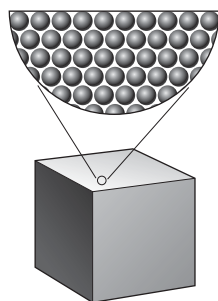


Figure 7.11 All matter is made up of particles.

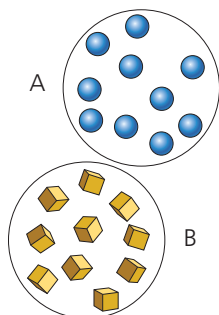


Figure 7.12 All particles of one substance are identical. A and B are different substances.

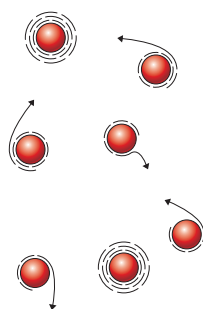


Figure 7.13 The particles of matter are in constant motion.

Matter and Particles

All matter is made up of particles (Figure 7.11). Different substances are made up of different particles.

Particles of a pure substance are all identical. Figure 7.12 shows that substances A and B are both pure substances because each one is made up of only one type of particle. For example, distilled water is made up of water particles that are all the same. All the water particles look the same because they are the same. The particles that make up mixtures are different. Mixtures contain varying amounts of their component particles. For example, a soft drink consists of particles of sweetener, particles of flavouring, particles of water, and particles of gas (to make the bubbles).

Particles in Motion

The particles of matter are in constant motion (Figure 7.13). They move and vibrate constantly. “Vibrate” means to move back and forth rapidly. Particles move because they have kinetic energy. **Kinetic energy** is the energy of movement. In solids, the particles vibrate and wiggle in one place. In liquids, the particles slide around and over each other. The liquid takes the shape of the container. For each substance, its particles move more and have more kinetic energy when the substance is in a liquid state than when it is in a solid state. In gases, the particles move around as far as the space they are in allows, completely filling the space in the container. The particles of a substance move more and have more kinetic energy when the substance is in a gaseous state than when it is in a liquid state.

C9 Learning Checkpoint



Particle Theory – Points to Ponder

Use a single term from the list that follows to complete each of the sentences at right.

- different
- a mixture
- a pure substance
- identical

1. The particles of a pure substance are _____.
2. The particles of a mixture are _____.
3. The composition of most foods can be classified as _____.
4. Oxygen and carbon dioxide are each classified as _____.

Temperature, Heat, and Motion

To understand the speed at which particles move, you need first to understand the concepts of temperature and heat.

Temperature is the measure of the average kinetic energy of the particles in a substance. It measures how hot a substance is.

Heat is the energy that transfers from a substance at a higher temperature to one at a lower temperature.

Temperature affects the speed at which particles move (Figure 7.14). As you just learned, particles in matter are in constant motion. When heat transfers from a hotter substance to a cooler one, the particles in the cooler substance start to move faster.

You can observe the effects of this motion by placing a spoon in a cup of hot chocolate and feeling the temperature increase in the spoon's handle (Figure 7.15). Even though parts of the spoon are not in the hot chocolate, the whole spoon gets warmer. Heat in the hot chocolate is transferred to the particles in the spoon. The particles in the spoon then move faster; you sense this as an increase in the spoon's temperature. If you then place the spoon in a glass of cold water, the temperature of the spoon will decrease. The particles in the spoon then move slower because heat is transferred from the spoon to the colder water.

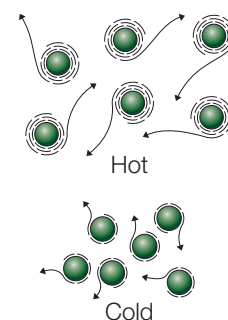


Figure 7.14 Temperature affects the speed at which particles move.

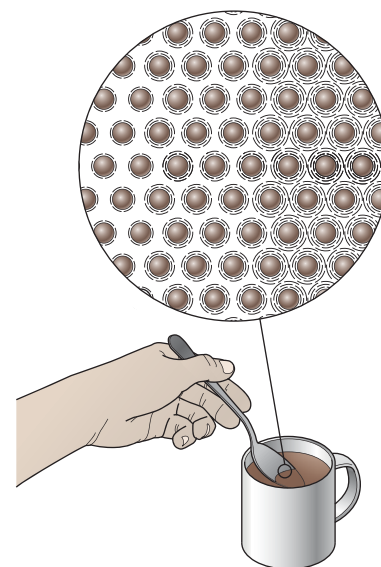


Figure 7.15 The particles of this spoon are moving faster because they are being heated by the hot chocolate.

Space and Attraction between Particles

There are spaces between particles. There are also forces of attraction between particles. Figure 7.16 illustrates how a substance has different amounts of space and attraction between particles when comparing that substance in its solid, liquid, and gaseous states.

Solid particles are much closer together and have greater attraction when compared to liquid particles. For example, the particles in a solid block of lead are closer together than the particles in a sample of lead that has been heated until it melts. Liquid particles are closer together and have greater attraction when compared to gas particles. For example, the particles in a glass of water are closer together and have greater attraction than the air particles in a balloon.

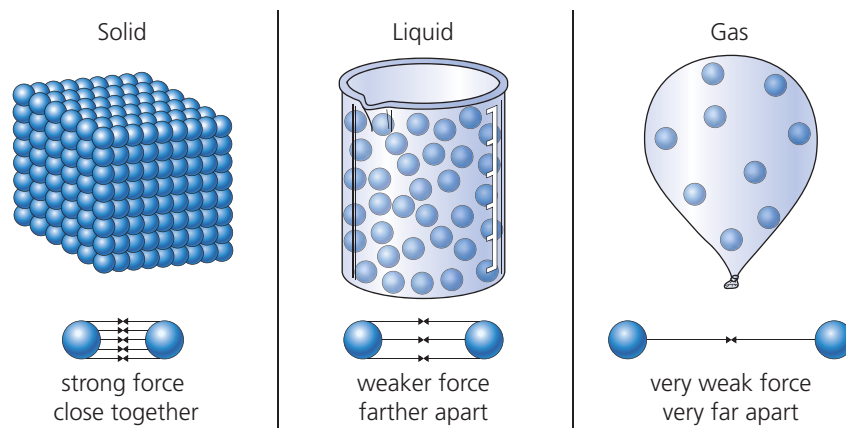


Figure 7.16 Particles have spaces and forces of attraction between them.

Temperature and Changes of State

Changes in temperature can also cause changes of state. A **change of state** is a change from one physical state of matter (solid, liquid, gas) to another. All matter exists as a solid, a liquid, or a gas. Changing the temperature of matter in one state can cause it to change to a different state. Figure 7.17, on the next page, shows how heat is necessary to overcome the degrees of attraction between particles of matter and result in a change of state.

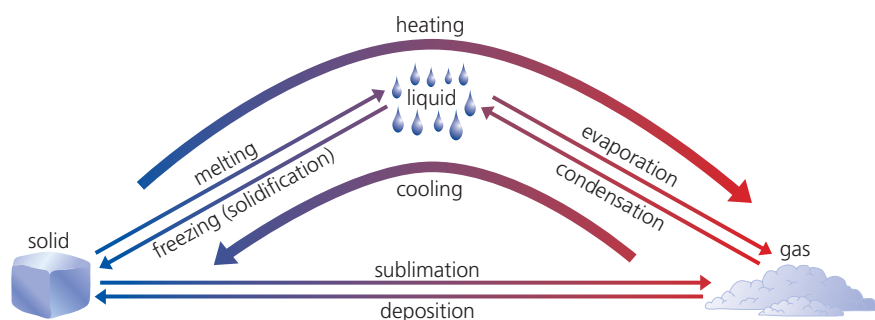


Figure 7.17 Energy is necessary to overcome the degrees of attraction between particles to change state from solid to liquid, liquid to gas, or directly from solid to gas. Energy is released when the substance changes state from gas to liquid, liquid to solid, or directly from gas to solid.

The change of state from a solid to a liquid is called **melting**. Heat must be added to make this happen. For example, think about a wax candle (Figure 7.18). Wax is a solid at room temperature. When the wick on the top of the wax candle burns, heat from the flame increases the temperature and melts the wax. The wax changes from solid to liquid.

The change of state from liquid to gas is called **evaporation**. Heat must also be added for this change of state to occur. When you boil water for a hot drink, you see steam rising from the surface of the water. This is water as a gas (vapour) evaporating from the liquid water.

The change of state from gas to liquid is called **condensation**. This change of state occurs when heat is removed. After you take a hot shower, you see water on the surface of the mirror in the bathroom. The mirror is cooler than the air so water vapour condenses from a gas to a liquid on the mirror.

The change of state from liquid to solid is called **freezing** or **solidification**. Liquid candle wax will solidify after a candle is extinguished and allowed to cool. Heat is removed, causing a decrease in the temperature of the wax so it solidifies.

The change of state from solid to gas is called **sublimation**. The change of state from gas to solid is called **deposition**. In both cases, there is no change to a liquid state. A change of state from solid to gas would occur when heat is added. You can see this in the spring sometimes. On a warm sunny day, some of the snow seems to disappear without melting. The solid water (snow) is changing directly to gas (vapour). A change of state from gas to solid would occur when heat is removed.



Figure 7.18 The wax in the candle changes state with changes in temperature.

Suggested Activity •
C11 Inquiry Activity on page 205

Take It Further

Sublimation is a change of state that receives little attention. For example, ice cubes left for more than a week in the freezer will shrink noticeably. Think about why this happens and where the water goes. Begin your search at ScienceSource.

C10 *Inquiry Activity***Toolkit 2****SKILLS YOU WILL USE**

- Asking questions
- Evaluating procedures

Acting Out the Particle Theory

It may be difficult to imagine how particles look when they are in solid, liquid, and gaseous form. Being able to see how they are arranged and move can give you a better understanding of particles. In this activity, you and your classmates will act like particles in the three states of matter.

Question

How can you and your classmates move and arrange yourselves to act like the particles that make up solids, liquids, and gases?

Materials & Equipment

- sheet of paper
- pen or pencil

Procedure

1. You will work in groups. Each group will work in a separate area. Treat each separate area as if it were a large container.
2. With your group, develop a way to represent a solid state of matter. Decide how to arrange yourselves and how to move to be particles of a solid.
3. Imagine that heat is being added to you. Your solid group changes positions and movements to represent liquid particles.
4. Now add more heat. Change your positions and movements again to represent gas particles.
5. Keep working together until your group is satisfied with the way you represent particles in the three states of matter. Then present one of these states to the rest of the class without saying what it is. Show yourselves changing from that state to another state (e.g., from a solid to a liquid).
6. Draw two rectangles on a sheet of paper. The rectangles represent “containers.” Use them to sketch the two states of matter your group represented. Draw arrows to show your movement. Include other information about the way and the speed that you (as particles) were moving.

Analyzing and Interpreting

7. As a class, judge each group’s presentation based on the following criteria:
 - How easy was it to infer the state of matter being represented? What were the best clues? How accurately did the group represent the state of matter?
 - How well did the group’s actions represent the level of kinetic energy of the particles? How accurate was this action?
 - How well did the group’s actions show changes in volume?

Skill Builder

8. What criteria did you use to evaluate and decide upon a method of representing states of matter?

Forming Conclusions

9. Review the scores that you gave your classmates’ presentations. Write three paragraphs that describe the best presentation for each state of matter: solid, liquid, and gas.

C11 Inquiry Activity

Toolkit 2

SKILLS YOU WILL USE

- Using appropriate equipment and tools
- Drawing conclusions

Melting and Freezing of Deodorizer Blocks

The deodorizer blocks found in washrooms, like all other matter, are composed of particles. You will closely observe the melting and freezing of samples of a deodorizer block. You will not be able to see the tiny particles, but you can imagine what they are doing inside the test tube.

Question

What happens to the particles of a sample of deodorizer block when it melts and freezes?

Materials & Equipment

- 5-mL sample of deodorizer block 
- OR
- 5-mL sample of salol (alternative to deodorizer block)
- test tube with stopper
- 50°C water bath

CAUTION: Do not eat or drink anything during this activity. Wash your hands thoroughly when you have finished the Procedure steps (after step 6).

Procedure

Part 1 — Melting a Sample of Deodorizer Block

1. Obtain a sample of 5 mL of deodorizer block, a test tube, and a stopper. Be careful to hold the test tube securely with your fingers on the glass rim.
2. Observe the sample very carefully and make a note of its appearance in your notebook (e.g., white crystals resembling ice).
3. Place the sample in the test tube and place the stopper loosely in the tube. Mark your test tube as instructed by your teacher.

4. Place the test tube in the warm water bath. In your notebook, describe what happens to the crystals.

Part 2 — Freezing a Sample of Deodorizer Block

5. Remove the test tube from the warm water bath by holding on to the rim at the top of the tube. **Do not hold onto the stopper.**
6. Hold the test tube upright in your hands. Note the appearance of the sample and any change of state.

Analyzing and Interpreting

7. What happened to the crystals when placed in the water bath?
8. What happened to the liquid when removed from the water bath?
9. Did the test tube feel cold when the liquid sample froze?

Skill Builder

10. What information will you use to draw conclusions in this experiment?

Forming Conclusions

11. What happened to the particles of the deodorizer block sample during the change of state from solid to liquid?
12. What happened to the forces between particles during the change of state from liquid to solid?



Key Concept Review

1. Explain why a solid substance occupies less space than the same substance in gaseous form.
2. Explain why the particles of a liquid are able to pour into a container and then take on the shape of that container.
3. Explain what happens to the particles of a substance that changes state from liquid to gas.
4. Explain why ice cubes placed in your refrigerator's freezer section become smaller over time.

Connect Your Understanding

5. Use the particle theory of matter to explain how the particles in an ice cube differ from the particles in a glass of water.
6. Use the particle theory of matter to explain what happens to the particles in a hot drink when it cools down.
7. Use the particle theory of matter to explain why heat is required to boil water.

Practise Your Skills

8. As shown in the photo below, particles of iodine form an amber solution in one liquid and a purple solution in another liquid. When combined with other substances, do iodine particles change or does the arrangement of iodine particles change? Use the particle theory of matter to explain your answer.



For more questions, go to ScienceSource.



C12 Thinking about Science and Technology



Using Models

We use models to help us explain things that we cannot see. For example, the particle theory of matter is a model that helps us to understand the structure of matter.

Work with a partner to identify and describe a model that you have seen or used to describe something. An example is the way textbooks show how planets orbit the Sun.

Science and Technology in Your World

Carbon Dioxide: Dry Ice and Greenhouse Gas



Figure 7.19 Carbon dioxide is a pure substance that sublimates. This means it changes state from solid to gas without becoming a liquid in between. That's why it is called "dry ice."

Carbon dioxide is mentioned in the news all the time because its increasing concentration in the atmosphere is thought to be one of the main causes of climate change. Carbon dioxide is one of the by-products of the combustion, or burning, of different types of natural resource fuels, such as coal, oil, and natural gas. However, we should take a closer look at this pure substance because it has some interesting chemical properties.

Sources

As mentioned, carbon dioxide is one of the products of the burning of different types of organic substances, such as wood, paper, and sugar. Along with water, carbon dioxide is also a by-product of the respiration that occurs in all plants and animals. Every time you breathe, you exhale carbon dioxide. Additionally, plants take in carbon dioxide and release oxygen and water as part of the process of photosynthesis.

Common Uses

The most common industrial use of carbon dioxide is as a refrigerant. At temperatures below -78°C , carbon dioxide becomes solid, and solid carbon dioxide is commonly known as dry ice (Figure 7.19). At ordinary temperature and air pressure, carbon dioxide changes state directly from solid to gas in a process known as sublimation. Thus, dry ice can be carried in a suitable container to keep food or other substances at temperatures below the freezing point of water.

Another common use of carbon dioxide is as a fire extinguisher. Since carbon dioxide is denser than air, it replaces the less dense air surrounding a burning material, preventing oxygen from supporting combustion.

Greenhouse Gas

In recent years, it has become known that carbon dioxide, along with other so-called greenhouse gases, has the ability to retain or trap heat from Earth's surface. This is necessary for life on Earth. However, since the middle of the 19th century (around 1860), the amount of atmospheric carbon dioxide has risen steadily. There has also been an increase in average temperature. Some environmentalists predict that, by the year 2050, the amount of carbon dioxide will have doubled from before 1900. This will lead to an increase in the average temperature on Earth (perhaps by as much as 5°C), resulting in a major and dangerous change in climate.

Questions

1. How is carbon dioxide produced naturally?
2. Why is dry ice useful?
3. Why is it important for Earth to have some carbon dioxide in its atmosphere?