

section 1 Matter and Thermal Energy

What You'll Learn

- the kinetic theory of matter
- how particles move in the four states of matter
- how particles behave at the melting and boiling points

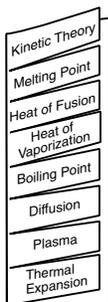
Mark the Text

Identify Concepts Highlight each heading in this section that asks a question. Then use a different color to highlight the answers to the questions.

FOLDABLES™

A Build Vocabulary

Make the following Foldable to help you learn the vocabulary terms in this section.



Before You Read

Everywhere you go, you are surrounded by the three states of matter—solids, liquids, and gases. Look around you and find a substance in each of the three states of matter. List these substances on the lines below.

Read to Learn

States of Matter

An everyday activity such as drinking tea may include solids, liquids, and gases. Think about heating water on the stove for a cup of hot tea. The boiling water is in the liquid state. The water vapor moving into the air is in the gaseous state. You might drop an ice cube into the tea to cool it. Ice is in the solid state. How are these states alike and different?

What is the kinetic theory of gases?

The **kinetic theory** is an explanation of how particles in gases behave. To explain the behavior of particles, you have to make some basic assumptions. An assumption is an idea that most people accept as true. The assumptions of the kinetic theory are:

1. All matter is composed of small particles—atoms, molecules, and ions.
2. These particles are in constant motion. The motion has no pattern.
3. These particles are colliding or crashing into each other and into the walls of their container.
4. Particles lose some energy when they bump into other particles. The amount of energy the particles lose is very small and can be ignored.

A model that you picture in your mind can help you understand the kinetic theory and how particles in matter move. Think of each particle as a tiny ball. These balls constantly are bouncing and bumping into one another.

What is thermal energy?

One assumption of the kinetic theory is that particles are in constant motion. Think about an ice cube. Does an ice cube seem to move? How can a frozen, solid ice cube have motion? Remember that the kinetic theory is describing particles. Atoms in solids are held in place by the attraction between the particles. This attraction gives solids a definite shape and volume. However, the thermal energy in the particles causes them to vibrate, even when the object stays in one place.

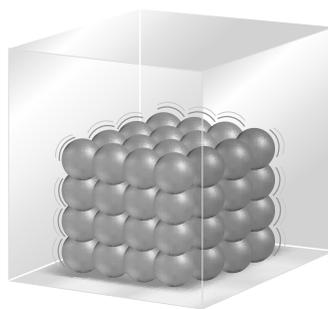
Thermal energy is the total energy of the particles in a material. Thermal energy includes kinetic energy and potential energy. Even though the ice cube does not appear to be moving, its particles are moving because of thermal energy. When the temperature of a substance is lowered, its particles will have less thermal energy and will vibrate more slowly. ✓

What is average kinetic energy?

The word *temperature* is used to explain how much thermal energy something has. Temperature is also the average kinetic energy of particles in a substance. On average, molecules of frozen water at 0°C will move slower than molecules at 100°C . Therefore, water molecules at 0°C have lower average thermal and kinetic energy than the molecules at 100°C . Molecules have kinetic energy at all temperatures, even at absolute zero. Absolute zero is about -273°C . Scientists theorize that at absolute zero, particles move so slowly that no more thermal energy can be removed from a substance.

How are particles in a solid arranged?

The figure shows how the particles of a solid are packed together. The particles vibrate constantly. The particles of most materials always will be in the same arrangement in the solid. The type of ordered arrangement formed by a solid is important. It gives the solid its chemical and physical properties.



Solid

✓ Reading Check

1. **Determine** What two kinds of energy are part of thermal energy?

Picture This

2. **Use a Model** Describe materials you might use to make a model of the particles in a solid.

Reading Check

3. **Explain** What is the temperature at which a solid begins to turn into a liquid called?
-

Think it Over

4. **Infer** Which particles have the least kinetic energy? Circle the correct answer.
- a. solid particles
 - b. liquid particles
 - c. gas particles

How do solids become liquids? Gases?

Think about the ice cube you dropped into the hot tea. The moving particles in the tea bump into the vibrating particles in the ice. These collisions transfer energy from the tea to the ice cube. The particles on the ice cube surface vibrate faster and transfer energy to particles inside the ice cube. When the particles have enough energy to overcome the attractive forces, they slip out of their ordered arrangement and the ice melts. The temperature at which a solid melts is the **melting point**. The thermal energy required to change a substance from a solid to a liquid is the **heat of fusion**.

Under certain conditions, a solid can go straight to a gas without becoming a liquid first. The process is known as **sublimation**. Dry ice (frozen carbon dioxide) is a common substance that undergoes sublimation. 

Why do liquids flow?

Particles in a liquid have more kinetic energy than particles in a solid. This extra kinetic energy lets particles overcome some of their attraction to other particles. The particles can slide past each other. This is why liquids flow and take the shape of their container. But the particles in a liquid have not overcome all of the attractive forces among them. The particles still cling together. Because of the attractive forces, liquids have a definite volume. A certain amount of liquid will always take up the same amount of space regardless of the shape of the container.

What is a gas state?

Gas particles have enough kinetic energy to overcome the attractions among them. Gases do not have a fixed volume or shape. They can spread far apart or move close together to fill a container. How does a liquid become a gas? The particles in a liquid are moving constantly. Some particles are moving faster than other particles. They have more kinetic energy. Particles that move fast enough can escape the attractive forces of other particles. They enter the gas state. This process is called vaporization. Vaporization can occur in two ways—evaporation and boiling.

How do liquids evaporate?

Vaporization occurs when liquids evaporate. Evaporation is vaporization that occurs at the surface of a liquid. It can occur at temperatures below the liquid's boiling point. To evaporate, particles must have enough kinetic energy to escape the attractive forces of the liquid. The particles must be at the surface of the liquid. They also must be traveling away from the liquid.

How does boiling vaporize liquids?

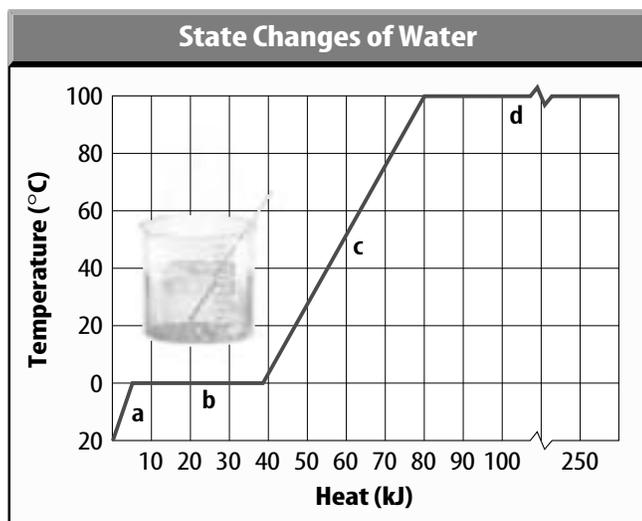
Another way that a liquid vaporizes is by boiling. Boiling occurs at a specific temperature. The temperature depends on the pressure on the surface of the liquid. Air exerts pressure on the surface of a liquid. This external pressure keeps particles from escaping from the liquid. The **boiling point** of a liquid is the temperature at which the pressure of the vapor in the liquid is equal to the external pressure on the surface of the liquid. Particles need energy to overcome the force of pressure. **Heat of vaporization** is the amount of thermal energy needed for the liquid at its boiling point to become a gas. ✓

Why do gases fill their containers?

Gas particles move so quickly and are so far apart that they overcome the attractive forces among them. Therefore, gases do not have a definite shape or a definite volume. The movement of particles and the collisions among them cause gases to diffuse. Diffusion is the spreading of particles throughout a given volume until they are evenly distributed. Diffusion occurs in solids, liquids, and gases, but it happens most quickly in gases. Imagine that you spray air freshener in one corner of a room. It is not long before you smell the scent all over the room. Gases will fill the container that they are in even if the container is rather large. The particles continue to move and collide in a random motion within their container.

What is the heating curve of a liquid?

The heating curve graph shows water being heated from -20°C to 100°C . It shows the temperature change as heat is added. In areas **a** and **c** the graph slopes upward because the water's kinetic energy is increasing. In areas **b** and **d** the graph is a horizontal line. The temperature of the water does not change.



✓ Reading Check

5. **Apply** What do particles need in order to overcome the force of pressure and become a gas?
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💡 Think it Over

6. **Sequence** List the following substances in the order in which their particles diffuse, slowest to fastest: liquid water, water vapor, ice.
- a. _____
- b. _____
- c. _____

Applying Math

7. **Interpret a Graph** At what temperature is the water turning into gas?
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B Find Information

Make the following Foldable from a quarter sheet of paper to help you take notes about plasma.



Melting Point At 0°C, ice is melting. All of the energy put into the ice at this temperature is used to overcome the attractive forces among the particles in the solid. The temperature stays the same during melting. After the attractive forces are overcome, the particles move more freely. Their temperature increases.

Boiling Point At 100°C, water is boiling or vaporizing. The temperature stays the same again. All of the energy that is put into the water goes to overcoming the remaining attractive forces among the water particles. When all the attractive forces in the water have been overcome, the energy returns to increasing the temperature of the particles.

What is the plasma state?

Solids, liquids, and gases are three familiar states of matter. However, scientists estimate that much of the matter in the universe is plasma. **Plasma** is matter made up of positively and negatively charged particles. The overall charge of plasma is neutral. Plasma is neutral because it contains equal numbers of positive and negative particles.

The faster the particles move, the greater the force when they collide. The forces produced from high-energy collisions are so large that electrons from the atoms are ripped off. This state of matter is called plasma. Plasma is found in stars, lightning bolts, neon and fluorescent tubes, and auroras.

Thermal Expansion

The kinetic theory explains other characteristics of matter. Recall that particles move faster and separate as temperature rises. The separation of the particles in a substance increases the size of the substance. **Thermal expansion** is an increase in the size of a substance when the temperature is increased.

The kinetic theory also explains contraction in objects. When the temperature of a substance is lowered, its particles slow down. The particles move closer together, and the substance shrinks. This is known as contraction. Expansion and contraction occur in most solids, liquids, and gases.

How does expansion occur in solids?

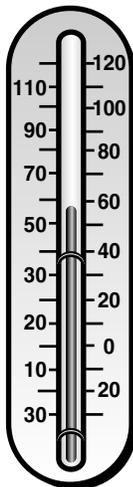
Have you ever noticed the lines in a concrete sidewalk? A gap often is left between the sections of concrete; these are called expansion joints. When concrete absorbs heat, its particles move faster and get farther apart. The concrete expands. When the concrete cools, it contracts. Expansion joints prevent concrete cracks when temperatures change.

 **Think it Over**

8. Explain How do expansion joints in a sidewalk keep the concrete from cracking?

How does expansion occur in liquids?

An example of expansion in liquids occurs in a thermometer. One kind of thermometer, as shown below, is a narrow glass tube with a liquid in it. The addition of energy makes the particles of the liquid in the thermometer move faster. The particles in the liquid move farther apart. Even if the liquid expands only a little, it will show a large change on the thermometer's temperature scale.



How does expansion occur in gases?

A hot-air balloon is an example of thermal expansion in gases. Hot-air balloons are able to rise because of the thermal expansion of air. When the air in the balloon is heated, the distance between the particles in the air increases. This makes the balloon expand. As the balloon expands, the number of particles per cubic centimeter inside the balloon decreases. The density of the hot air inside the balloon decreases also. The density of the air in the hot-air balloon is lower than the density of the cooler air outside the balloon. This makes the balloon rise. ✓

Why does water behave in a different way?

Why does ice float in water? Most substances contract as the temperature is lowered because the particles move closer together. However, water molecules are unusual. Water expands when it freezes. Water has some areas that have a highly positive charge and other areas that have a highly negative charge. The diagram shows these regions. The charged regions affect the behavior of water.

Partial negative charge



Partial positive charge

Picture This

9. **Infer** What will happen to the liquid in the thermometer as the temperature cools?

✓ Reading Check

10. **Infer** What happens to the density of the air inside a hot-air balloon as the balloon expands?

Picture This

11. **Identify** Circle the atom(s) that contribute(s) to the positive charged end of the molecule.

Think it Over

12. **Infer** What will happen if you completely fill an ice tray with water?

Reading Check

13. **Describe** What do the particles in amorphous solids resemble?

Unlike charges attract each other. As the temperature of water drops, the particles move closer together. The unlike charges attract each other. They line up so that only positive and negative areas are near each other. Because the water molecules line up according to charge, there are empty spaces in the structure. These empty spaces are larger in ice than in liquid water. So water expands when it goes from a liquid to a solid state. Solid ice is less dense than liquid water.

Solid or a Liquid?

Some other substances also have unusual behavior when they change states. Two kinds of materials that react unusually are amorphous solids and liquid crystals. It can be difficult to tell if these materials are in a solid state or a liquid state.

What are amorphous solids?

Ice melts at 0°C. Not all materials have a definite temperature when they change from solid to liquid. Some solids just get softer and slowly turn to liquid over a range of temperatures. These solids do not have the ordered structure of crystals. They are called amorphous (uh MOR fus) solids. Amorphous comes from the Greek word for “without form.”

You are familiar with two amorphous solids—glass and plastics. The particles in amorphous solids are like long chains. They can get jumbled and twisted instead of having an ordered structure. As a result, amorphous solids have different properties than crystalline solids. 

What are liquid crystals?

Liquid crystals are groups of materials that do not change states in the usual way. When a substance changes from a solid to a liquid, it usually loses its ordered structure. Liquid crystals start to flow in the melting phase, like most liquids. But liquid crystals keep their ordered structure. Liquid crystals respond to temperature changes and electric fields. Scientists use these properties to make liquid crystal displays. LCDs are used in watches and calculators.

● After You Read

Mini Glossary

boiling point: the temperature at which the pressure of the vapor in the liquid is equal to the external pressure acting on the surface of the liquid

heat of fusion: the amount of energy needed to change a substance from a solid to a liquid at its melting point

heat of vaporization: the amount of energy needed for the liquid at its boiling point to become a gas

kinetic theory: an explanation of how particles in matter behave

melting point: the temperature at which a solid begins to turn into a liquid

plasma: matter consisting of positively and negatively charged particles

sublimation: the change from a solid to a gas without the liquid state

thermal expansion: an increase in the size of a substance when the temperature is increased

1. Read the vocabulary terms and their definitions in the Mini Glossary. How are the heat of fusion and the heat of vaporization similar? How are they different?

2. Complete the graphic organizer about the arrangement and behavior of particles in solids, liquids, and gases.

