section 1

Kinetic Theory

Reading Guide

What You'll Learn
- **Explain** the kinetic theory of matter.
- **Describe** particle movement in the four states of matter.
- **Explain** particle behavior at the melting and boiling points.

Why It's Important
You can use energy that is lost or gained when a substance changes from one state to another.

Review Vocabulary
kinetic energy: energy in the form of motion

New Vocabulary
- kinetic theory
- melting point
- heat of fusion
- boiling point
- heat of vaporization
- diffusion
- plasma
- thermal expansion

States of Matter

You probably do not think of the states of matter as you do everyday activities. An everyday activity such as eating lunch may include solids, liquids, and gases. Look at **Figure 1.** Can you identify the states of matter present? The boiling soup on the stove and the visible steam above the boiling soup is in the liquid state. The ice cube dropped into the soup to cool it, is in the solid state. How are these states alike and different?

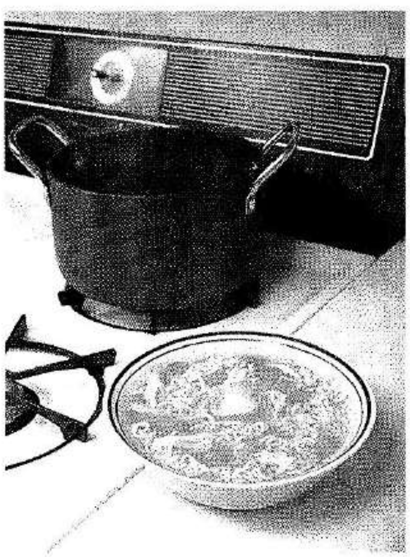


Figure 1 Two states of water are visible in this photograph. **Identify** *Can you identify the solid and liquid states of water?*

Kinetic Theory The **kinetic theory** is an explanation of how particles in matter behave. To explain the behavior of particles, it is necessary to make some basic assumptions. The three assumptions of the kinetic theory are as follows:

1. All matter is composed of small particles (atoms, molecules, and ions).
2. These particles are in constant, random motion.
3. These particles are colliding with each other and the walls of their container.

Particles lose some energy during collisions with other particles. But the amount of energy lost is very small and can be neglected in most cases.

To visualize the kinetic theory, think of each particle as a tiny table-tennis ball in constant motion. These balls are bouncing and colliding with each other. Mentally visualizing matter in this way can help you understand the movement of particles in matter.

Thermal Energy Think about the ice cube in the soup. Does the ice cube appear to be moving? How can a frozen, solid ice cube have motion? Remember to focus on the particles. Atoms in solids are held tightly in place by the attraction between the particles. This attraction between the particles gives solids a definite shape and volume. However, the thermal energy in the particles causes them to vibrate in place. Thermal energy is the total energy of a material's particles, including kinetic—vibrations and movement within and between the particles—and potential—resulting from forces that act within or between particles. When the temperature of the substance is lowered, the particles will have less thermal energy and will vibrate more slowly.

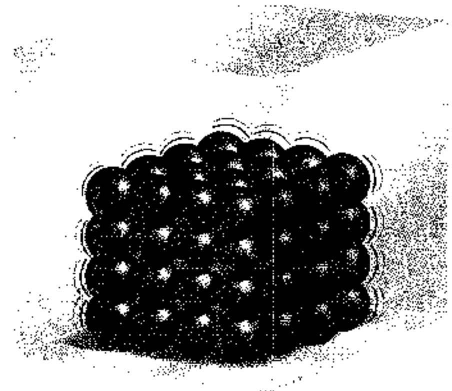


Figure 2 The particles in a solid are packed together tightly and are constantly vibrating in place.

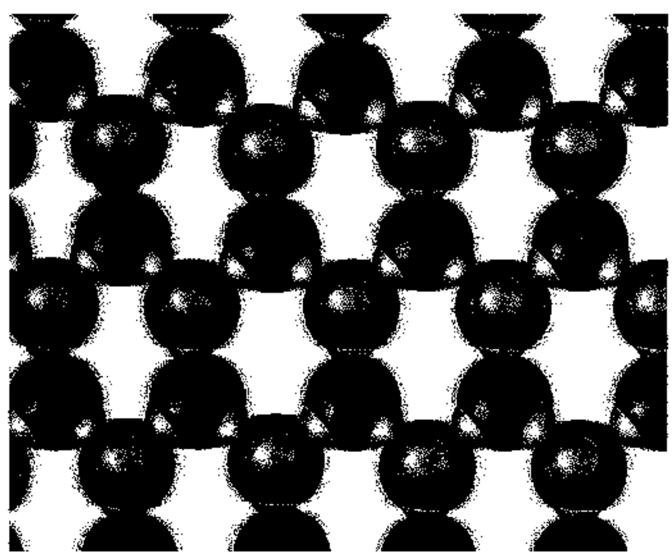
Reading Check *What is thermal energy?*

Average Kinetic Energy Temperature is the term used to explain how hot or cold an object is. In science, temperature means the average kinetic energy of particles in the substance, or how fast the particles are moving. On average, molecules of frozen water at 0°C will move slower than molecules of water at 100°C. Therefore, water molecules at 0°C have lower average kinetic energy than the molecules at 100°C. Molecules will have kinetic energy at all temperatures, including absolute zero. Scientists theorize that at absolute zero, or –273.15°C, particle motion is so slow that no additional thermal energy can be removed from a substance.

Reading Check *How are kinetic energy and temperature related?*

Solid State An ice cube is an example of a solid. The particles of a solid are closely packed together, as shown in **Figure 2.** Most solid materials have a specific type of geometric arrangement in which they form when cooled. The type of geometric arrangement formed by a solid is important. Chemical and physical properties of solids often can be attributed to the type of geometric arrangement that the solid forms. **Figure 3** shows the geometric arrangement of solid water. Notice that the hydrogen and oxygen atoms are alternately spaced in the arrangement.

Figure 3 The particles in solid water align themselves in an ordered geometric pattern. Even though a solid ice cube doesn't look like it is moving, its molecules are vibrating in place.



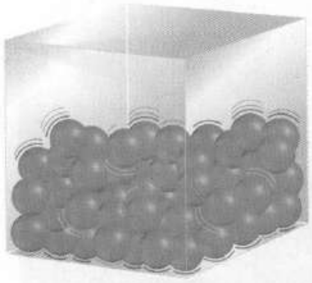


Figure 4 The particles in a liquid are moving more freely than the particles in a solid. They have enough kinetic energy to slip out of the ordered arrangement of a solid.

Liquid State What happens to a solid when thermal energy or heat is added to it? Think about the ice cube in the hot soup. The particles in the hot soup are moving fast and colliding with the vibrating particles in the ice cube. The collisions of the particles transfer energy from the soup to the ice cube. The particles on the surface of the ice cube vibrate faster. These particles collide with and transfer energy to other ice particles. Soon the particles of ice have enough kinetic energy to overcome the attractive forces. The particles of ice gain enough kinetic energy to slip out of their ordered arrangement and the ice melts. This is known as the **melting point,** or the temperature at which a solid begins to liquefy. Energy is required for the particles to slip out of the ordered arrangement. The amount of energy required to change a substance from the solid phase to the liquid phase at its melting point is known as the **heat of fusion.**

Reading Check *What is heat of fusion?*

Liquids Flow Particles in a liquid, shown in **Figure 4,** have more kinetic energy than particles in a solid. This extra kinetic energy allows particles to partially overcome the attractions to other particles. Thus, the particles can slide past each other, allowing liquids to flow and take the shape of their container. However, the particles in a liquid have not completely overcome the attractive forces between them. This causes the particles to cling together, giving liquids a definite volume.

Reading Check *Why do liquids flow?*

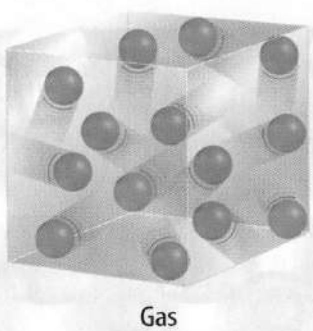


Figure 5 In gases, the particles are far apart and the attractive forces between the particles are overcome. Gases do not have a definite volume or shape.

Gas State Particles in the gas state are shown in **Figure 5.** Gas particles have enough kinetic energy to overcome the attractions between them. Gases do not have a fixed volume or shape. Therefore, they can spread far apart or contract to fill the container that they are in. How does a liquid become a gas? The particles in a liquid are constantly moving. Some particles are moving faster and have more kinetic energy than others. The particles that are moving fast enough can escape the attractive forces of other particles and enter the gas state. This process is called vaporization. Vaporization can occur in two ways—evaporation and boiling. Evaporation is vaporization that occurs at the surface of a liquid and 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. They must be at the liquid's surface and traveling away from the liquid.

Figure 6 Boiling occurs throughout a liquid when the pressure of the vapor in the liquid equals the pressure of the vapor on the surface of the liquid. **Explain** *the difference between boiling and evaporation.*

Boiling Point A second way that a liquid can vaporize is by boiling. Unlike evaporation, boiling occurs throughout a liquid at a specific temperature depending on the pressure on the surface of the liquid. Boiling is shown in **Figure 6.** 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 acting on the surface of the liquid. This external pressure is a force pushing down upon a liquid, keeping particles from escaping. Particles require energy to overcome this force. **Heat of vaporization** is the amount of energy required for the liquid at its boiling point to become a gas.

Reading Check *How does external pressure affect the boiling point of a liquid?*

Gases Fill Their Container What happens to the attractive forces between the particles in a gas? The gas particles are moving so quickly and are so far apart that they have overcome the attractive forces between them. Because the attractive forces between them are overcome, gases do not have a definite shape or a definite volume. The movement of particles and the collisions between them cause gases to diffuse. **Diffusion** is the spreading of particles throughout a given volume until they are uniformly distributed. Diffusion occurs in solids and liquids but occurs most rapidly in gases. For example, if you spray air freshener in one corner of a room, it's not long before you smell the scent all over the room. The particles of gas have moved, collided, and "filled" their container—the room. The particles have diffused. Gases will fill the container that they are in even if the container is a room. The particles continue to move and collide in a random motion within their container.

ScienceOnline

Topic: States of Matter
Visit gpscience.com for Web links to information about states of matter.

Activity Create a slide presentation about the states of matter using the computer and presentation software.

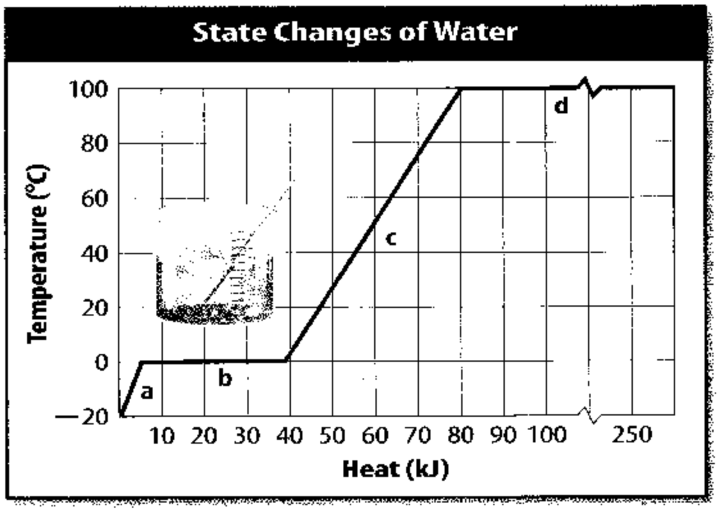


Figure 7 This graph shows the heating curve of water. At **a** and **c** the water is increasing in kinetic energy. At **b** and **d** the added energy is used to overcome the bonds between the particles.

Heating Curve of a Liquid A graph of water being heated from –20°C to 100°C is shown in **Figure 7.** This type of graph is called a heating curve because it shows the temperature change of water as thermal energy, or heat, is added. Notice the two areas on the graph where the temperature does not change. At 0°C, ice is melting. All of the energy put into the ice at this temperature is used to overcome the attractive forces between the particles in the solid. The temperature remains constant during melting. After the attractive forces are overcome, particles move more freely and their average kinetic energy, or temperature, increases. At 100°C, water is boiling or vaporizing and the temperature remains constant again. All of the energy that is put into the water goes to overcoming the remaining attractive forces between the water particles. When all of the attractive forces in the water are overcome, the energy goes to increasing the temperature of the particles.

Reading Check ***What is occurring at the two temperatures on the heat curve where the graph is a flat line?***

INTEGRATE Astronomy

Plasma State So far, you've learned about the three familiar states of matter—solids, liquids, and gases. But none of these is the most common state of matter in the universe. Scientists estimate that much of the matter in the universe is plasma. **Plasma** is matter consisting of positively and negatively charged particles. Although this matter contains positive and negative particles, its overall charge is neutral because equal numbers of both charges are present. Recall that on average, particles of matter move faster as the matter is heated to higher temperatures. The faster the particles move the greater the force is with which they collide. The forces produced from high-energy collisions are so great that electrons from the atom are stripped off. This state of matter is called plasma. All of the observed stars including the Sun, shown in **Figure 8,** consist of plasma. Plasma also is found in lightning bolts, neon and fluorescent tubes, and auroras.

Figure 8 Stars including the Sun contain matter that is in the plasma phase. Plasma exists where the temperature is extremely high. **Describe** *the plasma phase.*

Reading Check ***What is plasma?***