3 Thermal Energy and States of Matter

Reading Preview

Key Concepts

- What are three states of matter?
- What causes matter to change state?
- What happens to a substance as its thermal energy increases?

Key Terms

- state
- change of state
- melting
- freezing
- evaporation
- boiling
- condensation
- thermal expansion

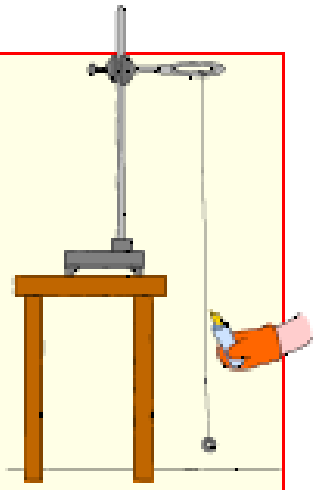
Target Reading Skill

Building Vocabulary Using a word in a sentence helps you think about how best to explain the word. After you read the section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a meaningful sentence for each Key Term.

Lab zone

Discover Activity

What Happens to Heated Metal?

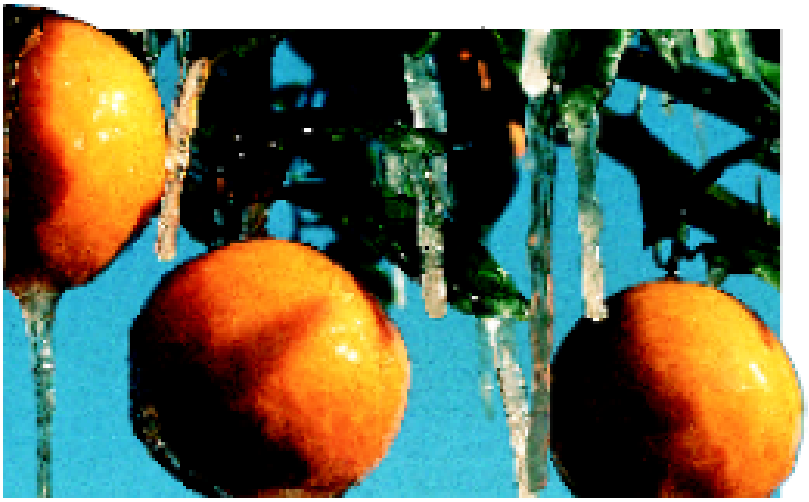


1. Wrap one end of a one-meter-long metal wire around a clamp on a ring stand.
2. Tie the other end through several washers. Adjust the clamp so that the washers swing freely, but nearly touch the floor.
3. Light a candle. Hold the candle with an oven mitt, and heat the wire. **CAUTION:** *Be careful near the flame, and avoid dripping hot wax on yourself.* Predict how heat from the candle will affect the wire.
4. With your hand in the oven mitt, swing the wire. Observe any changes in the motion of the washers.
5. Blow out the candle and allow the wire to cool. After several minutes, swing the wire again and observe its motion.

Think It Over

Inferring Based on your observations, what can you conclude about the effect of heating a solid?

Throughout the day, the temperature at an orange grove drops steadily. The anxious farmer awaits the updated weather forecast. The news is not good. The temperature is expected to fall even further during the night. Low temperatures could wipe out the entire crop. He considers picking the crop early, but the oranges are not yet ripe.



Oranges at 0°C sprayed with water

Instead, the farmer tells his workers to haul in hoses and spray the orange trees with water. As the temperature drops, the water begins to freeze. The ice keeps the oranges warm!

How can ice possibly keep anything warm? The answer has to do with how thermal energy is transferred as water becomes ice.

States of Matter

What happens when you hold an ice cube in your hand? It melts. The solid and the liquid are both the same material—water. Water can exist in three different **states,** or forms. **In fact, most matter on Earth can exist in three states—solid, liquid, and gas.** Although the chemical composition of matter remains the same, the arrangement of the particles that make up the matter differs from one state to another.

Solids The particles that make up a solid are packed together in relatively fixed positions. Particles of a solid cannot move out of their positions. They can only vibrate back and forth. This is why solids retain a fixed shape and volume. Because the shape and volume of the plastic helmets shown in Figure 10 do not change, the plastic is a solid.

Liquids The particles that make up a liquid are close together, but they are not held together as tightly as those of a solid. Because liquid particles can move around, liquids don't have a definite shape. But liquids do have a definite volume. In Figure 10, notice how the river water changes shape.

Gases In gases, the particles are moving so fast that they don't even stay close together. Gases expand to fill all the space available. They don't have a fixed shape or volume. Because air is a gas, it can expand to fill the raft in Figure 10 and also take the raft's shape.

FIGURE 10
Three States of Matter
The plastic helmets, the water in the river, and the air that fills the raft are examples of three states of matter—solid, liquid, and gas. Classifying *Which state of matter is represented by the plastic oars?*

Figure 11
Melted Chocolate
Though normally a solid at room temperature, this chocolate has absorbed enough thermal energy to become a liquid.

Changes of State

The physical change from one state of matter to another is called a **change of state.** The state of matter depends on the amount of thermal energy it has. The more thermal energy matter has, the faster its particles move. Since a gas has more thermal energy than a liquid, the particles of a gas move faster than the particles of the same matter in the liquid state.

Matter can change from one state to another when thermal energy is absorbed or released. The graph in Figure 12 shows that as thermal energy increases, matter changes from a solid to a liquid and then to a gas. A gas changes to a liquid and then to a solid as thermal energy is removed from it.

The flat regions of the graph show conditions under which thermal energy is changing but temperature remains the same. Under these conditions, matter is changing from one state to another. During a change of state, the addition or loss of thermal energy changes the arrangement of the particles. However, the average kinetic energy of those particles does not change. Since temperature is a measure of average kinetic energy, temperature does not change as the state of matter changes.

Solid–Liquid Changes of State The change of state from a solid to a liquid is called **melting.** Melting occurs when a solid absorbs thermal energy. As the thermal energy of the solid increases, the structure of its particles breaks down. The particles become freer to move around. The temperature at which a solid changes to a liquid is called the melting point.

The change of state from a liquid to a solid is called **freezing.** Freezing occurs when matter releases thermal energy. The temperature at which matter changes from a liquid to a solid is called its freezing point.

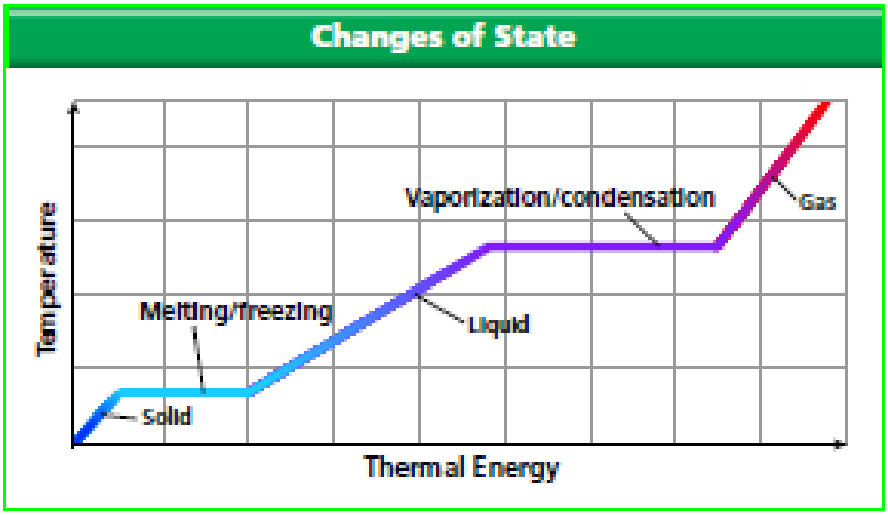


Figure 12
Thermal energy and temperature change as matter changes from one state to another.

For a given type of matter, the freezing point and melting point are the same. The difference between the two is whether the matter is gaining or releasing thermal energy. The farmer had his workers spray the orange trees with water because the freezing water releases thermal energy into the oranges.

Liquid–Gas Changes of State The process by which matter changes from the liquid to the gas state is called vaporization. During this process, particles in a liquid absorb thermal energy and move faster. Eventually they move fast enough to escape the liquid as gas particles. If vaporization takes place at the surface of a liquid, it is called **evaporation.** At higher temperatures, vaporization can occur below the surface of a liquid as well. This process is called **boiling.** When a liquid boils, gas bubbles that form within the liquid rise to the surface. The temperature at which a liquid boils is called its boiling point.

When a gas loses a certain amount of thermal energy, it will change into a liquid. A change from the gas state to the liquid state is called **condensation.** You have probably seen beads of water appear on the outside of a cold drinking glass. This occurs because water vapor that is present in the air loses thermal energy when it comes in contact with the cold glass.

Reading Checkpoint **What change of state occurs in evaporation?**

Lab zone Skills **Activity**

Observing

Put a teakettle on a stove or a lab burner and bring the water to a boil. Look carefully at the white vapor coming out of the spout. **CAUTION:** *Steam and boiling water can cause serious burns.* In what state of matter is the white vapor that you see? What is present, but not visible, in the small space between the white vapor and the spout?

FIGURE 13
Condensation
Under certain weather conditions, water vapor in the air can condense into fog. Applying Concepts *As it condenses, does water absorb or release thermal energy?*

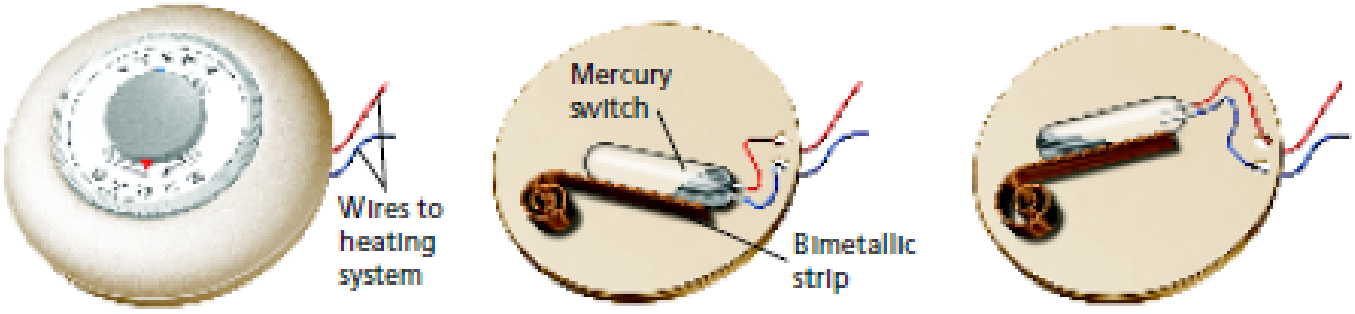


FIGURE 14
Thermostat
A bimetallic strip controls many thermostats. When it cools, the strip curls up and lowers the switch, allowing mercury to flow over the wires. When the strip warms up, it uncurls and raises the switch.

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Thermal Expansion

Have you ever loosened a tight jar lid by holding it under a stream of hot water? This works because the metal lid expands a little. Do you know why? **As the thermal energy of matter increases, its particles spread out and the substance expands.** With a few exceptions, this is true for all matter, even when the matter is not changing state. The expanding of matter when it is heated is known as **thermal expansion.**

When matter is cooled, thermal energy is released. The motion of the particles slows down and the particles move closer together. In nearly all cases, as matter is cooled, it contracts, or decreases in volume.

Heat-regulating devices called thermostats use thermal expansion to work. Many thermostats contain bimetallic strips, which are strips of two different metals joined together. Different metals expand at different rates. When the bimetallic strip is heated, one side expands more than the other. This causes the strip to uncurl. The movement of the strip operates a switch, which can turn a heating system on or off.

Section 3 Assessment

Target Reading Skill Building Vocabulary Use your sentences to help answer the questions.

Reviewing Key Concepts

1. a. Identifying Name three states of matter.
   b. Comparing and Contrasting How are the three states of matter different from each other? How are they the same?
2. a. Reviewing What causes a change in state?
   b. Describing Why does the temperature of matter remain the same while the matter changes state?
   c. Relating Cause and Effect What causes a solid to melt?
3. a. Defining How can a liquid expand without changing state?
   b. Applying Concepts Why should you poke holes in a potato before baking it?
   c. Interpreting Diagrams How does a thermostat make use of thermal expansion?

Lab zone **At-Home Activity**

Frosty Balloons Blow up two balloons so that they are the same size. Have a family member use a measuring tape to measure the circumference of the balloons. Place one of the balloons in the freezer for 15 to 20 minutes. Then measure both balloons again. Explain how changes in thermal energy cause the change in size.