SECTION 3

Matter and Heat

Have you ever eaten a frozen juice bar outside on a hot summer day? It's pretty hard to finish the entire thing before it starts to drip and make a big mess!

The juice bar melts because the sun radiates energy to the frozen juice bar. The energy absorbed by the juice bar increases the kinetic energy of the molecules in the juice bar, which starts to change to a liquid.

What You Will Learn

- Identify three states of matter.
- Explain how heat affects matter during a change of state.
- Describe how heat affects matter during a chemical change.
- Explain what a *calorimeter* is used for.

Vocabulary

states of matter
change of state

READING STRATEGY

Brainstorming The key idea of this section is the relationship between matter and heat. Brainstorm words and phrases related to matter and heat.

States of Matter

The matter that makes up a frozen juice bar has the same identity whether the juice bar is frozen or has melted. The matter is just in a different form, or state. The **states of matter** are the physical forms in which a substance can exist. Matter consists of particles that can move around at different speeds. The state a substance is in depends on the speed of its particles, the attraction between them, and the pressure around them. Three familiar states of matter are solid, liquid, and gas, shown in **Figure 1.**

Thermal energy is the total energy of all the particles that make up a substance. Suppose that you have equal masses of a substance in its three states, each at a different temperature. The substance will have the most thermal energy as a gas and the least thermal energy as a solid. The reason is that the particles of a gas move around fastest.

Figure 1 Particles of a Solid, a Liquid, and a Gas

Particles of a gas, such as carbon dioxide, move fast enough to overcome nearly all of the attraction between them. The particles move independently of one another.

Particles of a liquid move fast enough to overcome some of the attraction between them. The particles are able to slide past one another.

Particles of a solid, such as ice, do not move fast enough to overcome the strong attraction between them, so they are held tightly together. The particles vibrate in place.

Changes of State

When you melt cheese to make a cheese dip, such as that shown in **Figure 2,** the cheese changes from a solid to a thick, gooey liquid. A **change of state** is a change of a substance from one state of matter to another. A change of state is a *physical change* that affects one or more physical properties of a substance without changing the identity of the substance. Changes of state include *freezing* (liquid to solid), *melting* (solid to liquid), *boiling* (liquid to gas), and *condensing* (gas to liquid).

Figure 2 *When you melt cheese, you change the state of the cheese but not its identity.*

Energy and Changes of State

Suppose that you put an ice cube in a pan and set the pan on a stove burner. Soon, the ice will turn to water and then to steam. If you made a graph of the temperature of the ice versus the energy involved during this process, it would look something like the graph in **Figure 3.**

As the ice is heated, its temperature increases from –25°C to 0°C. As the ice melts, its temperature remains at 0°C even as more energy is added. This added energy changes the arrangement of the molecules in the ice. The temperature of the ice remains the same until all of the ice has become liquid water. At that point, the water's temperature starts to increase from 0°C to 100°C. At 100°C, the water begins to change to steam. Even as more energy is added, the water's temperature stays at 100°C as long as there is liquid water present. When all of the water has become steam, the temperature again increases.

Reading Check **What happens to the temperature of a substance while it is undergoing a change of state?** (*See the Appendix for answers to Reading Checks.*)

states of matter the physical forms of matter, which include solid, liquid, and gas

change of state the change of a substance from one physical state to another

Figure 3 **Changes of State for Water**

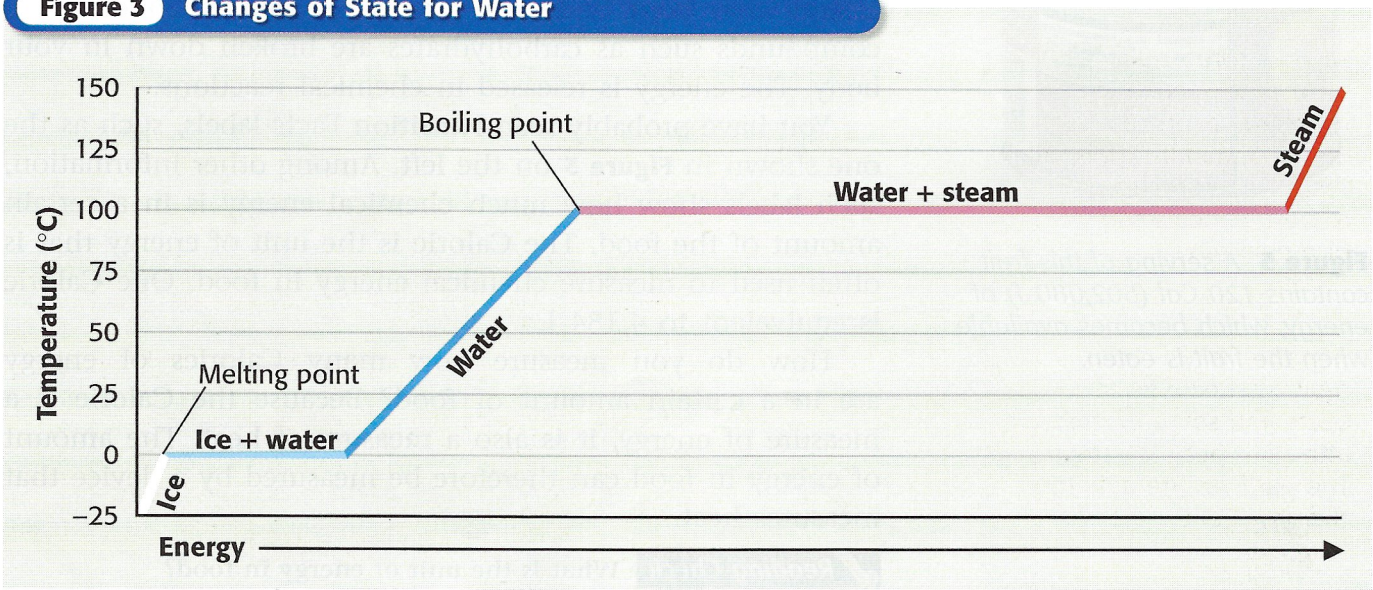

Figure 4 *In a natural-gas fireplace, the methane in natural gas and the oxygen in air change into carbon dioxide and water. As a result of the change, energy is given off, making a room feel warmer.*

Heat and Chemical Changes

Heat is involved not only in changes of state, which are physical changes, but also in *chemical changes*—changes that occur when one or more substances are changed into entirely new substances that have different properties. During a chemical change, new substances are formed.

For a new substance to form, old bonds between particles must be broken, and new bonds must be formed. The breaking and creating of bonds between particles involves energy. Sometimes, a chemical change requires that thermal energy be put into substances for a reaction to occur. Other times, a chemical change, such as the one shown in **Figure 4,** will result in a release of energy.

Figure 5 *A serving of this fruit contains 120 Cal (502,080 J) of energy, which becomes available when the fruit is eaten.*

Food and Chemical Energy

Food contains substances from which your body gets energy. Energy that your body can use is released when chemical compounds such as carbohydrates are broken down in your body. The energy is released in chemical reactions.

You have probably seen Nutrition Facts labels, such as the one shown in **Figure 5** on the left. Among other information, such labels show how much chemical energy is in a certain amount of the food. The Calorie is the unit of energy that is often used to measure chemical energy in food. One Calorie is equivalent to 4,184 J.

How do you measure how many Calories of energy are in a certain amount of food? Because the Calorie is a measure of energy, it is also a measure of heat. The amount of energy in food can therefore be measured by a device that measures heat.

Reading Check **What is the unit of energy in food?**

Calorimeters

A *calorimeter* (KAL uh RIM uht uhr) is a device that measures heat. When one object transfers thermal energy to another object, the energy lost by one object is gained by the other object. This is the key to how a calorimeter works. Inside a calorimeter, shown in **Figure 6,** thermal energy is transferred from a known mass of a test substance to a known mass of another substance, usually water.

The energy of food, in Calories, is found in this way. In a special kind of calorimeter called a *bomb calorimeter,* a food sample is burned. The energy that is released is transferred to the water. By measuring the temperature change of the water and using water's specific heat, you can determine the exact amount of energy transferred by the food sample to the water. This amount of energy (heat) equals the energy content of the food.

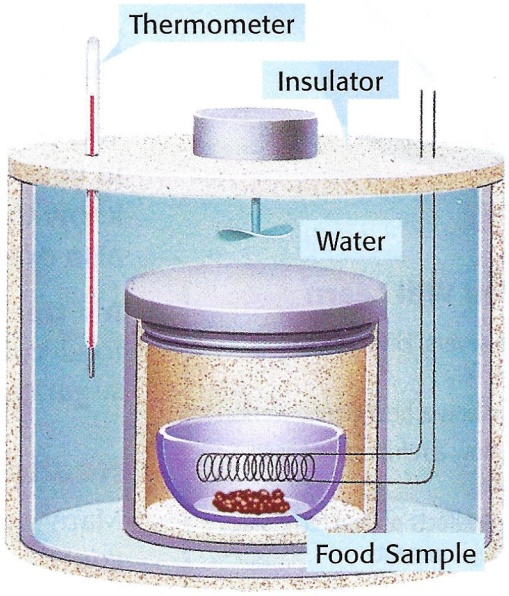

Figure 6 *A bomb calorimeter can measure energy content in food by measuring how much heat is given off by a food sample when it is burned.*

SECTION Review

Summary

- States of matter include solid, liquid, and gas.
- Thermal energy transferred during a change of state does not change a substance's temperature. Rather, it causes a substance's particles to be rearranged.
- Chemical changes can cause thermal energy to be released or absorbed.
- A calorimeter can measure energy changes by measuring heat.

Using Key Terms

1. Use each of the following terms in a separate sentence: *states of matter* and *change of state.*

Understanding Key Ideas

2. What determines a substance's state?
   - **a.** the size of its particles
   - **b.** the amount of the substance
   - **c.** the speed of its particles and the attraction between them
   - **d.** the chemical energy that the substance has
3. During a change of state, why doesn't the temperature of the substance change?

Math Skills

4. When burned in a calorimeter, a sample of popcorn released 627,600 J. How much energy, in Calories, did the popcorn have?

Critical Thinking

5. **Applying Concepts** Many cold packs used for sports injuries are activated by bending the package, causing the substances inside to chemically react. How is heat involved in this process?
6. **Analyzing Processes** When water evaporates (changes from a liquid to a gas), the air near the water's surface becomes cooler. Explain why.