9.1 Heat Energy

Objectives

- **Relate** heat energy to moving molecules.
- **Distinguish** between the Celsius and Kelvin temperature scales.
- **Compare** temperature, internal energy, and heat energy.
- **Define operationally** a temperature change.

ACTIVITY

Observing

Cold Hands, Warm Face

1. Press the palms of you hands to your face. Which is warmer, your hands or your face?

2. Now rapidly rub your hands together for 30 secor and then put them against your face again. Has the temperature of your hands changed? Explain.

SKILLS WARMU

You meet your friends for a game of basketball on a cool autumn day. While playing, you feel hot and take off your sweatshirt. During a break, you go for a drink. The ice in your soft drink is partially melted. You take a drink. It is still cold. If this were summer, the heat would have made the drink warm by now. You feel chilly and put your sweatshirt on again. You experience heat all the time, and you use words such as *hot*, *cold*, and *heat* often. In science, heat has a different and very specific meaning.

Molecules in Motion

Recall that all matter is made of molecules that are in constant motion. The gas molecules that make up air move freely all around you. Molecules of water move about in a container. The molecules in your chair constantly move back and forth, or vibrate. Matter that moves has kinetic energy. The measurement of the *average* kinetic energy of the molecules in a substance is called **temperature.**

If two objects with different temperatures come into contact, energy flows from the object with the higher temperature to the one with the lower temperature. Energy that is transferred from one substance to another is called **heat energy**. Heat is energy that flows between objects that have different temperatures. The official SI unit of heat is the joule.

When heat energy transfers to a substance, it adds to the **internal energy** of the substance. Internal energy is the total amount of energy a substance contains. Most of the internal energy of a substance is kinetic energy.

Figure 9.1 ▲
What happens to the tempe ture of the water that cools runner?

Measuring Temperature

You probably think about how hot or cold something is in terms of its temperature. When the temperature of a substance is high, its molecules are moving rapidly. Imagine that you fill a bucket and a teacup with water from a bathtub. The temperature of the water is the same in each container, because temperature is a measure of the *average* movement of the molecules in a substance. Volume doesn't affect temperature.

You measure temperature with a thermometer. Most thermometers are thin glass tubes connected to a reservoir of liquid mercury or colored alcohol. A numbered scale is marked on the outside of the tube. As a thermometer heats up, the molecules in its liquid begin to move faster and farther apart. The liquid expands and rises in the tube. The scale indicates the temperature reading. In SI, two different scales are used for temperature readings; the Celsius scale and the Kelvin scale.

storical Notebook

derstanding Heat

hundred years ago, most scientists thought ıeat was an invisible, weightless substance. called the substance caloric. People ved the hotter an object was, the more caloric ıtained. It was thought that a piece of matter ıined a specific amount of heat.

n 1798, the American-born scientist Benjamin ıpson, better known as Count Rumford, ques- d the caloric theory of heat. Count Rumford rved the hole-drilling process in cannon ls in Munich, Germany. He saw that heat was ıced as long as the cutting tool moved gh the cannon.

Vater was used to cool the cutting tool and annon as the hole was drilled. The water got g hot! As you can see in the picture above, is still sometimes used to cool cutting tools. ord noticed that no heat or matter was d during the drilling. Since matter cannot be

created out of nothing, he reasoned that heat could not be a material substance. Rumford hypothesized that the energy used to turn the drill was being transformed into heat. He concluded that heat, therefore, must be a form of energy. Rumford's theory was confirmed forty years later by the British scientist James Prescott Joule.

Celsius Temperature Scale In the metric system, the Celsius scale is commonly used to measure temperature. The Celsius scale was developed by Anders Celsius, a Swedish astronomer. Celsius temperature is also referred to as centigrade temperature.

Look at the Celsius thermometer in Figure 9.2. Find normal body temperature. Was it lower or higher than you expected? Normally, your body temperature changes several tenths of a degree during the day.

Kelvin Temperature Scale Another SI temperature scale is called the **Kelvin** scale. The Kelvin scale, also called the absolute scale, is named for its originator, Lord Kelvin. Kelvin thermometers are used primarily in the physical sciences.

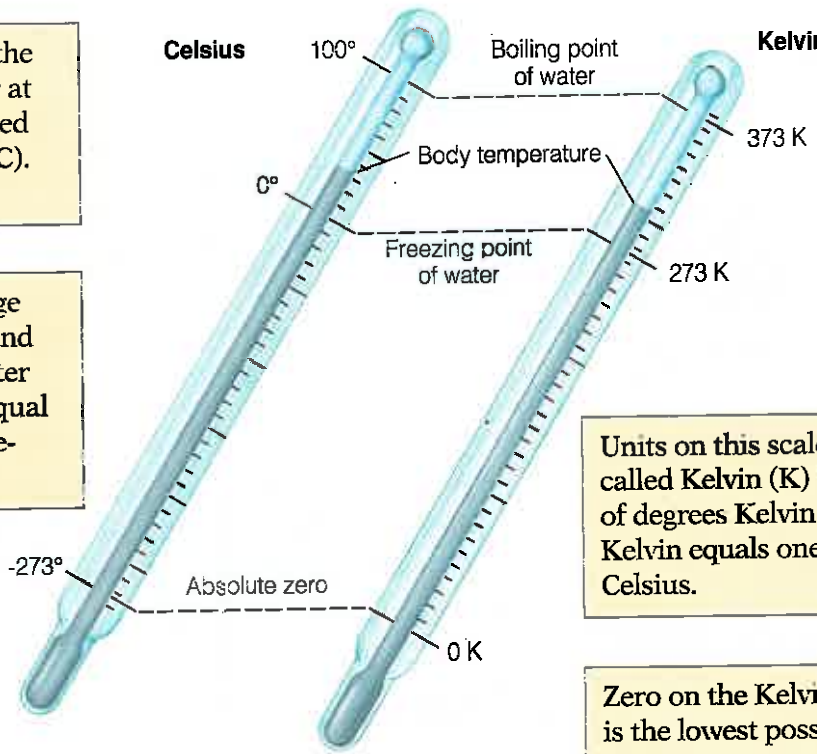
The Kelvin scale is based on the amount of energy in a substance. It is used to measure the temperature of supercold substances. The Kelvin scal identifies the temperature where mol cules in a substance are so cold they don't move. They have no kinetic ener This temperature is called **absolute zer**

Compare the Celsius and Kelvin thermometers in Figure 9.2. Notice that 0 K equals –273°C. You can conver the Celsius temperature of an object to the Kelvin temperature by adding 27 Since the boiling point of water is 100 the boiling point of water on the Kelv scale is 100 plus 273, or 373 K. Wha is the freezing point of water on the Kelvin scale?

The Kelvin temperature scale is use in science because it relates directly energy. For example, 1 cm^3 of a substance at 200 K has twice the kinetic energy of 1 cm^3 of the same substanc at 100 K.

On the Celsius scale, the boiling point of water at sea level is one hundred degrees Celsius (100°C). Water freezes at 0°C.

The temperature range between the boiling and freezing points of water is divided into 100 equal units. Each unit represents 1°C.



Units on this scale are called Kelvin (K) instea of degrees Kelvin. One Kelvin equals one degr Celsius.

Zero on the Kelvin sca is the lowest possible t perature matter can ha

Figure 9.2 ▲
SI Temperature Scales

Science and Technology *A Cool Engine*

What liquid does a car need to run properly? Most people answer "gasoline." However, another liquid—water—is just as vital to a car's performance.

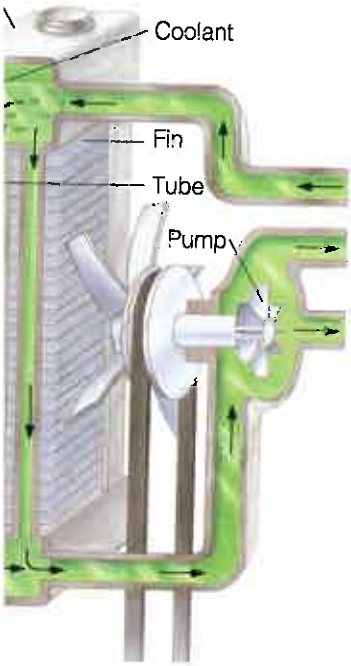
Large amounts of heat are given off when gasoline is burned in the cylinders of an engine. Also, an engine contains many moving parts that rub against each other. Even though oil lubricates engine parts, enough friction still exists to produce heat. Because excessive heat can seriously damage the engine, cars have a cooling system that controls engine temperature.

A car's cooling system consists of a radiator, hoses, and channels that are filled with a mixture of water and antifreeze, called a coolant. The channels carry the coolant through the engine block. The engine block contains the cylinders and other moving parts that get hot when the engine is running.

A pump circulates the coolant through the engine. Heat is transferred to the coolant as it flows over hot engine parts. The heated coolant then moves away from the engine and through the hoses to the car's radiator.

Look at the radiator in Figure 9.3. Follow the path of the coolant as it moves through the radiator. Inside the radiator, the heated coolant passes through metal tubes. Heat transfers from the coolant to the metal tubes by conduction. Metal fins surrounding the tubes absorb the heat and transfer it into air circulating around the fins. In this way, the coolant mixture loses the heat it receives from the engine. The coolant is no longer as hot and is pumped back to the engine where the cycle starts over again!

idiator



e 9.3 ▲
iator is part of a car's
ıg system. What happens
a car's radiator is broken?

Check and Explain

1. How are heat and moving molecules related?
2. Negative temperature readings are common on the Celsius scale. Explain why you don't get a negative reading on the Kelvin scale.
3. **Compare** How do the temperature, internal energy, and heat energy in a cup of hot tea change overnight?
4. **Define Operationally** Suppose you put some hot water in the refrigerator for two hours. Explain what happens to the molecules of water.