10

Heat and Heat Technology

The Big Idea Heat is energy that moves from an object at a higher temperature to an object at a lower temperature.

SECTION

1 Temperature 274

2 What Is Heat? 280

3 Matter and Heat 288

4 Heat Technology 292

About the PHOTO

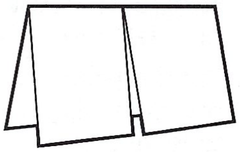
This ice climber is using a lot of special equipment. This equipment includes a rope, a safety helmet, an ice pick, and warm clothing. The climber's clothing, which includes insulating layers inside a protective outer layer, keeps his body heat from escaping into the cold air. If he weren't wearing enough protective clothing, he would be feeling very cold, because thermal energy always moves into areas of lower temperature.

PRE-READING ACTIVITY

FOLDNOTES

Two-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Two-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the two-panel flip chart with "Heat" and "Temperature." As you read the chapter, write information you learn about each category under the appropriate flap.



SECTION 1

Temperature

You probably put on a sweater or a jacket when it's cold. Likewise, you probably wear shorts in the summer when it gets hot. But how hot is hot, and how cold is cold?

What You Will Learn

- Describe how temperature relates to kinetic energy.
- Compare temperatures on different temperature scales.
- Give examples of thermal expansion.

Vocabulary

temperature
thermal expansion
absolute zero

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Think about the knobs on a water faucet: they are labeled "H" for hot and "C" for cold. But does only hot water come out when the hot-water knob is on? You may have noticed that when you first turn on the hot water, the water is warm or even cool. Is the label on the knob wrong? The terms *hot* and *cold* are not scientific terms. If you really want to specify how hot or cold something is, you must use temperature.

What Is Temperature?

You probably think of temperature as a measure of how hot or cold something is. But using the terms *hot* and *cold* can be confusing. Imagine that you are outside on a hot day. You step onto a shady porch where a fan is blowing. You think it feels cool there. Then, your friend comes out onto the porch from an air-conditioned house. She thinks it feels warm! Using the word *temperature* instead of words such as *cool* or *warm* avoids confusion. Scientifically, **temperature** is a measure of the average kinetic energy of the particles in an object.

temperature a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object

Temperature and Kinetic Energy

All matter is made of atoms or molecules that are always moving, even if it doesn't look like they are. Because the particles are in motion, they have kinetic energy. The faster the particles are moving, the more kinetic energy they have. Look at **Figure 1.** The more kinetic energy the particles of an object have, the higher the temperature of the object is.

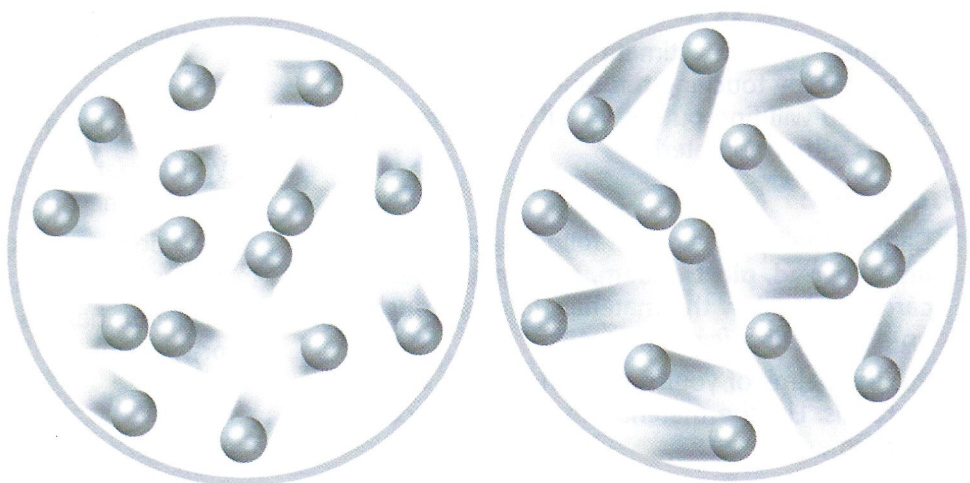


Figure 1 *The gas particles on the right have a higher average kinetic energy than those on the left. So, the gas on the right is at a higher temperature.*

Quick Lab

Hot or Cold?

1. Put both your hands into a **bucket of warm water,** and note how the water feels.
2. Now, put one hand into a **bucket of cold water** and the other into a **bucket of hot water.**
3. After a minute, take your hands out of the hot and cold water and put them back in the warm water. Note how the water feels to each hand.
4. Can you rely on your hands to determine temperature? Explain your observations.

Internet Activity

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5HOTW.**

Average Kinetic Energy of Particles

Particles of matter are always moving. But they move in different directions and at different speeds. The motion of particles is random. Because particles are moving at different speeds, individual particles have different amounts of kinetic energy. But the *average* kinetic energy of all the particles in an object can be measured. When you measure an object's temperature, you measure the average kinetic energy of all the particles in the object.

The temperature of a substance depends on the average kinetic energy of all its particles. Its temperature does not depend on how much of it you have. Look at **Figure 2.** A pot of tea and a cup of tea each have a different amount of tea. But their atoms have the same average kinetic energy. So, the pot of tea and the cup of tea are at the same temperature.

✓ Reading Check **How is temperature related to kinetic energy?** (*See the Appendix for answers to Reading Checks.*)

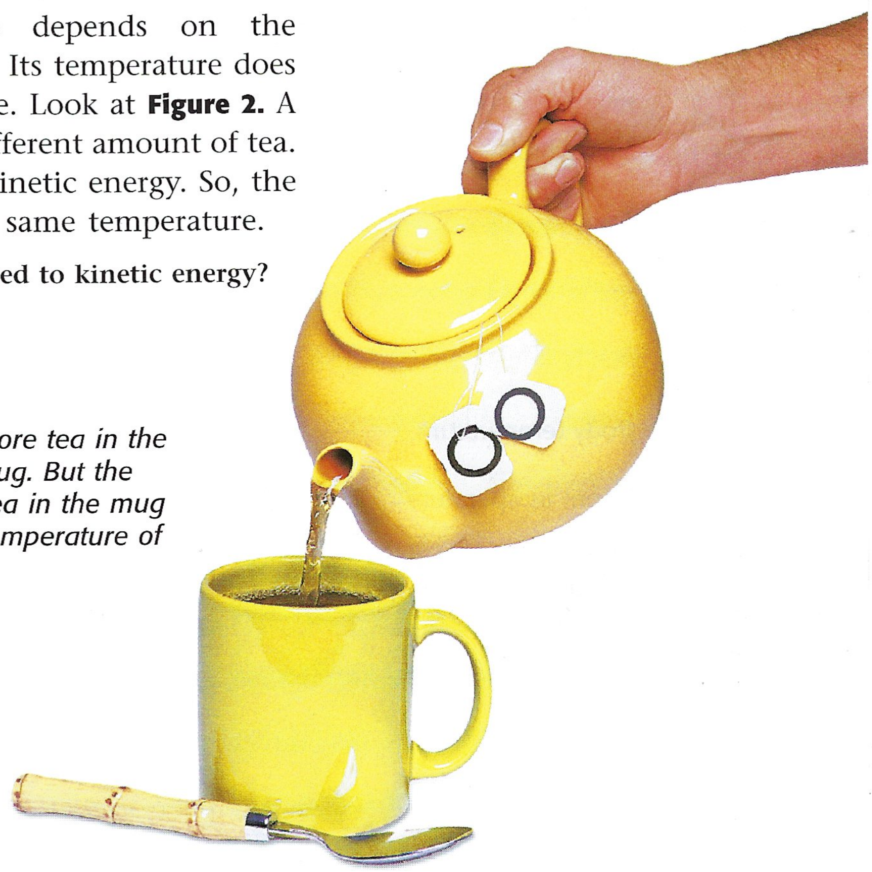


Figure 2 *There is more tea in the teapot than in the mug. But the temperature of the tea in the mug is the same as the temperature of the tea in the teapot.*

Measuring Temperature

How would you measure the temperature of a steaming cup of hot chocolate? Would you take a sip of it or stick your finger in it? You probably would not. You would use a thermometer.

Using a Thermometer

Many thermometers are thin glass tubes filled with a liquid. Mercury and alcohol are often used in thermometers because they remain in liquid form over a large temperature range.

Thermometers can measure temperature because of a property called thermal expansion. **Thermal expansion** is the increase in volume of a substance because of an increase in temperature. As a substance's temperature increases, its particles move faster and spread out. So, there is more space between them, and the substance expands. Mercury and alcohol expand by constant amounts for a given change in temperature.

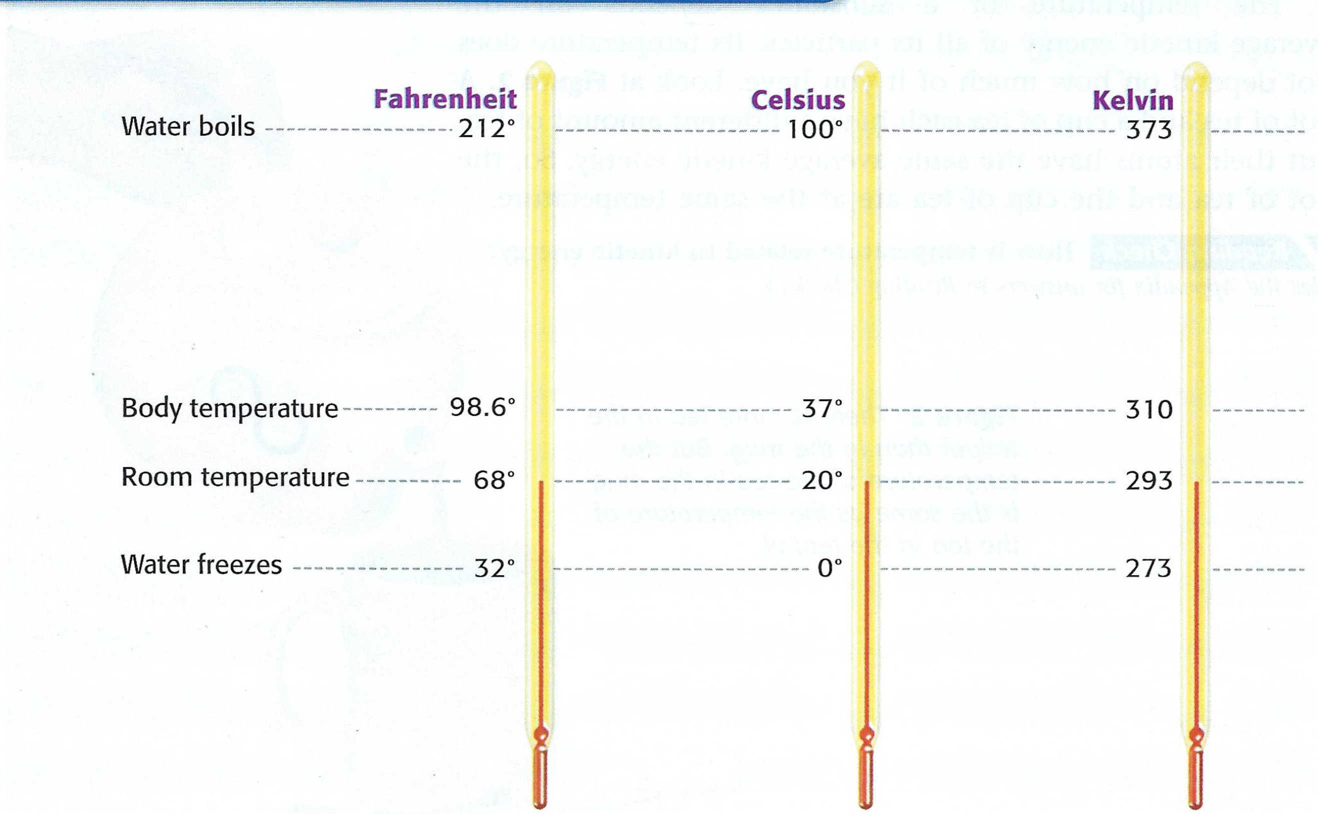
thermal expansion an increase in the size of a substance in response to an increase in the temperature of the substance

absolute zero the temperature at which molecular energy is at a minimum (0 K on the Kelvin scale or −273.16°C on the Celsius scale)

Look at the thermometers in **Figure 3.** They are all at the same temperature. So, the alcohol in each thermometer has expanded the same amount. But the number for each thermometer is different because a different temperature scale is marked on each one.

Reading Check **What property makes thermometers work?**

Figure 3 Three Temperature Scales



Temperature Scales

Look at **Figure 4.** When a weather report is given, you will probably hear the temperature given in degrees Fahrenheit (°F). Scientists, however, often use the Celsius scale. In the Celsius scale, the temperature range between the freezing point and boiling point of water is divided into 100 equal parts, called degrees Celsius (°C). A third scale, the Kelvin (or absolute) scale, is the official SI temperature scale. The Kelvin scale is divided into units called kelvins (K)—not degrees kelvin.

The lowest temperature on the Kelvin scale is 0 K, which is called **absolute zero.** Absolute zero (about –459°F) is the temperature at which all molecular motion stops. It is not possible to actually reach absolute zero, although temperatures very close to 0 K have been reached in laboratories.

Temperature Conversion

As shown by the thermometers on the previous page, a given temperature is represented by different numbers on the three temperature scales. For example, the freezing point of water is 32°F, 0°C, or 273 K.

The temperature 0°C is actually much higher than 0 K. But a *change* of one kelvin is equal to a change of one Celsius degree. The temperature 0°C is higher than 0°F, but a change of one Fahrenheit degree is *not* equal to a change of one Celsius degree. You can convert from one scale to another using the equations shown in **Table 1** below.

Table 1 **Converting Between Temperature Units**

To convert	Use the equation	Example
Celsius to Fahrenheit °C ⟶ °F	$°F = \left(\frac{9}{5} \times °C\right) + 32$	Convert 45°C to degrees Fahrenheit. $°F = \left(\frac{9}{5} \times 45°C\right) + 32 = 113°F$
Fahrenheit to Celsius °F ⟶ °C	$°C = \frac{5}{9} \times (°F - 32)$	Convert 68°F to degrees Celsius. $°C = \frac{5}{9} \times (68°F - 32) = 20°C$
Celsius to Kelvin °C ⟶ K	$K = °C + 273$	Convert 45°C to Kelvins. $K = 45°C + 273 = 318\ K$
Kelvin to Celsius K ⟶ °C	$°C = K - 273$	Convert 32 K to degrees Celsius. $°C = 32\ K - 273 = -241°C$

MATH PRACTICE

Converting Temperatures

Use the equations in **Table 1** to answer the following questions:

1. What temperature on the Celsius scale is equivalent to 373 K?
2. Absolute zero is 0 K. What is the equivalent temperature on the Celsius scale? on the Fahrenheit scale?
3. Which temperature is colder, 0°F or 200 K?

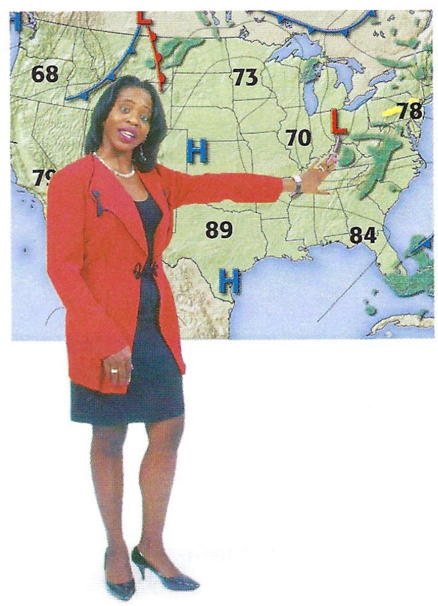


Figure 4 *Weather reports that you see on the news usually give temperatures in degrees Fahrenheit (°F).*

More About Thermal Expansion

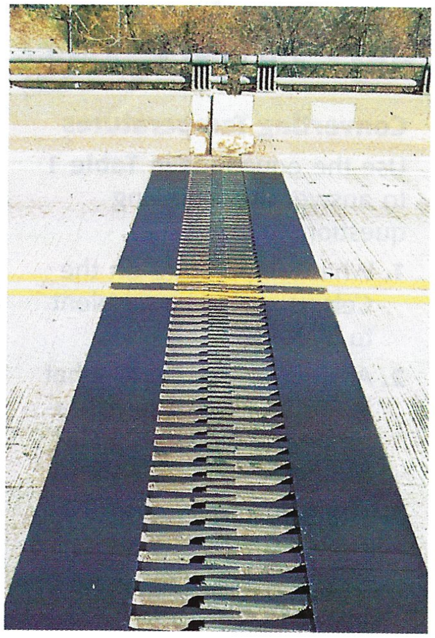


Figure 5 *This gap in the bridge allows the concrete to expand and contract without breaking.*

You have learned about how thermal expansion works in the liquids that fill thermometers. Thermal expansion has many other applications. Below, you will read about a case in which thermal expansion can be dangerous, one in which it can be useful, and one in which it can carry you into the air!

Expansion Joints on Highways

Have you ever gone across a highway bridge in a car? You probably heard and felt a "thuh-thunk" every couple of seconds as you went over the bridge. That sound is made when the car goes over small gaps called *expansion joints,* shown in **Figure 5.**

If the weather is very hot, the bridge can heat up enough to expand. As it expands, there is a danger of the bridge breaking. Expansion joints keep segments of the bridge apart so that they have room to expand without the bridge breaking.

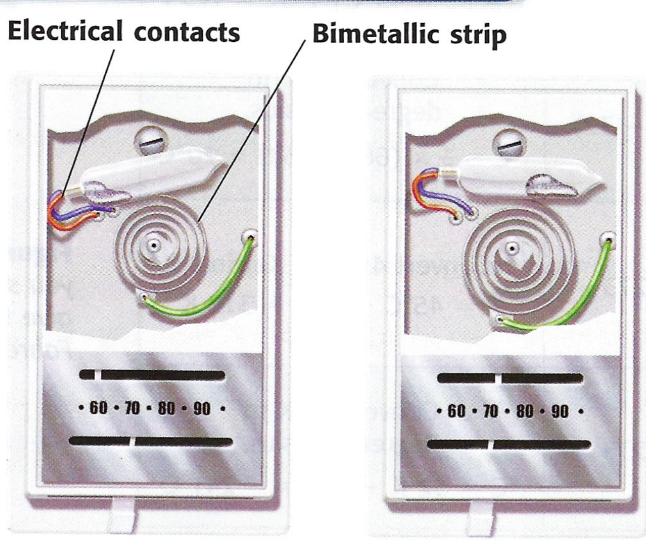
✓ *Reading Check* **What is the purpose of expansion joints in a bridge?**

Bimetallic Strips in Thermostats

Thermal expansion also occurs in a thermostat, the device that controls the heater in your home. Some thermostats have a bimetallic strip inside. A *bimetallic strip* is made of two different metals stacked in a thin strip. Because different materials expand at different rates, one of the metals expands more than the other when the strip gets hot. This makes the strip coil and uncoil in response to changes in temperature. This coiling and uncoiling closes and opens an electric circuit that turns the heater on and off in your home, as shown in **Figure 6.**

Figure 6 **How a Thermostat Works**

a As the room temperature drops below the desired level, the bimetallic strip coils more tightly, and the glass tube tilts. A drop of mercury closes an electric circuit that turns the heater on.



b As the room temperature rises above the desired level, the bimetallic strip uncoils slightly, becoming larger. The drop of mercury rolls back in the tube, opening the electric circuit, and the heater turns off.

Thermal Expansion in Hot-Air Balloons

You may have heard the expression "Hot air rises." If you have ever seen hot-air balloons peacefully gliding through the sky, you have seen this principle at work. But why does hot air rise?

When a gas is heated, as shown in **Figure 7,** its particles have more kinetic energy. They move around more quickly, so there is more space between them. The gas is then able to expand if it is not kept at the same volume by its container. When air (which is a mixture of gases) inside a hot-air balloon is heated, the air expands. As it expands, it becomes less dense than the air outside the balloon. So, the balloon goes up, up, and away!

Figure 7 *Thermal expansion helps get these hot-air balloons off the ground.*

SECTION Review

Summary

- Temperature is a measure of the average kinetic energy of the particles of a substance.
- Fahrenheit, Celsius, and Kelvin are three temperature scales.
- Thermal expansion is the increase in volume of a substance due to an increase in temperature.
- Absolute zero (0 K, or −273°C) is the lowest possible temperature.
- A thermostat works because of the thermal expansion of a bimetallic strip.

Using Key Terms

1. In your own words, write a definition for the term *temperature*.

2. Use each of the following terms in a separate sentence: *thermal expansion* and *absolute zero*.

Understanding Key Ideas

3. Which of the following is the coldest temperature possible?

a. 0 K
b. 0°C
c. 0°F
d. −273°F

4. Does temperature depend on the amount of the substance? Explain.

5. Describe the process of thermal expansion.

Math Skills

6. Convert 35°C to degrees Fahrenheit.

7. Convert 34°F to degrees Celsius.

8. Convert 0°C to kelvins.

9. Convert 100 K to degrees Celsius.

Critical Thinking

10. Predicting Consequences Why do you think heating a full pot of soup on the stove could cause the soup to overflow?

11. Analyzing Processes During thermal expansion, what happens to the density of a substance?

12. Forming Hypotheses A glass of cold water whose particles had a low average kinetic energy was placed on a table. The average kinetic energy in the cold water increased, while the average kinetic energy of the part of the table under the glass decreased. What do you think happened?

SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: What Is Temperature?
SciLinks code: HSM1664