Section 1

Temperature, Thermal Energy, and Heat

Objectives

After this lesson, students will be able to

M.6.1.1 Name the three common temperature scales.

M.6.1.2 Describe how thermal energy is related to temperature and heat.

M.6.1.3 Explain the significance of a high specific heat.

Target Reading Skill

Comparing and Contrasting Explain that comparing and contrasting information shows how ideas, facts, and events are similar and different. The results of the comparison can increase students' understanding.

Answers

Temperature—Average kinetic energy of particles, Fahrenheit or Celsius degrees, kelvins

Thermal energy—Total energy of all particles in an object, Joule

Heat—Energy transferred, Joule

All in One Teaching Resources

- Transparency M52

Preteach

Build Background Knowledge

L2

Temperature Measures Kinetic Energy

Have students use newspapers to locate the daily high and low temperatures for the past week. Invite students to describe the hottest and coldest temperatures they have experienced. Ask: **When the temperature of a substance is 25°C, what is that a measure of?** *(Sample answer: How hot or cold something is)* List the answers and use them as a basis for assessing misconceptions about temperature.

Section 1

Temperature, Thermal Energy, and Heat

Reading Preview

Key Concepts

- What are the three common temperature scales?
- How is thermal energy related to temperature and heat?
- What does having a high specific heat mean?

Key Terms

- temperature
- Fahrenheit scale
- Celsius scale
- Kelvin scale
- absolute zero
- heat
- specific heat

Target Reading Skill

Comparing and Contrasting

As you read, compare and contrast temperature, thermal energy, and heat by completing a table like the one below.

	Energy Measured	Units
Temp.	Average kinetic energy of particles	
Thermal energy		
Heat		

Lab zone Discover Activity

How Cold Is the Water?

1. Fill a plastic bowl with cold water, another with warm water, and a third with water at room temperature. Label each bowl and line them up.
2. Place your right hand in the cold water and your left hand in the warm water.
3. After about a minute, place both your hands in the third bowl at the same time.

Think It Over

Observing How did the water in the third bowl feel when you touched it? Did the water feel the same on both hands? If not, explain why.

The radio weather report says that today's high temperature will be 25 degrees. What should you wear? Do you need a coat to keep warm, or only shorts and a T-shirt? What you decide depends on what "25 degrees" means.

Temperature

You don't need a science book to tell you that the word *hot* means higher temperatures or the word *cold* means lower temperatures. When scientists think about high and low temperatures, however, they do not think about "hot" and "cold." Instead, they think about particles of matter in motion.

Recall that all matter is made up of tiny particles. These particles are always moving even if the matter they make up is stationary. Recall that the energy of motion is called kinetic energy. So all particles of matter have kinetic energy. The faster particles move, the more kinetic energy they have. **Temperature** is a measure of the average kinetic energy of the individual particles in matter.

Lab zone Discover Activity

Skills Focus Observing L1

Materials 3 large bowls, warm tap water, cold tap water, room temperature water, markers, paper

Time 10 minutes

Tips Keep paper towels on hand to clean up any water spills. **CAUTION:** *Students should not use water with a temperature greater than 45°C.*

Expected Outcome The water in the third bowl will feel warm to the hand that was in the cold water and cold to the hand that was in the warm water.

Think It Over The water in the third bowl (room temperature water) felt warm to the hand that was in the cold water and cold to the hand that was in warm water. The sense of temperature by the body is relative.

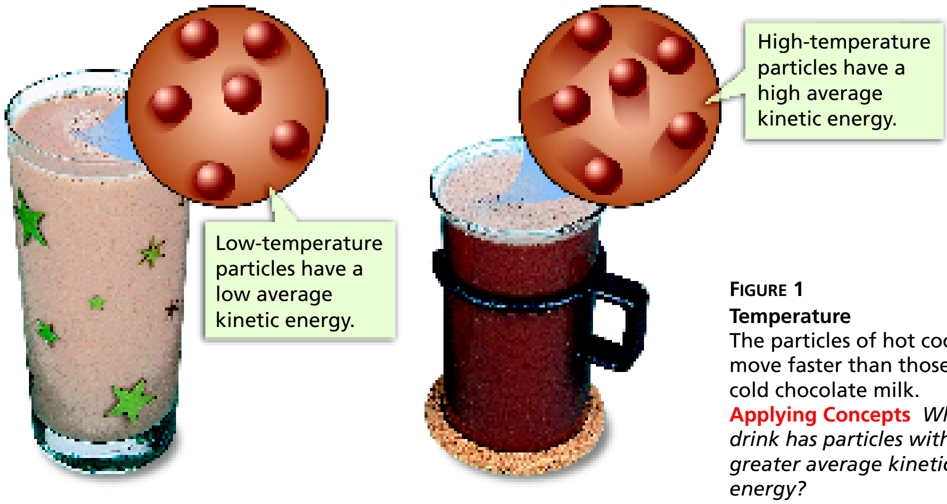


FIGURE 1
Temperature
The particles of hot cocoa move faster than those of cold chocolate milk.
Applying Concepts *Which drink has particles with greater average kinetic energy?*

In Figure 1, the hot cocoa has a higher temperature than the cold chocolate milk. The cocoa's particles are moving faster, so they have greater average kinetic energy. If the milk is heated, its particles will move faster, so their kinetic energy will increase. The temperature of the milk will rise.

Measuring Temperature To measure the temperature of the heated milk, you would probably use a thermometer like the one shown in Figure 2. A thermometer usually consists of a liquid such as mercury or alcohol sealed inside a narrow glass tube. When the tube is heated, the particles of the liquid speed up and spread out so the particles take up more space, or volume. You see the level of the liquid move up the tube. The reverse happens when the tube is cooled. The particles of the liquid slow down and move closer, taking up less volume. You see the level of the liquid move down in the tube.

A thermometer has numbers and units, or a scale, on it. When you read the scale on a thermometer, you read the temperature of the surrounding matter. Thermometers can have different scales. The temperature reading you see depends on the thermometer's scale.

Reading Checkpoint **What happens to the liquid particles inside a thermometer when it is heated?**

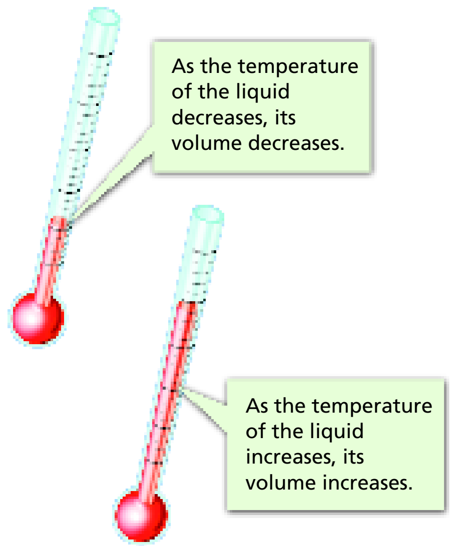


FIGURE 2
How a Thermometer Works
Temperature changes cause the level of the liquid inside a thermometer to rise and fall.

Instruct

Temperature

Teach Key Concepts L2

Describing and Measuring Temperature

Focus Tell students that in science the term *temperature* refers to the average kinetic energy of the tiny particles that make up matter.

Teach Ask: **If the kinetic energy of the particles in an object increases, what happens to the temperature of the object?** *(The temperature increases.)* **If the kinetic energy of the particles in an object decreases, what happens to the temperature of the object?** *(The temperature decreases.)* Tell students that temperature is measured using a thermometer. The higher the level of the liquid in the thermometer, the higher the temperature.

Apply Ask: **What temperature scale are you most familiar with?** *(Sample answer: Fahrenheit)* **Why?** *(Sample answer: It is used in weather forecasts and recipes.)* **learning modality: logical/mathematical**

Independent Practice L2

All in One **Teaching Resources**

- Guided Reading and Study Worksheet: *Temperature, Thermal Energy, and Heat*

Student Edition on Audio CD

Differentiated Instruction

English Learners/Beginning L1
Comprehension: Prior Knowledge
Students from countries other than the United States will most likely be familiar with hearing the temperature in weather reports given using the Celsius scale, rather than the Fahrenheit scale. Ask students to describe the typical high and low temperatures, in Celsius degrees, found in their home country. **learning modality: verbal**

English Learners/Intermediate L2
Comprehension: Prior Knowledge
Extend the Beginning by asking students to write several sentences describing the weather conditions, including temperatures, in their home country. Ask for volunteers to read their answers aloud. **learning modality: verbal**

Monitor Progress L2

Writing Have students write a paragraph comparing the water particles in a pot of boiling water to those in an ice cube tray in the freezer.

Answers

Figure 1 The hot cocoa has particles with greater average kinetic energy.

Reading Checkpoint The liquid particles speed up and spread out, so the liquid takes up more volume.

Thermal Energy and Heat

Teach Key Concepts

L2

Differentiating Between Temperature, Thermal Energy, and Heat

Focus Tell students that the terms *temperature*, *thermal energy*, and *heat* are related, but not identical, in meaning.

Teach Write the following sentences on the board: _____*(Thermal energy)* is the total energy of all the particles in an object. _____*(Temperature)* is the measure of the average kinetic energy of the particles in an object. The transfer of thermal energy is called _____. *(heat)* Ask for volunteers to supply the answer for each blank.

Apply Ask: **Can two objects have the same temperature but different amounts of thermal energy? Explain.** *(Yes, if the two objects have different numbers of particles, they can have the same temperature but different amounts of thermal energy.)* **learning modality: logical/mathematical**

Help Students Read

L1

SQ3R Refer to the Content Refresher in this chapter, which provides guidelines for using the SQ3R strategy.

Have students survey the section, noting the headings. Students should generate one written question for each heading, for example: *How are thermal energy and heat related?* Then have students read the section and look for answers to their questions. When students have completed reading they should recite, or state aloud, their questions and answers. As a review, have students write the answers to their questions. **learning modality: verbal**

All in One **Teaching Resources**

- Transparency M53

Go Online NSTA-PD LINKS

For: Links on temperature and heat
Visit: www.SciLinks.org
Web Code: scn-1361

Download a worksheet that will guide students' review of Internet sources on temperature and heat.

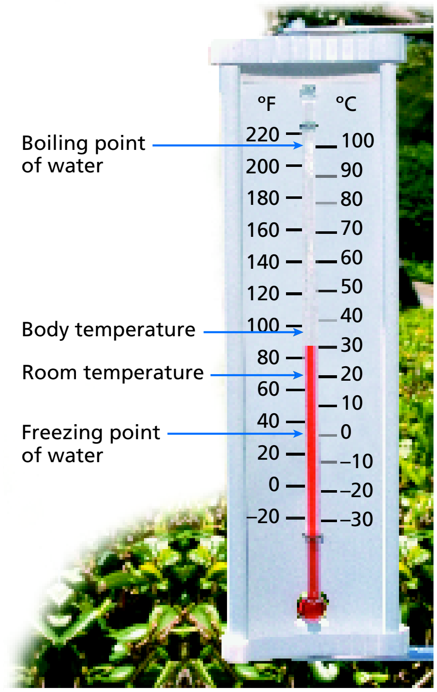


FIGURE 3
Temperature Scales
Many thermometers have both Celsius and Fahrenheit temperature scales.
Interpreting Photographs *What is the boiling point of water on the Celsius scale? On the Fahrenheit scale?*

Go Online SCI LINKS NSTA

For: Links on temperature and heat
Visit: www.SciLinks.org
Web Code: scn-1361

Temperature Scales **The three common scales for measuring temperature are the Fahrenheit, Celsius, and Kelvin scales.** Each of these scales is divided into regular intervals.

The temperature scale you are probably most familiar with is the Fahrenheit scale. In the United States, the **Fahrenheit scale** is the most common temperature scale. The scale is divided into degrees Fahrenheit (°F). On this scale, the freezing point of water is 32°F and the boiling point is 212°F.

In nearly all other countries, however, the most common temperature scale is the **Celsius scale.** The Celsius scale is divided into degrees Celsius (°C), which are larger units than degrees Fahrenheit. On the Celsius scale, the freezing point of water is 0°C and the boiling point is 100°C.

The temperature scale commonly used in physical science is the **Kelvin scale.** Units on the Kelvin scale, called kelvins (K), are the same size as degrees on the Celsius scale. So, an increase of 1 K equals an increase of 1°C. The freezing point of water on the Kelvin scale is 273 K, and the boiling point is 373 K. The number 273 is special. Scientists have concluded from experiments that –273°C is the lowest temperature possible. No more thermal energy can be removed from matter at –273°C. Zero on the Kelvin scale represents –273°C and is called **absolute zero.**

Thermal Energy and Heat

Different objects at the same temperature can have different energies. To understand this, you need to know about thermal energy and about heat. You may be used to thinking about thermal energy as heat, but they are not the same thing. Temperature, thermal energy, and heat are closely related, but they are all different.

Thermal Energy Recall from Chapter 5 that the total energy of all of the particles in an object is called thermal energy, or sometimes internal energy. The thermal energy of an object depends on the number of particles in the object, the temperature of the object, and the arrangement of the object's particles. You will learn about how the arrangement of particles affects thermal energy in Section 3.

The more particles an object has at a given temperature, the more thermal energy it has. For example, a 1-liter pot of hot cocoa at 75°C has more thermal energy than a 0.2-liter mug of hot cocoa at 75°C because the pot contains more cocoa particles. On the other hand, the higher the temperature of an object is, the more thermal energy the object has. So, if two 1-liter pots of hot cocoa have different temperatures, the pot with the higher temperature has more thermal energy. In Section 3, you will learn about how thermal energies differ for solids, liquids, and gases.

Heat Thermal energy that is transferred from matter at a higher temperature to matter at a lower temperature is called **heat.** The scientific definition of heat is different from its everyday use. In a conversation, you might say that an object contains heat. However, objects contain thermal energy, not heat. Only when thermal energy is transferred is it called heat. **Heat is thermal energy moving from a warmer object to a cooler object.** For example, when you hold an ice cube in your hand, as shown in Figure 4, the ice cube melts because thermal energy is transferred from your hand to the ice cube.

Recall from Chapter 5 that work also involves the transfer of energy. Since work and heat are both energy transfers, they are both measured in the same unit—joules.

Reading Checkpoint Why does an ice cube melt in your hand?

Math Skills

Converting Units

To convert a Fahrenheit temperature to a Celsius temperature, use the following formula.

$$°C = \frac{5}{9}(°F - 32)$$

For example, if the temperature in your classroom is 68°F, what is the temperature in degrees Celsius?

$$°C = \frac{5}{9}(68 - 32)$$

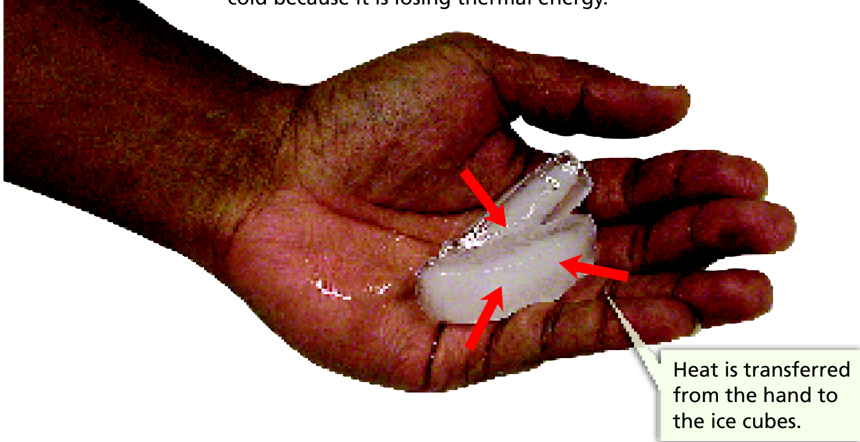
$$°C = \frac{5}{9} \times 36$$

$$°C = 20$$

The temperature of your classroom is 20°C.

Practice Problem While at the beach, you measure the ocean temperature as 77°F. What is the temperature of the ocean in degrees Celsius?

FIGURE 4
Heat Your hand transfers thermal energy to the ice cube. Even though your hand is cold, this transfer is called heat. Your hand feels cold because it is losing thermal energy.



Lab zone Teacher Demo L2

Comparing and Contrasting Temperature and Thermal Energy

Materials mug, bucket, 2 thermometers

Time 10 min

Focus Ask: **What is temperature?** *(The measure of the average kinetic energy of the particles in a substance)* **What is thermal energy?** *(The total energy of all the particles in an object)*

Teach Fill the bucket and the mug with water of the same temperature. Show students both containers with the thermometers inserted. Ask: **Which contains water with a greater temperature?** *(The temperature of the water in the containers is equal.)* Ask: **Which contains a greater thermal energy? Why?** *(The bucket, because there are a greater number of particles)*

Apply Ask: **What can you determine about the average kinetic energy of the individual particles in these containers?** *(The average kinetic energy of the particles is equal.)* **learning modality: visual**

Address Misconceptions L2

What Is Heat?

Students may have misconceptions about the meaning of the word *heat.* Some of these misconceptions are fostered by the everyday uses of the word that differ from the scientific usage. Write the word *heat* on the board. Ask: **In science, what does the term *heat* refer to?** *(The transfer of thermal energy)* **Can an object contain heat?** *(No)* **learning modality: verbal**

Math Skills

Math Skill Converting units

Time 10 minutes

Tip Remind students to insert known values into the formula. They can then solve for the unknown values.

Answer 25°C

Extend Have students determine the ocean temperature in degrees Celsius if the ocean temperature drops to 59°F. *(15°C)*

Monitor Progress L2

Skills Check Have students calculate the temperature in degrees Celsius if the outdoor thermometer on a summer day reads 95°F. *(35°C)*

Answers

Figure 3 100°C, 212°F

Reading Checkpoint An ice cube melts in your hand because thermal energy is transferred from your hand to the ice cube.

Specific Heat

Teach Key Concepts

L2

Specific Heat and Temperature Change

Focus Remind students that a material's specific heat is how much energy is required to raise the temperature of 1 kilogram of the material by 1 kelvin.

Teach Tell students that different materials have different specific heats. Direct students' attention to Figure 6. Ask: **Which material listed in the table has the lowest specific heat?** *(Silver)* **If 1 kilogram of each of the listed materials absorbed the same amount of energy, how would the temperature change of the silver compare with the temperature change of the other materials?** *(Silver would have a greater temperature change than any other listed material.)*

Apply Ask: **Why do foods that contain lots of water stay hot longer than those that don't contain much water?** *(Water changes temperature more slowly than many other substances, so foods containing lots of water stay warm longer than those that don't contain much water.)* **learning modality: logical/mathematical**

Math Analyzing Data

Math Skill Making and interpreting graphs

Focus Tell students that a bar graph is used to show information about separate but related items.

Teach Call students' attention to the graph. Explain that the lower the specific heat, the smaller the amount of heat required to raise the temperature of the material. A higher bar on the graph represents a greater specific heat. Of the materials shown, water has the highest specific heat. Ask: **Which material shown has the lowest specific heat?** *(Sand)*

Answers

1. water, sand, and iron
2. About 4,200 J would be required.
3. sand

FIGURE 5
Specific Heat of Sand and Water
The specific heat of water is greater than the specific heat of sand. On a sunny day the water feels cooler than the sand.

Specific Heat

Imagine running across hot sand toward the ocean. You run to the water's edge, but you don't go any farther—the water is too cold. How can the sand be so hot and the water so cold? After all, the sun heats both of them. The answer is that water requires more heat to raise its temperature than sand does.

When an object is heated, its temperature rises. But the temperature does not rise at the same rate for all objects. The amount of heat required to raise the temperature of an object depends on the object's chemical makeup. To change the temperature of different objects by the same amount, different amounts of heat are required.

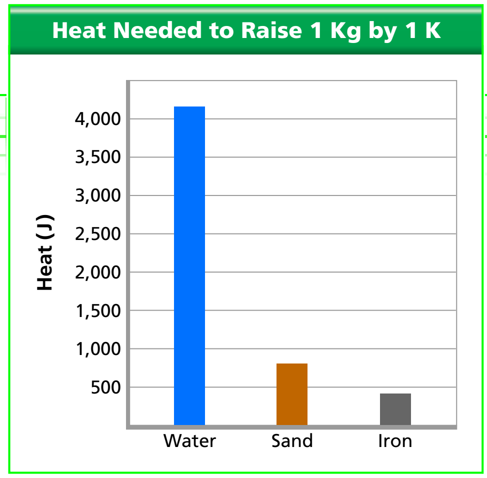
Scientists have defined a quantity to measure the relationship between heat and temperature change. The amount of energy required to raise the temperature of 1 kilogram of a material by 1 kelvin is called its **specific heat.** The unit of measure for specific heat is joules per kilogram-kelvin, or J/(kg·K).

Math Analyzing Data

Specific Heat

The specific heat of three different materials was measured. These data are shown in the graph.

1. **Reading Graphs** What three materials are compared in the graph?
2. **Interpreting Data** About how much heat is required to raise 1 kg of water by 1 K?
3. **Drawing Conclusions** According to the graph, which material requires more heat to raise its temperature by 1 K, iron or sand?



Differentiated Instruction

Gifted and Talented

L3

Making a Game Have students create a board game that can be used to review the material in this section. Possible game topics include definitions of key terms, calculations of specific heat, and questions based on the key concepts. When the games are complete, have students share their games with the class. **learning modality: logical/mathematical**

Less Proficient Readers

L1

Reviewing Key Terms Have students listen to this section of the chapter on the **Student Edition on Audio CD.** After they have completed listening, ask them to write the key terms from the section on index cards. Then pair students and have one display an index card, and the other define the term aloud. Students can take turns displaying cards and defining terms. **learning modality: verbal**

Look at the specific heats of the materials listed in Figure 6. Notice that the specific heat of water is quite high. One kilogram of water requires 4,180 joules of energy to raise its temperature 1 kelvin.

A material with a high specific heat can absorb a great deal of thermal energy without a great change in temperature. On the other hand, a material with a low specific heat would have a large temperature change after absorbing the same amount of thermal energy.

The energy gained or lost by a material is related to its mass, change in temperature, and specific heat. You can calculate thermal energy changes with the following formula.

Change in energy = Mass × Specific heat × Change in temperature

How much heat is required to raise the temperature of 5 kilograms of water by 10 kelvins?

$$\text{Change in energy} = 5 \text{ kg} \times 4{,}180 \text{ J/(kg·K)} \times 10 \text{ K} = 209{,}000 \text{ J}$$

You need to transfer 209,000 joules to the water to increase its temperature by 10 kelvins.

Reading Checkpoint **What formula allows you to determine an object's change in thermal energy?**

Specific Heat of Common Materials

Material	Specific Heat (J/(kg·K))
Aluminum	903
Copper	385
Glass	837
Ice	2,060
Iron	450
Sand	800
Silver	235
Water	4,180

FIGURE 6
This table lists the specific heats of several common materials.
Interpreting Tables *How much more energy is required to raise the temperature of 1 kg of iron by 1 K than to raise the temperature of 1 kg of copper by 1 K?*

Section 1 Assessment

Target Reading Skill Comparing and Contrasting Use the information in your table to help you answer Questions 1 and 2 below.

Reviewing Key Concepts

1. a. **Identifying** What is temperature?
   b. **Describing** How do thermometers measure temperature?
   c. **Comparing and Contrasting** How are the three temperature scales alike? How are they different?
2. a. **Defining** What is heat?
   b. **Explaining** What is the relationship between thermal energy and temperature? Between thermal energy and heat?
   c. **Relating Cause and Effect** What happens to the motion of an object's particles as their thermal energy increases? What happens to the temperature of the object?
3. a. **Reviewing** Why do some materials get hot more quickly than others?
   b. **Calculating** You stir your hot cocoa with a silver spoon that has a mass of 0.032 kg. The spoon's temperature increases from 20 K to 60 K. What is the change in the spoon's thermal energy? (*Hint:* Use the table in Figure 6 to find the specific heat of silver.)

Math Practice

4. **Converting Units** Convert 5.0°F to degrees Celsius.
5. **Converting Units** The surface temperature on the planet Venus can reach 860°F. Convert this temperature to degrees Celsius.

Monitor Progress L2

Answers

Figure 6 It requires 65 joules more energy to raise 1 kg of iron by 1K than to raise 1 kg of copper by the same amount.

Reading Checkpoint Change in energy = Mass × Specific Heat × Change in temperature

Assess

Reviewing Key Concepts

1. a. Temperature is a measure of the average kinetic energy of the individual particles in matter. **b.** Sample answer: When a thermometer is heated, the liquid level rises because particles of the liquid speed up and spread out. When the thermometer is cooled, the liquid level falls because particles of the liquid slow down and move closer together. **c.** Each of the three temperature scales is divided into degrees. Celsius degrees are the same size as Kelvin degrees, and both are larger than Fahrenheit degrees. The three scales give different readings for all temperatures, including absolute zero, the freezing point of water, and the boiling point of water.

2. a. Heat is thermal energy moving from a warmer object to a cooler object.
b. Temperature is one of the factors that determine an object's thermal energy. The others are the number of particles and the arrangement of the particles. Heat is the flow of thermal energy between objects. **c.** When the motion of an object's particles increase, its temperature rises. All else equal, this will result in an increase in the object's thermal energy.

3. a. Materials with smaller specific heats need less heat to change temperature by a given amount. **b.** 300.8 J (0.032 kg × 235 J/Kg•K × 40 K)

Reteach L1

Have students review the figures in the section. Then ask volunteers to state the main idea of each figure. Review the caption questions and answers aloud with students.

Performance Assessment L2

Skills Check Have students determine the energy gained by 10 kilograms of copper when its temperature increases by 15 kelvins. *(57,750 J)*

Math Skills

Math Skill Converting units

Answers

4. –15°C (°C = 5/9 (°F – 32); °C = 5/9 (5.0 – 32); °C = –15)
5. 460°C) °C = 5/9 (860 – 32); °C = about 460)

All in One Teaching Resources

- Section Summary: *Temperature, Thermal Energy, and Heat*
- Review and Reinforcement: *Temperature, Thermal Energy, and Heat*
- Enrich: *Temperature, Thermal Energy, and Heat*

Lab zone Technology Lab

Build Your Own Thermometer

L2

Prepare for Inquiry

Skills Objective

After this lab, students will be able to
- evaluate the design of a thermometer
- troubleshoot a technical design
- redesign and improve their thermometer based on the results of their testing

Prep Time 30 minutes
Class Time 40 minutes

Advance Planning

Gather required materials. Soften the clay to make it easier to work with. Set up a common hot water bath and ice bath.

Alternative Materials

One-hole rubber stoppers, glass flask, plastic tubing, index cards, plastic bottles

Safety

Caution students to be careful using thermometers, glass soda bottles, and hot water. Review the safety guidelines in Appendix A.

All in One Teaching Resources
- Lab Worksheet: *Build Your Own Thermometer*

Guide Inquiry

Introduce the Procedure

Prepare and display a sample of the thermometer for Part 1. Have students review the procedure and ask any questions they may have. Review the concept of thermal expansion.

Troubleshooting the Experiment

Be certain students obtain an airtight seal with the clay. Tilt the bottle and straw when adding water to the straw in Step 3.

Expected Outcome

When the thermometer was placed in cold water, the water in the straw decreased. When the thermometer was placed in the hot water, the water in the straw increased.

Lab zone Technology Lab
• Tech & Design •

Build Your Own Thermometer

Problem

Can you build a thermometer out of simple materials?

Design Skills

evaluating the design, measuring, making models

Materials

- bowl of hot water
- bowl of ice water
- water of unknown temperature
- tap water
- 500-mL beaker
- clear glass juice or soda bottle, 20–25 cm
- clear plastic straw, 18–20 cm
- food coloring
- plastic dropper
- cooking oil
- modeling clay
- metric ruler
- fine-point marker

Procedure

1. You can use simple materials to build a model of an alcohol thermometer. First, mix food coloring into a beaker of tap water. Then fill a glass bottle with the colored water.
2. Place a straw in the bottle. Use modeling clay to position the straw so that it extends at least 10 cm above the bottle mouth. Do not let the straw touch the bottom. The clay should completely seal off the bottle mouth. Make sure there is no air in the bottle.
3. Using a dropper, add colored water into the straw to a level 5 cm above the bottle. Place a drop of cooking oil in the straw to prevent evaporation.
4. Place your thermometer into a bowl of hot water. When the colored water reaches its highest level, place a mark on the straw.
5. Place your thermometer in the bowl of ice water. Place a mark on the straw when the water reaches its lowest level.
6. Create a scale for your model thermometer. Divide the distance between the two marks into 5-mm intervals. Starting with the lowest point, label the intervals on the straw 0, 1, 2, 3, and so on.
7. Measure the temperature of two unknown samples with your thermometer. Record both temperatures.

Analyze and Conclude

1. **Evaluating the Design** Do you think your model accurately represents an alcohol thermometer? How is it like a real thermometer? How is it different?
2. **Inferring** How can you use the concepts of matter and the kinetic energy of particles to explain the way your model works?
3. **Measuring** Approximately what Celsius temperatures do you think your model measures? Explain your estimate. (*Hint:* Refer to Figure 3 on page 178.)
4. **Making Models** Examine the structure and materials used in your model. Propose a change that would improve the model. Explain your choice.

Communicate

Create a poster to show how an alcohol thermometer works. Explain how the Celsius and Fahrenheit scales compare. For example, does 0° have the same meaning on both scales? Use a diagram with labels and captions to communicate your ideas. (*Hint:* Refer to Figure 3.)

Analyze and Conclude

1. Sample answer: The thermometer is a reasonable model of a real thermometer. It is like a real thermometer in that it has a scale that can be used to measure temperatures. The actual scale intervals are different than in a real thermometer. Water expands when it is heated, like alcohol, but not to the same extent.
2. When the thermometer is placed in hot water, thermal energy is transferred to the particles in the thermometer and these particles speed up and spread out (their kinetic energy increases). The opposite occurs when the thermometer is placed in ice water.
3. The thermometer measures temperatures between 0°C and 100°C.
4. Possible answers may include using a different liquid, using a finer scale, changing the thickness of the column of liquid, or changing the size of the reservoir of liquid.