# CHAPTER 9 Review

## TEMPERATURE AND THERMAL EQUILIBRIUM

### Review Questions

1. What is the relationship between temperature and internal energy?

2. What must be true of two objects if the objects are in a state of thermal equilibrium?

3. What are some physical properties that could be used in developing a temperature scale?

### Conceptual Questions

4. What property must a substance have in order to be used for calibrating a thermometer?

5. Which object in each of the following pairs has greater total internal energy, assuming that the two objects in each pair are in thermal equilibrium? Explain your reasoning in each case.
   a. a metal knife in thermal equilibrium with a hot griddle
   b. a 1 kg block of ice at −25°C or seven 12 g ice cubes at −25°C

6. Assume that each pair of objects in item 5 has the same internal energy instead of the same temperature. Which item in each pair will have the higher temperature?

7. Why are the steam and ice points of water better fixed points for a thermometer than the temperature of a human body?

8. How does the temperature of a tub of hot water as measured by a thermometer differ from the water's temperature before the measurement is made? What property of a thermometer is necessary for the difference between these two temperatures to be minimized?

### Practice Problems

*For problems 9–10, see Sample Problem A.*

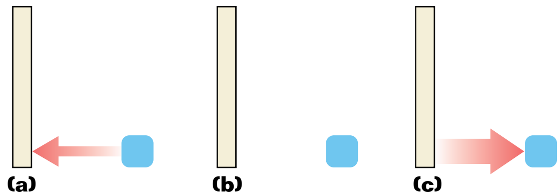
9. The highest recorded temperature on Earth was 136°F, at Azizia, Libya, in 1922. Express this temperature in degrees Celsius and in kelvins.

10. The melting point of gold is 1947°F. Express this temperature in degrees Celsius and in kelvins.

## DEFINING HEAT

### Review Questions

11. Which drawing below shows the direction in which net energy is transferred as heat between an ice cube and the freezer walls when the temperature of both is −10°C? Explain your answer.




12. A glass of water has an initial temperature of 8°C. In which situation will the rate of energy transfer be greater, when the air's temperature is 25°C or 35°C?

13. How much energy is transferred between a piece of toast and an oven when both are at a temperature of 55°C? Explain.

14. How does a metal rod conduct energy from one end, which has been placed in a fire, to the other end, which is at room temperature?

15. How does air within winter clothing keep you warm on cold winter days?

## Conceptual Questions

**16.** If water in a sealed, insulated container is stirred, is its temperature likely to increase slightly, decrease slightly, or stay the same? Explain your answer.

**17.** Given your answer to item 16, why does stirring a hot cup of coffee cool it down?

**18.** Given any two bodies, the one with the higher temperature contains more heat. What is wrong with this statement?

**19.** Explain how conduction causes water on the surface of a bridge to freeze sooner than water on the road surface on either side of the bridge.

**20.** A tile floor may feel uncomfortably cold to your bare feet, but a carpeted floor in an adjoining room at the same temperature feels warm. Why?

**21.** Why is it recommended that several items of clothing be worn in layers on cold days?

**22.** Why does a fan make you feel cooler on a hot day?

**23.** A paper cup is filled with water and then placed over an open flame, as shown at right. Explain why the cup does not catch fire and burn.

## Practice Problems

***For problems 24–25, see Sample Problem B.***

**24.** A force of 315 N is applied horizontally to a crate in order to displace the crate 35.0 m across a level floor at a constant velocity. As a result of this work, the crate's internal energy is increased by an amount equal to 14 percent of the crate's initial internal energy. Calculate the initial internal energy of the crate. (Disregard the work done on the floor, and assume that all work goes into the crate.)

**25.** A 0.75 kg spike is hammered into a railroad tie. The initial speed of the spike is equal to 3.0 m/s.

**a.** If the tie and spike together absorb 85 percent of the spike's initial kinetic energy as internal energy, calculate the increase in internal energy of the tie and spike.

**b.** What happens to the remaining energy?

# CHANGES IN TEMPERATURE AND PHASE

## Review Questions

**26.** What principle permits calorimetry to be used to determine the specific heat capacity of a substance? Explain.

**27.** Why does the temperature of melting ice not change even though energy is being transferred as heat to the ice?

## Conceptual Questions

**28.** Why does the evaporation of water cool the air near the water's surface?

**29.** Until refrigerators were invented, many people stored fruits and vegetables in underground cellars. Why was this more effective than keeping them in the open air?

**30.** During the winter, the people mentioned in item 29 would often place an open barrel of water in the cellar alongside their produce. Explain why this was done and why it would be effective.

## Practice Problems

***For problems 31–32, see Sample Problem C.***

**31.** A 25.5 g silver ring ($c_p$ = 234 J/kg•°C) is heated to a temperature of 84.0°C and then placed in a calorimeter containing $5.00 \times 10^{-2}$ kg of water at 24.0°C. The calorimeter is not perfectly insulated, however, and 0.140 kJ of energy is transferred to the surroundings before a final temperature is reached. What is the final temperature?

32. When a driver brakes an automobile, friction between the brake disks and the brake pads converts part of the car's translational kinetic energy to internal energy. If a 1500 kg automobile traveling at 32 m/s comes to a halt after its brakes are applied, how much can the temperature rise in each of the four 3.5 kg steel brake disks? Assume the disks are made of iron ($c_p$ = 448 J/kg•°C) and that all of the kinetic energy is distributed in equal parts to the internal energy of the brakes.

## MIXED REVIEW

33. Absolute zero on a temperature scale called the *Rankine* scale is $T_R = 0$°R, and the scale's unit is the same size as the Fahrenheit degree.
   a. Write a formula that relates the Rankine scale to the Fahrenheit scale.
   b. Write a formula that relates the Rankine scale to the Kelvin scale.

34. A 3.0 kg rock is initially at rest at the top of a cliff. Assuming the rock falls into the sea at the foot of the cliff and that its kinetic energy is transferred entirely to the water, how high is the cliff if the temperature of 1.0 kg of water is raised 0.10°C? (Neglect the heat capacity of the rock.)

35. The freezing and boiling points of water on the imaginary "Too Hot" temperature scale are selected to be exactly 50 and 200 degrees TH.
   a. Derive an equation relating the Too Hot scale to the Celsius scale. (Hint: Make a graph of one temperature scale versus the other, and solve for the equation of the line.)
   b. Calculate absolute zero in degrees TH.

## Graphing Calculator Practice

**Specific Heat Capacity**

Specific heat capacity ($c_p$), as you learned earlier in this chapter, is equal to the amount of energy required to change the temperature of 1 kg of a substance by 1°C. This relationship is expressed by the following equation:

$$\Delta T = \frac{Q}{mc_p}$$

In this equation, $\Delta T$ is the change in temperature, $Q$ is the amount of energy absorbed by the substance as heat, $c_p$ is the specific heat capacity of the substance, and $m$ is the mass of the substance.

This equation can be represented on a graphing calculator as follows:

$$Y_1 = T + (X/(MC))$$

A graph of this equation will illustrate the relationship between energy absorbed as heat and temperature.

In this graphing calculator activity, you will enter various values for the energy absorbed and will determine the resulting temperature. Then, you can explore how changing the specific heat capacity, mass, and initial temperature changes your results.

Visit go.hrw.com and type in the keyword **HF6HATX** to find this graphing calculator activity. Refer to **Appendix B** for instructions on downloading the program for this activity.

**36.** A hot-water heater is operated by solar power. If the solar collector has an area of 6.0 $m^2$ and the power delivered by sunlight is 550 $W/m^2$, how long will it take to increase the temperature of 1.0 $m^3$ of water from 21°C to 61°C?

**37.** A student drops two metallic objects into a 120 g steel container holding 150 g of water at 25°C. One object is a 253 g cube of copper that is initially at 85°C, and the other is a chunk of aluminum that is initially at 5°C. To the surprise of the student, the water reaches a final temperature of 25°C, its initial temperature. What is the mass of the aluminum chunk?

**38.** At what Fahrenheit temperature are the Kelvin and Fahrenheit temperatures numerically equal?

**39.** A 250 g aluminum cup holds and is in thermal equilibrium with 850 g of water at 83°C. The combination of cup and water is cooled uniformly so that the temperature decreases by 1.5°C per minute. At what rate is energy being removed?

**40.** A jar of tea is placed in sunlight until it reaches an equilibrium temperature of 32°C. In an attempt to cool the liquid, which has a mass of 180 g, 112 g of ice at 0°C is added. At the time at which the temperature of the tea (and melted ice) is 15°C, determine the mass of the remaining ice in the jar. Assume the specific heat capacity of the tea to be that of pure liquid water.

## *Alternative Assessment*

**1.** According to legend, Archimedes determined whether the king's crown was pure gold by comparing its water displacement with the displacement of a piece of pure gold of equal mass. But this procedure is difficult to apply to very small objects. Use the concept of specific heat capacity to design a method for determining whether a ring is pure gold. Present your plan to the class, and ask others to suggest improvements to your design. Discuss each suggestion's advantages and disadvantages.

**2.** The host of a cooking show on television claims that you can greatly reduce the baking time for potatoes by inserting a nail through each potato. Explain whether this advice has a scientific basis. Would this approach be more efficient than wrapping the potatoes in aluminum foil? List all arguments and discuss their strengths and weaknesses.

**3.** The graph of decreasing temperature versus time of a hot object is called its cooling curve. Design and perform an experiment to determine the cooling curve of water in containers of various materials and shapes. Draw cooling curves for each one. Which trends represent good insulation? Use your findings and graphs to design a lunch box that keeps food warm or cold.

**4.** Research the life and work of James Prescott Joule, who is best known for his apparatus demonstrating the equivalence of work and heat and the conservation of energy. Many scientists initially did not accept Joule's conclusions. Research the reasoning behind their objections. Prepare a presentation for a class discussion either supporting the objections of Joule's critics or defending Joule's conclusion before England's Royal Academy of Sciences.

**5.** Research how scientists measure the temperature of the following: the sun, a flame, a volcano, outer space, liquid hydrogen, mice, and insects. Find out what instruments are used in each case and how they are calibrated to known temperatures. Using what you learn, prepare a chart or other presentation on the tools used to measure temperature and the limitations on their ranges.

**6.** Get information on solar water heaters that are available where you live. How does each type work? Compare prices and operating expenses for solar water heaters versus gas water heaters. What are some of the other advantages and limitations of solar water heaters? Prepare an informative brochure for homeowners who are interested in this technology.

# Standardized Test Prep

## MULTIPLE CHOICE

1. What must be true about two given objects for energy to be transferred as heat between them?
   **A.** The objects must be large.
   **B.** The objects must be hot.
   **C.** The objects must contain a large amount of energy.
   **D.** The objects must have different temperatures.

2. A metal spoon is placed in one of two identical cups of hot coffee. Why does the cup with the spoon have a lower temperature after a few minutes?
   **F.** Energy is removed from the coffee mostly by conduction through the spoon.
   **G.** Energy is removed from the coffee mostly by convection through the spoon.
   **H.** Energy is removed from the coffee mostly by radiation through the spoon.
   **J.** The metal in the spoon has an extremely large specific heat capacity.

***Use the passage below to answer questions 3–4.***

The boiling point of liquid hydrogen is −252.87°C.

3. What is the value of this temperature on the Fahrenheit scale?
   **A.** 20.28°F
   **B.** −220.87°F
   **C.** −423.2°F
   **D.** 0°F

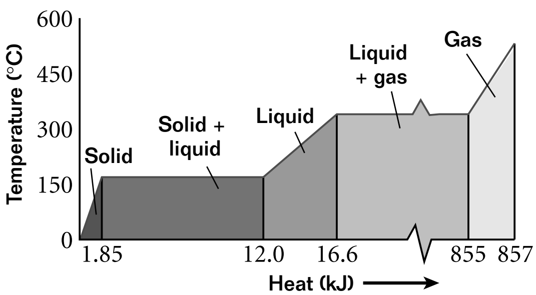
4. What is the value of this temperature in kelvins?
   **F.** 273 K
   **G.** 20.28 K
   **H.** −423.2 K
   **J.** 0 K

5. A cup of hot chocolate with a temperature of 40°C is placed inside a refrigerator at 5°C. An identical cup of hot chocolate at 90°C is placed on a table in a room at 25°C. A third identical cup of hot chocolate at 80°C is placed on an outdoor table, where the surrounding air has a temperature of 0°C. For which of the three cups has the most energy been transferred as heat when equilibrium has been reached?
   **A.** The first cup has the largest energy transfer.
   **B.** The second cup has the largest energy transfer.
   **C.** The third cup has the largest energy transfer.
   **D.** The same amount of energy is transferred as heat for all three cups.

6. What data are required in order to determine the specific heat capacity of an unknown substance by means of calorimetry?
   **F.** $c_{p,water}$, $T_{water}$, $T_{substance}$, $T_{final}$, $V_{water}$, $V_{substance}$
   **G.** $c_{p,substance}$, $T_{water}$, $T_{substance}$, $T_{final}$, $m_{water}$, $m_{substance}$
   **H.** $c_{p,water}$, $T_{substance}$, $m_{water}$, $m_{substance}$
   **J.** $c_{p,water}$, $T_{water}$, $T_{substance}$, $T_{final}$, $m_{water}$, $m_{substance}$

7. During a cold spell, Florida orange growers often spray a mist of water over their trees during the night. Why is this done?
   **A.** The large latent heat of vaporization for water keeps the trees from freezing.
   **B.** The large latent heat of fusion for water prevents it and thus the trees from freezing.
   **C.** The small latent heat of fusion for water prevents the water and thus the trees from freezing.
   **D.** The small heat capacity of water makes the water a good insulator.

*Use the heating curve below to answer questions 8–10. The graph shows the change in temperature of a 23 g sample of a substance as energy is added to the substance as heat.*




**8.** What is the specific heat capacity of the liquid?

**F.** $4.4 \times 10^5$ J/kg•°C
**G.** $4.0 \times 10^2$ J/kg•°C
**H.** $5.0 \times 10^2$ J/kg•°C
**J.** $1.1 \times 10^3$ J/kg•°C

**9.** What is the latent heat of fusion?

**A.** $4.4 \times 10^5$ J/kg
**B.** $4.0 \times 10^2$ J/kg•°C
**C.** $10.15 \times 10^3$ J
**D.** $3.6 \times 10^7$ J/kg

**10.** What is the specific heat capacity of the solid?

**F.** $1.85 \times 10^3$ J/kg•°C
**G.** $4.0 \times 10^2$ J/kg•°C
**H.** $5.0 \times 10^2$ J/kg•°C
**J.** $1.1 \times 10^3$ J/kg•°C

## SHORT RESPONSE

***Base your answers to questions 11–12 on the information below.***

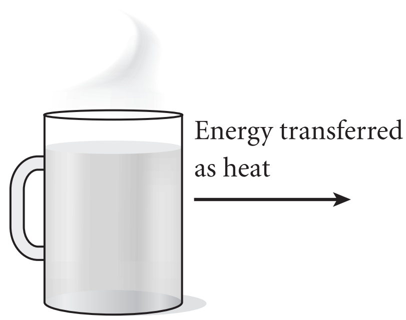
The largest of the Great Lakes, Lake Superior, contains $1.20 \times 10^{16}$ kg of fresh water, which has a specific heat capacity of 4186 J/kg•°C and a latent heat of fusion of $3.33 \times 10^5$ J/kg.

**11.** How much energy would be needed to increase the temperature of Lake Superior by 1.0°C?

**12.** If Lake Superior were still liquid at 0°C, how much energy would need to be removed from the lake for it to become completely frozen?

**13.** Ethyl alcohol has about one-half the specific heat capacity of water. If equal masses of alcohol and water in separate beakers at the same temperature are supplied with the same amount of energy, which will have the higher final temperature?

**14.** A 0.200 kg glass holds 0.300 kg of hot water, as shown below. The glass and water are set on a table to cool. After the temperature has decreased by 2.0°C, how much energy has been removed from the water and glass? (The specific heat capacity of glass is 837 J/kg•°C, and that of water is 4186 J/kg•°C.)




## EXTENDED RESPONSE

**15.** How is thermal energy transferred by the process of convection?

**16.** Show that the temperature –40.0° is unique in that it has the same numerical value on the Celsius and Fahrenheit scales. Show all of your work.

**Test TIP** Use dimensional analysis to check your work when solving mathematical problems. Include units in each step of your calculation. If you do not end up with the correct unit in your answer, check each step of your calculation for errors.

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**9.** 57.8°C, 331.0 K

**25.** **a.** 2.9 J

**b.** It goes into the air, the ground, and the hammer.

**31.** 25.0°C

**33.** **a.** $T_R = T_F + 459.7$, or $T_F = T_R - 459.7$

**b.** $T = \frac{5}{9}\,T_R$, or $T_R = \frac{9}{5}\,T$

**35.** **a.** $T_{TH} = \frac{3}{2}T_C + 50$, or $T_C = \frac{2}{3}(T_{TH} - 50)$

**b.** –360° TH

**37.** 330 g

**39.** $5.7 \times 10^3$ J/min = 95 J/s