TABLE 16-1

Specific Heat of Common Substances at 20°C	
Substance	Specific Heat (J/g°C)*
air	1.00
aluminum	0.895
carbon (diamond)	0.502
carbon (graphite)	0.711
carbon dioxide	0.832
copper	0.387
ethyl alcohol, C_2H_6O	2.45
gold	0.129
granite	0.803
iron	0.448
lead	0.128
paraffin	2.9
silver	0.233
stainless steel	0.51
water	4.18

* The SI unit for specific heat is J/kgK; a change of 1 K = a change of 1°C; therefore J/kgK = J/kg°C.

■ ***Apply a Strategy*** You can break this problem down into three parts. First, if you know the volume of water in the cup, you can calculate the mass, using the value of the density of water. The density of water is listed in Table 1-5 as 1.00 g/cm^3. Next, the temperature change can be found by subtracting the initial temperature from the final temperature. Finally, using these values of mass, ΔT, and the specific heat of water, you can calculate the quantity of heat needed to make a cup of coffee.

■ ***Work a Solution*** First determine the mass of the water. Recall that 1 mL = 1 cm^3, so 250.0 mL = 250.0 cm^3. Using the factor-label method, determine the mass from the volume and density.

$$250.0\,\cancel{\text{cm}^3} \times \frac{1.00\text{ g}}{1\,\cancel{\text{cm}^3}} = 250.0\text{ g}$$

You can also use the equation mass = density × volume to determine the mass of water.

The change of temperature, ΔT = 95.0°C − 25.0°C = 70.0°C. Finally, using the value for the specific heat of water found in Table 16-1, you can find the quantity of heat needed as follows.

$$\text{heat transferred} = \text{specific heat} \times \text{mass} \times \text{change in temperature}$$

$$= \left(4.18\,\frac{\text{J}}{\cancel{\text{g}}\cancel{{}^\circ\text{C}}}\right)(250.0\,\cancel{\text{g}})(70.0\cancel{{}^\circ\text{C}})$$

$$\text{heat transferred} = 731\,50\text{ J}$$

$$\text{heat transferred} = 73.2\text{ kJ}$$

■ ***Verify Your Answer*** Checking units is a good way to make sure that you have solved a problem correctly. You know that *quantity of heat* refers to the amount of energy transferred in order to increase the temperature of the water. Therefore, your answer should be expressed in units of energy. The kilojoule is a unit of energy.

The relationship between heat transferred, specific heat, mass, and change in temperature is given by this mathematical expression.

$$q = s \times m \times \Delta T$$

The symbol q represents the heat transferred, s is the specific heat, m is the mass, and ΔT is the change in temperature. The following practice problems can be solved using this equation.

Practice Problems

1. How much energy is required to heat a #10 iron nail with a mass of 7.0 g from 25°C until it becomes red hot at 750°C? *Ans.* 2.3 kJ

2. If 5750 J of energy are added to a 455-g piece of granite at 24.0°C, what is the final temperature of the granite?
Ans. 39.7°C

3. A 30.0-g sample of an unknown metal is heated from 22.0°C to 59.2°C. During the process, 1.00 kJ of energy is absorbed by the metal. What is the specific heat of the metal? Using Table 16-1, identify the metal.
Ans. 0.896 J/g°C

DO YOU KNOW?

Another energy unit is the Btu, which stands for British thermal unit. One Btu is the amount of energy needed to raise 1 pound of water 1°F, from 63°F to 64°F. You will usually find the energy ratings of air conditioners, gas grills, and home heating systems listed in Btus rather than joules (1 Btu = 1055 J).

Storing energy Can you store energy? Yes, a substance with a large value of specific heat has the capacity to store a large amount of energy. Compare the specific heats of water and granite with the values for other substances listed in Table 16-1. Both water and granite have relatively large values of specific heat and are used in solar heated homes to store energy from the sun. During the day, the granite or water is heated by the sun's energy. During the night, the energy stored in the water or granite is transferred to the air, warming the inside of the home.

Figure 16-5 *Many solar homes gather energy from the sun by circulating water in pipes in rooftop installations.*

16.3 Energy Changes Accompanying a Change of State

The specific heat of a substance indicates the amount of energy that must be added to or removed from one gram of a substance to change the substance's temperature by one degree Celsius. You will recall that changing the temperature of a substance can also cause it to change from one state to another. For example, a gas can be cooled until it condenses to a liquid. Further cooling can cause the liquid to freeze. These are changes of state that were discussed in *Section 14.3.*

$$\text{heat lost by aluminum} = s_{(aluminum)} \times m_{(aluminum)} \times \Delta T_{(aluminum)}$$

$$4390\ J = s_{(aluminum)}(75.25\ g)(99.3°C - 32.9°C)$$

$$s_{(aluminum)} = \frac{(4390\ J)}{(75.25\ g)(99.3°C - 32.9°C)}$$

$$s_{(aluminum)} = 0.879\ J/g°C$$

Verify Your Answer The value for the specific heat of aluminum listed in Table 16-1 is 0.895 J/g°C. This is very close to the calculated value of 0.879 J/g°C. The values recorded in Table 16-1 were determined using calorimeters that make more precise measurements than are possible with a simple calorimeter.

Practice Problem

6. A 25-g sample of a metal at 75.0°C is placed in a calorimeter containing 25 g of water at 20.0°C. The temperature stopped changing at 29.4°C. What is the specific heat of the metal.
Ans. 0.86 J/g°C

DO YOU KNOW?

Some appliances use phase changes to transfer energy. The cooling system of a refrigerator is filled with liquid Freon. The Freon absorbs heat from inside the refrigerator and vaporizes. The vapor is circulated to the refrigerator's exterior, where it is condensed. You can feel this heat being released behind or underneath your refrigerator when the compressor is running.

PROBLEM-SOLVING STRATEGY

You will need to ***use what you know*** *from Table 16-1 to compare your calculated value with the accepted value.* *(See Strategy, page 58.)*

PART 1 REVIEW

7. Compare and contrast energy and heat. How can you measure the transfer of energy?
8. The same quantity of heat is added to an iron nail (3.5 g) and to a metric ton (1000 kg) of iron. Which would reach the higher temperature? Explain your reasoning.
9. Solar homes often use granite or water to absorb heat from the sun by day. This heat is released into the house at night. If the temperature of 1000 kg of granite was raised 10°C in one house and the temperature of 1000 kg of water was raised 10°C in another house, which house absorbed more heat? Explain your answer.
10. How much heat is transferred when 25.0 g of ethyl alcohol vapor at its boiling point condenses to form a liquid at the same temperature? Is energy absorbed or released?
Ans. 22.0 kJ
11. A 30.00-g sample of an unknown metal was removed from boiling water and placed in a coffee-cup calorimeter containing 100.00 g of water. The water in the calorimeter was initially 20.0°C, while the boiling water was 99.0°C. When the temperature of the water in the calorimeter became constant, the final temperature of water and metal was 22.4°C. Identify the unknown metal by calculating its specific heat and comparing the calculated value with the accepted values of the substances, listed in Table 16-1. *Ans.* 0.44 J/g°C