Chapter 14

HEAT

Problems

1. **(a)** **Strategy** The gravitational potential energy of the 1.4 kg of water is converted to internal energy in the 6.4-kg system.

Solution Compute the increase in internal energy.

$U = mgh = (1.4\text{ kg})(9.80\text{ m/s}^2)(2.5\text{ m}) = \boxed{34\text{ J}}$

(b) **Strategy and Solution** $\boxed{\text{Yes; the increase in internal energy increases the average kinetic energy of the water molecules, thus the temperature is slightly increased}}$.

9. **Strategy** The conversion factor is $1\text{ kW}\cdot\text{h} = 3.600\text{ MJ}$.

Solution Convert 1.00 kJ to kilowatt-hours.

$$(1.00\times10^3\text{ J})\frac{1\text{ kW}\cdot\text{h}}{3.600\times10^6\text{ J}} = \boxed{2.78\times10^{-4}\text{ kW}\cdot\text{h}}$$

17. **Strategy** The heat capacity of an object is equal to its mass times its specific heat. The mass of an object is equal to its density times its volume.

Solution Find the heat capacities.

(a) $C = mc = \rho Vc = (2702\text{ kg/m}^3)(1.00\text{ m}^3)[0.900\text{ kJ/(kg}\cdot\text{K)}] = \boxed{2430\text{ kJ/K}}$

(b) $C = mc = \rho Vc = (7860\text{ kg/m}^3)(1.00\text{ m}^3)[0.44\text{ kJ/(kg}\cdot\text{K)}] = \boxed{3500\text{ kJ/K}}$

29. **(a)** **Strategy** Phase changes are indicated by the graph where the temperature is constant while heat is added.

Solution Initially, the substance is solid. As the temperature increases, the substance changes from the solid to the liquid phase, then from the liquid phase to the gas phase. There are two phase changes shown by the graph: from $\boxed{\text{B to C, solid to liquid}}$; and from $\boxed{\text{D to E, liquid to gas}}$.

(b) **Strategy and Solution** The beginning of the phase change from solid to liquid indicates the melting point of the substance. That point is labeled by the letter $\boxed{\text{B}}$.

(c) **Strategy and Solution** The beginning of the phase change from liquid to gas indicates the boiling point of the substance. That point is labeled by the letter $\boxed{\text{D}}$.

37. **Strategy** The sum of the heat flows is zero. The tea is basically water. The mass of the tea is found by multiplying the density of water by the volume of the tea. Do not neglect the temperature change of the glass. Use Eqs. (14-4) and (14-9).

Solution Find the mass of the ice required to cool the tea to 10.0°C. Let ΔT be the temperature change of the tea and the glass.

$$0 = Q_t + Q_{ice} + Q_g$$
$$0 = \rho_w V_t c_w \Delta T + m_{ice} L_f + m_{ice} c_{ice} \Delta T_1 + m_{ice} c_w \Delta T_2 + m_g c_g \Delta T$$
$$0 = (\rho_w V_t c_w + m_g c_g)\Delta T + m_{ice}(L_f + c_{ice}\Delta T_1 + c_w \Delta T_2)$$
$$m_{ice} = \frac{-(\rho_w V_t c_w + m_g c_g)\Delta T}{L_f + c_{ice}\Delta T_1 + c_w \Delta T_2}$$
$$= \frac{-\{(1.00\times10^3\ \text{kg/m}^3)(2.00\times10^{-4}\ \text{m}^3)[4.186\ \text{kJ/(kg}\cdot\text{K)}] + (0.35\ \text{kg})[0.837\ \text{kJ/(kg}\cdot\text{K)}]\}(-85.0\ \text{K})}{333.7\ \text{kJ/kg} + [2.1\ \text{kJ/(kg}\cdot\text{K)}](10.0\ \text{K}) + [4.186\ \text{kJ/(kg}\cdot\text{K)}](10.0\ \text{K})}$$
$$= \boxed{242\ \text{g}}$$

The percentage change from the answer for Problem 40 is $\frac{242\ \text{g} - 179\ \text{g}}{179\ \text{g}} \times 100\% = \boxed{35\%}$.

49. Strategy Use Eq. (14-12).

Solution Compute the thermal resistance for each material.

(a) $R = \frac{d}{\kappa A} = \frac{2.0\times10^{-2}\ \text{m}}{[0.17\ \text{W/(m}\cdot\text{K)}](1.0\ \text{m}^2)} = \boxed{0.12\ \text{K/W}}$

(b) $R = \frac{2.0\times10^{-2}\ \text{m}}{[80.2\ \text{W/(m}\cdot\text{K)}](1.0\ \text{m}^2)} = \boxed{2.5\times10^{-4}\ \text{K/W}}$

(c) $R = \frac{2.0\times10^{-2}\ \text{m}}{[401\ \text{W/(m}\cdot\text{K)}](1.0\ \text{m}^2)} = \boxed{5.0\times10^{-5}\ \text{K/W}}$

61. Strategy Use Stefan's law of radiation, Eq. (14-16).

Solution Compute the power radiated by the bulb.
$3 = e\sigma AT^4 = 0.32[5.670\times10^{-8}\ \text{W/(m}^2\cdot\text{K}^4)](1.00\times10^{-4}\ \text{m}^2)(3.00\times10^3\ \text{K})^4 = \boxed{150\ \text{W}}$

73. Strategy Use Eq. (14-4) and the relationship between power and intensity.

Solution The energy provided by the sunlight is converted to heat in the water. The energy provided is $3\,\Delta t = IA\Delta t.$ Compute the time to heat the water.
$Q = mc\Delta T = IA\Delta t,$ so $\Delta t = \frac{mc\Delta T}{IA} = \frac{(1.0\ \text{L})(1000\ \text{g/L})[4.186\ \text{J/(g}\cdot\text{K)}](100.0-15.0)\ \text{K}}{(750\ \text{W/m}^2)(1.5\ \text{m}^2)} = \boxed{320\ \text{s}}$.

89. Strategy Gravitational potential energy is converted into internal energy. Use Eq. (14-9) and $U = mgh$.

Solution Find the mass of the ice melted by friction.
$Q = m_m L_f = 0.75U = 0.75mgh,$ so $m_m = \frac{0.75mgh}{L_f} = \frac{0.75(75\ \text{kg})(9.80\ \text{m/s}^2)(2.43\ \text{m})}{333{,}700\ \text{J/kg}} = \boxed{4.0\ \text{g}}$.

101. Strategy Multiply the energy required to melt the urethane by the molar mass and divide by the total mass to find the latent heat.

Solution Find the latent heat of fusion of urethane.

$$\frac{(17.10\ \text{kJ})[3(12.011)+7(1.00794)+2(15.9994)+14.00674]\ \text{g/mol}}{1.00\times 10^{2}\ \text{g}}=\boxed{15.2\ \text{kJ/mol}}$$