Chapter 6: Thermal Energy and Society

Mini Investigation: Will It Pop?, page 269

A. Answers may vary. Sample answer:
For the water-filled balloon: water has a high heat capacity. This means that it takes lots of heat to increase the thermal energy of the water. When the temperature of the water increases, the liquid boils becoming a gas. The gas expands the balloon sides until the balloon bursts.
For the air-filled balloon: air has a low heat capacity. It is a ready conductor of heat. Heating the balloon quickly increases the thermal energy of the air, causing the gas to expand until the balloon bursts.

Section 6.1: Warmth and Coldness

Tutorial 1 Practice, page 273

1. (a) Given: $T_C = 32$ °C
Required: T_K
Analysis: $T_K = T_C + 273$
Solution:

$$\begin{aligned} T_K &= T_C + 273 \\ &= 32 + 273 \\ T_K &= 305 \text{ K} \end{aligned}$$

Statement: The temperature 32 °C is equal to 305 K.
(b) Given: $T_C = -10$ °C
Required: T_K
Analysis: $T_K = T_C + 273$
Solution:

$$\begin{aligned} T_K &= T_C + 273 \\ &= -10 + 273 \\ T_K &= 263 \text{ K} \end{aligned}$$

Statement: The temperature – 10 °C is equal to 263 K.
(c) Given: $T_C = 95$ °C
Required: T_K
Analysis: $T_K = T_C + 273$
Solution:

$$\begin{aligned} T_K &= T_C + 273 \\ &= 95 + 273 \\ T_K &= 368 \text{ K} \end{aligned}$$

Statement: The temperature 95 °C is equal to 368 K.
2. (a) Given: $T_K = 200$ K
Required: T_C
Analysis: $T_C = T_K - 273$
Solution:

$$\begin{aligned} T_C &= T_K - 273 \\ &= 200 - 273 \\ T_C &= -73 \text{ °C} \end{aligned}$$

Statement: The temperature 200 K is equal to –73 °C.
(b) Given: $T_K = 373$ K
Required: T_C
Analysis: $T_C = T_K - 273$
Solution:

$$\begin{aligned} T_C &= T_K - 273 \\ &= 373 - 273 \\ T_C &= 100 \text{ °C} \end{aligned}$$

Statement: The temperature 373 K is equal to 100 °C.
(c) Given: $T_K = 298$ K
Required: T_C
Analysis: $T_C = T_K - 273$
Solution:

$$\begin{aligned} T_C &= T_K - 273 \\ &= 298 - 273 \\ T_C &= 25 \text{ °C} \end{aligned}$$

Statement: The temperature 298 K is equal to 25 °C.

Mini Investigation: Film Canister Thermometer, page 273

A. The density of a liquid changes with temperature. This is the basis of any liquid thermometer. For a film canister thermometer, the density of liquid water decreases as the temperature of the water increases from 0 °C to room temperature. The density decreases because the volume of the liquid water increases as its temperature increases.
B. The distance the liquid rises will be noticeable but measurements will vary from student to student. Therefore, the thermometer cannot be very accurate.
C. The thermometer could be improved if narrower straws or very narrow hollow cylinders like capillary needles were used so that minute increases in the height of the water in the straw could be measured. Another improvement would be to use a liquid with a lower boiling point than water, like alcohol, but then the thermometer must be airtight to prevent evaporation of the alcohol.

D. The canister thermometer is not practical when measuring the temperature of a liquid because each student's thermometer will be calibrated a little differently, so the results will not all be the same.

Section 6.1 Questions, page 274

1. Temperature is a measure of the average kinetic energy of the particles in a substance. Thermal energy is the sum of the total potential energy and the total kinetic energy possessed by the particles in a substance.

2. The kinetic molecular theory states that as particles of matter gain kinetic energy, they move faster and further apart, raising the temperature and changing substances from a solid to a liquid or from a liquid to a solid. It also states that as particles of matter lose kinetic energy, they move more slowly and get closer together, lowering the temperature and changing a gas to a liquid or a liquid to a solid.

3. A temperature thermometer is a sealed glass tube containing liquid mercury (or coloured alcohol). When placed into a liquid or gas substance, the substance particles bump into the thermometer glass particles. When the temperature of the substance increases, the kinetic energy of the particles increases, causing a greater number of collisions with the glass particles. This increases the kinetic energy of the glass particles. The faster glass particles collide with the slower mercury particles inside the thermometer. This causes the mercury particles to move faster, making them collide more frequently with each other and to spread out. Therefore, the liquid rises up the thermometer. If the temperature of the mercury is lowered, the glass particles collide with the slower moving mercury particles. The glass particles slow down. The mercury particles, which are faster, transfer energy to the glass particles, slowing the mercury particles. The mercury particles have fewer collisions so the space between particles decreases, causing the mercury to go down the thermometer.

4.

Substance	Boiling point (°C)	Boiling point (K)
sodium	882.9	**1155.9**
helium	**–268.78**	4.22
copper	2567	**2840**
mercury	**357**	630

Sodium: Given: T_C = 882.9 °C
Required: T_K
Analysis: $T_K = T_C + 273$
Solution:

$$\begin{aligned} T_K &= T_C + 273 \\ &= 882.9 + 273 \\ T_K &= 1155.9\text{ K} \end{aligned}$$

Statement: The boiling point of sodium is 1155.9 K.

Helium: Given: T_K = 4.22 K
Required: T_C
Analysis: $T_C = T_K - 273$
Solution:

$$\begin{aligned} T_C &= T_K - 273 \\ &= 4.22 - 273 \\ T_C &= -268.78\ ^\circ\text{C} \end{aligned}$$

Statement: The boiling point of helium is –268.78 °C.

Copper: Given: T_C = 2567 °C
Required: T_K
Analysis: $T_K = T_C + 273$
Solution:

$$\begin{aligned} T_K &= T_C + 273 \\ &= 2567 + 273 \\ T_K &= 2840\text{ K} \end{aligned}$$

Statement: The boiling point of copper is 2840 K.

Mercury: Given: T_K = 630 K
Required: T_C
Analysis: $T_C = T_K - 273$
Solution:

$$\begin{aligned} T_C &= T_K - 273 \\ &= 630 - 273 \\ T_C &= 357\ ^\circ\text{C} \end{aligned}$$

Statement: The boiling point of mercury is 357 °C.

5. Answers may vary. Sample answer:
The caloric theory was disproved over a number of years and through experiments by James Prescott Joule and William Thomson (Lord Kelvin). One of Joule's experiments showed that heat was generated in a conductor, not transferred from another area. In another experiment, he measured the heat generated by compressing a gas. Both of these experiments disproved the caloric theory that heat moved from one object to another.

6. The volume of alcohol in a thermometer decreases when it is moved from a warm environment to a colder environment because the glass particles of the thermometer collide with the slower-moving particles of the alcohol, transferring energy to them. This causes the glass particles to slow down. The particles of the alcohol in the thermometer collide with the glass, and transfer energy to them. The particles of the alcohol move more slowly and get closer to each other, decreasing in volume.

7. The freezing point and the melting point of most substances are the same.

Section 6.2: Heat

Mini Investigation: Observing Convection, page 278

Note: Step 5 in the Mini-Investigation was changed to Step 4 after the first printing (the original Step 4 was deleted). The answer to Question B reflects this change.

A. In Step 3, the cold water bottle is placed on top of the warm water bottle. The cold water then falls and pushes up the warmer, less dense water and creates a convection current. This is shown by the movement of the yellow water into the blue water to form a green mixture. This green mixture has a temperature that is a combination of the temperatures for the warm water and cold water.

B. In Step 4, the hot water bottle is placed on top of the cold water bottle. The hot water is less dense than the cold water so it does not fall and push up the colder, denser water. No convection current is created and therefore, the two coloured waters do not mix. The colours of the waters stay pretty much the same.

Section 6.2 Questions, page 280

1. Thermal energy is the *sum* of the potential and kinetic energies possessed by the particles in a substance, but temperature is a measure of the *average* kinetic energy of the particles in a substance. Heat is the transfer of that thermal energy from a substance with a higher temperature to a substance with a lower temperature.

2. Thermal conduction is the movement of thermal energy from a warmer object to a colder object when those objects are touching. Convection is the transfer of thermal energy through a fluid that occurs when a colder, denser fluid falls and pushes a warmer, less dense fluid upwards. Radiation is the movement of thermal energy as electromagnetic waves.

3. A tile floor feels colder than a thick carpet on my bare feet because tile is a better conductor. It allows the thermal energy in my feet to pass from my feet to the tile. The thick carpet is a thermal insulator so it does not allow the thermal energy to move out of my feet.

4. The 4 % of the electricity lost in an inefficient furnace is released as exhaust or heats the furnace itself rather than heating the home.

5. (a) A copper pot is used to heat food because copper is a good thermal conductor and transfers the thermal energy from the stove to the food.

(b) A wooden spoon is used to stir food because it's a good thermal insulator and doesn't transfer the thermal energy from the food into the cook's hand.

(c) A metal ice-cube tray is a good thermal conductor and transfers the thermal energy out of the water and into the freezer, making the ice freeze faster.

(d) A down-filled sleeping bag is a good thermal insulator because it traps air between the feathers. Both air and feathers are good thermal insulators so they slow down the transfer of thermal energy from the sleeper's body to the external environment.

Section 6.3: Heat Capacity

Tutorial 1 Practice, page 283

1. Given: $m = 2.0$ kg; $c_W = 4.18 \times 10^3$ J/(kg • °C); $\Delta T = 10.0$ °C
Required: Q
Analysis: $Q = mc_W\Delta T$
Solution:

$$Q = mc_W\Delta T$$
$$= (2.0\ \cancel{\text{kg}})\left(4.18\times10^3\ \frac{\text{J}}{\cancel{\text{kg}}\bullet\cancel{^\circ\text{C}}}\right)(10\ \cancel{^\circ\text{C}})$$
$$Q = 8.4\times10^4\ \text{J}$$

Statement: The water requires 8.4×10^4 J of thermal energy to raise its temperature by 10.0 °C.

2. Given: $m = 20.0$ kg; $c = 8.4 \times 10^2$ J/(kg • °C); $T_1 = 32.0$ °C; $T_2 = 5.0$ °C
Required: Q
Analysis: $\Delta T = T_2 - T_1$; $Q = mc\Delta T$
Solution:

$$\Delta T = T_2 - T_1$$
$$= 5.0\ ^\circ\text{C} - 32.0\ ^\circ\text{C}$$
$$\Delta T = -27\ ^\circ\text{C}$$

$$Q = mc\Delta T$$
$$= (20.0\ \cancel{\text{kg}})\left(8.4\times10^2\ \frac{\text{J}}{\cancel{\text{kg}}\bullet\cancel{^\circ\text{C}}}\right)(-27\ \cancel{^\circ\text{C}})$$
$$Q = -4.5\times10^5\ \text{J}$$

Statement: The glass window releases 4.5×10^5 J of thermal energy into the surroundings at night.

3. Given: $Q = 1.0 \times 10^4$ J; $\Delta T = 5.0$ °C; $c = 9.2 \times 10^2$ J/(kg • °C)
Required: m
Analysis: $Q = mc\Delta T$
Solution:

$$Q = mc\Delta T$$
$$m = \frac{Q}{c\Delta T}$$
$$= \frac{1.0\times10^4\ \cancel{\text{J}}}{\left(9.2\times10^2\ \frac{\cancel{\text{J}}}{\text{kg}\bullet\cancel{^\circ\text{C}}}\right)(5.0\ \cancel{^\circ\text{C}})}$$
$$m = 2.2\ \text{kg}$$

Statement: The mass of the aluminum block is 2.2 kg.

Tutorial 2 Practice, page 286

1. Given: $m_m = 2.0$ kg; $c_m = 9.2 \times 10^2$ J/(kg • °C); $T_{1m} = 100.0$ °C; $m_a = 1.5$ kg; $c_a = 2.46 \times 10^3 \times$ J/(kg • °C); $T_{1a} = 18.0$ °C
Required: final temperature of aluminum–ethyl alcohol mixture, T_2
Analysis: $Q_{\text{released}} + Q_{\text{absorbed}} = 0$; $Q = mc\Delta T$
Solution:

$$0 = Q_{\text{released}} + Q_{\text{absorbed}}$$
$$0 = m_m c_m \Delta T_m + m_a c_a \Delta T_a$$
$$0 = (2.0\ \cancel{\text{kg}})\left(9.2\times10^2\ \frac{\text{J}}{\cancel{\text{kg}}\bullet{^\circ\text{C}}}\right)(T_2 - 100\ ^\circ\text{C})$$
$$+ (1.5\ \cancel{\text{kg}})\left(2.46\times10^3\ \frac{\text{J}}{\cancel{\text{kg}}\bullet{^\circ\text{C}}}\right)(T_2 - 18.0\ ^\circ\text{C})$$
$$0 = \left(1840\ \frac{\text{J}}{^\circ\text{C}}\right)(T_2 - 100.0\ ^\circ\text{C})$$
$$+ \left(3690\ \frac{\text{J}}{^\circ\text{C}}\right)(T_2 - 18.0\ ^\circ\text{C})$$
$$0 = \left(1840\ \frac{\text{J}}{^\circ\text{C}}\right)T_2 - 184\ 000\ \text{J}$$
$$+ \left(3690\ \frac{\text{J}}{^\circ\text{C}}\right)T_2 - 66\ 420\ \text{J}$$
$$0 = \left(5530\ \frac{\text{J}}{^\circ\text{C}}\right)T_2 - 250\ 420\ \text{J}$$
$$T_2 = \frac{250\ 420\ \cancel{\text{J}}}{5530\ \frac{\cancel{\text{J}}}{^\circ\text{C}}}$$
$$T_2 = 45\ ^\circ\text{C}$$

Statement: The final temperature of the mixture is 45 °C.

2. Given: $m_m = 4.0$ kg; $T_{1m} = 100.0$ °C; $V_w = 500.0$ mL; $T_{1w} = 20.0$ °C; $T_2 = 35.0$ °C
Required: c_m, specific heat capacity of the metal
Analysis: $Q_{\text{released}} + Q_{\text{absorbed}} = 0$; $Q = mc\Delta T$
Solution: Since the quantity of heat equation is based on the mass of a substance, first calculate the mass of water, m_w, in kilograms, using the volume of water, V_w, provided and the density of water.

$$m_w = 500\ \cancel{\text{mL}} \times \frac{1\ \cancel{\text{g}}}{1\ \cancel{\text{mL}}} \times \frac{1\ \text{kg}}{1000\ \cancel{\text{g}}}$$
$$m_w = 0.50\ \text{kg}$$

$$0 = Q_{\text{released}} + Q_{\text{absorbed}}$$
$$0 = m_m c_m \Delta T_m + m_w c_w \Delta T_w$$
$$0 = (4.0\ \text{kg})(c_m)(35.0\ ^\circ\text{C} - 100\ ^\circ\text{C})$$
$$+ (0.50\ \text{kg})\left(4.18\times10^3\ \frac{\text{J}}{\text{kg}\bullet{^\circ\text{C}}}\right)(35.0\ ^\circ\text{C} - 20.0\ ^\circ\text{C})$$

$$0 = (4.0\ \text{kg})(c_m)(-65.0\ °\text{C}) + (0.50\ \text{kg})\left(4.18\times10^3\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(15.0\ °\text{C})$$

$$0 = (-260\ \text{kg}\cdot°\text{C})(c_m) + 31\ 350\ \text{J}$$

$$c_m = \frac{31\ 350\ \text{J}}{260\ \text{kg}\cdot°\text{C}}$$

$$c_m = 1.2\times10^2\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}$$

Statement: The specific heat capacity of the metal is 1.2×10^2 J/(kg • °C).

Section 6.3 Questions, page 287

1. Specific heat capacity is the amount of energy, in joules, required to increase the temperature of 1 kg of a substance by 1 °C. It tells you how much energy a certain substance needs to change its temperature, or how much energy will be released as the substance cools.

2. Given: m = 25.0 g = 0.0250 kg; $c = 2.4 \times 10^2$ J/(kg • °C); T_1 = 50.0 °C; T_2 = 80.0 °C

Required: Q

Analysis: $\Delta T = T_2 - T_1$; $Q = mc\Delta T$

Solution:

$$\Delta T = T_2 - T_1 = 80.0\ °\text{C} - 50.0\ °\text{C}$$

$$\Delta T = 30\ °\text{C}$$

$$Q = mc\Delta T = (0.0250\ \text{kg})\left(2.4\times10^2\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(30\ °\text{C})$$

$$Q = 1.8\times10^2\ \text{J}$$

Statement: The amount of thermal energy required is 1.8×10^2 J.

3. Given: m = 260.0 g = 0.260 kg; $c = 2.1 \times 10^2$ J/(kg • °C); T_1 = –1.0 °C; T_2 = –20.0 °C

Required: Q

Analysis: $\Delta T = T_2 - T_1$; $Q = mc\Delta T$

Solution:

$$\Delta T = T_2 - T_1 = -20.0\ °\text{C} - (-1.0\ °\text{C})$$

$$\Delta T = -19\ °\text{C}$$

$$Q = mc\Delta T = (0.260\ \text{kg})\left(2.1\times10^3\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(-19\ °\text{C})$$

$$Q = -1.0\times10^4\ \text{J}$$

Statement: The amount of thermal energy released is 1.0×10^4 J.

4. Given: Q = –1520 J; m = 50.0 g = 0.0500 kg; T_1 = 100. 0 °C; T_2 = 20.0 °C

Required: c, specific heat capacity of the metal

Analysis: $\Delta T = T_2 - T_1$; $Q = mc\Delta T$

Solution:

$$\Delta T = T_2 - T_1 = 20.0\ °\text{C} - 100.0\ °\text{C}$$

$$\Delta T = -80.0\ °\text{C}$$

$$Q = mc\Delta T$$

$$-1520\ \text{J} = (0.0500\ \text{kg})(c)(-80.0\ °\text{C})$$

$$-1520\ \text{J} = (-4.00\ \text{kg}\cdot°\text{C})c$$

$$c = \frac{-1520\ \text{J}}{-4.00\ \text{kg}\cdot°\text{C}}$$

$$c = 3.8\times10^2\ \text{J/(kg}\cdot°\text{C)}$$

Statement: The specific heat capacity for the sample of metal is 3.8×10^2 J/(kg • °C), so the metal is copper.

5. Given: $c = 6.3 \times 10^2$ J/(kg • °C); Q = 302 J; m = 60.0 g = 0.0600 kg; T_1 = 10.0 °C

Required: T_2

Analysis: $\Delta T = T_2 - T_1$; $Q = mc\Delta T$

Solution:

$$Q = mc\Delta T$$

$$-302\ \text{J} = (0.06\ \text{kg})\left(6.3\times10^2\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(T_2 - 10.0\ °\text{C})$$

$$-302\ \text{J} = \left(37.8\ \frac{\text{J}}{°\text{C}}\right)(T_2 - 10.0\ °\text{C})$$

$$\frac{-302\ \text{J}}{37.8\ \frac{\text{J}}{°\text{C}}} = T_2 - 10.0\ °\text{C}$$

$$8.0\ °\text{C} = T_2 - 10.0\ °\text{C}$$

$$T_2 = 18\ °\text{C}$$

Statement: The final temperature of the calcium is 18 °C.

6. Given: $c_m = 1.29 \times 10^2$ J/(kg • °C); T_{1m} = 95 °C; V_a = 500 mL; $c_a = 2.46 \times 10^3$ J/(kg • °C); T_{1a} = 25.0 °C; T_2 = 27.0 °C

Required: m_m, the mass of the gold

Analysis: $Q_{released} + Q_{absorbed} = 0$; $Q = mc\Delta T$

Solution: Since the quantity of heat equation is based on the mass of a substance, first calculate the mass of ethyl alcohol, m_a, in kilograms, using the volume of ethyl alcohol, V_a, provided and the density of ethyl alcohol.

$$m_a = 500\ \text{mL} \times \frac{0.789\ \text{g}}{1\ \text{mL}} \times \frac{1\ \text{kg}}{1000\ \text{g}}$$

$m_a = 0.395$ kg (two extra digits carried)

$$0 = Q_{\text{released}} + Q_{\text{absorbed}}$$
$$0 = m_m c_m \Delta T_m + m_w c_w \Delta T_w$$
$$0 = (m_m)\left(1.29 \times 10^2\ \frac{\text{J}}{\text{kg•°C}}\right)(27.0\ °\text{C} - 95.0\ °\text{C}) + (0.395\ \text{kg})\left(2.46 \times 10^3\ \frac{\text{J}}{\text{kg•°C}}\right)(27.0\ °\text{C} - 25.0\ °\text{C})$$
$$0 = (m_m)\left(1.29 \times 10^2\ \frac{\text{J}}{\text{kg•}\cancel{°\text{C}}}\right)(-68.0\ \cancel{°\text{C}}) + (0.395\ \cancel{\text{kg}})\left(2.46 \times 10^3\ \frac{\text{J}}{\cancel{\text{kg}}•\cancel{°\text{C}}}\right)(2.0\ \cancel{°\text{C}})$$
$$0 = (m_m)\left(-8.772 \times 10^3\ \frac{\text{J}}{\text{kg}}\right) + 1.943 \times 10^3\ \text{J}$$
$$m_m = \frac{1.943 \times 10^3\ \cancel{\text{J}}}{8.772 \times 10^3\ \frac{\cancel{\text{J}}}{\text{kg}}} = 0.222\ \text{kg}$$
$$m_m = 220\ \text{g}$$

Statement: The mass of the gold is 220 g.

7. Given: $m_m = 2.0$ kg; $T_{1m} = -25.0$ °C; $V_w = 3.0$ L; $T_{1w} = 40.0$ °C; $T_2 = 36.0$ °C

Required: c_m, specific heat capacity of the metal

Analysis: $Q_{\text{released}} + Q_{\text{absorbed}} = 0$; $Q = mc\Delta T$

Solution: Since the quantity of heat equation is based on the mass of a substance, first calculate the mass of water, m_w, in kilograms, using the volume of water, V_w, provided and the density of water.

$$m_w = 3000\ \text{mL} \times \frac{1\ \text{g}}{1\ \text{mL}} \times \frac{1\ \text{kg}}{1000\ \text{g}}$$
$$m_w = 3.0\ \text{kg}$$

$$0 = Q_{\text{released}} + Q_{\text{absorbed}}$$
$$0 = m_m c_m \Delta T_m + m_w c_w \Delta T_w$$
$$0 = (2.0\ \text{kg})(c_m)(36.0\ °\text{C} - (-25.0\ °\text{C})) + (3.0\ \text{kg})\left(4.18 \times 10^3\ \frac{\text{J}}{\text{kg•°C}}\right)(36.0\ °\text{C} - 40.0\ °\text{C})$$
$$0 = (122.0\ \text{kg•°C})(c_m) - 50\ 160\ \text{J}$$
$$c_m = \frac{50\ 160\ \text{J}}{122.0\ \text{kg•°C}}$$
$$c_m = 4.1 \times 10^2\ \text{J/(kg•°C)}$$

Statement: The specific heat capacity of the metal is 4.1×10^2 J/(kg • °C).

8. Given: $m_m = 1.50 \times 10^2$ g = 0.150 kg; $c_m = 3.80 \times 10^2$ J/(kg • °C); $V_w = 400.0$ mL; $c_w = 4.18 \times 10^3$ J/(kg • °C); $T_{1w} = 27.7$ °C; $T_2 = 28.0$ °C

Required: T_{1m}

Analysis: $Q_{\text{released}} + Q_{\text{absorbed}} = 0$; $Q = mc\Delta T$

Solution: Since the quantity of heat equation is based on the mass of a substance, first calculate the mass of water, m_w, in kilograms, using the volume of water, V_w, provided and the density of water.

$$m_w = 400\ \text{mL} \times \frac{1\ \text{g}}{1\ \text{mL}} \times \frac{1\ \text{kg}}{1000\ \text{g}}$$
$$m_w = 0.4\ \text{kg}$$

$$0 = Q_{\text{released}} + Q_{\text{absorbed}}$$
$$0 = m_m c_m \Delta T_m + m_w c_w \Delta T_w$$
$$0 = (0.15\ \cancel{\text{kg}})\left(3.80 \times 10^2\ \frac{\text{J}}{\cancel{\text{kg}}•°\text{C}}\right)(28.0\ °\text{C} - T_{1m}) + (0.4\ \text{kg})\left(4.18 \times 10^3\ \frac{\text{J}}{\text{kg•°C}}\right)(28.0\ °\text{C} - 27.7\ °\text{C})$$
$$0 = \left(57.00\ \frac{\text{J}}{°\text{C}}\right)(28.0\ °\text{C} - T_{1m}) + (0.4\ \cancel{\text{kg}})\left(4.18 \times 10^3\ \frac{\text{J}}{\cancel{\text{kg}}•\cancel{°\text{C}}}\right)(0.3\ \cancel{°\text{C}})$$
$$0 = \left(57.00\ \frac{\text{J}}{°\text{C}}\right)(28.0\ °\text{C} - T_{1m}) + 501.6\ \text{J}$$
$$-501.6\ \text{J} = \left(57.00\ \frac{\text{J}}{°\text{C}}\right)(28.0\ °\text{C} - T_{1m})$$
$$\frac{-501.6\ \cancel{\text{J}}}{57.00\ \frac{\cancel{\text{J}}}{°\text{C}}} = 28.0\ °\text{C} - T_{1m}$$
$$T_{1m} = 28.0\ °\text{C} + 8.8\ °\text{C}$$
$$T_{1m} = 36.8°\text{C}$$

Statement: The initial temperature of the brass was 36.8 °C.

9. Answers may vary. Sample answer:
Civil engineers must consider temperature changes when designing building structures so that when the materials expand and contract in hot and cold temperatures, respectively, the building or structure is not damaged. For example, bridges have expansion joints so that when the metal components expand on hot summer days, the pressure will not bend the bridge.

10. Answers may vary. Sample answer:
Thermal expansion refers to the increase in volume of a material as its temperature increases. Thermal contraction refers to the decrease in volume of a material as its temperature decreases. Thermal expansion is an important factor to consider in the design of homes. Thermal expansion of water in plumbing is often a problem in older homes. For example, when water is heated, it expands. The extra volume of water must go somewhere. When the plumbing system is closed, the extra volume has no place to go, so the pressure in a home's plumbing system can increase. Symptoms of high pressure are pressure surges, chronic dripping of the home's water heater temperature and pressure valve, dripping faucets, and leaking ballcocks (assuming plumbing seals are in good condition). Innovations in plumbing products such as pressure-reducing valves, backflow preventers, and other types of valves are now part of most home building codes.

Section 6.4: States of Matter and Changes of State

Tutorial 1 Practice, page 293

1. Since a change of state is occurring, use $Q = mL_i$ to solve the problem.

Given: V_w = 2.0 L = 2000 mL; L_f = 3.4 × 10^5 J/kg

Required: Q, latent heat of fusion

Analysis: $Q = mL_i$

Solution: Since the latent heat equation is based on the mass of a substance, first calculate the mass of water, m_w, in kilograms, using the volume of water, V_w, provided and the density of water.

$$m_w = 2000\ \cancel{\text{mL}} \times \frac{1\ \cancel{\text{g}}}{1\ \cancel{\text{mL}}} \times \frac{1\ \text{kg}}{1000\ \cancel{\text{g}}}$$

$$m_w = 2.0\ \text{kg}$$

$$Q = mL_f$$
$$= (2.0\ \cancel{\text{kg}})(3.4 \times 10^5\ \text{J}/\cancel{\text{kg}})$$
$$Q = 6.8 \times 10^5\ \text{J}$$

Statement: The liquid water releases 6.8 × 10^5 J of thermal energy when it freezes.

2. Since a change of state is occurring, use $Q = mL_i$ to solve the problem.

Given: m_m = 350 g = 0.35 kg; L_f = 1.1 × 10^6 J/kg

Required: Q, latent heat of fusion

Analysis: $Q = mL_i$

Solution:

$$Q = mL_f$$
$$= (0.35\ \cancel{\text{kg}})(1.1 \times 10^6\ \text{J}/\cancel{\text{kg}})$$
$$Q = 3.9 \times 10^5\ \text{J}$$

Statement: When the gold melts, 3.9 × 10^5 J of thermal energy is absorbed.

3. Given: m_w = 500 g = 0.5 kg; L_v = 2.3 × 10^6 J/kg; c = 4.18 × 10^3 J/(kg • °C); T_1 = 100 °C; T_2 = 50 °C

Required: Q_{total}, total amount of thermal energy released

Analysis: $Q_1 = mL_v$; $Q_2 = mc\Delta T$; $Q_{total} = Q_1 + Q_2$

Solution:

$$Q_1 = mL_v$$
$$= (0.5\ \cancel{\text{kg}})(2.3 \times 10^6\ \text{J}/\cancel{\text{kg}})$$
$$Q_1 = 1.15 \times 10^6\ \text{J (one extra digit carried)}$$

$$Q_2 = mc\Delta T$$
$$= (0.5\ \cancel{\text{kg}})\left(4.18 \times 10^3\ \frac{\text{J}}{\cancel{\text{kg}} \bullet \cancel{°\text{C}}}\right)(50\ \cancel{°\text{C}} - 100\ \cancel{°\text{C}})$$
$$Q_2 = 1.05 \times 10^5\ \text{J (one extra digit carried)}$$

$$Q_{total} = Q_1 + Q_2$$
$$= 1.15 \times 10^6\ \text{J} + 1.05 \times 10^5\ \text{J}$$
$$Q_{total} = 1.3 \times 10^6\ \text{J}$$

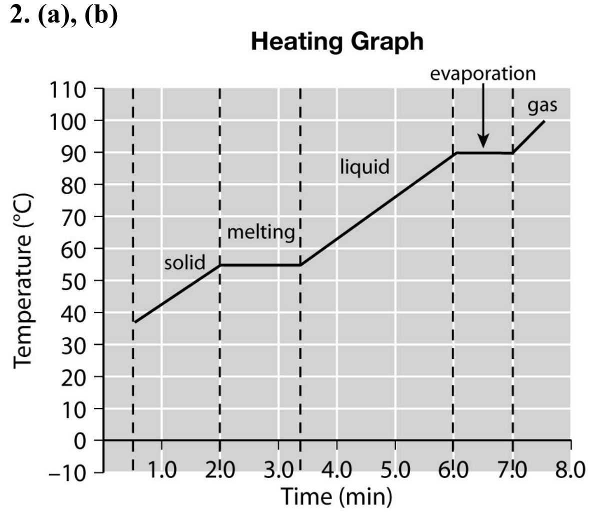
Statement: The total amount of thermal energy released is 1.3 × 10^6 J.

Section 6.4 Questions, page 295

1. (a) The first section of the graph, where the line is going down, shows a single-state substance cooling down. The second section of the graph, where the line is horizontal and the temperature is stable, shows a substance changing states, either from a gas to a liquid or from a liquid to a solid. The third section of the graph, where the line is again going down, shows the substance, in its new state, cooling down again.

(b) This is a cooling graph. It is a cooling graph because the temperature is decreasing.

2. (a), (b)



(c) The melting point of the substance occurs at 55 °C. The boiling point of the substance occurs at 90 °C.

3. Liquid water cannot reach a temperature of 110 °C. At 100 °C, liquid water begins to change state into its gas state: water vapour. It remains at 100 °C until all the water has evaporated, at which point the gas can heat up to 110 °C.

4. Latent heat of fusion is the amount of thermal energy required to change a solid into a liquid or a liquid into a solid. Latent heat of vaporization is the amount of thermal energy required to change a liquid into a gas or a gas into a liquid.

5. Frost can damage fruit because it forms ice crystals on the outside of the fruit. This causes moisture to be drawn out of the fruit, dehydrating it. Fruit growers can prevent fruit from freezing by spraying the fruit with water because, as the water freezes and evaporation starts, the fruit releases its thermal energy to the fruit. The theory of latent heat says that the water will remain at 0 °C until all of it has frozen, so it protects the fruit from dropping below 0 °C and freezing, even if the outside air drops below zero.

6. Since a change of state is occurring, use $Q = mL_f$ to solve the problem.

Given: m_m = 2.40 kg; $L_f = 1.1 \times 10^6$ J/kg

Required: Q, latent heat of fusion

Analysis: $Q = mL_f$

Solution:

$$Q = mL_f$$
$$= (2.40 \not{kg})(1.1\times10^6 \text{ J}/\not{kg})$$
$$Q = 2.6\times10^5 \text{ J}$$

Statement: The latent heat of fusion is 2.6×10^6 J.

7. Given: m = 100 g = 0.1 kg; $c_w = 4.18 \times 10^3$ J/(kg • °C); T_1 = –20 °C; T_2 = 0 °C; $L_f = 3.4 \times 10^5$ J/kg; T_3 = 0 °C; T_4 = 100 °C; $L_v = 2.3 \times 10^6$ J/kg; T_5 = 100 °C; T_6 = 110 °C

Required: Q, thermal energy required

Analysis: $Q = mL_f$; $Q = mL_v$; $Q = mc\Delta T$

Solution: To find the total thermal energy required, break the problem down into six steps.

Step 1: Calculate the energy required to bring the ice from –20 °C to its melting point at 0 °C.

$$Q_1 = mc\Delta T$$
$$= (0.1 \not{kg})\left(4.18\times10^3 \frac{\text{J}}{\not{kg}\bullet\not{°C}}\right)(20 \not{°C})$$
$$Q_1 = 8.36\times10^3 \text{ J (one extra digit carried)}$$

Step 2: Calculate the energy required to change the state of the water from ice to liquid water.

$$Q_2 = mL_f$$
$$= (0.1 \not{kg})(3.4\times10^5 \text{ J}/\not{kg})$$
$$Q_2 = 3.4\times10^4 \text{ J}$$

Step 3: Calculate the energy required to bring the water from 0 °C to its vaporizing point at 100 °C.

$$Q_3 = mc\Delta T$$
$$= (0.1 \not{kg})\left(4.18\times10^3 \frac{\text{J}}{\not{kg}\bullet\not{°C}}\right)(100 \not{°C})$$
$$Q_3 = 4.18\times10^4 \text{ J (one extra digit carried)}$$

Step 4: Calculate the energy required to change the state of the water from liquid to gas.

$$Q_4 = mL_v$$
$$= (0.1 \not{kg})(2.3\times10^6 \text{ J}/\not{kg})$$
$$Q_4 = 2.3\times10^5 \text{ J}$$

Step 5: Calculate the energy required to bring the water from its vaporizing point of 100 °C to 110 °C.

$$Q_5 = mc\Delta T$$
$$= (0.1 \not{kg})\left(4.18\times10^3 \frac{\text{J}}{\not{kg}\bullet\not{°C}}\right)(10 \not{°C})$$
$$Q_5 = 4.18\times10^3 \text{ J (one extra digit carried)}$$

Step 6: Calculate the total thermal energy.

$$Q_{total} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$$
$$= 8.36\times10^3 \text{ J} + 3.4\times10^4 \text{ J} + 4.18\times10^4 \text{ J}$$
$$+ 2.3\times10^5 \text{ J} + 4.18\times10^3 \text{ J}$$
$$Q_{total} = 3.2\times10^5 \text{ J}$$

Statement: The thermal energy required to change the ice into steam is 3.2×10^5 J.

8. Given: m = 1.50 kg; $c_a = 9.2 \times 10^2$ J/(kg • °C); T_1 = 2700 °C; T_2 = 2519 °C; $L_f = 6.6 \times 10^5$ J/kg; T_3 = 2519 °C; T_4 = 23.0 °C

Required: Q, thermal energy released

Analysis: $Q = mL_f$; $Q = mc\Delta T$

Solution: To calculate the total thermal energy released, break the problem down into four steps.

Step 1: Calculate the energy released when the aluminum cools from 2700 °C to its freezing (melting) point at 2519 °C.

$$Q_1 = mc\Delta T$$
$$= (1.5 \not{kg})\left(9.2\times10^2 \frac{\text{J}}{\not{kg}\bullet°\text{C}}\right)(2519 \text{ °C} - 2700 \text{ °C})$$
$$= \left(13.8\times10^2 \frac{\text{J}}{\not{°C}}\right)(-181 \not{°C})$$
$$Q_1 = -2.498\times10^5 \text{ J (two extra digits carried)}$$

Step 2: Calculate the energy released when the aluminum changes state from a liquid to a solid.

$$Q_2 = mL_f$$
$$= (1.5\ \cancel{\text{kg}})(6.6\times10^5\ \text{J}/\cancel{\text{kg}})$$
$$Q_2 = 9.9\times10^5\ \text{J}$$

Step 3: Calculate the energy released in cooling the solid aluminum from its freezing point at 2519 °C to 23 °C.

$$Q_3 = mc\Delta T$$
$$= (1.5\ \cancel{\text{kg}})\left(9.2\times10^2\ \frac{\text{J}}{\cancel{\text{kg}}\bullet{}^\circ\text{C}}\right)(23\ ^\circ\text{C} - 2519\ ^\circ\text{C})$$
$$= \left(13.8\times10^2\ \frac{\text{J}}{\cancel{^\circ\text{C}}}\right)(-2496\ \cancel{^\circ\text{C}})$$
$$Q_3 = -3.444\times10^6\ \text{J (two extra digits carried)}$$

Step 4: Calculate the total thermal energy released.

$$Q_{\text{total}} = Q_1 + Q_2 + Q_3$$
$$= -2.498\times10^5\ \text{J} + 9.9\times10^5\ \text{J} + (-3.444\times10^6\ \text{J})$$
$$Q_{\text{total}} = -2.7\times10^6\ \text{J}$$

Statement: The thermal energy released during the process was 2.7×10^6 J.

9. In most substances, the solid form sinks within the liquid form because the solid form is denser than the liquid. However, the solid state of water, ice, is less dense than liquid water, so it floats on top. This is because of the structure of the water molecule. The hydrogen atoms of one water molecule have a small positive charge and are attracted to the small negative charge of the oxygen atoms in the neighbouring water molecule. At temperatures above 4 °C, the molecules of water move too fast for the forces of attraction to pull the molecules together. As the temperature decreases, the forces of attraction place the molecules into an organized structure, freezing the water, which takes up more space than the disorganized molecules in liquid water.

Section 6.5: Heating and Cooling Systems

6.5 Questions, page 299

1. Answers may vary. Sample answer:
Forced-air heating systems are popular for a number of reasons: Their duct work can accommodate air conditioning, a humidifier and a filter, they are cheaper to replace than a boiler, they respond quickly to programmable thermostats, and the homeowner does not have to worry about the water pipes causing water damage.

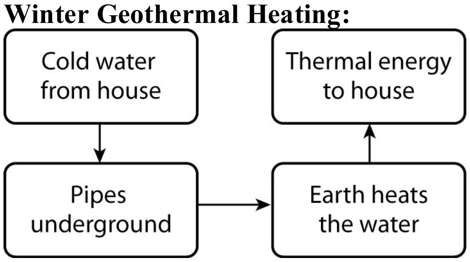
2. Answers may vary. Sample answer:
CFCs are also used as solvents to clean electronic components and as blowing agents in the production of plastic foams.

3. Programmable thermostats work by turning off the furnace or air conditioner when the homeowner does not need them. For example, in the winter at night or when he/she is at work, the homeowner can set the thermostat to a lower temperature. Therefore it will not turn the furnace on until temperatures have really dipped. A smart thermostat gives the homeowner control of the thermostat through a computer. The system sends information about whether a furnace, boiler, or air conditioner is on or off, functioning well, or needs attention. The homeowner can monitor the system from a distance to adjust the temperature. This is especially useful for second homes where the homeowner lives far away.

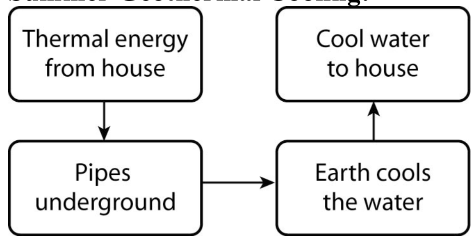
4. Geothermal systems can be used as both a heating system and a cooling system because they use Earth's natural thermal energy for heating and cooling. In the winter, thermal energy is transferred from below Earth's surface into a building to heat it. In the summer, thermal energy is transferred from the building into Earth's surface to cool it.

5.

Winter Geothermal Heating:



Summer Geothermal Cooling:



6. (a) The specific heat capacity value for air is 1.0×10^3 J/(kg • °C).

(b) Answers may vary. Sample answer:
Furnaces and hot water boilers come in different levels of efficiency. As of December 31, 2009, all furnaces in Canada must have an efficiency of at least 90 %. This means low- and mid-efficiency furnaces should no longer be available.
The annual fuel utilization efficiency (AFUE) rating is the ratio of heat output of the unit to the total energy used by the unit in a year. An AFUE of 90 % means that 90 % of the fuel's energy is used for the home, while the other 10 % is lost through the chimney or other vents.
High-efficiency forced-air furnaces and hot water boilers will be compared.
Forced-air furnaces have improved efficiency with the addition of a second heat exchanger. The thermal energy exchanger condenses any gases and uses the thermal energy from this condensation. Hot water boilers also have a second thermal energy exchanger that condenses any water vapour and uses the thermal energy from the condensation. Furnaces usually have a chimney and duct work as part of their thermal energy transport system. Hot water boilers usually have radiators or baseboards to transport heat. Hot water boilers can have higher efficiency ratings than high-efficiency furnaces. More thermal energy is retained because there is no chimney. However, most hot water boilers run on electricity, which currently can be more expensive than fuels for furnaces such as natural gas.

(c) Answers may vary. Sample answer:
Based on cost alone, I would choose a forced-air furnace that uses natural gas. Electricity rates are steadily increasing while natural gas rates will vary depending on demand. The rates will increase during high demand periods and decrease during low demand periods.

Section 6.7: Physics Journal
Section 6.7 Questions, page 303

1. Joule's discoveries changed our understanding of thermal energy because he proved that energy was neither created nor destroyed but that it could be transformed from one form (e.g., mechanical or electrical) into another (e.g., thermal). This disproved the caloric theory, which said that an object became warmer if a fluid-like substance called "caloric" moved from a warm object to a cooler object through contact.

2. Answers may vary. Sample answer:
In science we repeat investigations or conduct a number of related investigations in order to avoid human error and eliminate bias. Sometimes, investigators will unwittingly arrange an investigation to create a desired outcome. By creating a number of related investigations, some of that bias can be eliminated. In addition, established ideas about science are deeply engrained and difficult to change, but if a scientist has approached the problem from a number of angles and consistently received the same information, he or she may persuade fellow scientists. Joule used electricity to heat water and mechanical energy to produce friction and heat water. When those experiments did not convince other scientists, he used a falling mass to turn a paddlewheel, which heated the water. He measured the amount of mechanical energy needed to generate the heat. By showing the same results in several different ways, Joule managed to convince his fellow scientists that energy is conserved.

3. Joule's experiments were not taken seriously because he was a brewer and did not have a scientific education. In fact, he didn't even have formal education. His work was finally accepted by fellow scientists because he was persistent, tried a number of different experiments that showed the same results, and made precise measurements. He was also correct.

4. Joule used a falling mass to turn a paddlewheel suspended in water. As the mass fell over and over again, the wheeled turned continuously until it eventually heated the water. The mechanical energy or heat was measured using a thermometer suspended in the water. All of the apparatus was placed into a barrel with the water.
Today's equivalent of Joule's equipment would be a calorimeter. A calorimeter is usually a sealed but insulated chamber that is filled with water. A thermometer or other heat-measuring device is attached. It is used to measure the thermal energy of reactions, whether chemical or mechanical.

Chapter 6 Review, pages 310–315

Knowledge

1. (d)
2. (b)
3. (d)
4. (b)
5. (c)
6. (a)
7. (a)
8. (d)
9. True
10. True
11. False. In a liquid, the particles vibrate *and can* easily slide past each other or move from place to place.
12. True
13. False. All air conditioners, refrigerators, and freezers use the *evaporation* of a liquid to absorb thermal energy from the air.
14. True
15. True
16. (a) (ii)
(b) (iii)
(c) (i)
(d) (iv)
17. Answers may vary. Sample answer:
Caloric theory states that heat moves from a warm object to a cold object. Three examples from everyday life that disprove that theory are as follows: Rub two cold hands together and the friction created is transferred to thermal energy so both hands warm up; rub two cold sticks together and you may be able to create enough thermal energy to light a fire; a light bulb becomes hot as an electrical current flows through it. It goes from cold to hot.
18. The equation for the quantity of heat is $Q = mc\Delta T$.
19. When water has a temperature of 112 °C it is a gas.
20. Joule initially studied chemistry to learn more about the brewing process so he could work in the family business.
21. When substances are mixed, the thermal energy from the warmer substance makes the particles in the cooler substance vibrate more quickly until both substances have the same amount of thermal energy. At that point, the temperature of both substances will be the same.

Understanding

22. (a) Scientists in the eighteenth century used the theory of caloric to explain warmth and coldness. They believed there was a massless fluid called "caloric" that flowed naturally from warmer objects to colder objects.
(b) James Joule and Benjamin Thompson disproved the theory by showing that mechanical and electrical energy could be transferred into thermal energy. For example, they used friction to show how two cool objects could become hot.
23. For a solid, the particles are very close together. The particles can only move back and forth within a very limited range. For a liquid, the particles are farther apart than in a solid but still close to each other. The particles can move back and forth and slide past each other. For a gas, the particles are father apart than in a liquid or solid. They can move back and forth and freely past each other.
24. (a) When the temperature of the substance increases, the kinetic energy of the particles increases, causing a greater number of collisions with the glass particles of the thermometer. This increases the kinetic energy of the glass particles. The faster glass particles collide with the slower mercury particles inside the thermometer. This causes the mercury particles to move faster, making them collide more frequently with each other and to spread out. Therefore, the liquid rises up the thermometer.
(b) If the temperature of the mercury is lowered, the glass particles collide with the slower moving mercury particles. The glass particles slow down. The mercury particles, which are faster, transfer energy to the glass particles, slowing the mercury particles. The mercury particles have fewer collisions so the space between particles decreases, causing the mercury to go down the thermometer.
25. The three temperature scales used are the Celsius, Fahrenheit, and Kelvin scales. The Celsius scale is based on the temperature at which water boils and freezes. On the Celsius scale, pure water freezes at 0 °C and boils at 100 °C. The Fahrenheit scale is based on the temperature at which a salt-water solution freezes and boils. On the Fahrenheit scale, pure water freezes at 32 °F and boils at 212 °F. The Kelvin scale is based on the amount of thermal energy a substance possesses. Absolute zero on the Kelvin scale is the temperature at which particles of a substance have slowed down so much that they hardly move at all and their

kinetic energy approaches zero. Absolute zero, or 0 K, occurs at –273 °C.

26. Object A can have more thermal energy transferred during the heating process if it has more particles (a greater mass) or is made from a different material.

27. In common language, the word "heat" is incorrectly used to describe a substance that makes objects become warmer. In scientific language, heat is used to describe the transfer of thermal energy from a warmer object to a cooler one.

28. (a) A spoon becomes warm when stirring a cup of hot tea because the particles in the tea that have a lot of thermal energy vibrate and bump into the particles in the spoon, making them vibrate and have more thermal energy.

(b) The Sun emits electromagnetic waves that transfer thermal energy by radiation and warms Earth.

(c) The handle of a metal spoon becomes hot if it is left inside a cooking pot on the stove because the thermal energy from the stove is transferred to the pot. The pot transfers the energy to the bottom of the spoon and the thermal energy transfers up the length of the spoon to the handle.

(d) The second floor of a house becomes warmer than the first floor because of convection: the colder, denser air in the house falls, forcing the warmer, less dense air to rise.

29. If the ring is heated, it, too, would grow in size. Then the ball should have no problems fitting through the ring.

In both heating the ball and the ring, the increase in thermal energy makes the particles of the metal vibrate and the particles move apart, expanding both objects.

30. Your finger sticks to a metal ice tray because metal is a good conductor and it quickly conducts the thermal energy away from the skin on your finger, making a layer of ice form between your finger and the tray.

31. Specific heat capacity is the amount of energy needed to raise the temperature of 1 kg of a substance by 1 °C. If an object has a large specific heat capacity, it means it requires more energy to raise its temperature. If an object has a small specific heat capacity, it means it requires less energy to raise its temperature.

32. (a) I would want the wire filaments in a toaster to be made of a material with a small specific heat capacity so that it would require less energy to heat up and cook the toast.

(b) I would want insulation for electric wires to be made of a material with a large specific heat capacity so that they would require a lot of energy to become hot.

(c) I would want the handles for cookware to be made of a material with a large specific heat capacity so that they would require a lot of energy to become hot.

(d) I would want the part of cookware that is in contact with the stove to be made of a material with a small specific heat capacity so that it would require less energy to heat up and cook the food.

33. Given: $m = 300$ g = 0.3 kg; $T_1 = 120$ °C; $T_2 = 55$ °C; $c = 9.2 \times 10^2$ J/(kg • °C)

Required: Q

Analysis: $\Delta T = T_2 - T_1$; $Q = mc\Delta T$

Solution:

$$\begin{aligned}\Delta T &= T_2 - T_1 \\ &= 55\ °\text{C} - 120\ °\text{C} \\ \Delta T &= -65\ °\text{C}\end{aligned}$$

$$\begin{aligned}Q &= mc\Delta T \\ &= (0.3\ \cancel{\text{kg}})\left(9.2\times10^2\ \frac{\text{J}}{\cancel{\text{kg}}\bullet\cancel{°\text{C}}}\right)(-65\ \cancel{°\text{C}}) \\ Q &= -1.8\times10^4\ \text{J}\end{aligned}$$

Statement: The thermal energy lost is 1.8×10^4 J.

34. Given: $Q = 8.7 \times 10^2$ J; $m = 50$ g = 0.05 kg; $c = 1.3 \times 10^2$ J/(kg·°C); $T_1 = 22$ °C

Required: T_2

Analysis: $\Delta T = T_2 - T_1$; $Q = mc\Delta t$

Solution: Rearrange $Q = mc\Delta t$ to solve for T_2.

$$Q = mc\Delta T$$

$$8.7\times10^2\ \text{J} = (0.05\ \cancel{\text{kg}})\left(1.3\times10^2\ \frac{\text{J}}{\cancel{\text{kg}}\bullet°\text{C}}\right)(T_2 - 22\ °\text{C})$$

$$8.7\times10^2\ \text{J} = \left(6.5\ \frac{\text{J}}{°\text{C}}\right)(T_2 - 22\ °\text{C})$$

$$\frac{8.7\times10^2\ \cancel{\text{J}}}{6.5\ \frac{\cancel{\text{J}}}{°\text{C}}} = T_2 - 22\ °\text{C}$$

$$\begin{aligned}T_2 &= 134\ °\text{C} + 22\ °\text{C} \\ &= 156\ °\text{C} \\ T_2 &= 160\ °\text{C}\end{aligned}$$

Statement: The final temperature of the lead was 160 °C.

35. Given: $Q = 1.2 \times 10^6$ J; $T_1 = 28$ °C; $T_2 = 440$ °C; $c = 8.4 \times 10^2$ J/(kg • °C)
Required: m
Analysis: $Q = mc\Delta t$
Solution:

$$Q = mc\Delta T$$

$$1.2\times10^6 \text{ J} = m\left(8.4\times10^2 \ \frac{\text{J}}{\text{kg•°C}}\right)(440 \text{ °C} - 28 \text{ °C})$$

$$1.2\times10^6 \text{ J} = m\left(8.4\times10^2 \ \frac{\text{J}}{\text{kg•}\cancel{\text{°C}}}\right)(412 \ \cancel{\text{°C}})$$

$$1.2\times10^6 \text{ J} = m\left(3.46\times10^5 \ \frac{\text{J}}{\text{kg}}\right) \text{ (one extra digit carried)}$$

$$m = \frac{1.2\times10^6 \ \cancel{\text{J}}}{3.46\times10^5 \ \frac{\cancel{\text{J}}}{\text{kg}}}$$

$$m = 3.5 \text{ kg}$$

Statement: The mass of the block is 3.5 kg.

36. (a) The thermal energy in the silver ring is passed into the mould, making the mould's molecules vibrate and heat up. The thermal energy in the mould is passed into the surrounding air.
(b) As the silver cools, its molecules vibrate less and arrange themselves in a tighter configuration. The liquid freezes into a solid in a process called fusion. In addition, the silver decreases in volume through the process of contraction.

37. (a) The symbols for quantity of heat and latent heat are both Q.
(b) They are the same because they both represent amounts of thermal energy absorbed or released.

38. As the thermal energy increases from point A to point B, the substance is in a solid state but its temperature is rising. From point B to point C, the temperature remains constant so there is a change of state occurring, from a solid to a liquid. From point C to point D, the thermal energy and temperature are both rising in the liquid. From point D to point E, the temperature remains the same so there is a change of state occurring, from a liquid to a gas. From point E to point F, the temperature and thermal energy are both rising as the gas continues to heat up.

39. When a substance changes state—melts, boils, condenses or freezes—the absorbed or released thermal energy is being transferred into potential energy not kinetic energy. Since the kinetic energy of the particles does not change, the temperature of the substance remains constant during a change of state.

40. Given: $m = 275$ g = 0.275 kg; $L_v = 8.6 \times 10^5$ J/kg
Required: Q
Analysis: $Q = mL_v$
Solution:

$$Q = mL_v$$

$$= (0.275 \ \cancel{\text{kg}})\left(8.6\times10^5 \ \frac{\text{J}}{\cancel{\text{kg}}}\right)$$

$$Q = 2.4\times10^5 \text{ J}$$

Statement: Ethyl alcohol releases 2.4×10^5 J of thermal energy when it condenses from a gas to a liquid.

41. Given: $Q = 2.1 \times 10^3$ J; $m = 0.10$ kg; $T_1 = 19$ °C; $T_2 = 44$ °C
Required: c
Analysis: $Q = mc\Delta T$
Solution: Rearrange $Q = mc\Delta t$ to solve for c.

$$2.1\times10^3 \text{ J} = (0.10 \text{ kg})(c)(44 \text{ °C} - 19 \text{ °C})$$

$$2.1\times10^3 \text{ J} = (0.10 \text{ kg})(c)(25 \text{ °C})$$

$$c = \frac{2.1\times10^3 \text{ J}}{2.5 \text{ kg•°C}}$$

$$c = 8.4\times10^2 \text{ J/(kg•°C)}$$

Statement: The specific heat capacity for the substance is 8.4×10^2 J/(kg • °C). According to Table 1, the substance is glass.

42. (a) Water behaves differently from most other substances because the solid state floats on top of the liquid state rather than sinking.
(b) When water is in a liquid state the small force of attraction experienced between neighbouring hydrogen atoms and oxygen atoms is weak, so the molecules are disorganized and move past one another.

43. If thermal energy is added to a substance that is changing state, it works to break the bonds that hold particles together, making a solid become a liquid or a liquid become a gas. However, if thermal energy is removed, the released energy allows the particles to move closer together and become more organized, making a gas become a liquid or a liquid become a solid.

44. Given: $Q = 2.1 \times 10^4$ J; $L_f = 2.5 \times 10^4$ J/kg
Required: m
Analysis:

$Q = mL_v$

$m = \dfrac{Q}{L_v}$

Solution:

$$m = \frac{Q}{L_v} = \frac{2.1\times10^4 \text{ J}}{2.5\times10^4 \ \frac{\text{J}}{\text{kg}}}$$

$m = 0.84$ kg

Statement: The mass of lead is 0.84 kg.

45. Given: $Q = 6.0 \times 10^4$ J; $L_v = 8.5 \times 10^5$ J/kg
Required: V_a
Analysis:

$Q = m_a L_v$

$m_a = \dfrac{Q}{L_v}$

$V_a = m_a\left(\dfrac{1000 \text{ mL}}{0.789 \text{ kg}}\right)$

Solution:

$$m_a = \frac{Q}{L_v} = \frac{6.0\times10^4 \text{ J}}{8.5\times10^5 \ \frac{\text{J}}{\text{kg}}}$$

$m_a = 0.07$ kg

$$V_a = m_a\left(\frac{1000 \text{ mL}}{0.789 \text{ kg}}\right) = (0.07 \text{ kg})\left(\frac{1000 \text{ mL}}{0.789 \text{ kg}}\right)$$

$V_a = 88$ mL

Statement: The volume of the ethyl alcohol is 88 mL.

46. A coolant system uses the evaporation of a liquid to absorb thermal energy from the air, cooling the interior of the refrigerator or freezer. A compressor puts the refrigerant under pressure, increasing its temperature. The warmed refrigerant gas runs through a series of tubes, releasing thermal energy. Then the liquid refrigerant passes through an expansion valve, moving from a high-pressure area to a low-pressure area. Then the refrigerant absorbs thermal energy from the surrounding air and evaporates back into a gas. The surrounding air is cooled as a result. The compressor releases unwanted thermal energy into the air when compressing the gas so it must be kept away from the area that is to be cooled. Air conditioners are kept outside the house and refrigerator compressors are kept on the outside of the insulated refrigerator. In both situations the unwanted thermal energy is released to the surrounding air.

47. (a) Metals expand when they absorb thermal energy and contract when they release it. Engineers must account for the changes in size when building structures. However, the expansion and contraction of metals is what makes a thermostat work.

(b) A thermostat has a strip made of two kinds of metal bonded together and wrapped in a coil. The two metals expand and contract at different rates. When the temperature in a building is above or below the set temperature, the metals expand or contract making the coil wind or unwind. As the metal coil winds or unwinds, it comes in contact with a mercury switch that moves against bare wires, sending a message to turn on the air conditioner or furnace.

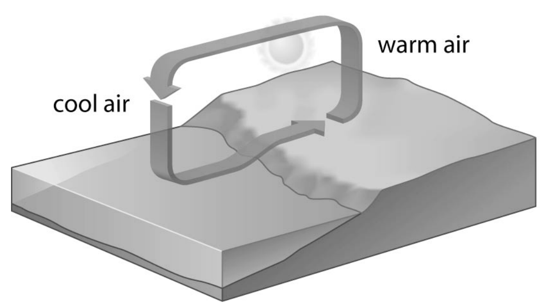
48. Geothermal systems pump an antifreeze–water mixture down into Earth's crust, where the temperature remains at 9 °C all year. In the winter, the thermal energy from the ground is transferred into the mixture by conduction and brought up into the house through convection. There, a heat pump uses the thermal energy to change a liquid refrigerant into a gas. A compressor puts pressure on the gas, increasing the temperature. The resulting hot air is blown through the house. In the summer, hot air from the house is pumped over the refrigerant, causing it to warm up and the house air to cool down. The refrigerant transfers its thermal energy to the antifreeze–water mixture. That thermal energy is transferred through the underground pipes into the ground by conduction.

49. (a) Joule investigated thermal energy from both electric and mechanical sources. He used electricity to warm up a volume of water, and he used mechanical energy to produce friction and increase the temperature of water. He became convinced that energy—the "grand agents of nature"—was indestructible but could be changed from one form to another.

(b) The scientists at the British Association for the Advancement of Science did not take Joule's results seriously because he was a brewer, not a fellow scientist.
(c) Joule's breakthrough experiment that brought him recognition from the science community involved using a falling mass to turn a paddlewheel placed inside an insulated barrel of water. As the paddlewheel turned, the water inside the barrel warmed up. The increase in temperature indicated that mechanical energy could be transformed into thermal energy.

Analysis and Application

50. Temperature is defined in terms of average kinetic energy instead of total kinetic energy because individual particles in the object will have different amounts of kinetic energy—some will be moving faster than others. Therefore you must look at the average to determine whether the object is warmer or colder.
51. The drop of the liquid with a lower boiling point than water feels cooler. The lower boiling point means that the liquid evaporates faster than water, so heat is transferred away from your skin and into the surrounding air more quickly.
52. If the counter is warmer, it would transfer the thermal energy to the alcohol, making the alcohol particles vibrate more quickly and evaporate into a gas more quickly. If the counter is cooler, there would be less thermal energy so the alcohol would remain as a liquid longer.
53. (a) The water–crystal mixture made with hot water would become uniform in colour first.
(b) The higher temperature of the hot water means that the hot water molecules possess greater average kinetic energy than the cold water molecules. The hot water molecules vibrate more rapidly than the cold water molecules, spreading the colour more quickly. Furthermore, the hot water would tend to have more convection currents that would also help distribute the dye throughout the water, as the surface of the water cooled rapidly, sinking, and pushing the warmer water up.
54. Wind chill is a measure of the "temperature" that your skin feels when the wind blows over it. The wind cools your skin temperature. You feel cooler on a windy day than on a calm day with the same temperature as the windy day because the heat from your body (or the water in your body) is transferred into the surrounding, colder air.
55. (a) Snakes are able to sense thermal radiation through pit organs near the front of their face. They use this ability to target prey.
(b) Humans use thermal imaging cameras to see in the dark. This technology is especially useful in law-enforcement and the military, where it can be used to seek out criminals and enemy combatants.
56. Thermal energy can be raised or lowered without changing the temperature when a change of state is occurring. In a car radiator, the thermal energy would be elevated when the water is boiled and being changed into a gas. The temperature would remain at 100 °C even as the thermal energy increased.
57. A firewalker can walk safely across red-hot coals because the coals are coated with a layer of burned carbon. Carbon is not a good heat conductor. This covering of ash becomes insulation for the coal therefore, reducing even further the transfer of thermal energy. The sole of the foot only makes brief contact with the burned carbon, which insulates the foot from the heat of the coal. Water has a high heat capacity. Our bodies contain a great deal of water. Our bodies require lots of energy to raise our body temperatures even one degree. Also in most cases of firewalking, contact with the burning coals is extremely short and uneven due to the curvature of the bottoms of our feet, lessening the chance of severe burn.
58. Reverse the arrows:



59. (a) A fuzzy fleece lining would keep a person warmer in cold weather.
(b) The fleece acts as an insulator, trapping thermal energy from the body in the air between its fibres.
60. The solar energy heating system works to keep the building warm at night because during the day thermal energy from the sun hits the rocks, turning to thermal energy and warming them up. The rocks have a higher specific heat capacity than the

surrounding air so they hold the heat longer. As the interior air cools, the rocks release thermal energy, warming up the interior.

61. In a closed system where you are mixing two elements of different temperatures, say cool water and hot metal, the thermal energy of the hot metal will be transferred to the water. The temperature of the water will increase while the temperature of the metals decreases. The temperature of the system will equalize and change without further thermal heat transfer.

62. Suntan when applied to the skin works as insulator by coating pores in the skin, inhibiting the transfer of heat from the body through sweating.

63. (a) Given: $V_w = 3$ L = 3 kg; $T_1 = 18$ °C; $T_2 = 60$ °C; $c = 4.18 \times 10^3$ J/(kg • °C)

Required: Q

Analysis: $Q = mc\Delta T$

Solution:

$$Q = mc\Delta T$$
$$= (3\ \text{kg})\left(4.18\times10^3\ \frac{\text{J}}{\text{kg}\bullet°\text{C}}\right)(60\ °\text{C} - 18\ °\text{C})$$
$$= \left(12.54\times10^3\ \frac{\text{J}}{°\text{C}}\right)(42\ °\text{C})\ \text{(three extra digits carried)}$$
$$= 5.3\times10^5\ \text{J}$$
$$Q = 5\times10^5\ \text{J}$$

Statement: The change in thermal energy is 5×10^5 J.

(b) In this process, thermal energy is absorbed by the water.

(c) The indicator of whether energy is absorbed or released during thermal energy transfer is whether Q, thermal energy transfer, is positive or negative. If it is positive, energy was absorbed. If it is negative, energy was released.

64. Cold packs are used to absorb thermal energy from areas that have sustained injury and allow that area to cool. If a material has a high specific heat capacity, then it takes a lot of energy to raise the temperature of that material and it stays cooler for longer. It can absorb more thermal energy from the injury.

65. The order in which the metals will heat up is silver, copper, iron, and then aluminum (from smallest specific heat capacity to largest).

66. Given: $m_m = 3.8$ kg; $T_{1m} = 396$ °C; $V_w = 1.0$ L; $m_w = 1$ kg; $c_w = 4.18 \times 10^3$ J/(kg • °C); $T_{1w} = 22$ °C; $T_2 = 89$ °C

Required: c_m

Analysis: $Q_{\text{released}} + Q_{\text{absorbed}} = 0$; $Q = mc\Delta T$

Solution: Calculate c_m by rearranging the equation $Q_{\text{released}} + Q_{\text{absorbed}} = 0$ and solving for c_m.

$$0 = m_m c_m \Delta T_m + m_w c_w \Delta T_w$$
$$0 = (3.8\ \text{kg})(c_m)(89\ °\text{C} - 396\ °\text{C})$$
$$+ (1\ \text{kg})\left(4.18\times10^3\ \frac{\text{J}}{\text{kg}\bullet°\text{C}}\right)(89\ °\text{C} - 22\ °\text{C})$$
$$0 = (3.8\ \text{kg})(c_m)(-307\ °\text{C})$$
$$+ \left(4.18\times10^3\ \frac{\text{J}}{°\text{C}}\right)(67\ °\text{C})$$
$$0 = (c_m)(-1.17\times10^3\ \text{kg}\bullet°\text{C}) + (2.80\times10^5\ \text{J})$$
$$c_m = \frac{2.80\times10^5\ \text{J}}{1.17\times10^3\ \text{kg}\bullet°\text{C}}$$
$$c_m = 2.4\times10^2\ \text{J/(kg}\bullet°\text{C)}$$

Statement: The specific heat capacity is 2.4×10^2 J/(kg·°C), so the substance is silver.

67. Given: $c_m = 3.8 \times 10^2$ J/(kg • °C); $T_{1m} = 520$ °C; $V_w = 350$ mL; $T_{1w} = 18$ °C; $T_2 = 31$ °C; $c_w = 4.18 \times 10^3$ J/(kg • °C);

Required: m_m

Analysis: $Q_{\text{released}} + Q_{\text{absorbed}} = 0$; $Q = mc\Delta T$

Solution: First, determine the mass of the water.

$$m_w = 350\ \text{mL} \times \frac{1\ \text{g}}{1\ \text{mL}} \times \frac{1\ \text{kg}}{1000\ \text{g}}$$
$$m_w = 0.35\ \text{kg}$$

Calculate m_m by rearranging the equation $Q_{\text{released}} + Q_{\text{absorbed}} = 0$ and solving for m_m.

$$0 = m_m c_m \Delta T_m + m_w c_w \Delta T_w$$
$$0 = (m_m)\left(3.8\times10^2\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}\right)(31\ °\text{C} - 520\ °\text{C})$$
$$+ (0.35\ \text{kg})\left(4.18\times10^3\ \frac{\text{J}}{\text{kg}\bullet°\text{C}}\right)(31\ °\text{C} - 18\ °\text{C})$$
$$0 = (m_m)\left(3.8\times10^2\ \frac{\text{J}}{\text{kg}\bullet°\text{C}}\right)(-489\ °\text{C})$$
$$+ \left(1.5\times10^3\ \frac{\text{J}}{°\text{C}}\right)(13\ °\text{C})$$
$$0 = (m_m)\left(-1.9\times10^5\ \frac{\text{J}}{\text{kg}\bullet°\text{C}}\right) + (1.9\times10^4\ \text{J})$$
$$m_m = \frac{1.9\times10^4\ \text{J}}{1.9\times10^5\ \frac{\text{J}}{\text{kg}}}$$
$$m_m = 0.10\ \text{kg}$$

Statement: The mass of the copper wire is 0.10 kg.

68. Dentists must use substances that do not expand or contract when heated or cooled to fill cavities. Once the substance is put in the cavity hole, any expansion would crack the tooth and any contraction would make the filling fall out of the hole.

69. (a) If you wanted to lower the temperature of a substance, you would remove the faster molecules.

(b) When water in a kettle gets heated, the water molecules closest to the heat source (bottom of kettle) absorb more thermal energy, increasing their average kinetic energy. They vibrate more rapidly, colliding with other molecules and spreading apart. The warmer water near the bottom of the kettle is less dense and so it is pushed up by the heavier water above. This cycle continues, creating a convection current. As the water heats up, gas bubbles form on the sides of the kettle because as temperature increases, air becomes less soluble in water. When the average kinetic energy is high enough, the gas bubbles will leave the water. True boiling occurs when gas bubbles on the bottom of the kettle can no longer form and they rise to the surface of water to escape as steam.

(c) When you blow on food to cool it, your breath is cooler than the hot food. The thermal energy of the food is transferred to your breath, cooling the food. The faster molecules are slowed down due to the transfer of thermal energy.

70. Water should not be used as an indicator of temperature in a thermometer because it has a high specific heat capacity. This means it takes a lot of thermal energy to cause an increase in temperature. Mercury has a much lower specific heat capacity relative to water, so it readily shows any changes in temperature.

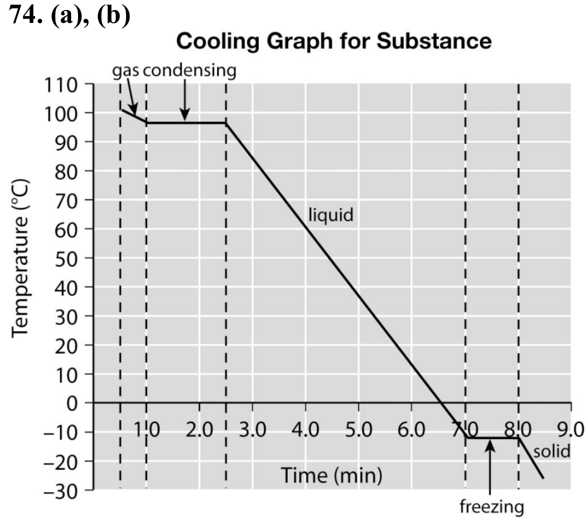
71. Jars that have been in the fridge are difficult to open because the metal lid contracted in the cold and now fits too tightly around the glass jar. A vacuum was created where the air inside the jar contracted due to the transfer of thermal energy to the glass container walls. If you run the lid under hot water, you will make the metal expand, releasing the jar lid.

72. Water has a high specific heat capacity. When you touch your cool, wet finger on a hot iron, the thermal energy of the hot iron is transferred to the water on your finger. For a few seconds, the water undergoes a change of state from liquid to gas. The latent heat of vaporization is the amount of energy needed to change the water to gas.

73. (a) In the winter months, lakes, slower rivers and the polar oceans develop a layer of solid ice on the surface. Aquatic life can swim below the ice and survive, protected from the cold air.

(b) If ice sank instead of floating, the layer of ice would build up from the bottom of the ocean, freezing and killing all plant life above the lake floor. Any animals that survived would not be able to find a food source. In addition, if the cold weather continued, the whole body of water would freeze, trapping and killing fish and animals.

74. (a), (b)



(c) The melting point of the substance occurs at –12 °C. The boiling point of the substance occurs at 96 °C.

75. If caloric theory had not been disproved, we would be counting on the transfer of heat from a warm object to a cool object. To keep food cold, we would have to keep our food next to something even colder—like ice—so that the heat would transfer out of the food.

76. (a) Assume the cylinder is tightly sealed so that no gas molecules escape and therefore the number of gas molecules remains the same under different conditions.

If the disc is forced downward, the volume of space the gas particles can fill is increased. This means there is more space between particles and with the sides of the tank, reducing the number of collisions between particles. This reduces the average kinetic energy of the gas. The pressure of the gas is then reduced.

(b) If the disc is forced upwards, the gas molecules have a smaller volume of space to occupy, so the number of collision between molecules and the sides of the tank increases. This increases the

average kinetic energy of the molecules. Therefore, the pressure inside the tank increases.
(c) If the disc is forced downward, the volume of space the gas particles can fill is increased. This means there is more space between particles and with the sides of the tank, reducing the number of collisions between particles. This reduces the average kinetic energy of the gas. The pressure of the gas is decreased.
(d) If the disc is forced upwards, the gas molecules have a smaller volume of space to occupy, so the number of collision between molecules and the sides of the tank increases. This increases the average kinetic energy of the molecules. Therefore, the temperature of the gas increases.
77. An underground stream does not freeze because 3 m below the surface of Earth, temperatures remain at approximately 9 °C all year round, which is above the freezing point of water.
78. Answers may vary. Sample answer:
Other factors to consider when choosing the type of field loop for a geothermal system are whether the loop will be a closed or an open system, the moisture content of the underground, the thermal and hydraulic traits of the underground, and the affordability and efficiency of the loop installed for the given terrain.
79. (a) James Joule used a number of experiments to show that mechanical and electrical energy could be converted into thermal energy. In one example, he let a falling object turn a paddlewheel that was encased in a barrel of water. He carefully measured the temperature change in the barrel of water. In another experiment, he passed an electrical current through a wire that was in water and measured the temperature change.
(b) Benjamin Thompson also showed that mechanical energy could be transferred into heat by drilling one piece of metal through another. He showed that the friction between the two metals warmed up two previously cool objects.

Evaluation

80. Answers may vary. Sample answer:
Newton's thermometer scale has larger increments than the Celsius scale, which could lead to less exact results. As well, 12 N is body temperature, but body temperature has a range of a few degrees, so, again, that scale is less exact.
The fluid in Newton's thermometer is linseed oil, which has a tendency to stick to the inside walls of the thermometer. The thermometer has to be cleaned quite often by baking off the oil that stuck to the inside walls. However, since linseed oils has a high boiling point, it can be used to measure substances with temperatures up to 232 °C. The long stem of the thermometer
81. Heat conduction involves the transfer of kinetic energy from fast-moving particles of a warm substance to slower-moving particles of a cooler substance. For conduction to occur, the two substances must be in contact. Wave propagation is the transfer of kinetic energy of vibrating air molecules to air molecules creating a wave pattern. In heat conduction, particle paths or collisions are often random. In wave propagation, collisions follow a wave pattern.
82. Answers may vary. Sample answer:
For cooking utensils like pots, which I would want to heat up quickly, I would want a high thermal conductivity so they would transfer the energy from the stove to the food quickly. I would also want low specific heat capacity so that it does not require very much energy to heat up, reducing my gas or electrical bills. I would want a low coefficient of expansion so that the pot would not change shape. For a cooking utensil that would come in contact with my hand, like a pot lid or a stirring spoon, I would want low thermal conductivity so that the thermal energy would not transfer up into my hand. I would want it to have a high specific heat capacity so that it takes a lot of energy to heat up. I would still want it to have a low coefficient of expansion so that it would not expand with the thermal energy input.
83. (a) Geothermal systems have economic advantages in the long term because they require no gas and very little electricity to run. During the winter, a liquid antifreeze–water mixture is pumped though a network of plastic pipe in a geothermal system. The disadvantage is that the pipes are difficult, and therefore expensive, to install.
(b) Geothermal systems reduce the burning of fossil fuels, so they do not contribute greenhouse gases to the atmosphere. Although they reduce our dependence on coal and on nuclear power, they still require some electricity to operate the heat pump. That electricity can be created by nearby solar panels. There is also a small chance that the pipes will break and release antifreeze into the surrounding water table.
(c) Geothermal is limited to places that can accommodate the pipes. Homes or businesses with little surrounding land, like older homes in large cities, cannot always accommodate the pipes and

the digging needed to lay the pipes. In addition, many places in Canada are very cold for long stretches of the year, so the heat pump uses more electrical power to keep the house warm. In warmer areas of North America, where the winters are shorter and less intense, will use less electricity for heat. Warmer areas, which require air conditioning, would benefit from geothermal systems because the air conditioning uses little electricity.

Reflect on Your Learning

84. Answers may vary.
(a) Students will indicate that they have a better understanding of thermal energy transfer.
(b) Sample answer:
I learned to distinguish between the terms "heat" and "thermal energy". I was surprised that during the heating of water, when water is absorbing thermal energy, there is long period during which it does this before the water starts to boil.
85. Answers may vary. Sample answer:
Yes, I have a better understanding of the heating and cooling systems in Canada. The general workings of the systems have been explained in the chapter. Diagrams were provided for clarity. I do not plan to enter a career in home heating and cooling and therefore, would not be interested in learning more.

Research

86. Answers may vary. Students should indicate that absolute zero has never been reached in experimentation, but that values close to it have been reached. Some properties of substances with temperatures close to absolute zero that may be mentioned include superconductivity, superfluidity, and Bose-Einstein condensation. Students should explain in detail any of these that they mention. One possible substance that exhibits odd behaviour as its temperature approaches zero is helium; it exhibits superfluidity and seems to defy the laws of gravity, creeping along surfaces against the force of gravity.
87. Answers may vary. Students should indicate where the thermal energy was transported or transferred from (from passive areas beneath Earth's surface, from hot springs or geysers, etc.), how it was transported, and any structures that were built to accommodate the thermal energy transport and its utilization.
88. Answers vary. Students may choose one or more ancient alternative energy source that utilized wind, water, or passive solar heating or cooling. Detailed descriptions or drawings of any designs should be included, as well as how and in what region(s)/culture(s) the systems were used.
89. Answers may vary. Students can choose their own city or another city in Canada that they are familiar with. Types of alternative energy systems can be described in text or drawn on a design document or map. Students should include information about proposed costs and savings and a timeline (textual or pictorial) of conversion to 100 % alternative energy. Students can weigh both environmental and economic savings and costs against each other.
90. Answers may vary. Some scientists that students might choose include Galileo Galilei, Isaac Newton, Charles Darwin, Copernicus, etc. Students should include discussion of at least one theory or finding that led to the scientist being ignored, chastised, or persecuted, and how that theory or finding compares with current scientific knowledge.