Chapter 17

Phases and Phase Changes

Answers to Even-numbered Conceptual Questions

2. Carbon is monatomic, whereas oxygen is diatomic. Therefore, one mole of oxygen has twice as many atoms as one mole of carbon.

4. The bubble wrap is more effective on a warm day because the air pressure within the bubbles will be greater, leading to more effective cushioning. At low temperature, the bubbles are almost flat.

6. If the temperature of the air in a house is increased, and the amount of air in the house remains constant, it follows from the ideal-gas law that the pressure will increase as well.

8. Yes. If the pressure and volume are changed in such a way that their product remains the same, it follows from the ideal-gas law that the temperature of the gas will remain the same. If the temperature of the gas is the same, the average kinetic energy of its molecules will not change.

10. Both types of molecules have the same average kinetic energy, because they experience the same temperature. Since the oxygen molecules are more massive, however, it follows that their rms speed is less than the rms speed of the nitrogen. In general, heavier molecules move more slowly for a given temperature.

12. The ratio of oxygen to nitrogen decreases with increasing altitude. The reason is that oxygen molecules move more slowly than nitrogen molecules, on average, and are therefore unable to rise as high above the ground as nitrogen molecules.

14. Airplanes can have a difficult time taking off from high-altitude airports because the air is thin, and provides less lift than air at sea level. When the air is cool, however, its density is greater than when it is warm. Therefore, taking off in the morning or evening will provide the airplane with more lift – which can be very important at high altitude.

16. If the absolute temperature of an ideal gas is doubled, the average kinetic energy of its molecules doubles as well. Recall that kinetic energy depends on speed squared, however. It follows, then, that the average speed of the molecules increases by a factor less than 2; in fact, the speed increases by a factor of the square root of 2.

18. The change in length is inversely proportional to the cross sectional area, as we see in Equation 17-17. The solid rod has the greater effective cross-sectional area – since the hollow part of the other rod doesn't resist compression. Therefore, the hollow rod has the greater change in length.

20. No. The temperature at which water boils on a mountain top is less than its boiling temperature at sea level – due to the low atmospheric pressure on the mountain. Therefore, if the stove is barely able to boil water on the mountain, it will not be able to boil it at sea level, where the required temperature is greater.

22. If we look at the phase diagram in Figure 17-16, we can see that in order to move upward from the sublimation curve to the fusion curve the pressure acting on the system must be increased.

24.   No. Water is at 0 ˚C whenever it is in equilibrium with ice. The ice cube thrown into the
pool will soon melt, however, showing that the ice cube-pool system is not in equilibrium.
As a result, there is no reason to expect that the water in the pool is at 0 ˚C.

Solutions to Problems

1. $PV = nRT$

$$V = \frac{nRT}{P} = \frac{(1 \text{ mol})\left(8.31 \frac{\text{J}}{\text{mol·K}}\right)(273.15 \text{ K})}{1.013 \times 10^5 \text{ Pa}} = \boxed{0.0224 \text{ m}^3}$$

2. $\dfrac{V_i}{T_i} = \dfrac{V_f}{T_f}$

$$V_f = \frac{V_i T_f}{T_i} = \frac{(4.2 \text{ L})(273.15+37) \text{ K}}{273.15 \text{ K}} = 4.77 \text{ L}$$

$$\Delta V = V_f - V_i = 4.77 \text{ L} - 4.2 \text{ L} = \boxed{0.6 \text{ L}}$$

3. $\dfrac{P_i V_i}{n_i R T_i} = \dfrac{P_f V_f}{n_f R T_f}$

$$\frac{P_i}{T_i} = \frac{P_f}{T_f}$$

$$T_f = \frac{P_f T_i}{P_i} = \frac{(552 \text{ kPa})(288 \text{ K})}{505 \text{ kPa}} = \boxed{315 \text{ K}}$$

4. $n_i = \dfrac{P_i V_i}{R T_i} = \dfrac{(212 \times 10^3 \text{ Pa})(0.0185 \text{ m}^3)}{\left(8.31 \frac{\text{J}}{\text{mol·K}}\right)(294 \text{ K})} = 1.605 \text{ moles}$

$$n_f = \frac{P_i V_i}{R T_i} = \frac{(252 \times 10^3 \text{ Pa})(0.0185 \text{ m}^3)}{\left(8.31 \frac{\text{J}}{\text{mol·K}}\right)(294 \text{ K})} = 1.908 \text{ moles}$$

$$\Delta n = n_f - n_i = 1.908 \text{ moles} - 1.605 \text{ moles} = \boxed{0.303 \text{ moles}}$$

5. $m_{\text{total}} = nM = \dfrac{PVM}{RT} = \dfrac{(112 \times 10^3 \text{ Pa})(7023 \text{ m}^3)\left(4.00260 \frac{\text{g}}{\text{mol}}\right)}{\left(8.31 \frac{\text{J}}{\text{mol·K}}\right)(285 \text{ K})} = \boxed{1.33 \times 10^3 \text{ kg}}$

6. $\dfrac{P_i V_i}{T_i} = \dfrac{P_f V_f}{T_f}$

$$V_f = \frac{P_i T_f V_i}{P_f T_i}$$

$$= \frac{(850 \text{ kPa})(303 \text{ K})(0.500 \text{ m}^3)}{(101 \text{ kPa})(285 \text{ K})}$$

$$= \boxed{4.5 \text{ m}^3}$$

7. $P = \dfrac{kNT}{V} = \dfrac{\left(1.38 \times 10^{-23} \frac{\text{J}}{\text{K}}\right)(10^6)(100 \text{ K})}{1 \text{ m}^3} = \boxed{10^{-15} \text{ Pa}}$

8. $\dfrac{V_i}{T_i} = \dfrac{V_f}{T_f}$

   $V_f = \dfrac{T_f V_i}{T_i}$

   $= \dfrac{(273.15 + 23)\ \text{K}\ (3.0\ \text{L})}{87\ \text{K}}$

   $= \boxed{10\ \text{L}}$

9. **(a)** $PV = NkT$

   $N = \dfrac{PV}{kT}$

   $= \dfrac{P\left(\frac{4}{3}\pi r^3\right)}{kT}$

   $= \dfrac{\left(2.4 \times 10^5\ \text{Pa}\right)\frac{4}{3}\pi (0.25\ \text{m})^3}{\left(1.38 \times 10^{-23}\ \frac{\text{J}}{\text{K}}\right)(273.15 + 18)\ \text{K}} = \boxed{3.9 \times 10^{24}\ \text{atoms}}$

   (b) The volume doubles.

   $v_2 = \dfrac{4}{3}\pi r_2^3 = 2v_1 = 2\left(\dfrac{4}{3}\pi r_1^3\right)$

   $r_2 = 2^{1/3} r_1 = 1.26 r_1$

   $\dfrac{r_2 - r_1}{r_1} = \dfrac{1.26 r_1 - r_1}{r_1} = \boxed{0.26\ \text{or}\ 26\%}$

10. **(a)** $V = \dfrac{nRT}{P} = \dfrac{(1.25\ \text{mol})\left(8.31\ \frac{\text{J}}{\text{mol·K}}\right)(310\ \text{K})}{101 \times 10^3\ \text{Pa}} = \boxed{0.032\ \text{m}^3}$

    (b) V_{mol} = the volume of one molecule

    $\dfrac{nV_{\text{mol}}}{V} = \dfrac{n\left(\frac{4}{3}\pi r^3\right)}{V}$

    $= \dfrac{n\pi d^3}{6V}$

    $= \dfrac{(1.25\ \text{mol})\left(6.022 \times 10^{23}\ \frac{\text{molecules}}{\text{mol}}\right)\pi\left(2.5 \times 10^{-10}\ \text{m}\right)^3}{6(0.0319\ \text{m}^3)}$

    $= \boxed{1.9 \times 10^{-4}}$

    (c) $\boxed{\text{Since the molecules represent less than 0.02\% of the total volume of the gas, the assumption is valid.}}$

11. $n = \dfrac{PV}{RT} = \dfrac{\left(153 \times 10^3\ \text{Pa}\right)(515\ \text{cm}^3)\left(\frac{1\ \text{m}}{100\ \text{cm}}\right)^3}{\left(8.31\ \frac{\text{J}}{\text{mol·K}}\right)(322\ \text{K})} = 2.945 \times 10^{-2}\ \text{moles}$

    $M = \dfrac{0.460\ \text{g}}{2.945 \times 10^{-2}\ \text{mol}} = \boxed{15.6\ \text{g/mol}}$

12. (a) $T_c = \dfrac{5}{9}(T_f - 32) = \dfrac{5}{9}(-64 - 32) = -53.3 \ °C$

$T_k = (273.15 - 53.3)K = 219.8 \ K$

$\dfrac{N}{V} = \dfrac{P}{kT} = \dfrac{0.92 \times 10^3 \ Pa}{\left(1.38 \times 10^{-23} \ \frac{J}{K}\right)(219.8 \ K)} = \boxed{3.0 \times 10^{23} \ molecules/m^3}$

(b) The number of molecules per volume on Earth is $\boxed{\text{greater than}}$ that on Mars. The temperatures of Earth and Mars have the same order of magnitude, but the pressure on Earth is far greater than that on Mars.

(c) Earth at STP:

$\dfrac{N}{V} = \dfrac{P}{kT} = \dfrac{1.01 \times 10^5 \ Pa}{\left(1.38 \times 10^{-23} \ \frac{J}{k}\right)(273.15 \ K)} = \boxed{2.68 \times 10^{25} \ molecules/m^3}$

13. $P_i V_i = P_f V_f$

$P_i(\pi r^2 h_i) = P_f(\pi r^2 h_f)$

$P_f = \dfrac{P_i h_i}{h_f}$

$= \dfrac{(137 \ kPa)(23.4 \ cm)}{20.0 \ cm}$

$= \boxed{160 \ kPa}$

14. $\dfrac{V_i}{T_i} = \dfrac{V_f}{T_f}$

$T_f = \dfrac{V_f T_i}{V_i}$

$= \dfrac{\pi r^2 h_f T_i}{\pi r^2 h_i}$

$= \dfrac{h_f T_i}{h_i}$

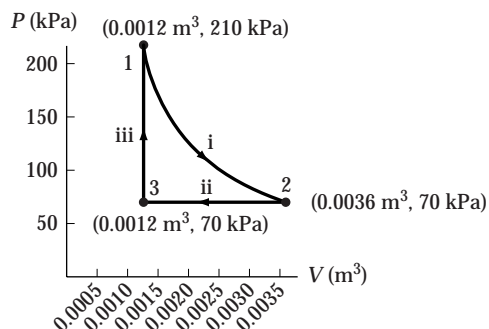$= \dfrac{(26.0 \ cm)(313 \ K)}{23.4 \ cm}$

$= \boxed{348 \ K}$

15. $\dfrac{\rho_{in}}{\rho_{out}} = \dfrac{\frac{m_{in}}{V_{in}}}{\frac{m_{out}}{V_{out}}}$

Let $m_{in} = m_{out}$.

$\dfrac{\rho_{in}}{\rho_{out}} = \dfrac{V_{out}}{V_{in}} = \dfrac{T_{out}}{T_{in}} = \dfrac{(273.15 + 20.0) \ K}{(273.15 + 75.0) \ K} = \boxed{0.842}$

16. $P_1V_1 = P_2V_2$

$$P_2 = \frac{P_1V_1}{V_2} = \frac{P_1V_1}{3V_1} = \frac{210 \text{ kPa}}{3} = 70 \text{ kPa}$$

17. $\left(\frac{1}{2}mv^2\right)_{av} = \frac{3}{2}kT$

Since temperature is proportional to mass, the oxygen, which is more massive, is at the higher temperature. The answer is (e).

18. $\left(\frac{1}{2}mv^2\right)_{av} = \frac{3}{2}kT$

$$\frac{1}{2}m(v^2)_{av} = \frac{3}{2}kT$$

$$(v^2)_{av} = \frac{3kT}{m}$$

$$\left(\frac{3kT}{m}\right)_O = \left(\frac{3kT}{m}\right)_H$$

$$\frac{T_O}{m_O} = \frac{T_H}{m_H}$$

$$T_H = \frac{T_O m_H}{m_O}$$

$$= (303 \text{ K})\left(\frac{1.00794 \frac{g}{mol}}{15.9994 \frac{g}{mol}}\right)$$

$$= \boxed{19.1 \text{ K}}$$

19. $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(8.31 \frac{J}{mol \cdot K})(273.15 \text{ K})}{\left[14.00674 \frac{g}{mol} + 3\left(1.00794 \frac{g}{mol}\right)\right]\left(\frac{1 \text{ kg}}{1000 \text{ g}}\right)}} = \boxed{630 \text{ m/s}}$

20. (a) $P = \frac{nRT}{V} = \frac{(3 \text{ mol})(8.31 \frac{J}{mol \cdot K})(295 + 273.15) \text{ K}}{0.0035 \text{ m}^3} = \boxed{4.0 \times 10^6 \text{ Pa}}$

(b) $(KE)_{av} = \frac{3}{2}kT = \frac{3}{2}\left(1.38 \times 10^{-23} \frac{J}{K}\right)(295 + 273.15) \text{ K} = \boxed{1.18 \times 10^{-20} \text{ J}}$

(c) Pressure decreases by a factor of 2 because pressure is inversely proportional to volume. The average kinetic energy of a molecule remains the same, because it depends only on temperature.

21. (a) The rms speed of H_2O is more than the rms speed of O_2, since it is less massive but has the same average kinetic energy.

(b) $$\frac{v_{rms_{H_2O}}}{v_{rms_{O_2}}} = \frac{\sqrt{\frac{3RT}{M_{H_2O}}}}{\sqrt{\frac{3RT}{M_{O_2}}}} = \sqrt{\frac{M_{O_2}}{M_{H_2O}}} = \sqrt{\frac{2(15.9994 \text{ g/mol})}{2(1.00794 \text{ g/mol}) + 15.9994 \text{ g/mol}}}$$

$$= 1.333$$

$$v_{rms_{H_2O}} = 1.333 v_{rms_{O_2}} = 1.333(1550 \text{ m/s}) = \boxed{2070 \text{ m/s}}$$

22. (a) By doubling the number of molecules while holding the volume and pressure constant, the temperature must decrease (by the Ideal Gas Law). Since the temperature decreases, the rms speed decreases.

(b) $PV = NkT = $ constant

$$NkT_i = 2NkT_f$$

$$T_f = \frac{1}{2}T_i$$

$$v_{rms,i} = \sqrt{\frac{3kT_i}{m}}$$

$$v_{rms,f} = \sqrt{\frac{3kT_f}{m}} = \sqrt{\frac{3kT_i}{2m}} = \sqrt{\frac{3k}{2m}\left(\frac{mv_{rms,i}^2}{3k}\right)} = \frac{v_{rms,i}}{\sqrt{2}} = \frac{1200 \frac{m}{s}}{\sqrt{2}} = \boxed{850 \text{ m/s}}$$

23. $v_{rms} = \sqrt{\frac{3RT}{M}}$

$$T = \frac{v_{rms}^2 M}{3R} = \frac{(339 \frac{m}{s})^2 \left(0.0440 \frac{kg}{mol}\right)}{3(8.31 \frac{J}{mol \cdot K})} = \boxed{203 \text{ K}}$$

24. (a) $$\frac{v_{rms}^2 M}{3R} = T$$

$$\frac{(1.01 v_{rms})^2 M}{3R} = 1.0201 \, T$$

$$1.0201 - 1 = 0.0201 \times 100\% = \boxed{2.01\%}$$

(b) $$\frac{P_f}{P_i} = \frac{T_f}{T_i} = \frac{1.0201 T_i}{T_i} = 1.0201$$

$$1.0201 - 1 = 0.0201 \times 100\% = \boxed{2.01\%}$$

25. $v_{rms} = \sqrt{\frac{3RT}{M}}$

$$\frac{v_{rms,\,238}}{v_{rms,\,235}} = \sqrt{\frac{M_{235}}{M_{238}}} = \sqrt{\frac{235 \text{ u} + 114 \text{ u}}{238 \text{ u} + 114 \text{ u}}} = \boxed{0.996}$$

26. $PV = NkT$

$$P = \frac{NkT}{V}$$

$$F = PA = \frac{NkTA}{V}$$

Find A as a function of V.

$$V = \frac{4}{3}\pi r^3$$

$$r = \left(\frac{3V}{4\pi}\right)^{1/3}$$

$$A = 4\pi r^2 = 4\pi\left(\frac{3V}{4\pi}\right)^{2/3} = (36\pi)^{1/3}V^{2/3}$$

Substitute.

$$F = \frac{NkT}{V}(36\pi)^{1/3}V^{2/3}$$

$$= \frac{(36\pi)^{1/3}NkT}{V^{1/3}}$$

$$= \frac{(36\pi)^{1/3}(1)\left(1.38\times10^{-23}\ \frac{J}{k}\right)(293\ K)}{(0.350\ L)^{1/3}\left(\frac{10^{-3}\ m^3}{L}\right)^{1/3}}$$

$$= \boxed{2.8\times10^{-19}\ N}$$

27. $F = Y\left(\frac{\Delta L}{L_0}\right)A$

$$mg = Y\left(\frac{\Delta L}{L_0}\right)\left(\frac{\pi D^2}{4}\right)$$

$$m = \frac{Y}{g}\left(\frac{\Delta L}{L_0}\right)\left(\frac{\pi D^2}{4}\right)$$

$$= \left(\frac{0.37\times10^{10}\ \frac{N}{m^2}}{9.81\ \frac{m}{s^2}}\right)\left(\frac{0.047\ m}{12\ m}\right)\left(\frac{\pi(0.0055\ m)^2}{4}\right)$$

$$= \boxed{35\ kg}$$

28. $F = Y\left(\frac{\Delta L}{L_0}\right)A$

$$Y = \frac{F}{A}\left(\frac{L_0}{\Delta L}\right)$$

$$= \frac{25\ N}{\left(47\ cm^2\right)\left(\frac{1\ m}{100\ cm}\right)^2}\left(\frac{24\ cm}{2.5\ cm}\right) = \boxed{5.1\times10^4\ N/m^2}$$

29. $F = S\left(\dfrac{\Delta x}{L_0}\right)A$

$S = \dfrac{F}{A}\left(\dfrac{L_0}{\Delta x}\right)$

$ = \dfrac{mg}{\frac{\pi D^2}{4}}\left(\dfrac{L_0}{\Delta x}\right)$

$ = \dfrac{(22\ \text{kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)}{\frac{\pi(0.046\ \text{m})^2}{4}}\left(\dfrac{1.1\ \text{m}}{0.13\ \text{m}}\right) = \boxed{1.1\times10^6\ \text{N}/\text{m}^2}$

30. $\Delta P = -B\left(\dfrac{\Delta V}{V_0}\right)$

$\Delta V = -\dfrac{V_0 \Delta P}{B}$

$ = -\dfrac{\left(\frac{\pi D^2}{4}\right)\Delta P}{B}$

$ = \dfrac{-\left[\frac{\pi(0.100\ \text{m})^2}{4}\right](1.10\times10^8\ \text{Pa}-1.01\times10^5\ \text{Pa})}{14\times10^{10}\ \frac{\text{N}}{\text{m}^2}}$

$ = -6.2\times10^{-6}\ \text{m}^3$

The volume decreases by $\boxed{6.2\times10^{-6}\ \text{m}^3}$.

31. (a) $F = Y\left(\dfrac{\Delta L}{L_0}\right)A$

$F = Y\left(\dfrac{\Delta L}{L_0}\right)\left(\dfrac{\pi D^2}{4}\right)$

$D = \sqrt{\dfrac{4F}{\pi Y}\left(\dfrac{L_0}{\Delta L}\right)}$

$ = \sqrt{\dfrac{4(370\ \text{N})}{\pi\left(20\times10^{10}\ \frac{\text{N}}{\text{m}^2}\right)}\left(\dfrac{4.5\ \text{m}}{0.0015\ \text{m}}\right)}$

$ = \boxed{0.27\ \text{cm}}$

(b) The diameter should be $\boxed{\text{increased}}$ because a wire's cross-sectional area and its elongation are inversely related.

32. (a) $F = Y\left(\dfrac{\Delta L}{L_0}\right)A$

$\dfrac{\Delta L}{L_0} = \dfrac{F}{YA} = \dfrac{mg}{Y(\pi r^2)} = \dfrac{(0.26\ \text{g})\left(\frac{1\ \text{kg}}{1000\ \text{g}}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)}{\left(4.7\times10^9\ \frac{\text{N}}{\text{m}^2}\right)\pi\left(9.8\times10^{-6}\ \text{m}\right)^2} = \boxed{1.8\times10^{-3}}$

(b) $mg = Y\left(\dfrac{\Delta L}{L_0}\right)(\pi r^2)$

$$r = \sqrt{\dfrac{mg}{Y\pi}\left(\dfrac{L_0}{\Delta L}\right)}$$

$$= \sqrt{\dfrac{(76\ \text{kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)}{\left(0.37\times10^{10}\ \frac{\text{N}}{\text{m}^2}\right)\pi}\left(\dfrac{1}{1.80\times10^{-3}}\right)}$$

$$= \boxed{0.60\ \text{cm}}$$

33. (a) $\quad F = Y\left(\dfrac{\Delta L}{L_0}\right)\left(\dfrac{\pi D^2}{4}\right)$

$$\Delta L = \dfrac{4L_0 F}{Y\pi D^2}$$

$$(\Delta L)_{\text{total}} = \dfrac{4L_0 F}{\pi D^2}\left(\dfrac{1}{Y_{\text{Al}}} + \dfrac{1}{Y_{\text{Br}}}\right)$$

$$= \dfrac{4(0.45\ \text{m})(8400\ \text{N})}{\pi(0.015\ \text{m})^2}\left(\dfrac{1}{6.9\times10^{10}\ \frac{\text{N}}{\text{m}^2}} + \dfrac{1}{9.0\times10^{10}\ \frac{\text{N}}{\text{m}^2}}\right)$$

$$= \boxed{0.55\ \text{mm}}$$

(b) $\boxed{\text{Aluminum}}$, because it has the smaller Young's Modulus.

34. $\Delta F = Y\left(\dfrac{\Delta L}{L_0}\right)A$

$\Delta L = \pi D_{\text{peg}} = \pi(3.5\ \text{mm})\left(\dfrac{1\ \text{m}}{1000\ \text{mm}}\right) = 1.10\times10^{-2}\ \text{m}$

$\Delta F = Y\left[\dfrac{\Delta L}{L_0}\right]\left(\dfrac{\pi D^2}{4}\right) = \left(2.4\times10^{10}\ \frac{\text{N}}{\text{m}^2}\right)\left[\dfrac{1.10\times10^{-2}\ \text{m}}{0.84\ \text{m}}\right]\dfrac{\pi}{4}(0.95\ \text{mm})^2\left(\dfrac{1\ \text{m}}{1000\ \text{mm}}\right)^2 = 223\ \text{N}$

$F = F_0 + \Delta F = 12\ \text{N} + 223\ \text{N} = \boxed{235\ \text{N}}$

35. $\Delta P = -B\left(\dfrac{\Delta V}{V_0}\right)$

$$\Delta V = \dfrac{(\Delta P)V_0}{-B}$$

$$= \dfrac{\rho_{\text{w}}gh\left(\frac{\pi}{6}D_0^{\,3}\right)}{-B}$$

$$= \dfrac{\left(1025\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(923\ \text{m})\frac{\pi}{6}\left[(4.75\ \text{ft})\left(\frac{1\ \text{m}}{3.281\ \text{ft}}\right)\right]^3}{-16\times10^{10}\ \frac{\text{N}}{\text{m}^2}}$$

$$\Delta V = \boxed{-9.2\times10^{-5}\ \text{m}^3}$$

36.

$$\sum F_y = 0$$

$$T + B - mg = 0$$

$$T = mg - B$$

$$= mg - \rho_{w}Vg$$

$$= g\left[m - \rho_{w}V\right] = g\left[m - \rho_{w}\left(\tfrac{4}{3}\pi r^3\right)\right]$$

$$= \left(9.81 \ \frac{m}{s^2}\right)\left\{12,700 \ \text{kg} - \left(1000 \ \frac{kg}{m^3}\right)\frac{4}{3}\pi\left[\left(\frac{4.75 \ \text{ft}}{2}\right)\left(\frac{m}{3.281 \ \text{ft}}\right)\right]^3\right\}$$

$$= 109 \ \text{kN}$$

$$F = Y\left(\frac{\Delta L}{L_0}\right)A = Y\left(\frac{\Delta L}{L_0}\right)\pi r^2$$

$$\Delta L = \frac{FL_0}{Y\pi r^2} = \frac{\left(109\times10^3 \ \text{N}\right)(923 \ \text{m})}{\left(20\times10^{10} \ \frac{N}{m^2}\right)\pi(0.0185 \ \text{m})^2} = \boxed{47 \ \text{cm}}$$

37. Temperature remains constant during phase changes, but heat must be removed from the water to change it to a less energetic state. The answer is (d).

38. about 4.3 kPa

39. about 14°C

40. (a) about 3.5 Mpa

(b) An increase in the boiling temperature is associated with an increase in the boiling pressure, as seen in the graph.

41. (a) about –28 °C

(b) An increase in the boiling pressure results in an increase in the boiling temperature, as seen in the graph.

42. (a) 0 °C

(b) 100 °C

(c) It increases since the fusion curve has negative slope.

(d) It increases since the slope of the vapor-pressure curve has positive slope.

43. (a) gas

(b) solid

(c) 5707 kPa

44. (a) First the water ice changes from solid to liquid. Then the liquid changes to a gas.

(b) The solid water sublimates to a gas.

45. (a) The liquid turns to gas.

(b) First the liquid turns to solid. Then the solid sublimates to gas.

46. (a) First the solid turns to liquid. Then the liquid turns to gas.

(b) First the solid turns to liquid. Then the liquid turns to gas.

47. $Q = mL_f = (0.84 \text{ kg}) \left(33.5 \times 10^4 \frac{\text{J}}{\text{kg}} \right) = \boxed{280 \text{ kJ}}$

48. $Q = mc_{\text{ice}}(\Delta T)_1 + mL_f + mc_{\text{water}}(\Delta T)_2$
$Q = m \left[c_{\text{ice}}(\Delta T)_1 + L_f + c_{\text{water}}(\Delta T)_2 \right]$

$m = \dfrac{Q}{c_{\text{ice}}(\Delta T)_1 + L_f + c_{\text{water}}(\Delta T)_2}$

$= \dfrac{9.5 \times 10^5 \text{ J}}{\left(2090 \frac{\text{J}}{\text{kg·C}°} \right)(12 \text{ °C}) + 33.5 \times 10^4 \frac{\text{J}}{\text{kg}} + \left(4186 \frac{\text{J}}{\text{kg·C}°} \right)(12 \text{ °C})}$

$= \boxed{2.3 \text{ kg}}$

49. $Q = mL_f = (1.5 \text{ kg}) \left(20.7 \times 10^4 \frac{\text{J}}{\text{kg}} \right) = \boxed{310 \text{ kJ}}$

50. (a) $Q_1 = mc_{\text{ice}} \Delta T = (1.1 \text{ kg}) \left(2090 \frac{\text{J}}{\text{kg·C}°} \right)(5.0 \text{ °C}) = 1.15 \times 10^4 \text{ J}$

$Q_2 = mL_f = (1.1 \text{ kg}) \left(33.5 \times 10^4 \frac{\text{J}}{\text{kg}} \right) = 3.685 \times 10^5 \text{ J}$

$Q_3 = Q_{\text{total}} - Q_1 - Q_2$
$= 5.2 \times 10^5 \text{ J} - 1.15 \times 10^4 \text{ J} - 3.685 \times 10^5 \text{ J}$
$= 1.40 \times 10^5 \text{ J}$

$Q_3 = mc_{\text{water}}(T_f - 0 \text{ °C})$

$T_f = \dfrac{Q_3}{mc_{\text{water}}} = \dfrac{1.40 \times 10^5 \text{ J}}{(1.1 \text{ kg}) \left(4186 \frac{\text{J}}{\text{kg·C}°} \right)} = \boxed{30 \text{ °C}}$

(b) The mass must increase by a factor of 2. All the temperature changes, specific heat values and the latent heat value remain the same, so doubling the amount of heat added requires doubling the mass because they are proportional.

51. (a) No. $2.6 \times 10^5 \text{ J}$ is not sufficient heat to melt the entire block of ice. Therefore a mixture of ice and water remains at a temperature of 0°C.

(b) $Q_1 = mc\Delta T$

$Q_1 = (1.1 \text{ kg}) \left(2090 \frac{\text{J}}{\text{kg·C}°} \right)(5.0 \text{ °C}) = 1.15 \times 10^4 \text{ J}$

$Q_2 = Q_{\text{total}} - Q_1 = 2.6 \times 10^5 \text{ J} - 1.15 \times 10^4 \text{ J} = 2.49 \times 10^5 \text{ J}$

$Q_f = mL_f = (1.1 \text{ kg}) \left(33.5 \times 10^4 \frac{\text{J}}{\text{kg}} \right) = 3.69 \times 10^5 \text{ J}$

Since $Q_f > Q_2$, not all of the ice melts, so the final temperature of the water is $\boxed{0 \text{ °C}}$.
The mass that melts:

$$m_f = \frac{Q_2}{L_f} = \frac{2.49 \times 10^5 \text{ J}}{33.5 \times 10^4 \frac{\text{J}}{\text{kg}}} = 0.74 \text{ kg}$$

The mass that remains:

$$m_{ice} = 1.1 \text{ kg} - m_f = 1.1 \text{ kg} - 0.74 \text{ kg} = \boxed{0.4 \text{ kg}}$$

52. (a) point A

$$Q_A = mc\Delta T = (1.000 \text{ kg})\left(2090 \ \frac{\text{J}}{\text{kg}\cdot\text{C}°}\right)(20.0 \text{ C}°) = \boxed{4.18 \times 10^4 \text{ J}}$$

point B

$$Q_B = 4.18 \times 10^4 \text{ J} + mL_f = 4.18 \times 10^4 \text{ J} + (1.000 \text{ kg})(33.5 \times 10^4 \text{ J}) = \boxed{3.77 \times 10^5 \text{ J}}$$

point C

$$Q_C = 37.7 \times 10^4 \text{ J} + mc\Delta T = 37.7 \times 10^4 \text{ J} + (1.000 \text{ kg})\left(4186 \ \frac{\text{J}}{\text{kg}\cdot\text{C}°}\right)(100 \text{ C}°) = \boxed{7.96 \times 10^5 \text{ J}}$$

point D

$$Q_D = 7.96 \times 10^5 \text{ J} + mL_v = 7.96 \times 10^5 \text{ J} + (1.000 \text{ kg})(22.6 \times 10^5 \text{ J}) = \boxed{3.06 \times 10^6 \text{ J}}$$

(b) $\text{slope} = \dfrac{T_C - T_B}{Q_C - Q_B} = \dfrac{100 \text{ C}°}{4.186 \times 10^5 \text{ J}} = \boxed{2.39 \times 10^{-4} \ \dfrac{\text{C}°}{\text{J}}}$

$\dfrac{1}{c} = \dfrac{1}{4186 \ \frac{\text{J}}{\text{kg}\cdot°\text{C}}} = \boxed{2.39 \times 10^{-4} \ \dfrac{\text{kg}\cdot\text{C}°}{\text{J}}}$

53. (a) $t_{AB} = \dfrac{Q_{AB}}{\Delta Q/\Delta t} = \dfrac{mL_f}{\Delta Q/\Delta t} = \dfrac{(1.000 \text{ kg})\left(33.5 \times 10^4 \ \frac{\text{J}}{\text{kg}}\right)}{12{,}250 \ \frac{\text{J}}{\text{s}}} = \boxed{27.3 \text{ s}}$

(b) $t_{BC} = \dfrac{Q_{BC}}{\Delta Q/\Delta t} = \dfrac{mc\Delta T}{\Delta Q/\Delta t} = \dfrac{(1.000 \text{ kg})\left(4186 \ \frac{\text{J}}{\text{kg}\cdot\text{K}}\right)(100 \text{ C}°)}{12{,}250 \ \frac{\text{J}}{\text{s}}} = 34.2 \text{ s}$

$t_{AC} = t_{AB} + t_{BC} = 27.3 \text{ s} + 34.2 \text{ s} = \boxed{61.5 \text{ s}}$

(c) $t_{CD} = \dfrac{Q_{CD}}{\Delta Q/\Delta t} = \dfrac{mL_v}{\Delta Q/\Delta t} = \dfrac{(1.000 \text{ kg})\left(22.6 \times 10^5 \ \frac{\text{J}}{\text{kg}}\right)}{12{,}250 \ \frac{\text{J}}{\text{s}}} = 184.5 \text{ s}$

$t_{AD} = t_{AB} + t_{BC} + t_{CD} = 27.3 \text{ s} + 34.2 \text{ s} + 184.5 \text{ s} = \boxed{246 \text{ s}}$

(d) $\boxed{\text{boiling water}}$

54. (a) $Q_A = 0$, $Q_B = mc\Delta T = (0.550 \text{ kg})\left(2090 \; \dfrac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)(20.0 \text{ C}^\circ) = 2.30 \times 10^4 \text{ J}$

$$\text{slope} = \frac{T_B - T_A}{Q_B - Q_A} = \frac{0^\circ\text{C} - (-20.0^\circ\text{C})}{2.30 \times 10^4 \text{ J} - 0} = \boxed{8.70 \times 10^{-4} \; \frac{\text{C}^\circ}{\text{J}}}$$

$$\frac{1}{mc} = \frac{1}{(0.550 \text{ kg})\left(2090 \; \frac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)} = \boxed{8.70 \times 10^{-4} \; \frac{\text{C}^\circ}{\text{J}}} = \text{slope}$$

(b) $\text{slope} = \dfrac{T_D - T_C}{Q_D - Q_C} = \dfrac{20.0^\circ\text{C} - 0^\circ\text{C}}{(0.550 \text{ kg})\left(4186 \; \frac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)(20.0 \text{ C}^\circ)} = \boxed{4.34 \times 10^{-4} \; \frac{\text{C}^\circ}{\text{J}}}$

$$\frac{1}{mc} = \frac{1}{(0.550 \text{ kg})\left(4186 \; \frac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)} = \boxed{4.34 \times 10^{-4} \; \frac{\text{C}^\circ}{\text{J}}} = \text{slope}$$

55. (a) $Q = mc\Delta T = (0.0125 \text{ kg})\left(4186 \; \dfrac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)(50.0 \text{ °C}) = \boxed{2.62 \text{ kJ}}$

(b) $Q = mc\Delta T + mL_v = 2.62 \text{ kJ} + (0.0125 \text{ kg})\left(22.6 \times 10^5 \; \dfrac{\text{J}}{\text{kg}}\right) = \boxed{3.09 \times 10^4 \text{ J}}$

(c) $m = \dfrac{Q}{c\Delta T} = \dfrac{2.62 \text{ kJ}}{\left(3500 \; \frac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)(13.0 \text{ C}^\circ)} = \boxed{0.058 \text{ kg}}$

$$m = \frac{3.09 \times 10^4 \text{ J}}{\left(3500 \; \frac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)(13.0 \text{ C}^\circ)} = \boxed{0.68 \text{ kg}}$$

56. $m = \rho_{\text{ice}} V = \rho_{\text{ice}} \; Ad = \left(917 \; \dfrac{\text{kg}}{\text{m}^3}\right)(1.6 \text{ m}^2)(0.0050 \text{ m}) = 7.336 \text{ kg}$

$$Q = mc_{\text{ice}}\Delta T + mL_f = m(c_{\text{ice}}\Delta T + L_f) = (7.336 \text{ kg})\left[\left(2090 \; \frac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)(2.0 \text{ °C}) + 33.5 \times 10^4 \; \frac{\text{J}}{\text{kg}}\right] = \boxed{2.5 \text{ MJ}}$$

57. $Q_i =$ heat gained by ice

$\qquad = m_{\text{ice}} c_{\text{ice}} (10.2 \text{ °C}) + m_{\text{ice}} L_f + m_{\text{ice}} c_{\text{water}} (T_f - 0 \text{ °C})$

$Q_w =$ heat lost by lemonade

$\qquad = m_{\text{lem}} c_{\text{water}} (20.0 \text{ °C} - T_f)$

$Q_i = Q_w$

$m_{\text{ice}} c_{\text{ice}} (10.2 \text{ °C}) + m_{\text{ice}} L_f + m_{\text{ice}} c_{\text{water}} (T_f - 0 \text{ °C}) = m_{\text{lem}} c_{\text{water}} (20.0 \text{ °C} - T_f)$

$$T_f = \frac{m_{\text{lem}} c_{\text{water}} (20.0 \text{ °C}) - m_{\text{ice}} \left[c_{\text{ice}} (10.2 \text{ °C}) + L_f\right]}{(m_{\text{ice}} + m_{\text{lem}}) c_{\text{water}}}$$

$$= \frac{(3.95 \text{ kg})\left(4186 \; \frac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)(20.0 \text{ °C}) - (0.0450 \text{ kg})\left[\left(2090 \; \frac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)(10.2 \text{ °C}) + 33.5 \times 10^4 \; \frac{\text{J}}{\text{kg}}\right]}{(0.0450 \text{ kg} + 3.95 \text{ kg})\left(4186 \; \frac{\text{J}}{\text{kg} \cdot \text{C}^\circ}\right)}$$

$= \boxed{18.8 \text{ °C}}$

58. Assume that $T_f = 0$.

Q_{Al} = heat gained by aluminum

$= m_{Al}c_{Al}\left(T_f - T_{Al,i}\right)$

$= (0.155 \text{ kg})\left(653 \dfrac{\text{J}}{\text{kg}\cdot\text{C}°}\right)\left[0°\text{C}-(-196°\text{C})\right]$

$= 19{,}838 \text{ J}$

Q_{wb} = heat lost by water before it freezes

$= m_w c_w \Delta T$

$= (0.0800 \text{ kg})\left(4186 \dfrac{\text{J}}{\text{kg}\cdot\text{C}°}\right)(15.0°\text{C})$

$= 5023 \text{ J}$

Since $Q_{Al} > Q_{wb}$, we know that $T_f \leq 0°\text{C}$.

Q_F = heat lost by 0 °C water during freezing = $m_w L_f = (0.0800 \text{ kg})(33.5\times10^4 \text{ J}) = 26{,}800 \text{ J}$

Since $Q_{Al} < Q_{wb} + Q_{wf}$, not all of the water freezes, so $T_f = \boxed{0°\text{C}}$.

Let m_f = the mass of water that freezes.

$Q_{Al} = Q_{wb} + m_f L_f$

$m_f = \dfrac{Q_{Al} - Q_{wb}}{L_f}$

$= \dfrac{19{,}838 \text{ J}-5023 \text{ J}}{33.5\times10^4 \frac{\text{J}}{\text{kg}}}$

$= \boxed{44.2 \text{ g}}$

59. Assume that $T_f = 100$ °C.

Q_{Fe} = heat lost by iron

$= -m_{Fe}c_{Fe}(T_f - T_{Fe,i})$

$= -(0.825 \text{ kg})\left(560 \dfrac{\text{J}}{\text{kg}\cdot\text{C}°}\right)(100 \text{ °C}-352 \text{ °C})$

$= 116 \text{ kJ}$

Q_w = heat gained by water before boiling

$= m_w c_{water}\left(T_f - T_{w,i}\right)$

$= (0.0400 \text{ kg})\left(4186 \dfrac{\text{J}}{\text{kg}\cdot\text{C}°}\right)(100 \text{ °C}-20.0 \text{ °C})$

$= 13.4 \text{ kJ}$

Since $Q_{Fe} > Q_w$, we know that $T_f \geq 100°\text{C}$.

Q_v = heat gained by water during boiling

$= m_w L_v$

$= (0.0400 \text{ kg})\left(22.6\times10^5 \dfrac{\text{J}}{\text{kg}}\right) = 90.4 \text{ kJ}$

Since $Q_{Fe} > Q_w + Q_v$, $\boxed{\text{all the water vaporizes}}$.

Q_s = heat gained by steam

$$= m_w c_{steam}(T_f - 100\ °C)$$

$$Q_{Fe} = Q_w + Q_v + Q_s$$

$$m_{Fe}c_{Fe}(T_{Fe,i} - T_f) = Q_w + Q_v + m_w c_{steam}(T_f - 100\ °C)$$

$$T_f = \frac{m_{Fe}c_{Fe}T_{Fe,i} + m_w c_{steam}(100\ °C) - Q_w - Q_v}{m_{Fe}c_{Fe} + m_w c_{steam}}$$

$$= \frac{(0.825\ \text{kg})\left(560\ \frac{J}{kg\cdot K}\right)(352\ °C) + (0.0400\ \text{kg})\left(2010\ \frac{J}{kg\cdot K}\right)(100\ °C) - 13.4\times10^3\ \text{J} - 90.4\times10^3\ \text{J}}{(0.825\ \text{kg})\left(560\ \frac{J}{kg\cdot K}\right) + (0.0400\ \text{kg})\left(2010\ \frac{J}{kg\cdot K}\right)}$$

$$= \boxed{123\ °C}$$

60. (a) heat gained by ice cube = heat lost by cup and water

$$m_{ice}L_f + m_{ice}c_w(T_f - 0.0°C) = m_c c_{Al}(23°C - T_f) + m_w c_w(23°C - T_f)$$

$$T_f = \frac{-m_{ice}L_f + (m_c c_{Al} + m_w c_w)(23°C)}{c_w(m_{ice} + m_w) + m_c c_{Al}}$$

$$= \frac{-(0.035\ \text{kg})\left(33.5\times10^4\ \frac{J}{kg}\right) + \left[(0.062\ \text{kg})\left(900\ \frac{J}{kg\cdot C°}\right) + (0.110\ \text{kg})\left(4186\ \frac{J}{kg\cdot C°}\right)\right](23°C)}{\left(4186\ \frac{J}{kg\cdot C°}\right)(0.035\ \text{kg} + 0.110\ \text{kg}) + (0.062\ \text{kg})\left(900\ \frac{J}{kg\cdot C°}\right)}$$

$$= \boxed{0.22°C}$$

(b) The equilibrium temperature with silver is $\boxed{\text{less than}}$ with aluminum. In fact, not all the ice will melt. Less heat loss is required to lower the temperature of silver because it has a smaller specific heat.

61. (a) Heat gained by copper = heat lost by water and cup

$$m_{Cu}c_{Cu}[T_f - (-12°C)] = m_w c_w(4.1°C - T_f) + m_{Al}c_{Al}(4.1°C - T_f)$$

$$(0.048\ \text{kg})\left(387\ \frac{J}{kg\cdot °C}\right)(T_f + 12°C) = (0.110\ \text{kg})\left(4186\ \frac{J}{kg\cdot °C}\right)(4.1°C - T_f)$$

$$+ (0.075\ \text{kg})\left(900\ \frac{J}{kg\cdot °C}\right)(4.1°C - T_f)$$

$$\left(18.6\ \frac{J}{°C}\right)T_f + 223\ \text{J} = 1888\ \text{J} - \left(460.5\ \frac{J}{°C}\right)T_f + 277\ \text{J} - \left(67.5\ \frac{J}{°C}\right)T_f$$

$$T_f = \frac{1888\ \text{J} + 277\ \text{J} - 223\ \text{J}}{\left(18.6\ \frac{J}{°C} + 460.5\ \frac{J}{°C} + 67.5\ \frac{J}{°C}\right)} = \boxed{3.6°C}$$

(b) Since $T_f > 0°C$, $\boxed{\text{no ice is present.}}$

62. (a) Heat gained by ice = heat lost by water
First determine whether all the ice melts.

$$Q = mL_f = (0.075\ \text{kg})(33.5\times10^4\ \text{J}) = 2.5\times10^4\ \text{J needed}$$

$$Q = mc\Delta T = (0.33\ \text{kg})\left(4186\ \frac{J}{kg\cdot °C}\right)(14°C) = 1.9\times10^4\ \text{J available}$$

Not all the ice melts.
The final temperature will be $\boxed{0°C}$.

$$m = \frac{Q}{L_f} = \frac{1.93 \times 10^4 \text{ J}}{33.5 \times 10^4 \frac{\text{J}}{\text{kg}}} = 0.058 \text{ kg}$$

Ice remaining is 0.075 kg − 0.058 kg = $\boxed{0.017 \text{ kg}}$.

(b) $\Delta T = \frac{Q}{mc} = \frac{2.51 \times 10^4 \text{ J}}{(0.33 \text{ kg})\left(4186 \frac{\text{J}}{\text{kg} \cdot \text{°C}}\right)} = 18\text{°C}$

The water would need to start at $\boxed{18\text{°C}}$.

63. $Pt = mc_{\text{water}}(20.0\text{°C} - 0\text{°C}) + mL_f$

$\quad = m[c_{\text{water}}(20.0\text{°C}) + L_f]$

$t = \frac{m[c_{\text{water}}(20.0\text{°C}) + L_f]}{P}$

$\quad = \frac{(845 \text{ kg})\left[\left(4186 \frac{\text{J}}{\text{kg} \cdot \text{K}}\right)(20.0 \text{ °C}) + 33.5 \times 10^4 \frac{\text{J}}{\text{kg}}\right]}{2.00 \times 10^3 \frac{\text{J}}{\text{s}}}$

$\quad = \boxed{49.1 \text{ h}}$

64. $m = \rho_w V = \rho_w \frac{4}{3} \pi r^3$

$n = \frac{m}{m_{\text{H}_2\text{O}}}$

$\quad = \frac{\frac{4}{3}\rho_w \pi r^3}{\frac{M}{N_A}}$

$\quad = \frac{\frac{4}{3}\left(\frac{10^6 \text{ g}}{\text{m}^3}\right)\pi(9.2 \times 10^{-4} \text{ m})^3}{\frac{2\left(1.00794 \frac{\text{g}}{\text{mol}}\right) + 15.9994 \frac{\text{g}}{\text{mol}}}{6.022 \times 10^{23} \frac{\text{molecules}}{\text{mol}}}}$

$\quad = \boxed{1.1 \times 10^{20} \text{ molecules}}$

65. (a) $n_{\text{H}_2} = \frac{m_{\text{H}_2}}{M_{\text{H}_2}} = \frac{8.06 \text{ g}}{2\left(1.00794 \frac{\text{g}}{\text{mol}}\right)} = 4.00 \text{ mol}$

$\quad\quad n_{\text{O}_2} = \frac{m_{\text{O}_2}}{M_{\text{O}_2}} = \frac{64.0 \text{ g}}{2\left(15.9994 \frac{\text{g}}{\text{mol}}\right)} = 2.00 \text{ mol}$

$\quad\quad n_{\text{total}} = n_{\text{H}_2} + n_{\text{O}_2} = 4.00 \text{ mol} + 2.00 \text{ mol} = 6.00 \text{ mol}$

$\quad\quad V = \frac{n_{\text{total}}RT}{P} = \frac{(6.00 \text{ mol})\left(8.313 \frac{\text{J}}{\text{mol} \cdot \text{K}}\right)(273.15 + 125) \text{ K}}{1.013 \times 10^5 \text{ Pa}} = \boxed{0.196 \text{ m}^3}$

(b) Since $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$, $n_{\text{H}_2\text{O}} = 4.00$ mol.

$\quad P = \frac{n_{\text{H}_2\text{O}}RT}{V} = \frac{(4.00 \text{ mol})\left(8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}}\right)(273.15 + 125) \text{ K}}{0.196 \text{ m}^3} = \boxed{67.5 \text{ kPa}}$

66. $V = Ah = A(2\pi r)$

$$N = \frac{PV}{kT}$$

$$= \frac{2PA\pi r}{kT}$$

$$= \frac{2\left(62\,\frac{\text{lb}}{\text{in.}^2}\right)\left(\frac{1.01 \times 10^5\,\text{Pa}}{14.7\,\frac{\text{lb}}{\text{in.}^2}}\right)(0.0028\,\text{m}^2)\pi(0.66\,\text{m})}{\left(1.38 \times 10^{-23}\,\frac{\text{J}}{\text{K}}\right)(273.15 + 34)\,\text{K}}$$

$$= \boxed{1.2 \times 10^{24}\ \text{molecules}}$$

67. **(a)** $F = Y\left(\dfrac{\Delta L}{L_0}\right)A$

$$\frac{\Delta L}{L_0} = \frac{F}{YA}$$

$$= \frac{mg}{Y\left(\frac{\pi D^2}{4}\right)}$$

$$= \frac{(4.8\,\text{kg})\left(9.81\,\frac{\text{m}}{\text{s}^2}\right)}{\left(5.1 \times 10^9\,\frac{\text{N}}{\text{m}^2}\right)\frac{\pi}{4}(0.54\,\text{mm})^2\left(\frac{1\,\text{m}}{1000\,\text{mm}}\right)^2}$$

$$= \boxed{0.040}$$

(b) Constant speed implies zero acceleration and, therefore, no force. So, $\Delta L / L_0 = \boxed{0.040}$.

(c) $\sum F = ma$

$$T - mg = ma$$

$$T = m(a + g)$$

$$\frac{\Delta L}{L_0} = \frac{m(a+g)}{Y\left(\frac{\pi D^2}{4}\right)}$$

$$= \frac{(4.8\,\text{kg})\left(1.5\,\frac{\text{m}}{\text{s}^2} + 9.81\,\frac{\text{m}}{\text{s}^2}\right)}{\left(5.1 \times 10^9\,\frac{\text{N}}{\text{m}^2}\right)\frac{\pi}{4}(0.54\,\text{mm})^2\left(\frac{1\,\text{m}}{1000\,\text{mm}}\right)^2}$$

$$= \boxed{0.046}$$

68. **(a)** $F = S\left(\dfrac{\Delta x}{L_0}\right)A = \left(8.1 \times 10^{10}\,\frac{\text{N}}{\text{m}^2}\right)\left(\dfrac{1.1 \times 10^{-4}\,\text{m}}{0.28\,\text{m}}\right)(2.3 \times 10^{-4}\,\text{m}^2) = \boxed{7.3\ \text{kN}}$

(b) It is $\boxed{\text{reduced by a factor of 2}}$ because it is inversely proportional to the cross-sectional area.

69. (a) <u>top of the circle</u>

$$\sum F = T + mg = ma_{cp}$$

$$T = m(a_{cp} - g)$$

$$= \rho V \left(\frac{v^2}{r} - g \right)$$

$$= \rho \left(\frac{\pi}{6} D^3 \right) \left(\frac{v^2}{r} - g \right)$$

$$T = Y \left(\frac{\Delta L}{L_0} \right) A$$

$$\Delta L = \frac{L_0 T}{YA}$$

$$= \frac{L_0 \rho \left(\frac{\pi}{6} D^3 \right) \left(\frac{v^2}{r} - g \right)}{Y \frac{\pi}{4} d^2}$$

$$= \frac{2 L_0 \rho D^3}{3 Y d^2} \left(\frac{v^2}{r} - g \right)$$

$$= \frac{2(0.82 \text{ m}) \left(7860 \frac{\text{kg}}{\text{m}^3} \right) (0.064 \text{ m})^3}{3 \left(6.9 \times 10^{10} \ \frac{\text{N}}{\text{m}^2} \right) \left(2.5 \times 10^{-3} \text{ m} \right)^2} \left[\frac{\left(7.8 \ \frac{\text{m}}{\text{s}} \right)^2}{0.82 \text{ m} + 0.032 \text{ m}} - 9.81 \ \frac{\text{m}}{\text{s}^2} \right]$$

$$= \boxed{0.16 \text{ mm}}$$

(b) <u>bottom of the circle</u>

$$\sum F = T - mg = ma_{cp}$$

$$T = m \left(\frac{v^2}{r} + g \right)$$

$$= \frac{\pi}{6} \rho D^3 \left(\frac{v^2}{r} + g \right)$$

$$\Delta L = \frac{L_0 T}{YA}$$

$$= \frac{2 L_0 \rho D^3}{3 Y d^2} \left(\frac{v^2}{r} + g \right)$$

$$= \frac{2(0.82 \text{ m}) \left(7860 \ \frac{\text{kg}}{\text{m}^3} \right) (0.064 \text{ m})^3}{3 \left(6.9 \times 10^{10} \ \frac{\text{N}}{\text{m}^2} \right) \left(2.5 \times 10^{-3} \text{ m} \right)^2} \left[\frac{\left(9.3 \ \frac{\text{m}}{\text{s}} \right)^2}{0.82 \text{ m} + 0.032 \text{ m}} + 9.81 \ \frac{\text{m}}{\text{s}^2} \right]$$

$$= \boxed{0.29 \text{ mm}}$$

70. (a) $F = Y\left(\dfrac{\Delta L}{L_0}\right)A$

$$\Delta L = \dfrac{FL_0}{YA}$$

$$= \dfrac{FL_0}{Y\ell w}$$

$$= \dfrac{(2400 \text{ N})(\sin 25°)(0.020 \text{ m})}{\left(1.6\times10^{10} \frac{\text{N}}{\text{m}^2}\right)(0.060 \text{ m})(0.050 \text{ m})}$$

$$= \boxed{4.2\times10^{-7} \text{ m}}$$

(b) $F = S\left(\dfrac{\Delta x}{L_0}\right)A$

$$\Delta x = \dfrac{FL_0}{SA}$$

$$= \dfrac{FL_0}{S\ell w}$$

$$= \dfrac{(2400 \text{ N})(\cos 25°)(0.020 \text{ m})}{\left(0.54\times10^{10} \frac{\text{N}}{\text{m}^2}\right)(0.060 \text{ m})(0.050 \text{ m})}$$

$$= \boxed{2.7\times10^{-6} \text{ m}}$$

71. (a) $v_{\text{av}} = \dfrac{221 \frac{\text{m}}{\text{s}} + 301 \frac{\text{m}}{\text{s}} + 412 \frac{\text{m}}{\text{s}} + 44.0 \frac{\text{m}}{\text{s}} + 182 \frac{\text{m}}{\text{s}}}{5} = \boxed{232 \text{ m/s}}$

(b) $(v^2)_{\text{av}}$ will be $\boxed{\text{greater than}}$ $(v_{\text{av}})^2$ because in general, $v_{\text{rms}} > v_{\text{av}}$.

(c) $(v^2)_{\text{av}} = \dfrac{\left(221 \frac{\text{m}}{\text{s}}\right)^2 + \left(301 \frac{\text{m}}{\text{s}}\right)^2 + \left(412 \frac{\text{m}}{\text{s}}\right)^2 + \left(44.0 \frac{\text{m}}{\text{s}}\right)^2 + \left(182 \frac{\text{m}}{\text{s}}\right)^2}{5} = \boxed{6.88\times10^4 \text{ m}^2/\text{s}^2}$

$$\boxed{6.88\times10^4 \frac{\text{m}^2}{\text{s}^2} > \left(232 \frac{\text{m}}{\text{s}}\right)^2}$$

72. (a) $Q = mc_{\text{steam}}(120°\text{C} - 100°\text{C}) + mL_v + mc_w(100°\text{C} - 0°\text{C}) + mL_f$

$\qquad = m[c_{\text{steam}}(20°\text{C}) + L_v + c_w(100°\text{C}) + L_f]$

$\qquad = (1.0 \text{ kg})\left[\left(2010 \dfrac{\text{J}}{\text{kg}\cdot\text{K}}\right)(20 \text{ °C}) + 22.6\times10^5 \dfrac{\text{J}}{\text{kg}} + \left(4186 \dfrac{\text{J}}{\text{kg}\cdot\text{K}}\right)(100 \text{ °C}) + 33.5\times10^4 \dfrac{\text{J}}{\text{kg}}\right]$

$\qquad = \boxed{3.1 \text{ MJ}}$

(b) $Q = KE$

$$Q = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2Q}{m}}$$

$$= \sqrt{\frac{2(3.05 \times 10^6 \text{ J})}{1.0 \text{ kg}}}$$

$$= \boxed{2.5 \text{ km/s}}$$

73. $\dfrac{\Delta V}{V_0} = \dfrac{-0.0905}{1 + 0.0905} = -0.08300$

$$\Delta P = -B\left(\frac{\Delta V}{V_0}\right)$$

$$= -\left(0.80 \times 10^{10} \frac{\text{N}}{\text{m}^2}\right)(-0.08300) = 6.64 \times 10^8 \frac{\text{N}}{\text{m}^2}$$

$$P_f = P_i + \Delta P = 1.01 \times 10^5 \text{ Pa} + 6.64 \times 10^8 \text{ Pa} = \boxed{6.6 \times 10^8 \text{ Pa}}$$

74. (a) To warm the ice up to the melting point takes

$$Q = mc\Delta T = (0.550 \text{ kg})\left(2090 \frac{\text{J}}{\text{kg} \cdot °\text{C}}\right)(20°\text{C}) = 2.30 \times 10^4 \text{ J}$$

$$Q = 5.00 \times 10^4 \text{ J} - 2.30 \times 10^4 \text{ J} = 2.70 \times 10^4 \text{ J}$$

$$m = \frac{Q}{L_f} = \frac{2.70 \times 10^4 \text{ J}}{33.5 \times 10^4 \frac{\text{J}}{\text{kg}}} = 0.081 \text{ kg}$$

ice remaining = 0.550 kg – 0.081 kg = $\boxed{0.469 \text{ kg}}$

(b) $Q = 1.00 \times 10^5 \text{ J} - 0.23 \times 10^5 \text{ J} = 0.77 \times 10^5 \text{ J}$

$$m = \frac{0.77 \times 10^5 \text{ J}}{33.5 \times 10^4 \frac{\text{J}}{\text{kg}}} = 0.230 \text{ kg}$$

ice remaining = 0.550 kg – 0.230 kg = $\boxed{0.320 \text{ kg}}$

(c) $Q = 1.50 \times 10^5 \text{ J} - 0.23 \times 10^5 \text{ J} = 1.27 \times 10^5 \text{ J}$

$$m = \frac{1.27 \times 10^5 \text{ J}}{33.5 \times 10^4 \frac{\text{J}}{\text{kg}}} = 0.379 \text{ kg}$$

ice remaining = 0.550 kg – 0.379 kg = $\boxed{0.171 \text{ kg}}$

75. (a) heat flow rate $= kA\left(\dfrac{\Delta T}{L}\right) = \left(0.030 \dfrac{\text{W}}{\text{m} \cdot \text{C}°}\right)(1.5 \text{ m}^2)\left(\dfrac{21 \text{ °C} - 0.0 \text{ °C}}{0.042 \text{ m}}\right) = \boxed{23 \text{ W}}$

(b) Q_{melt} = heat required to melt the ice $= mL_f = (5.5 \text{ kg})\left(33.5 \times 10^4 \dfrac{\text{J}}{\text{kg}}\right) = 1.84 \times 10^6 \text{ J}$

$$t = \frac{Q_{\text{melt}}}{\text{heat flow rate}} = \frac{1.84 \times 10^6 \text{ J}}{22.5 \text{ W}} = \boxed{23 \text{ h}}$$

76. $Q = -\Delta KE = -\dfrac{1}{2}m(v_{\mathrm{f}}^2 - v_{\mathrm{i}}^2) = -\dfrac{1}{2}(5.0 \text{ kg})\left[\left(5.5 \dfrac{\text{m}}{\text{s}}\right)^2 - \left(6.9 \dfrac{\text{m}}{\text{s}}\right)^2\right] = 43.4 \text{ J}$

$Q = m_{\mathrm{melts}} L_{\mathrm{f}}$

$\begin{aligned}
m_{\mathrm{melts}} &= \dfrac{Q}{L_{\mathrm{f}}}\\
&= \dfrac{43.4 \text{ J}}{33.5 \times 10^4 \ \frac{\text{J}}{\text{kg}}}\\
&= \boxed{1.3 \times 10^{-4} \text{ kg}}
\end{aligned}$

77. $Q = kA\left(\dfrac{\Delta T}{L}\right)t = mL_f$

$\begin{aligned}
t &= \dfrac{mL_{\mathrm{f}} L}{kA\Delta T}\\
&= \dfrac{4mL_{\mathrm{f}} L}{k\pi d^2 \Delta T}\\
&= \dfrac{4(0.025 \text{ kg})\left(33.5 \times 10^4 \ \frac{\text{J}}{\text{kg}}\right)(0.37 \text{ m})}{\left(390 \ \frac{\text{W}}{\text{m·k}}\right)\pi(0.075 \text{ m})^2(120 \text{ K})}\\
&= \boxed{15 \text{ s}}
\end{aligned}$