11.60   (a)   This will form a homogeneous solution. There will only be dispersion forces present.

          (b)   This will not form a homogeneous solution, since one is polar and one is nonpolar.

          (c)   This will form a homogeneous solution. There will be ion–dipole interactions between the Li^+ and NO_3^- ions and the water molecules. There will also be dispersion forces, dipole–dipole forces, and hydrogen bonding between the water molecules.

          (d)   This will not form a homogeneous solution, since one is polar and one is nonpolar.

Surface Tension, Viscosity, and Capillary Action

11.61   Water will have the higher surface tension since it exhibits hydrogen bonding, a strong intermolecular force. Acetone cannot form hydrogen bonds.

11.62   (a)   Water "wets" surfaces that are capable of dipole–dipole interactions. The water will form strong adhesive forces with the surface when these dipole–dipole forces are present and so the water will spread to cover as much of the surface as possible. Water does not experience strong intermolecular forces with oil and other nonpolar surfaces. The water will bead up, maximizing the cohesive interactions, which involve strong hydrogen bonds. So water will bead up on surfaces that can only exhibit dispersion forces.

          (b)   Mercury will bead up on surfaces since it is not capable of forming strong intermolecular interactions (only dispersion forces).

11.63   Compound A will have the higher viscosity since it can interact with other molecules along the entire molecule. The more branched isomer has a smaller surface area allowing for fewer interactions. Also the molecule is very flexible and the molecules can get tangled with each other.

11.64   Multigrade oils contain polymers (long molecules made up of repeating structural units) that coil at low temperatures but unwind at high temperatures. At low temperatures, the coiled polymers—because of their compact shape—do not contribute very much to the viscosity of the oil. As the temperature increases, however, the molecules unwind and their long shape results in intermolecular forces and molecular entanglements that prevent the viscosity from decreasing as much as it would normally. The result is an oil whose viscosity is less temperature-dependent than it would be otherwise, allowing the same oil to be used over a wider range of temperatures.

11.65   In a clean glass tube the water can generate strong adhesive interactions with the glass (due to the dipoles at the surface of the glass). Water experiences adhesive forces with glass that are stronger than its cohesive forces, causing it to climb the surface of a glass tube. When grease or oil coats the glass this interferes with the formation of these adhesive interactions with the glass, since oils are nonpolar and cannot interact strongly with the dipoles in the water. Without experiencing these strong intermolecular forces with oil, the water's cohesive forces will be greater and it will be drawn away from the surface of the tube.

11.66   Water can generate strong adhesive interactions with the glass (due to the dipoles at the surface of the glass), but hexane is nonpolar and cannot interact strongly with the glass surface.

Vaporization and Vapor Pressure

11.67   The water in the 12 cm diameter beaker will evaporate more quickly because there is more surface area for the molecules to evaporate from. The vapor pressure will be the same in the two containers because the vapor pressure is the pressure of the gas when it is in dynamic equilibrium with the liquid (evaporation rate = condensation rate). The vapor pressure is dependent only on the substance and the temperature. The 12 cm diameter container will reach this dynamic equilibrium faster.

11.68   The acetone will evaporate more quickly since it is not capable of forming hydrogen bonds, so the intermolecular forces are much weaker. This will result in a larger vapor pressure at the same temperature as the water.

11.69   The boiling point and higher heat of vaporization of oil are much higher than that of water, so it will not vaporize as quickly as the water. The evaporation of water cools your skin because evaporation is an endothermic process.

11.70   Water molecules have a lower kinetic energy at room temperature than at 100 °C. The heat of vaporization is the energy difference between the molecules in the liquid phase and the gas phase. Since the energy of the liquid is lower at room temperature, then the energy difference that must be overcome to become steam is greater, so the heat of vaporization is greater.

11.71   **Given:** 915 kJ from candy bar, water $d = 1.00$ g/ml   **Find:** L(H_2O) vaporized at 100.0 °C
Other: $\Delta H°_{vap} = 40.7$ kJ/mol
Conceptual Plan: $q \rightarrow$ mol $H_2O \rightarrow$ g $H_2O \rightarrow$ mL $H_2O \rightarrow$ L H_2O

$$\frac{1\ mol}{40.7\ kJ} \qquad \frac{18.01\ g}{1\ mol} \qquad \frac{1.00\ mL}{1.00\ g} \qquad \frac{1\ L}{1000\ mL}$$

Solution: $915\ kJ \times \dfrac{1\ mol}{40.7\ kJ} \times \dfrac{18.02\ g}{1\ mol} \times \dfrac{1.00\ mL}{1\ g} \times \dfrac{1\ L}{1000\ mL} = 0.405\ L\ H_2O$

Check: The units (L) are correct. The magnitude of the answer (< 1 L) makes physical sense because we are vaporizing about 22 moles of water.

11.72   **Given:** 100.0 mL water, $d = 1.00$ g/ml, heated to 100.0 °C   **Find:** heat (kJ) to vaporize at 100.0 °C
Other: $\Delta H°_{vap} = 40.7$ kJ/mol
Conceptual Plan: mL $H_2O \rightarrow$ g $H_2O \rightarrow$ mol $H_2O \rightarrow q$

$$\frac{1.00\ g}{1.00\ mL} \qquad \frac{1\ mol}{18.01\ g} \qquad \frac{40.7\ kJ}{1\ mol}$$

Solution: $100.0\ mL \times \dfrac{1.00\ g}{1.00\ mL} \times \dfrac{1\ mol}{18.02\ g} \times \dfrac{40.7\ kJ}{1\ mol} = 226\ kJ$

Check: The units (kJ) are correct. The magnitude of the answer (226 kJ) makes physical sense because we are vaporizing about 6 moles of water.

11.73   **Given:** 0.95 g water condenses on iron block 75.0 g at $T_i = 22$ °C   **Find:** T_f (iron block)
Other: $\Delta H°_{vap} = 44.0$ kJ/mol; $C_{Fe} = 0.449$ J/g·°C from text
Conceptual Plan: g $H_2O \rightarrow$ mol $H_2O \rightarrow q_{H_2O}$ (kJ) $\rightarrow q_{H_2O}$ (J) $\rightarrow q_{Fe}$ then $q_{Fe},\ m_{Fe},\ T_i \rightarrow T_f$

$$\frac{1\ mol}{18.01\ g} \qquad \frac{-44.0\ kJ}{1\ mol} \qquad \frac{1000\ J}{1\ kJ} \qquad -q_{H_2O} = q_{Fe} \qquad q = mC_s(T_f - T_i)$$

Solution: $0.95\ g \times \dfrac{1\ mol}{18.02\ g} \times \dfrac{-44.0\ kJ}{1\ mol} \times \dfrac{1000\ J}{1\ kJ} = -2319.64\ J$ then $-q_{H_2O} = q_{Fe} = 2319.64\ J$ then

$q = m\,C_s(T_f - T_i)$. Rearrange to solve for T_f.

$$T_f = \frac{m\,C_s T_i + q}{m\,C_s} = \frac{\left(75.0\ g \times 0.449\ \dfrac{J}{g\cdot°C} \times 22\ °C\right) + 2319.64\ J}{75.0\ g \times 0.449\ \dfrac{J}{g\cdot°C}} = 91\ °C.$$

Check: The units (°C) are correct. The temperature rose, which is consistent with heat being added to the block. The magnitude of the answer (91 °C) makes physical sense because even though we have $\sim \frac{1}{20}$ of a mole, the energy involved in condensation is very large.

11.74   **Given:** 1.15 g rubbing alcohol (C_3H_8O) evaporated from aluminum block 65.0 g at $T_i = 25$ °C
Find: T_f (aluminum block)   **Other:** $\Delta H°_{vap} = 45.4$ kJ/mol; $C_{Al} = 0.903$ J/g·°C from text
Conceptual Plan: g $C_3H_8O \rightarrow$ mol $C_3H_8O \rightarrow q_{C_3H_8O}$ (kJ) $\rightarrow q_{C_3H_8O}$ (J) $\rightarrow q_{Al}$ then $q_{Al},\ m_{Fe},\ T_i \rightarrow T_f$

$$\frac{1\ mol}{60.09\ g} \qquad \frac{-45.4\ kJ}{1\ mol} \qquad \frac{1000\ J}{1\ kJ} \qquad -q_{H_2O} = q_{Al} \qquad q = m\,C_s(T_f - T_i)$$

Solution: $1.15\ g \times \dfrac{1\ mol}{60.09\ g} \times \dfrac{45.4\ kJ}{1\ mol} \times \dfrac{1000\ J}{1\ kJ} = 868.8634\ J$ then $-q_{H_2O} = q_{Al} = -868.8634\ J$ then

$q = m\,C_s(T_f - T_i)$. Rearrange to solve for T_f.

$$T_f = \frac{m\,C_s\,T_i + q}{m\,C_s} = \frac{\left(65.0\ \cancel{g} \times 0.903\ \dfrac{J}{\cancel{g}\cdot\cancel{°C}} \times 25\ \cancel{°C}\right) - 868.8634\ J}{65.0\ \cancel{g} \times 0.903\ \dfrac{J}{\cancel{g}\cdot °C}} = 10.19698\ °C = 10.\ °C.$$

Check: The units (°C) are correct. The temperature dropped, which is consistent with heat being removed from the block. The magnitude of the answer (10 °C) makes physical sense because even though we have only a fraction of a mole, the energy involved in vaporization is very large.

11.75 **Given**: <u>Temperature (K)</u>   <u>Vapor Pressure (torr)</u> **Find**: $\Delta H°_{vap}$ (NH_3) and normal boiling point

Temperature (K)	Vapor Pressure (torr)
200	65.3
210	134.3
220	255.7
230	456.0
235	597.0

Conceptual Plan: To find the heat of vaporization, use Excel or similar software to make a plot of the natural log of vapor pressure (ln P) as a function of the inverse of the temperature in K (1/T). Then fit the points to a line and determine the slope of the line. Since the slope = $-\Delta H_{vap}/R$, we find the heat of vaporization as follows:

slope = $-\Delta H_{vap}/R \rightarrow \Delta H_{vap} = -$ slope x R then J $\xrightarrow{\frac{1\,kJ}{1000\,J}}$ kJ.

For the normal boiling point, use the equation of the best fit line, substitute 760 torr for the pressure and calculate the temperature.

Solution: Data was plotted in Excel.
The slope of the best fitting line is -2969.9 K.

$$\Delta H_{vap} = -\text{slope} \times R = -(-2969.9\ K) \times \frac{8.314\ J}{K\,mol} = \frac{2.46917 \times 10^4\ J}{mol} \times \frac{1\ kJ}{1000\ J} = 24.7\ \frac{kJ}{mol}$$
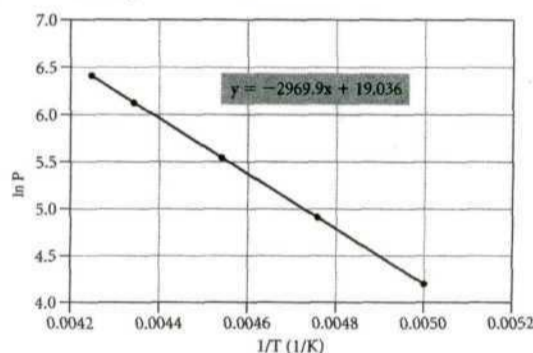
$$\ln P = -2969.9\ K\left(\frac{1}{T}\right) + 19.036 \rightarrow$$

$$\ln 760 = -2969.9\ K\left(\frac{1}{T}\right) + 19.036 \rightarrow$$

$$2969.9\ K\left(\frac{1}{T}\right) = 19.036 - 6.63332 \rightarrow$$

$$T = \frac{2969.9\ K}{12.40268} = 239\ K$$

Check: The units (kJ/mol) are correct. The magnitude of the answer (25) is consistent with other values in the text.

11.76 **Given**: <u>Temperature (K)</u>   <u>Vapor Pressure (torr)</u> **Find**: $\Delta H°_{vap}$ (N_2) and normal boiling point

Temperature (K)	Vapor Pressure (torr)
65	130.5
70	289.5
75	570.8
80	1028
85	1718

Conceptual Plan: To find the heat of vaporization, use Excel or similar software to make a plot of the natural log of vapor pressure (ln P) as a function of the inverse of the temperature in K (1/T). Then fit the points to a line and determine the slope of the line. Since the slope = $-\Delta H_{vap}/R$, we find the heat of vaporization as follows:

slope = $-\Delta H_{vap}/R \rightarrow \Delta H_{vap} = -$ slope x R then J $\xrightarrow{\frac{1\,kJ}{1000\,J}}$ kJ.

For the normal boiling point, use the equation of the best fit line, substitute 760 torr for the pressure, and calculate the temperature.

Solution: Data was plotted in Excel.
The slope of the best fitting line is -711.98 K.

$$\Delta H_{vap} = -\text{ slope} \times R = -(-711.98 \text{ K}) \times \frac{8.314 \text{ J}}{\text{K mol}} =$$

$$= \frac{5.91940 \times 10^3 \text{ J}}{\text{mol}} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = 5.92 \frac{\text{kJ}}{\text{mol}}$$
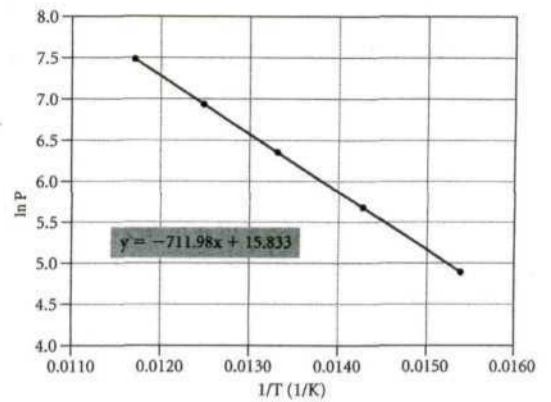
$$\ln P = -711.98 \text{ K}\left(\frac{1}{T}\right) + 15.833 \rightarrow$$

$$\ln 760 = -711.98 \text{ K}\left(\frac{1}{T}\right) + 15.833 \rightarrow$$

$$711.98 \text{ K}\left(\frac{1}{T}\right) = 15.833 - 6.63332 \rightarrow$$

$$T = \frac{711.98 \text{ K}}{9.19968} = 77.4 \text{ K}$$

Check: The units (kJ/mol) are correct. The magnitude of the answer is lower than other values quoted in the text. This is consistent with the fact that nitrogen boils at such a low temperature.

11.77 **Given:** ethanol, $\Delta H°_{vap} = 38.56$ kJ/mol; normal boiling point = 78.4 °C **Find:** P_{Ethanol} at 15 °C
Conceptual Plan: °C $\rightarrow$ K and kJ $\rightarrow$ J then $\Delta H°_{vap}, T_1, P_1, T_2 \rightarrow P_2$

$$K = °C + 273.15 \qquad \frac{1000 \text{ J}}{1 \text{ kJ}} \qquad \ln\frac{P_2}{P_1} = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Solution: $T_1 = 78.4$ °C + 273.15 = 351.6 K; $T_2 = 15$ °C + 273.15 = 288 K;

$$\frac{38.56 \text{ kJ}}{\text{mol}} \times \frac{1000 \text{ J}}{1 \text{ kJ}} = 3.856 \times 10^4 \frac{\text{J}}{\text{mol}} \quad P_1 = 760 \text{ torr} \quad \ln\frac{P_2}{P_1} = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right).$$ Substitute values in

equation. $\ln\dfrac{P_2}{760 \text{ torr}} = \dfrac{-3.856 \times 10^4 \frac{\text{J}}{\text{mol}}}{8.314 \frac{\text{J}}{\text{K}\cdot\text{mol}}}\left(\dfrac{1}{288 \text{ K}} - \dfrac{1}{351.6 \text{ K}}\right) = -2.91302 \rightarrow$

$\dfrac{P_2}{760 \text{ torr}} = e^{-2.91302} = 0.054311 \rightarrow P_2 = 0.054311 \times 760 \text{ torr} = 41 \text{ torr}.$

Check: The units (torr) are correct. Since 15 °C is significantly below the boiling point, we expect the answer to be much less than 760 torr.

11.78 **Given:** benzene, $\Delta H°_{vap} = 30.72$ kJ/mol; normal boiling point = 80.1 °C; $P_2 = 445$ torr **Find:** T_2
Conceptual Plan: °C $\rightarrow$ K and kJ $\rightarrow$ J then $\Delta H°_{vap}, T_1, P_1, T_2 \rightarrow P_2$

$$K = °C + 273.15 \qquad \frac{1000 \text{ J}}{1 \text{ kJ}} \qquad \ln\frac{P_2}{P_1} = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Solution: $T_1 = 80.1$ °C + 273.15 = 353.3 K; $\dfrac{30.72 \text{ kJ}}{\text{mol}} \times \dfrac{1000 \text{ J}}{1 \text{ kJ}} = 3.072 \times 10^4 \dfrac{\text{J}}{\text{mol}}; P_1 = 760 \text{ torr};$

$P_2 = 445 \text{ torr} \quad \ln\dfrac{P_2}{P_1} = \dfrac{-\Delta H_{vap}}{R}\left(\dfrac{1}{T_2} - \dfrac{1}{T_1}\right).$ Substitute values in equation.

$\ln\dfrac{445 \text{ torr}}{760 \text{ torr}} = \dfrac{-3.072 \times 10^4 \frac{\text{J}}{\text{mol}}}{8.314 \frac{\text{J}}{\text{K}\cdot\text{mol}}}\left(\dfrac{1}{T_2} - \dfrac{1}{353.3 \text{ K}}\right) \rightarrow -0.535244 = -3.694972 \times 10^3 \text{ K}\left(\dfrac{1}{T_2} - 0.002830456\right)$

$\rightarrow \dfrac{1.44857 \times 10^{-4}}{\text{K}} = \left(\dfrac{1}{T_2} - \dfrac{0.002830456}{\text{K}}\right) \rightarrow \dfrac{1}{T_2} = \dfrac{2.97531 \times 10^{-3}}{\text{K}} \rightarrow T_2 = 336.0990 \text{ K} = 63 \text{ °C}.$

Check: The units (°C) are correct. Since the pressure is over half of 760 torr, we expect a temperature a little lower than the boiling point.

Types of Solids and Their Structures

11.95 **Given:** X-ray with $\lambda = 154$ pm, maximum reflection angle of $\theta = 28.3°$, assume $n = 1$
Find: distance between layers
Conceptual Plan: $\lambda , \theta, n \rightarrow d$
$$n\lambda = 2d\sin\theta$$
Solution: $n\lambda = 2d\sin\theta$. Rearrange to solve for d. $d = \dfrac{n\lambda}{2\sin\theta} = \dfrac{1 \times 154 \text{ pm}}{2\sin 28.3°} = 162$ pm.
Check: The units (pm) are correct. The magnitude (164 pm) makes sense since n = 1 and the *sin* is always < 1. The number is consistent with interatomic distances.

11.96 **Given:** distance between layers $= 286$ pm, maximum reflection angle of $\theta = 7.23°$, assume $n = 1$
Find: λ (X-ray) with
Conceptual Plan: $d , \theta, n \rightarrow \lambda$
$$n\lambda = 2d\sin\theta$$
Solution: $n\lambda = 2d\sin\theta$. Rearrange to solve for λ. $\lambda = \dfrac{2d\sin\theta}{n} = \dfrac{2 \times 286 \text{ pm} \times \sin 7.23°}{1} = 72.0$ pm
Check: The units (pm) are correct. The magnitude (72 pm) makes sense since n = 1 and the *sin* is always < 1. The number is consistent with X-ray wavelengths.

11.97 (a) 8 corner atoms x (1/8 atom / unit cell) = 1 atom / unit cell

(b) 8 corner atoms x (1/8 atom / unit cell) + 1 atom in center = (1 + 1) atoms / unit cell = 2 atoms / unit cell

(c) 8 corner atoms x (1/8 atom / unit cell) + 6 face-centered atoms x (1/2 atom / unit cell) = (1 + 3) atoms / unit cell = 4 atoms / unit cell

11.98 (a) coordination number of 12 since this is a face-centered cubic structure

(b) coordination number of 12 since this is a hexagonal closest packed structure

(c) coordination number of 8 since this is a body-centered cubic structure

11.99 **Given:** platinum, face-centered cubic structure, $r = 139$ pm **Find:** edge length of unit cell and density (g/cm^3)
Conceptual Plan: $r \rightarrow l$ and $l \rightarrow V(\text{pm}^3) \rightarrow V(\text{cm}^3)$ and M, FCC structure $\rightarrow m$ then $m, V \rightarrow d$
$$l = 2\sqrt{2}r \qquad V = l^3 \qquad \frac{(1 \text{ cm})^3}{(10^{10} \text{ pm})^3} \qquad\qquad m = \frac{4 \text{ atoms}}{\text{unit cell}} \times \frac{M}{N_A} \qquad d = m/V$$
Solution: $l = 2\sqrt{2}r = 2\sqrt{2} \times 139$ pm $= 393.151$ pm $= 393$ pm and

$V = l^3 = (393.151 \text{ pm})^3 \times \dfrac{(1 \text{ cm})^3}{(10^{10} \text{ pm})^3} = 6.07682 \times 10^{-23}$ cm^3 and

$m = \dfrac{4 \text{ atoms}}{\text{unit cell}} \times \dfrac{M}{N_A} = \dfrac{4 \text{ atoms}}{\text{unit cell}} \times \dfrac{195.09 \text{ g}}{1 \text{ mol}} \times \dfrac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 1.295848 \times 10^{-21} \dfrac{\text{g}}{\text{unit cell}}$ then

$d = \dfrac{m}{V} = \dfrac{1.295848 \times 10^{-21} \dfrac{\text{g}}{\text{unit cell}}}{6.07682 \times 10^{-23} \dfrac{\text{cm}^3}{\text{unit cell}}} = 21.3 \dfrac{\text{g}}{\text{cm}^3}$

Check: The units (pm and g/cm^3) are correct. The magnitude (393 pm) makes sense because it must be larger than the radius of an atom. The magnitude (21 g/ cm^3) is consistent for Pt from Chapter 1.

11.100 **Given:** molybdenum, body-centered cubic structure, $r = 136$ pm
Find: edge length of unit cell and density (g/cm^3)
Conceptual Plan: $r \rightarrow l$ and $l \rightarrow V(\text{pm}^3) \rightarrow V(\text{cm}^3)$ and M, BCC structure $\rightarrow m$ then $m, V \rightarrow d$
$$l = \frac{4r}{\sqrt{3}} \qquad V = l^3 \qquad \frac{(1 \text{ cm})^3}{(10^{10} \text{ pm})^3} \qquad\qquad m = \frac{2 \text{ atoms}}{\text{unit cell}} \times \frac{M}{N_A} \qquad d = m/V$$

Solution: $l = \dfrac{4r}{\sqrt{3}} = \dfrac{4 \times 136 \text{ pm}}{\sqrt{3}} = 314.079 \text{ pm} = 314 \text{ pm}$ and

$V = l^3 = (314.079 \text{ pm})^3 \times \dfrac{(1 \text{ cm})^3}{(10^{10} \text{ pm})^3} = 3.09823 \times 10^{-23} \text{ cm}^3$ and

$m = \dfrac{2 \text{ atoms}}{\text{unit cell}} \times \dfrac{\mathcal{M}}{N_A} = \dfrac{2 \text{ atoms}}{\text{unit cell}} \times \dfrac{95.94 \text{ g}}{1 \text{ mol}} \times \dfrac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 3.186317 \times 10^{-22} \dfrac{\text{g}}{\text{unit cell}}$ then

$d = \dfrac{m}{V} = \dfrac{3.186317 \times 10^{-22} \dfrac{\text{g}}{\text{unit cell}}}{3.09823 \times 10^{-23} \dfrac{\text{cm}^3}{\text{unit cell}}} = 10.3 \dfrac{\text{g}}{\text{cm}^3}$

Check: The units (pm and g/cm³) are correct. The magnitude (314 pm) makes sense because it must be larger than the radius of an atom. The magnitude (10 g/ cm³) is reasonable for a metal density.

11.101 **Given:** rhodium, face-centered cubic structure, $d = 12.41 \text{ g/cm}^3$ **Find:** r (Rh)
Conceptual Plan: $\mathcal{M}$, FCC structure $\rightarrow m$ then $m, V \rightarrow d$ then $V(\text{cm}^3) \rightarrow l \text{ (cm)} \rightarrow l \text{ (pm)}$ then $l \rightarrow r$

$$m = \dfrac{4 \text{ atoms}}{\text{unit cell}} \times \dfrac{\mathcal{M}}{N_A} \qquad d = m/V \qquad V = l^3 \qquad \dfrac{10^{10} \text{ pm}}{1 \text{ cm}} \qquad l = 2\sqrt{2}\,r$$

Solution: $m = \dfrac{4 \text{ atoms}}{\text{unit cell}} \times \dfrac{\mathcal{M}}{N_A} = \dfrac{4 \text{ atoms}}{\text{unit cell}} \times \dfrac{102.905 \text{ g}}{1 \text{ mol}} \times \dfrac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 6.835271 \times 10^{-22} \dfrac{\text{g}}{\text{unit cell}}$

then $d = \dfrac{m}{V}$. Rearrange to solve for V. $V = \dfrac{m}{d} = \dfrac{6.835271 \times 10^{-22} \dfrac{\text{g}}{\text{unit cell}}}{12.41 \dfrac{\text{g}}{\text{cm}^3}} = 5.507873 \times 10^{-23} \dfrac{\text{cm}^3}{\text{unit cell}}$

then $V = l^3$. Rearrange to solve for l.

$l = \sqrt[3]{V} = \sqrt[3]{5.507873 \times 10^{-23} \text{ cm}^3} = 3.804831 \times 10^{-8} \text{ cm} \times \dfrac{10^{10} \text{ pm}}{1 \text{ cm}} = 380.4831 \text{ pm}$ then $l = 2\sqrt{2}r$.

Rearrange to solve for r. $r = \dfrac{l}{2\sqrt{2}} = \dfrac{380.4831 \text{ pm}}{2\sqrt{2}} = 134.5 \text{ pm}$.

Check: The units (pm) are correct. The magnitude (135 pm) is consistent with an atomic diameter.

11.102 **Given:** barium, body-centered cubic structure, $d = 3.59 \text{ g/cm}^3$ **Find:** r (Ba)
Conceptual Plan: $\mathcal{M}$, BCC structure $\rightarrow m$ then $m, V \rightarrow d$ then $V(\text{cm}^3) \rightarrow l \text{ (cm)} \rightarrow l \text{ (pm)}$ then $l \rightarrow r$

$$m = \dfrac{2 \text{ atoms}}{\text{unit cell}} \times \dfrac{\mathcal{M}}{N_A} \qquad d = m/V \qquad V = l^3 \qquad \dfrac{10^{10} \text{ pm}}{1 \text{ cm}} \qquad l = \dfrac{4r}{\sqrt{3}}$$

Solution: $m = \dfrac{2 \text{ atoms}}{\text{unit cell}} \times \dfrac{\mathcal{M}}{N_A} = \dfrac{2 \text{ atoms}}{\text{unit cell}} \times \dfrac{137.34 \text{ g}}{1 \text{ mol}} \times \dfrac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 4.561275 \times 10^{-22} \dfrac{\text{g}}{\text{unit cell}}$ then

$d = \dfrac{m}{V}$. Rearrange to solve for V. $V = \dfrac{m}{d} = \dfrac{4.561275 \times 10^{-22} \dfrac{\text{g}}{\text{unit cell}}}{3.59 \dfrac{\text{g}}{\text{cm}^3}} = 1.270550 \times 10^{-22} \dfrac{\text{cm}^3}{\text{unit cell}}$

then $V = l^3$. Rearrange to solve for l.

$l = \sqrt[3]{V} = \sqrt[3]{1.270550 \times 10^{-22} \text{ cm}^3} = 5.027336 \times 10^{-8} \text{ cm} \times \dfrac{10^{10} \text{ pm}}{1 \text{ cm}} = 502.7336 \text{ pm}$

then $l = \dfrac{4r}{\sqrt{3}}$. Rearrange to solve for r. $r = \dfrac{l\sqrt{3}}{4} = \dfrac{502.7336 \text{ pm} \times \sqrt{3}}{4} = 217.7 \text{ pm}$.

Check: The units (pm) are correct. The magnitude (218 pm) is consistent with an atomic diameter.

11.103 **Given:** polonium, simple cubic structure, $d = 9.3 \text{ g/cm}^3$; $r = 167 \text{ pm}$; $\mathcal{M} = 209 \text{ g/mol}$ **Find:** estimate N_A
Conceptual Plan: $r \rightarrow l$ and $l \rightarrow V(\text{pm}^3) \rightarrow V(\text{cm}^3)$ then $d, V \rightarrow m$ then $\mathcal{M}$, SC structure $\rightarrow m$

$$l = 2r \qquad V = l^3 \qquad \dfrac{(1 \text{ cm})^3}{(10^{10} \text{ pm})^3} \qquad d = m/V \qquad m = \dfrac{1 \text{ atom}}{\text{unit cell}} \times \dfrac{\mathcal{M}}{N_A}$$