Exc.1

Refer to Table F.1 for pressure conversion factors.

(a) $p = 110\ \text{kPa} \times \dfrac{760\ \text{Torr}}{101.325\ \text{kPa}} = \boxed{825\ \text{Torr}}$.

(b) $p = 0.997\ \text{bar} \times \dfrac{100\ \text{kPa}}{1\ \text{bar}} \times \dfrac{1\ \text{atm}}{101.325\ \text{kPa}} = \boxed{0.984\ \text{atm}}$.

(c) $p = (21.5\ \text{kPa}) \times \left(\dfrac{1\ \text{atm}}{101.325\ \text{kPa}}\right) = \boxed{0.212\ \text{atm}}$.

(d) $p = 723\ \text{Torr} \times \left(\dfrac{101.325 \times 10^3\ \text{Pa}}{760\ \text{Torr}}\right) = \boxed{9.64 \times 10^4\ \text{Pa}}$.

Exc.2

Solve the perfect gas law [F.6] for n and recognize the volume unit of the data needs to be converted to dm^3 so that units cancel conveniently in the calculation.

$V = 250.0\ \text{cm}^3 = 0.2500\ \text{dm}^3$ and $T = (273.15 + 19.5)\ \text{K} = 292.65\ \text{K}$.

$$n = \frac{pV}{RT} = \frac{(24.5\ \text{kPa}) \times (0.2500\ \text{dm}^3)}{(8.3145\ \text{dm}^3\ \text{kPa}\ \text{K}^{-1}\ \text{mol}^{-1}) \times (292.65\ \text{K})} = 2.52 \times 10^{-3}\ \text{mol} = \boxed{2.52\ \text{mmol}}$$

Exc.3

According to the perfect gas law, $p_1V_1 = p_2V_2$ when n and T are constant because $nRT = pV =$ a constant. (The subscripts 1 and 2 represent two different gaseous states.) Solving for p_2 gives

$$p_2 = \frac{V_1}{V_2} \times p_1 \text{ where}$$

$V_1 = 1.00\ \text{dm}^3 = 1.00 \times 10^3\ \text{cm}^3$, $p_1 = 1.00\ \text{atm}$, and $V_2 = 1.00 \times 10^2\ \text{cm}^3$. Therefore,

$$p_2 = \frac{V_1}{V_2} \times p_1 = \left(\frac{1.00 \times 10^3\ \text{cm}^3}{100\ \text{cm}^3}\right) \times (1.00\ \text{atm}) = \boxed{10.0\ \text{atm}}$$

Exc.4

According to the perfect gas law, $\dfrac{p_1V_1}{T_1} = \dfrac{p_2V_2}{T_2}$ or $V_2 = \dfrac{p_1T_2}{p_2T_1} \times V_1$ when n is constant because $nR = pV/T =$ a constant.

(a) $V_2 = \dfrac{p_1T_2}{p_2T_1} \times V_1 = \dfrac{(104\ \text{kPa}) \times (268.15\ \text{K})}{(52\ \text{kPa}) \times (294.25\ \text{K})} \times (2.0\ \text{m}^3) = \boxed{3.6\ \text{m}^3}$

(b) $V_2 = \dfrac{p_1T_2}{p_2T_1} \times V_1 = \dfrac{(104 \times 10^3\ \text{Pa}) \times (221.15\ \text{K})}{(880\ \text{Pa}) \times (294.25\ \text{K})} \times (2.0\ \text{m}^3) = \boxed{1.8 \times 10^2\ \text{m}^3}$

Exc.5

$Work_{lift} = (force_{gravity}) \times (vertical\ displacement) = mgd$ [F.11 and associated *brief illustration*]

$= (65\ \text{kg}) \times (9.81\ \text{m s}^{-2}) \times (3.5\ \text{m}) = 2.2 \times 10^3\ \text{kg m}^2\ \text{s}^{-2} = \boxed{2.2\ \text{kJ}}$ $[1\ \text{kg m}^2\ \text{s}^{-2} = 1\ \text{J}]$

Exc.6

$E_k = \frac{1}{2}mv^2$ [F.12]

$$= \tfrac{1}{2}(1.5\ \text{t}) \times (50\ \text{km h}^{-1})^2 \times \left(\frac{1000\ \text{kg}}{1\ \text{t}}\right) \times \left(\frac{1000\ \text{m}}{1\ \text{km}}\right)^2 \times \left(\frac{1\ \text{h}}{3600\ \text{s}}\right)^2$$

$$= 1.4 \times 10^5\ \text{J} = \boxed{1.4 \times 10^2\ \text{kJ}}.$$

Exc.7

We estimate the average kinetic energy of a molecule with $v = 400\ \text{m s}^{-1}$ and $m = M/N_A = (29\ \text{g mol}^{-1})/N_A$ in eqn F.12, $E_k = \frac{1}{2}mv^2$. The number of molecules, N, is given by $N = nN_A$ and the total energy stored as molecular kinetic energy is NE_k.

$$NE_k = (nN_A) \times (\tfrac{1}{2}mv^2) = (nN_A) \times \left\{\tfrac{1}{2}\left(\frac{M}{N_A}\right) \times v^2\right\} = \tfrac{1}{2}nMv^2$$

$$= \tfrac{1}{2}(1\ \text{mol}) \times (0.029\ \text{kg mol}^{-1}) \times (400\ \text{m s}^{-1})^2$$

$$= 2.3 \times 10^3\ \text{kg m}^2\ \text{s}^{-2} = 2.3 \times 10^3\ \text{J} = \boxed{2.3\ \text{kJ}}$$

Exc.8

The Coulomb potential, ϕ, is

$\phi = \dfrac{Q_2}{4\pi\varepsilon_0 r}$ where r is the separation of point charge Q_1 and the nuclear charge Q_2

Q_1 interacts with two nuclei in this exercise and the interactions are additive.

$$\phi = \left(\frac{Q_2}{4\pi\varepsilon_0 r}\right)_{\text{Li nucleus}} + \left(\frac{Q_2}{4\pi\varepsilon_0 r}\right)_{\text{H nucleus}}$$

$$= \left(\frac{Ze}{4\pi\varepsilon_0 r}\right)_{\text{Li nucleus}} + \left(\frac{Ze}{4\pi\varepsilon_0 r}\right)_{\text{H nucleus}}$$

$$= \frac{e}{4\pi\varepsilon_0} \times \left\{\left(\frac{Z}{r}\right)_{\text{Li nucleus}} + \left(\frac{Z}{r}\right)_{\text{H nucleus}}\right\}$$

$$= \left(\frac{1.6022 \times 10^{-19}\ \text{C}}{1.113 \times 10^{-10}\ \text{J}^{-1}\ \text{C}^2\ \text{m}^{-1}}\right) \times \left\{\frac{3}{200 \times 10^{-12}\ \text{m}} + \frac{1}{150 \times 10^{-12}\ \text{m}}\right\}$$

$$= 31.2\ \text{J C}^{-1} = \boxed{31.2\ \text{V}}$$

Exc.9 $\lambda = \frac{c}{\nu}$ [F.16] $= \frac{2.998 \times 10^{8}\ \mathrm{m\ s^{-1}}}{92.0 \times 10^{6}\ \mathrm{s^{-1}}} = \boxed{3.26\ \mathrm{m}}$

Exc.10 (a) $E = h\nu = \frac{hc}{\lambda}$ [F.17 and F.16]

$$= \frac{(6.62608 \times 10^{-34}\ \mathrm{J\ s}) \times (2.99792 \times 10^{8}\ \mathrm{m\ s^{-1}})}{670 \times 10^{-9}\ \mathrm{m}}$$

$= 0.296$ aJ [atto, a $\equiv 10^{-18}$] $= \boxed{296\ \mathrm{zJ}}$ [zepto, z $\equiv 10^{-21}$]

(b) $E(\text{per mole}) = N_{\mathrm{A}}E = \frac{N_{\mathrm{A}}hc}{\lambda}$

$$= (6.022 \times 10^{23}\ \mathrm{mol^{-1}}) \times \frac{(6.62608 \times 10^{-34}\ \mathrm{J\ s}) \times (2.99792 \times 10^{8}\ \mathrm{m\ s^{-1}})}{670 \times 10^{-9}\ \mathrm{m}}$$

$$= \boxed{179\ \mathrm{kJ\ mol^{-1}}}$$

Exc.11 Let the subscripts 1 and 2 represent the random coil and fully stretched macromolecules, respectively.

$\frac{N_2}{N_1} = e^{-(E_2-E_1)/RT}$ [F.19b]

$$= e^{-(2.4\times10^{3}\ \mathrm{J\ mol^{-1}})/\{(8.3145\ \mathrm{J\ K^{-1}\ mol^{-1}})\times(293.15\ \mathrm{K})\}} = \boxed{0.37}$$

Exc.12 Let the subscripts 1 and 2 represent the lower and upper energies, respectively. Then, $E_1 = -\mu_{\mathrm{B}}\mathcal{B}$ and $E_2 = \mu_{\mathrm{B}}\mathcal{B}$.

$\frac{N_2}{N_1} = e^{-(E_2-E_1)/kT}$ [F.19a] $= e^{-2\mu_{\mathrm{B}}\mathcal{B}/kT}$

$$= e^{-2(9.274\times10^{-24}\ \mathrm{J\ T^{-1}})\times(1.0\ \mathrm{T})/\{(1.381\times10^{-23}\ \mathrm{J\ K^{-1}})\times T\}} = e^{-1.34\overline{3}/(T/\mathrm{K})}$$

(a) At 4.0 K: $\frac{N_2}{N_1} = e^{-1.34\overline{3}/(4.0)} = \boxed{0.71}$

(b) At 298 K: $\frac{N_2}{N_1} = e^{-1.34\overline{3}/(298)} = \boxed{0.99\overline{6}}$

These calculations demonstrate that a majority of molecules occupy the low energy state at low temperature while all energy states are equally occupied at extremely high temperature. The values of the "low temperature" and the "high temperature" depend upon the spacing of the energy levels.