CHAPTER 18

9. (a) From table 16.3. Argon gas is monatomic gas.

$m = 40u = 40(1.661\times10^{-27} kg) = 6.64\times10^{-26} kg$

From equation 18.18

$p = \frac{1}{3}\frac{N}{V}mv_{rms}^2 = \frac{1}{3}(2.0\times10^{25} m^{-3})(6.64\times10^{-26} kg)(455 m/s)^2 = 9.16\times10^4 Pa$

(b) $pV = Nk_BT \Rightarrow T = \frac{pV}{Nk_B} = \frac{p}{(N/V)k_B} = \frac{9.16\times10^4 Pa}{(2.0\times10^{25} m^{-3})(1.38\times10^{-23} J/K)} = 332 K$

10 $p = \frac{F}{A} = N_{collision}\frac{\Delta mv}{\Delta t}\frac{1}{A} = 2mv\left(\frac{N_{collision}}{\Delta t}\right)\frac{1}{A}$

$= 2\cdot(28\times1.66\times10^{-27} kg)(400 m/s)(5.0\times10^{23} s^{-1})/(1.0\times10^{-3} m^2) = 1.86\times10^4 Pa$

11 $p = \frac{F}{A} = \frac{\Delta(mv)N_{collision}}{A\Delta t}$

$\frac{N_{collision}}{\Delta t} = \frac{pA}{\Delta(mv)} = \frac{pA}{2mv} = \frac{(1.013\times10^5 Pa)(1.0\times10^{-3} m^2)}{2(32\times1.66\times10^{-27} kg)(500 m/s)} = 1.91\times10^{24}/s$

20 (a) $\varepsilon_{Avg} = \frac{3}{2}k_BT$, so ε_{Avg} becomes doubled.

(b) $\varepsilon_{Avg} = \frac{1}{2}mv_{rms}^2 \Rightarrow v_{rms} \propto \sqrt{\varepsilon_{Avg}} \propto \sqrt{T}$, so v_{rms} becomes $\sqrt{2}v_{rms,old}$

(c) $\lambda = \frac{1}{4\sqrt{2}\pi(N/V)r^2}$ (18.3). The density N/V doesn't change because we keep the volume constant. So, λ doesn't change.

21. $K_{th} = \frac{3}{2}nRT$

(a) (b), (c) $K_{th} = \frac{3}{2}(1.0 mol)(8.31 J/mol K)(273K) = 3400 J$

22 (a) $\lambda = \frac{1}{4\sqrt{2}\pi(N/V)r^2}$ (18.3) $r \approx 0.5\times10^{-10} m$ for monatomic gas
$r \approx 1.0\times10^{-10} m$ for diatomic gas

$r \approx 0.5\times10^{-10} m$

$pV = Nk_BT \Rightarrow \frac{N}{V} = \frac{p}{k_BT} = \frac{0.1\times101300 Pa}{(1.38\times10^{-23} J/K)(10K)} = 7.34\times10^{25} m^{-3}$

$\lambda = \frac{1}{4\sqrt{2}\pi(7.34\times10^{25}/m^3)(0.5\times10^{-10} m)^2} = 3.07\times10^{-7} m$

(b) $\epsilon_{avg} = \frac{1}{2}mv_{rms}^2 = \frac{3}{2}k_BT$

$$v_{rms} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3(1.38\times10^{-23}\,J/K)(10K)}{4\times1.661\times10^{-27}\,kg}} = 250\ m/s$$

(c) $\epsilon_{avg} = \frac{3}{2}k_BT = \frac{3}{2}(1.38\times10^{-23}\,J/K)(10K) = 2.07\times10^{-22}\,J$

24 (a) $\epsilon_{AVG} = \frac{3}{2}k_BT = \frac{3}{2}(1.38\times10^{-23}\,J/K)(6\times10^3\,K) = 1.24\times10^{-19}\,J$

(b) $\frac{1}{2}mv_{rms}^2 = \frac{3}{2}k_BT \Rightarrow v_{rms} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3(1.38\times10^{-23}\,J/K)(6000K)}{1\times1.67\times10^{-27}\,kg}} = 1.22\times10^4\ m/s$

CHAPTER 17

32 $n = \frac{pV}{RT} = \frac{(2\times1.013\times10^5\,Pa)(1530\times10^{-6}\,m^3)}{(8.31\,J/mol\,K)(373\,K)} = 0.10\ mol$

$m(H_2O) = (1+1+16)u = 18u$

the mass of the steam $M = (0.10\,mol)(18\,g/mol) = 1.8\,g$

① 100°C steam → 100°C water

$Q_1 = -ML_v = -(1.8\times10^{-3}\,kg)(22.6\times10^5\,J/kg) = -4068\,J$

② 100°C water → 0°C water

$Q_2 = Mc_w\Delta T = -(1.8\times10^{-3}\,kg)(4190\,J/kg\,K)(100°C) = -754.2\,J$

③ 0°C water → 0°C ice

$Q_3 = -ML_f = -(1.8\times10^{-3}\,kg)(3.33\times10^5\,J/kg) = -599.4\,J$

④ 0°C ice → -20°C ice

$Q_4 = Mc_{ice}\Delta T = -(1.8\times10^{-3}\,kg)(2090\,J/kg\,K)(20°C) = -75.24\,J$

$Q = Q_1+Q_2+Q_3+Q_4 = -5497\,J$

38. $Q_1 = M_{ice} c_{ice} \Delta T = (0.1\,kg)(2090\,J/kg\,K)(10\,K) = 2090\,J$

$Q_2 = M_{ice} L_f = (0.1\,kg)(3.33\times10^5\,J/kg) = 33300\,J$

$Q_3 = M_{ice} c_w \Delta T = (0.1\,kg)(4190\,J/kg\,K)(20\,K) = 8380\,J$

$Q_4 = M_{AL} c_{AL} \Delta T = M_{AL}(900\,J/kg\,K)(-50\,K) = -(45000\,J/kg)M_{AL}$

$Q = Q_1 + Q_2 + Q_3 + Q_4 = 0$

$(45000\,J/kg)M_{AL} = 43770\,J$

$M_{AL} = 0.973\,kg$

44. $M = \rho V = (810\,kg/m^3)(1\,L) = (810\,kg/m^3)(10^{-3}\,m^3) = 0.810\,kg$

the number of N_2 gas molecule $n = \dfrac{810\,g}{(2\times14\,g/mol)} = 28.9$ mols

① 293K gas → 77K gas

$Q_1 = n C_p \Delta T = (28.9\,mols)(29.1\,J/mol\,K)(77K - 293K)$

② 77K gas → 77K liquid

$Q_2 = -M L_v = -(0.810\,kg)(1.99\times10^5\,J/kg)$

$Q = Q_1 + Q_2 = -3.43\times10^5\,J$

49 (a) $\epsilon_{Avg} = \frac{1}{2} m v_{rms}^2 = \frac{1}{2}(2\times1.661\times10^{-27}\,kg)(700\,m/s)^2 = 8.13\times10^{-22}\,J$

~~(b) $\Delta E_{th} = W + Q = -300\,J + 500\,J = 200\,J$~~ ~~$E_{th}$~~

$N = \dfrac{1\,g}{2\times1.661\times10^{-27}\,kg} = 3.01\times10^{23}$

$E_{th} = N\epsilon_{Avg} = (3.01\times10^{23})(8.13\times10^{-22}\,J) = 245\,J$

(b) $\Delta E_{th} = W + Q = -300\,J + 500\,J = 200\,J$

$E_{th,new} = E_{th,old} + \Delta E_{th} = 445\,J$

$\epsilon_{Avg} = E_{th,new}/N = 1.487\times10^{-21}\,J$, $v_{Avg} = \sqrt{\dfrac{2\epsilon_{Avg}}{m}} = 944\,m/s$

52

(a) $F = pA = (3\ \text{atm} \times 1.013 \times 10^5\ \text{Pa/atm})(\pi \times 0.08^2\ \text{m}^2) = 6110\ \text{N}$

(b) 6110 N in the opposite direction

(c) $W = -F\Delta x = -(6110\ \text{N})(10\ \text{cm}) = -611\ \text{J}$

(d) $W_{gas} = -W = 611\ \text{J}$

(e) $\Delta E_{th} = W + Q$

$Q = \Delta E_{th} - W = 196\text{J} + 611\text{J} = 807\ \text{J}$

So, the heat was transferred to the gas

57 $M = 5\text{g}$, $T_1 = 293\text{K}$, $p_1 = 3\ \text{atm}$

(a) $n = \dfrac{5\text{g}}{28\text{g/mol}} = 0.1786\ \text{mol}$

$V_1 = \dfrac{nRT_1}{p_1} = \dfrac{(0.1786\ \text{mol})(8.31\ \text{J/mol K})(293\text{K})}{3 \times 1.013 \times 10^5\ \text{Pa}} = 1.430 \times 10^{-3}\ \text{m}^3$

$V_2 = 3V_1 = 4290\ \text{cm}^3$

isobaric $\Rightarrow p_1 = p_2 \Rightarrow \dfrac{T_2}{V_2} = \dfrac{T_1}{V_1} \Rightarrow T_2 = \dfrac{V_2}{V_1} T_1 = 3T_1 = 3 \times 293\text{K} = 879\text{K}$

(b) $Q = nC_p\Delta T = (0.1786\ \text{mol})(29.1\ \text{J/mol K})(T_2 - T_1) = 3050\ \text{J}$

(c) $V_2 = V_3$

$\dfrac{p_3}{T_3} = \dfrac{p_2}{T_2} \Rightarrow p_3 = \dfrac{T_3}{T_2} p_2 = \dfrac{293\text{K}}{879\text{K}} \times 3\ \text{atm} = 1.0\ \text{atm}$

(d) $Q = nC_v\Delta T = (0.1786\ \text{mol})(20.8\ \text{J/mol K})(293\text{K} - 879\text{K}) = -2180\text{J}$

So 2180J Heat was transferred from the gas.

(e)