Solutions to ~~Sixth~~ Problem Set PHY 132

(1) $v_{RMS} = \sqrt{\dfrac{3RT}{M}}$

so $\dfrac{v_{RMS}(He)}{v_{RMS}(N_2)} = \dfrac{\sqrt{\dfrac{3RT}{M_{He}}}}{\sqrt{\dfrac{3RT}{M_{N_2}}}} = \sqrt{\dfrac{M_{N_2}}{M_{He}}} = \sqrt{\dfrac{28}{4}} = \sqrt{7}$

$v_{RMS}(He) = 511\sqrt{7}\ m/s = \boxed{1352\ m/s}$

(2) $PV = NkT$

$\dfrac{N}{V} = \dfrac{P}{kT} = \dfrac{10^{-18}(1.013 \times 10^{5}\ N/m^2)}{(1.38 \times 10^{-23}\ \frac{J}{K})\ 300\ °K} = 2.45 \times 10^{7}\ \dfrac{mol}{m^3}$

$= 2.45 \times 10^{7}\ \dfrac{mol}{m^3}\ \dfrac{1\ m^3}{10^6\ cm^3} = \boxed{24.5\ \dfrac{molecules}{cm^3}}$

(3) For an isobaric process $p =$ constant,

so $W = p(V_2 - V_1)$

$= p\left[\dfrac{AT_2 - BT_2^2}{p} - \dfrac{(AT_1 - BT_1^2)}{p}\right]$

$= \boxed{A(T_2 - T_1) - B(T_2^2 - T_1^2)}$

(4) $\frac{Q}{t} = kA\frac{\Delta T}{L} = \left(1.1\,\frac{W}{m\,^\circ C}\right)(1\,m^2)\frac{20^\circ}{.006\,m} \approx 3666\ \frac{J}{s}$

In one hour

$Q = 3666\ \frac{J}{s}(3600\ s) = \boxed{1.32\times10^7\ J}$

(5) The heat transfer is the same at all junctions

$$k_{gold}\frac{A(80-T)}{.02} = \frac{k_{silver}A(T-20)}{.04}$$

$$\frac{314}{.02}(80-T) = \frac{427}{.04}(T-20)$$

$$80 - T = .68(T-20)$$

$$T = \frac{80+20(.68)}{1.68} = \boxed{55.7^\circ}$$

(6) For an adiabatic process, $PV^\gamma = \text{const}$

or $\frac{nRT}{V}V^\gamma = \text{const} \Rightarrow \boxed{TV^{\gamma-1} = \text{const}}$

so $T = T_0\left(\frac{V_0}{V}\right)^{\gamma-1}$

He is a monatomic gas, so $\gamma = 5/3$

$$T = 300(2)^{2/3} = \boxed{476^\circ K}$$

(6 cont) at 300°K D_2, a diatomic gas, has

$c_V = \frac{5}{2}R$ and $c_p = \frac{7}{2}R$, so $\gamma = \frac{7}{5}$

$$T = 300\,(2)^{2/5} = \boxed{396\,°K}$$

So the He reaches a higher temperature.

(7)

$$W_{A\to B} = \boxed{0}$$

$$Q_{A\to B} = n C_V \Delta T = n\frac{3}{2}R\Delta T = \frac{3}{2}\Delta(nRT)$$

$$= \frac{3}{2}\Delta(PV) = \frac{3}{2}(200-100) = \boxed{150\ J}$$

$$T_A = \frac{P_A V_A}{nR} = \frac{100}{8.314} = 12.0\,°K$$

$$T_B = 2T_A = 24.1\,°K$$

$\gamma = 5/3$ for monatomic gas

$$P_c V_c^{\gamma} = P_B V_B^{\gamma}$$

$$V_c = \left(\frac{P_b}{P_c}\right)^{\frac{1}{\gamma}} V_B = (2)^{3/5}\,(10^{-3}\,m^3)$$

$$\underline{V_c = 1.526\times 10^{-3}\,M^3}$$

$$T_c = \frac{P_c V_c}{nR} = \frac{10^5(1.526\times 10^{-3})}{8.314} = \underline{18.23\,°K}$$

(7 cont)

$$W_{C\to A} = P(V_A - V_C) = 10^5(1-1.526)\times 10^{-3} = \boxed{-52.6\,J}$$

$$Q_{C\to A} = nC_p\Delta T = \frac{5}{2}R\Delta T = \frac{5}{2}(8.314)(12-18.23)$$

$$Q_{C\to A} = \boxed{-129.4\,J}$$

$$Q_{B\to C} = \boxed{0}$$ adiabatic process

$$W_{B\to C} = -\Delta U = -\frac{3}{2}nR\Delta T = -\frac{3}{2}(8.314)(18.23-24.1)$$

$$W_{B\to C} = \boxed{73.2\,J}$$

Filling in the table: $\Delta U = Q - W$

Process	Q	W	ΔU
A → B	150 J	0	150 J
B → C	0	73.2	−73.2 J
C → A	−129.4 J	−52.6	−76.8
cycle	20.6 J	20.6 J	0

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$W = \int P\,dV =$ area under the line

$W = \left(\frac{3}{2}P_1\right)(2V_1 - V_1) = \boxed{\frac{3}{2}V_1P_1}$

$\Delta U = \Delta\left(\frac{3}{2}nRT\right) = \frac{3}{2}\Delta(nRT)$

$= \frac{3}{2}\Delta(PV) = \frac{3}{2}\left((2V_1)(2P_1) - V_1P_1\right)$

$\Delta U = \boxed{\frac{9}{2}V_1P_1}$

$\Delta U = Q - W$

$Q = \Delta U + W$

$Q = \frac{9}{2}V_1P_1 + \frac{3}{2}V_1P_1 = \boxed{6V_1P_1}$