Physics 161 Test 1 Solutions Spring 2009

(1) Let V_g^i = initial volume of glass flask
V_m^i = " " " mercury in flask

We know $V_g^i - V_M^i = 4\,ml$

and $V_g^f - V_M^f = 0$ (ie, mercury just fills flask)

Subtraction

$$(V_g^f - V_g^i) - (V_m^f - V_m^i) = -4\,ml$$

or $$\Delta V_g - \Delta V_m = -4\,ml$$

But $\Delta V = \beta V \Delta T$

So $$\beta_g V_g \Delta T - \beta_M V_M \Delta T = -4\,ml$$

So $$\Delta T = \frac{4\,ml}{\beta_M V_M - \beta_g V_g}$$ where we can take initial volumes

$$= \frac{4\,ml}{\left(\frac{18\times10^{-5}}{K}\right)(496\,ml) - \left(\frac{2.0\times10^{-5}}{K}\right)(500\,ml)}$$

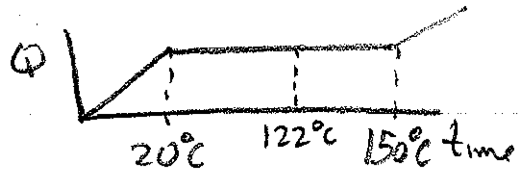
$$= 50.4\,K = 50.4\,C^\circ$$

But

$$\Delta T = T_f - T_i$$

so $$T_f = T_i + \Delta T = 20^\circ C + 50.4^\circ C$$

$$\underline{T_f = 70.4^\circ C} \quad \underline{(E)}$$

(2) 

$$Q = m\,C_{solid}\,(20°C - 3°C) + mL + m\,C_{liq}\,(122°C - 20°C)$$

$$= m\left[C_{solid} * 17C° + L + C_{liq} * 102C°\right)$$

$$= 0.10\,kg\left[600\,\frac{J}{kg\cdot K} * 17\,K + 1.5\times10^{4}\,\frac{J}{kg} + 1000\,\frac{J}{kg\cdot K} * 102\,K\right]$$

$$= 12{,}700\,J = \underline{12.7\,kJ} \quad \underline{(A)}$$

(3) $\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{L}$, ie $\underline{\frac{\Delta Q}{\Delta t} \propto -\frac{1}{L}}$ $\underline{(C)}$

(4) $\left.\begin{array}{l} P_2V_2 = nRT_2 \\ P_1V_1 = nRT_1 \end{array}\right\}$ divide using $V_2 = V_1 = const$

$$\frac{P_2}{P_1} = \frac{T_2}{T_1} \Rightarrow P_2 = P_1\frac{T_2}{T_1} = 2.00\,atm\left(\frac{273K + 50K}{273K + 25K}\right)$$

$$\underline{P_2 = 2.17\,atm} \quad \underline{(B)}$$

(5) $Q = nC_V\Delta T = n\left(\frac{5}{2}R\right)\Delta T$

$$= (0.020\,mol)\left(\frac{5}{2} * 8.314\,\frac{J}{mol\cdot K}\right)(300K - 290K)$$

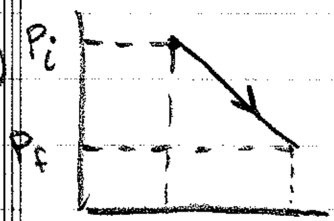
$$\underline{Q = 4.16\,J} \quad \underline{(C)}$$

(6) $P_2 V_2 = nRT_2$ } divide
$P_1 V_1 = nRT_1$ }

$$T_2 = \left(\frac{P_2}{P_1}\right)\left(\frac{V_2}{V_1}\right) \cdot T_1 = \left(\frac{2P_1}{P_1}\right)\left(\frac{V_1/4}{V_1}\right) \cdot T_1 = \frac{T_1}{2}$$

$$T_2 = \frac{(273+27)\,K}{2} = 150K = \underline{-123\,°C} \quad \underline{\underline{(D)}}$$

(7)



$$W = \begin{pmatrix}\text{area}\\ \text{under}\\ \text{curve}\end{pmatrix} = \left(\frac{P_i + P_f}{2}\right)(V_f - V_i)$$

But $V_f = \dfrac{nRT_f}{P_f}$

also $n = \dfrac{P_i V_i}{RT_i} \Rightarrow V_f = \left(\dfrac{P_i V_i}{RT_i}\right)\left(\dfrac{RT_f}{P_f}\right)$

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

So $W = \left(\dfrac{P_i + P_f}{2}\right)\left[\dfrac{P_i}{P_f}\,\dfrac{T_f}{T_i}\,V_i - V_i\right]$. Plugging in values,

$$W = 5.44\,kJ = \underline{5440\,J} \quad \underline{\underline{(A)}}$$

(8) $\underline{\underline{(A)}}$

(9) For adiabatic processes

$$TV^{\gamma-1} = \text{const} \quad , \text{so} \quad T_i V_i^{\gamma-1} = T_f V_f^{\gamma-1}$$

$$V_f^{\gamma-1} = \frac{T_i}{T_f} V_i^{\gamma-1}$$

or $$V_f = V_i \left(\frac{T_i}{T_f}\right)^{\frac{1}{\gamma-1}}$$

But $V_i = nRT_i / P_i$

so $$V_f = \left(\frac{nRT_i}{P_i}\right)\left(\frac{T_i}{T_f}\right)^{\frac{1}{\gamma-1}}$$. Plugging in numbers:

$$\underline{V_f = 0.312 \text{ m}^3} \quad \underline{(A)}$$

(10) For adiabatic process $Q = 0 \Rightarrow \Delta U = -W$

But $\Delta U = nC_V(T_f - T_i)$

Since Argon is an ideal monatomic gas,

$$C_V = \frac{3}{2}R$$

so $\Delta U = + n\left(\frac{3}{2}R\right)(T_f - T_i)$, Plug in:

$$\underline{\Delta U = -168 \text{J}} \quad \underline{(C)}$$

(11) $$e = 1 - \frac{|Q_c|}{Q_H}$$

But $Q_H = W + |Q_c|$

$$\Rightarrow e = 1 - \frac{|Q_c|}{W + |Q_c|} = 1 - \frac{8.2\ kJ}{2.7\,kJ + 8.2\,kJ}$$

$\underline{e = 0.25}$ $\underline{\underline{(B)}}$

(12) For a Carnot engine

$$e = 1 - \frac{T_c}{T_H} = \frac{W}{Q_H}$$

But $W = \text{Power} \cdot \text{time} = P \cdot t$

$$Q_H = \left(\begin{matrix}\text{Rate heat}\\ \text{delivered}\end{matrix}\right) \cdot \text{time} = \left(38 \frac{kJ}{s}\right) \cdot t$$

So $$\frac{W}{Q_H} = \frac{P \cdot t}{\left(38 \frac{kJ}{s}\right) \cdot t} = \frac{P}{38\ kJ/s}$$

So $$P = \left(38 \frac{kJ}{s}\right)\left(1 - \frac{T_c}{T_H}\right)$$

$$= 5.7\,kW = \underline{5700\,W} \quad \underline{\underline{(B)}}$$

(13) $\Delta S = \frac{\Delta Q}{T} = \frac{-mL}{T} = \frac{-(0.46\,kg)(1.04\times10^5\,\frac{J}{kg})}{(273-114.4)\,K}$

$= -302\,\frac{J}{K}$ (D)

(14) For path ab, Volume = const

Also $Q = nC_V(T_b - T_a)$. But $T_b = 640K$

Find T_a from ideal gas law:

$T_a = \frac{P_a V_a}{nR}$ But $P_a = P_c = \frac{nRT_c}{V_c}$

So $T_a = \left(\frac{nRT_c}{V_c}\right)\frac{V_a}{nR} = T_c\frac{V_a}{V_c} = T_b\frac{V_a}{V_c}$ (since $T_c = T_b$)

$\Rightarrow Q = nC_V\left[T_b - T_b\frac{V_a}{V_c}\right]$ Plug in:

$Q = 79{,}600\,J = 79.6\,kJ$ (c)

Note: This is "closest to" answer (c).