Solution

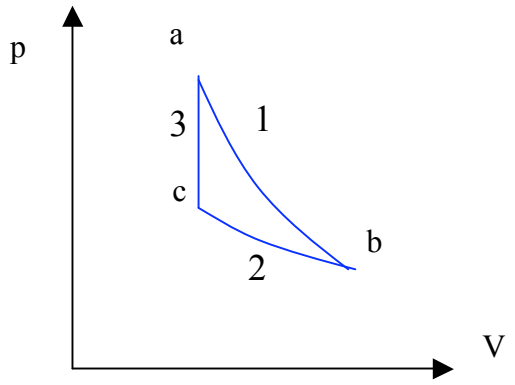
Physics 213 **Problem 2** **Week 3**

Closed Cycle

Nitrogen gas initially at 300K and atmospheric pressure in a volume of 1 liter (state a) is adiabatically expanded to 2 liters (state b), then isothermally returned to 1 liter (state c). How much heat is required to restore the gas to its initial conditions?

1. Draw and label a pV diagram and complete the following tables.

Hints: Start by using the ideal gas law pV = nRT and the known values of p, V and T to find nR. Remember the relationships for isothermal work and adiabatic work.



For a diatomic gas, $\alpha = 5/2$ and $\gamma = (\alpha+1)/\alpha = 7/5$. n = # moles

$U = \alpha nRT = \alpha pV$ $\quad nR = pV/T = .00333$ l-atm/K

state	p	V	T
a	1 A	1 ℓ	300 K
b	0.38 A	2 ℓ	227.4 K
c	0.76 A	1 ℓ	227.4 K

process	Q	$W_{by\ gas}$
1 (a→b)	0	0.60 ℓ-atm
2 (b→c)	-0.52 ℓ-atm	-0.52 ℓ-atm
3 (c→a)	0.60 ℓ-atm	0

The calculations:

Process 1: $V_bT_b^{\alpha} = V_aT_a^{\alpha} \rightarrow T_b = T_a(V_a/V_b)^{1/\alpha} = 227.4$ K

(Q = 0) $p_aV_a^{\gamma} = p_bV_b^{\gamma} \rightarrow p_b = p_a(V_a/V_b)^{\gamma} = .379$ atm

$W_{by} = -\Delta U = \alpha(p_aV_a - p_bV_b) = .605$ l-atm

or use $W_{by} = -\Delta U = \alpha nR(T_a - T_b) = .605$ l-atm (don't need to compute p)

Process 2: $p_bV_b/T_b = p_cV_c/T_c \rightarrow p_c = p_b(V_b/V_c) = .758$ atm

($\Delta U = 0$) $W_{by} = nRT_b \ln(V_c/V_b) = -.524$ l-atm $= Q$

Process 3: $Q = \Delta U = \alpha nR(T_a - T_c) = .605$ l-atm (W = 0)