Hoje: continuar resolvendo o problema da aula passada

$R = 8{,}3\,J/mol.K = 8{,}2\times10^{-2}\,L\,atm/molK$

Condições iniciais $T_0 = 20°C = 293K$

$P_0 = 5atm$; $n = 1mol$

Processos: (1) expansão adiabática $\Rightarrow P_1 = 1atm$

(2) aquecimento a pressão constante $\Rightarrow T_2 = 293K$

(3) aquecimento a volume constante $\Rightarrow P_3 = 5atm$

(4) compressão a pressão constante $\Rightarrow T_0, P_0$

gás de N_2

$c_v = \frac{5}{2}R$

$c_p = c_v + R$

$c_p = \frac{7}{2}R$

$\gamma = \frac{c_p}{c_v} = \frac{7}{5}$

$PV = nRT$

$U = n c_v \Delta T$

unidade

$U\left[\cancel{mol}\,\frac{L.atm}{\cancel{mol.K}}\,\cancel{K}\right]$

$U\,[L.atm]$

Condições ($T_0 = 293K$, $P_0 = 5atm$, $V_0 = 4{,}8L$

$PV = nRT \Rightarrow V_0 = \frac{nRT_0}{P_0} = \frac{1\times 8{,}2\times10^{-2}\times 293}{5}$

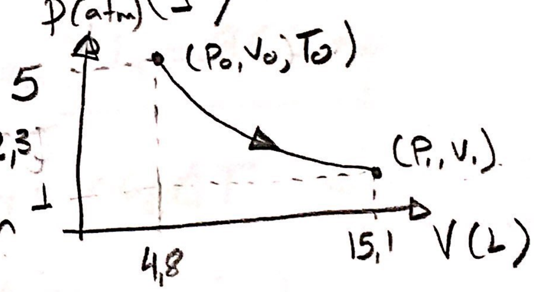
$C_v = \frac{5}{2}nR$

*processo adiabático $\boxed{PV^\gamma = const}$ $P_1V_1^\gamma = P_0V_0^\gamma$

$V_1^\gamma = \frac{P_0V_0^\gamma}{P_1} \therefore V_1 = \left(\frac{P_0}{P_1}\right)^{1/\gamma}V_0 \Rightarrow V_1 = \left(\frac{5}{1}\right)^{5/7}4{,}8 = 3{,}157\times 48$

$\frac{5}{7} = 0{,}7143$

$V_1 = 15{,}1\,L$



$\Delta U_1 = n c_v \Delta T = \frac{5}{2}nR\Delta T = \frac{5}{2}\times 0{,}082\times -108{,}9 = -22{,}3$

$Q_1 = 0$ (adiabático)

$\boxed{\Delta U_1 = -22{,}3\,L.atm}$

W_1

$\Delta U = Q - W \Rightarrow W_1 = 22{,}3\,L.atm$

$PV = nRT \therefore T_1 = \frac{P_1V_1}{nR} = \frac{1\times 15{,}1}{1\times 8{,}2\times10^{-2}}$

$\boxed{Q_1 = 0}$ e $\boxed{W_1 = 22{,}3\,L.atm}$

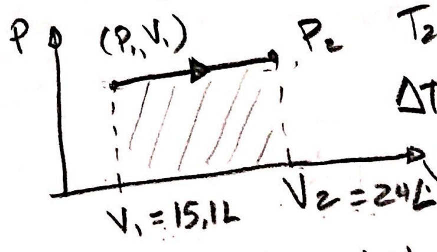
$T_1 = 184{,}1\,K$

$\Delta T = (T_1 - T_0) = 184{,}1 - 293 = -108{,}9$

$Q_2 = \Delta U_2 + W_2$ ou $Q_2 = n c_p \Delta T$

* aquecimento $P = const$

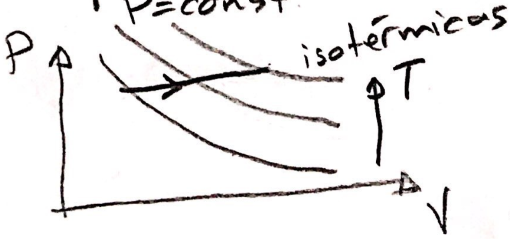
$P_2 = P_1 = 1atm$ $V_1 = 15{,}1L$



$T_2 = 293K$

$\Delta T = (T_2 - T_1)$

$\Delta T = 108{,}9$



$PV = nRT$

$V_2 = \frac{nRT_2}{P_2}$

$V_2 = \frac{1\times 0{,}082\times 293}{1} = 24L$

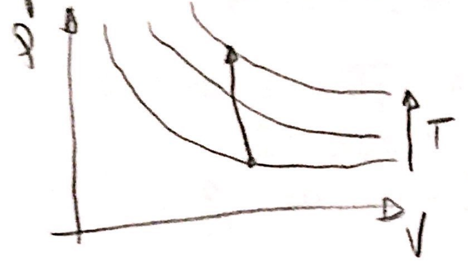
$\Delta U = n c_v R \Delta T$

$\boxed{\Delta U_2 = 22{,}3\,L.atm}$

$W_2 = P_2\Delta V = 1\times(24 - 15{,}1) = 8{,}9\,L.atm \Rightarrow$ $\boxed{W_2 = 8{,}9\,L.atm}$ $\boxed{Q_2 = 31{,}2\,L.atm}$

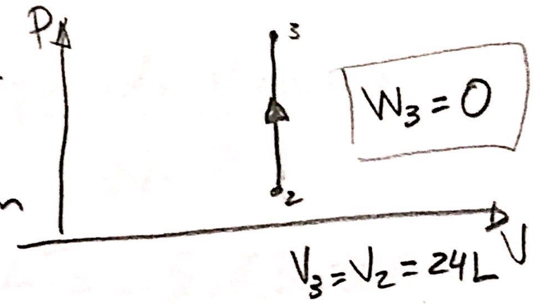
* aquecimento a $V = \text{const}$ $V_2 = 24L$; $P_2 = 1atm$

$T_2 = 293\,K$



$V_3 = 24L$; $P_3 = 5atm$

$T_3 = \dfrac{P_3 V_3}{nR}$



$\boxed{W_3 = 0}$

$V_3 = V_2 = 24L$

$T_3 = \dfrac{5 \times 24}{0{,}082} = 1463{,}4K$

$\Delta U_3 = nc_vR\Delta T = 1 \times \frac{5}{2} \times 0{,}082 \times (1463{,}4 - 293)$

$\Delta U_3 = 0{,}205 \times 1170{,}4 = 240\,L.atm$

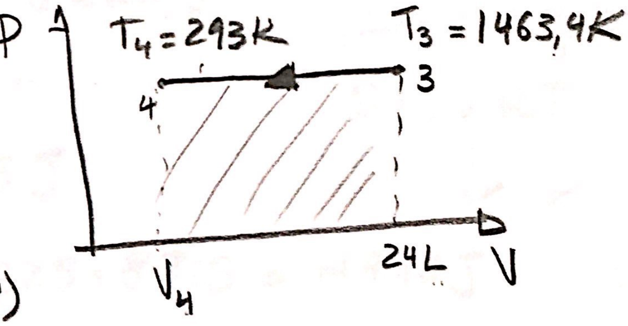
$\boxed{\Delta U_3 = 240\,L.atm}$

$\Delta U_3 = Q_3 - \cancel{W_3}^{\,0} \Rightarrow \boxed{Q_3 = 240\,L.atm}$

* compressão a $P = \text{const} \Rightarrow$ inicial

$P_4 = P_3 = P_0 = 5atm$

$V_4 = V_0 = 4{,}8L$ $\quad T_4 = T_0 = 293K$



$\Delta U_4 = nc_vR\Delta T = 1 \times \frac{5}{2} \times 0{,}082(293 - 1463{,}4)$

$\boxed{\Delta U_4 = -240\,L.atm}$

$W_4 = P_4\Delta V = 5 \times (4{,}8 - 24) = -96J \Rightarrow \boxed{W_4 = -96\,L.atm}$

$Q_4 = \Delta U_4 + W_4 = -336J$ ou $Q_4 = nc_p\Delta T \Rightarrow \boxed{Q_4 = -336\,L.atm}$

em L.atm

	1	2	3	4	ciclo (inicio = fim)
ΔU	-22,3	22,3	240	-240	0 ✓
Q	0	31,2	240	-336	-64,8L.atm = Q_{total}
W	22,3	8,9	0	-96	-64,8L.atm = Q_{total}
1ª	✓	✓	✓	✓	✓

$\Delta U - Q + W = 0$

Prob. 61 (Tipler) $n = 1$ mol gás ideal <u>aquecido $V = const.$</u>

$T_0 = 300K$ e $T_F = 600K$ $\quad \Delta U = ?$ $\quad W = ?$ $\quad Q = ?$

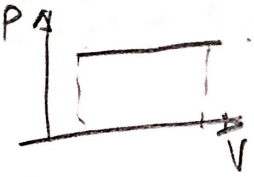
$\Delta T = 300K$

<u>diatômico</u> $\Rightarrow c_V = \frac{5}{2}R$ $\qquad \Delta U = n c_V \Delta T = 1 \times \frac{5}{2} \times 8{,}3 \times 300$

$R = 8{,}3\ J/mol.K$ $\qquad \boxed{\Delta U = 6\,225\ J}$

$V = const \Rightarrow \boxed{W = 0}$ $\qquad \Delta U = Q - \cancel{W}^{0} \Rightarrow \boxed{Q = 6225J}$

<u>aquecimento $P = const.$</u>



$\Delta T = 300K \Rightarrow \Delta U = \Delta U_{anterior} = 6\,225\ J$

$W = P\Delta V$ $\qquad c_p = c_V + R = \frac{7}{2}R$ $\qquad PV = nRT$

$Q = n c_p \Delta T = 1 \times \frac{7}{2} \times 8{,}3 \times 300 = 8\,715\ J$

$\Delta U = W - Q \therefore W = \Delta U + Q = 6225 + 8715 = 14940J$

$\boxed{\Delta U = 6\,225J}$ $\quad \boxed{Q = 8715J}$ $\quad \boxed{W = 14940J}$

$dU = n c_V dT$ <u>se c_V não for constante</u> $\Delta U = \int_{T_i}^{T_f} n c_V dT$

se c_V for constante $\Delta U = n c_V \Delta T$ sempre independente do processo pois U é uma <u>função de estado</u>.

Função de estado é uma grandeza termodinâmica que independe do processo, ou seja, só depende dos estados (P, V, n, T) inicial e final.

Vamos supor que ocorreu um processo onde P e V modificaram simultaneamente.

$$P = P_0 + BV \qquad P_0 = 1\,atm = 10^5\,Pa$$

$T_0 = 300K$; $T_f = 600K$ aquecimento

$n = 1 mol$ gás ideal diatômico

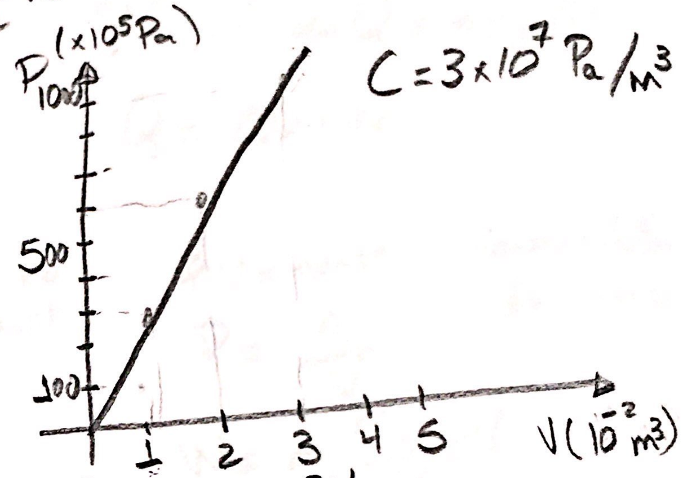
$\hookrightarrow c_V = \frac{5}{2}R$ e $c_p = \frac{7}{2}R$

$B = 3\ atm/L = \frac{3\times10^5}{10^{-2}}\ Pa/m^3$

$\Delta U = ?\quad Q = ?\quad W = ?$

$C = 3\times10^7\ Pa/m^3$

$\Delta U = \Delta U_{antes} = n c_V \Delta T = 6225J$



$1L = 1000\,cm^3 = 10^3\,cm^3$

$= 0{,}001\,m^3 = 10^{-3}\,m^3$

$PV = nRT$

$V_0 = \frac{nRT_0}{P_0} = \frac{1\times 8{,}3\times 300}{10^5}$

$V_0 = 24{,}9\times10^{-3}\,m^3 \cong 25\times10^{-3}\,m^3$

$P = P_0 + BV$

$P = 10^5 + 3\times10^7\,V$

$= 10^5(1 + 300V)$

V	P(10^5)
0	1
1	301
2	601
3	901

$P_f V_f = nRT_f$ e $P_f = P_0 + CV_f$

$(P_0 + BV_f)V_f = nRT_f$

$BV_f^2 + P_0V_f - nRT_f = 0$

$\frac{P_0}{B} = \frac{10^5}{3\times10^7} = \frac{10^{-2}}{3}$

$V_f^2 + \frac{P_0}{B}V_f - \frac{nRT_f}{B} = 0$

$\frac{nRT}{B} = \frac{1\times8{,}3\times600}{10^5}$

$V_f^2 + \frac{100}{3}V_f - 0{,}05 = 0$

$V_f = -\frac{100}{3} \pm \sqrt{\left(\frac{100}{3}\right)^2 + 4\times0{,}05} = -33{,}3333 \pm 33{,}3363 = 0{,}003\,m^3$

$= 3\times10^{-3}\,m^3$

$dW = PdV \Rightarrow W = \int_{V_0}^{V_f} PdV = \int_{V_0}^{V_f}(P_0 + BV)dV = \int_{V_0}^{V_f} P_0 dV + \int_{V_0}^{V_f} BVdV$

$W = P_0 V\Big|_{V_0}^{V_f} + \frac{BV^2}{2}\Big|_{V_0}^{V_f} = 10^5(25-3)\times10^{-3} + \frac{3\times10^7}{2}\left[(25\times10^{-3})^2 - (3\times10^{-3})^2\right]$

$$W = 22\times10^2 + \frac{3}{2}\times10\left[25^2-3^2\right] = 2200 + 15(625-9)$$

$$W = 2200 + 9240 = 11440\,J$$

$$\boxed{W = 11440\,J}$$

$$\Delta U = Q - W \quad \therefore \quad Q = \Delta U + W = 6225 + 11440$$

$$\boxed{Q = 17665\,J}$$

Quando isocórico $V = const \Rightarrow Q = n c_v \Delta T$

isobárico $P = const \Rightarrow Q = n c_p \Delta T$

$$Q = \Delta U + W$$

$$W = \int_{V_i}^{V_f} P\,dV$$

Quando isotérmico $T = const$

$PV = const$ $\quad const = nRT_0$

$P = \frac{A}{V}$ $\quad A = nRT_0$

$$W = A\int_{V_0}^{V_f} \frac{1}{V}\,dV$$

adiabático $Q = 0$, $PV^\gamma = const$

$$W = -\Delta U = -n c_v \Delta T$$

$$W = \int_{V_i}^{V_f} \frac{A}{V^\gamma}\,dV$$

$const = P_0 V_0^\gamma$

$A = P_0 V_0^\gamma$

qualquer $P(V)$

$$W = \int_{V_i}^{V_f} P(V)\,dV$$