(1) (i) Adiabatic compression

$T_1 = 70^\circ C = 343\,K$

$P_1 = 1\,bar = 10^5\,Pa$

$T_2 = 150^\circ C = 423\,K$

$c_v = 1.5R$

$c_p = 2.5R$

$\gamma = \frac{c_p}{c_v} = \frac{5}{3}$

$\gamma - 1 = \frac{5}{3} - 1$

$= \frac{2}{3}$

$1 - \gamma = 1 - \frac{5}{3}$

$= -\frac{2}{3}$

$Q = 0$

$PV^\gamma = \text{constant}$

$Pv = RT$

$TV^{\gamma-1} = \text{constant}$

$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

$$\left(\frac{V_2}{V_1}\right)^{\gamma-1} = \frac{T_1}{T_2} = \frac{343}{423}$$

$(V_2 = 0.73V_1) \Leftarrow \left(\frac{V_2}{V_1}\right) = \left(\frac{343}{423}\right)^{3/2} = 0.73$

Now,

$P^{\gamma-1} T^{\gamma} = \text{constant}$

$P_1^{\gamma-1} T_1^{\gamma} = P_2^{\gamma-1} T_2^{\gamma}$

$$\left(\frac{P_2}{P_1}\right)^{\gamma-1} = \left(\frac{T_1}{T_2}\right)^{\gamma}$$

$$\Rightarrow \frac{P_2}{P_1} = \left(\frac{T_1}{T_2}\right)^{\frac{\gamma}{\gamma-1}} = \left(\frac{343}{423}\right)^{5/2}$$

$P_2 = (1\,bar)$

$\frac{\gamma}{1-\gamma} = \frac{\frac{5}{3}}{-\frac{2}{3}}$ $\frac{2-5}{2}$

$$P^{1-\gamma} T^{\gamma} = \text{constant}$$

$$P_1^{1-\gamma} T_1^{\gamma} = P_2^{1-\gamma} T_2^{\gamma}$$

$$\left(\frac{P_2}{P_1}\right)^{1-\gamma} = \left(\frac{T_1}{T_2}\right)^{\gamma}$$

$$\frac{P_2}{P_1} = \left(\frac{T_1}{T_2}\right)^{\frac{\gamma}{1-\gamma}} = \left(\frac{343}{423}\right)^{-5/2}$$

$$\cancel{P_2 = (1\ \text{bar})} \qquad P_2 = 1.69\ \text{bar}$$

$$\cancel{P_1 V_1^{\gamma} = P_2 V_2^{\gamma}}$$

$$\cancel{\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}}$$

$$V_1 = \frac{RT_1}{P_1} \qquad V_2 = \frac{RT_2}{P_2}$$

$$V_1 = \frac{8.314 \times 343\text{K}}{1\ \text{bar}}$$

$$V_1 = 2851\ \frac{\text{J}}{(\text{mol}\cdot\text{bar})} = 0.02851\ \text{m}^3/\text{mol}$$

$$V_2 = (0.73)(0.02851) = 0.02081\ \text{m}^3/\text{mol}$$

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$$W_{adiabatic} = \frac{P_2V_2 - P_1V_1}{1-\gamma}$$

$$= \frac{(1.69\ bar)\left(\cancel{2851}\ 2081\ \frac{J}{mol\cdot bar}\right) - (1\ bar)\left(\cancel{2081}\ 2851\ \frac{J}{mol\cdot bar}\right)}{1 - 5/3}$$

$$= \frac{(\cancel{4818.19}\ 3516.89 - \cancel{2081}\ 2851)}{2}(-\cancel{1}3)\left(\frac{J}{mol}\right)$$

$$W \approx \cancel{[\ ]}\ -998\ J/mol$$

$\Delta U = W$ and also $\Delta U = n\,C_v(T_2 - T_1)$

$$\Delta U = (1.5)\left(8.314\right)\frac{J}{(mol\cdot K)} \times 80$$

$$\boxed{\Delta U \approx 998\ (J/mol)}$$

$$\Delta H = C_p\ (80\ K)$$
$$= 2.5 \times 8.314 \times 80$$
$$\Delta H = 1662.8\ (J/mol)$$

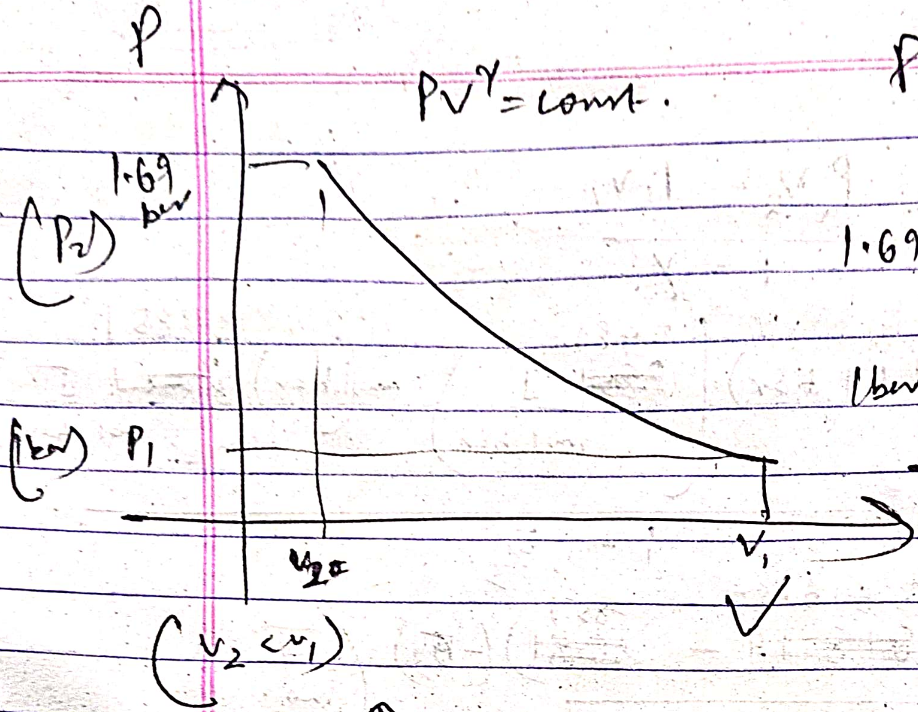
So, finally for adiabatic process.

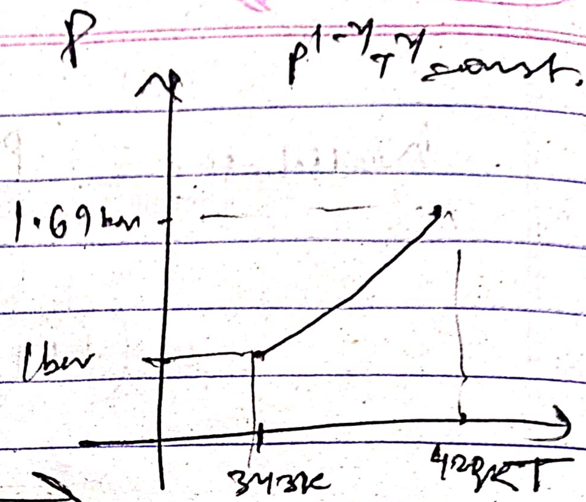
$Q_1 = 0$

$W_1 \approx 998\ J/mol$

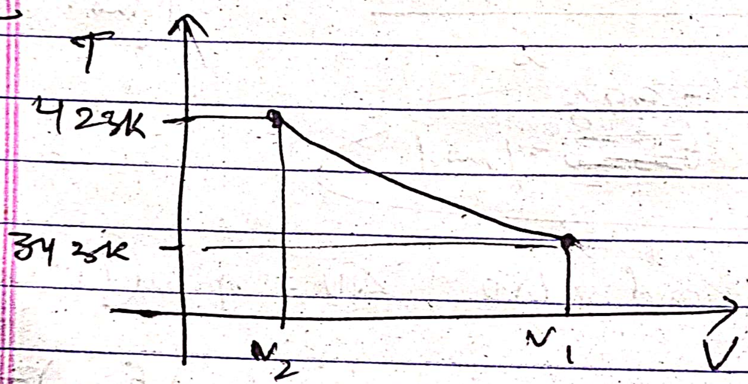
$\Delta U_1 \approx 998\ J/mol$

$\Delta H_1 = 1662.8\ J/mol.$





$TV^{\gamma-1} = const.$



(2) Isochoric cooling

$T_2 = 150°C = 423K$

$T_3 = 70°C = 343K$

Constant Pressure

$\hookrightarrow \boxed{W_2 = 0}$

$$\Delta U_2 = n C_v (T_3 - T_2)$$
$$= (1.5)(8.314)(-80)$$
$$\Delta U_2 \approx -998 \ (J/mol)$$

$\cancel{Q_2 = \Delta U_2 = 998 \ (J/mol)}$

$$\Delta H_2 = n C_p (-80)$$
$$= (2.5)(8.314)(-80)$$
$$Q_2 = \Delta H_2 = -1662.8 \ (J/mol)$$

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(3) Isothermal expansion

$\Delta U_3 = 0 \Rightarrow \quad Q_3 = W_{iso}$

$\Delta H_3 = 0$

$W_{iso} = nRT_3 \ln\left(\frac{V_4}{V_3}\right)$

$W_3 = (8.314)(343K) \ln\left(\frac{2851}{1686}\right)$

$= (8.314)(343)(0.524)$

$\boxed{W_3 \approx 1494 = Q_3}$

Overall

$W_{net} = W_1 + \cancel{W_2} + W_3 = 1494 - 998 = 496 \, (J/mol)$

$Q_{net} = \cancel{Q_1} + Q_2 + Q_3$

$= -998 + (-895.4)$

$= -1893.4 \, (J/mol)$

$\Delta U_{net} = 0$

$\Delta H_{net} = 0.$

For Irreversible case,

$W_1 irr = 0.75 \times W_1$, $Q_1 irr = 0$, $Q_3 irr = W_3 irr$

$W_2 irr = 0.75 \times W_2$

$W_3 irr = 0.75 \times W_3$