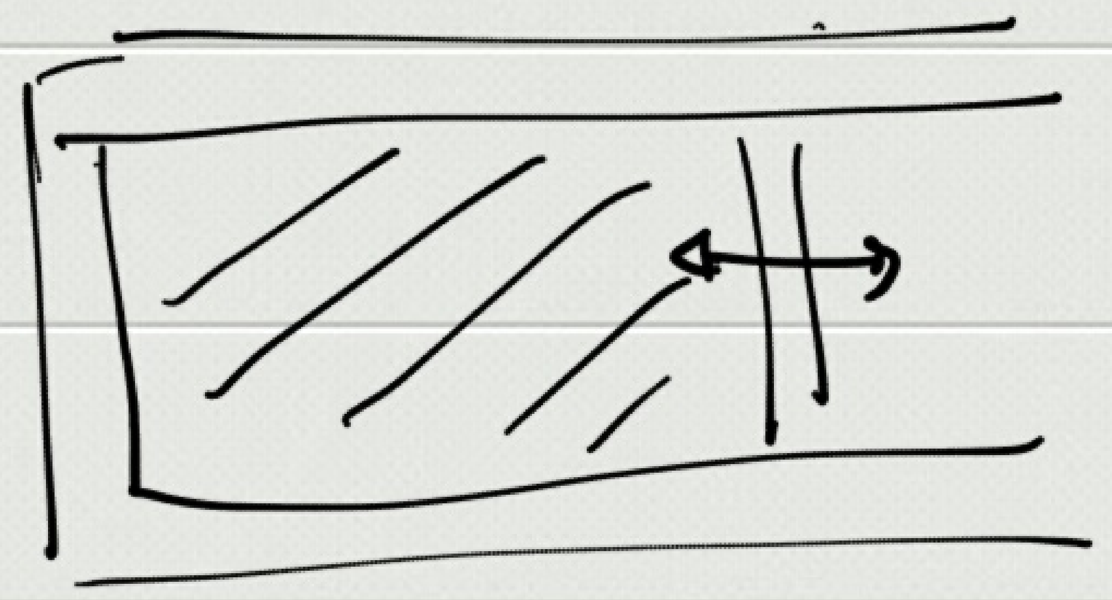
$$Q = \Delta U + W$$



$$\delta W = \vec{F}\, d\vec{s} = pS\, ds = p\, dV$$

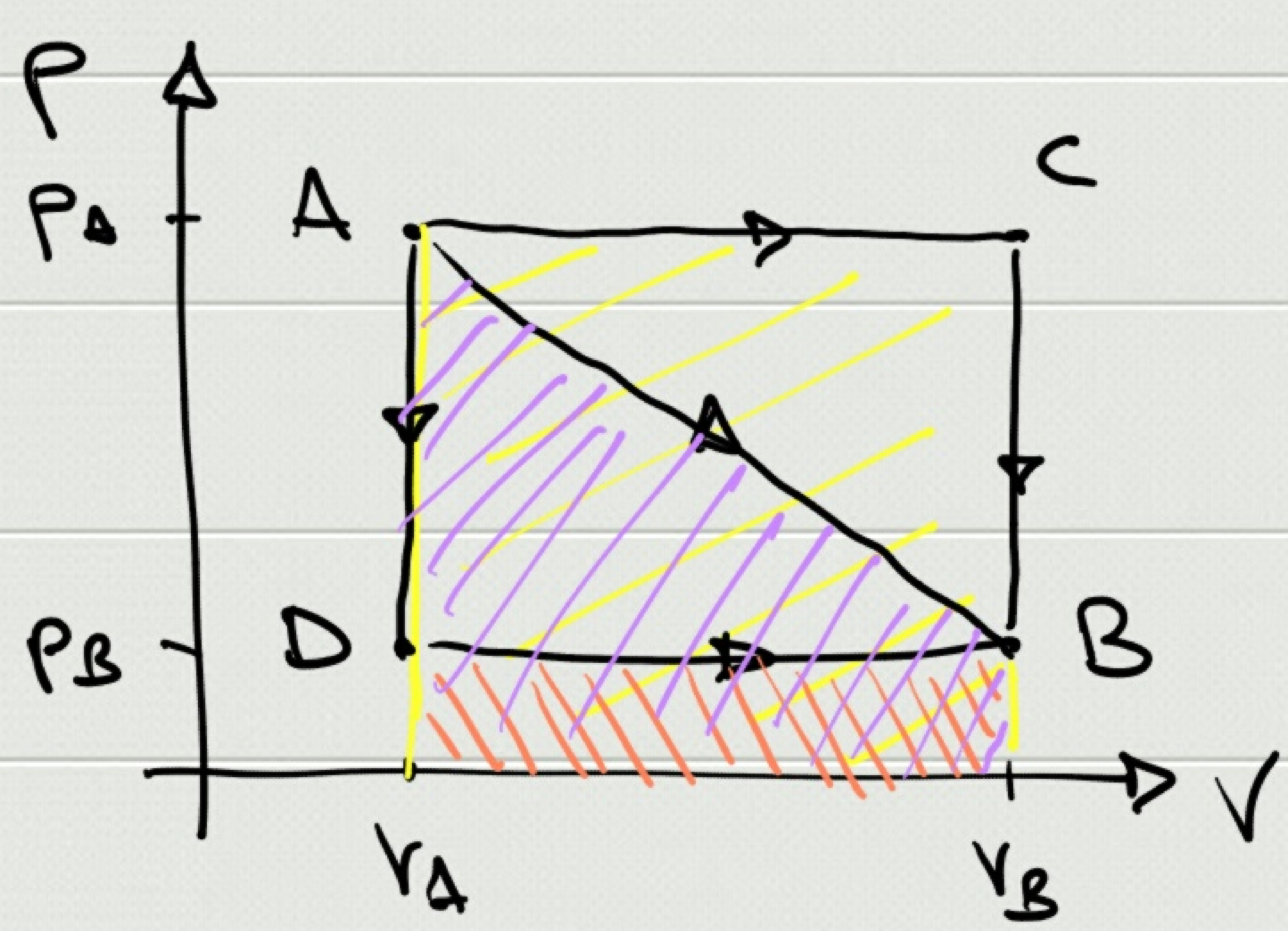
$$\Rightarrow W_{i \to f} = \int_{V_i}^{V_f} p(V,T)\, dV$$

$$\boxed{pV = nRT}$$

$$p = \frac{nRT}{V}$$

quasi statico

$$\Rightarrow W_{i \to f} = \int_{V_i}^{V_f} \frac{nRT(V)}{V}\, dV$$



$$W_{AB} = ?$$

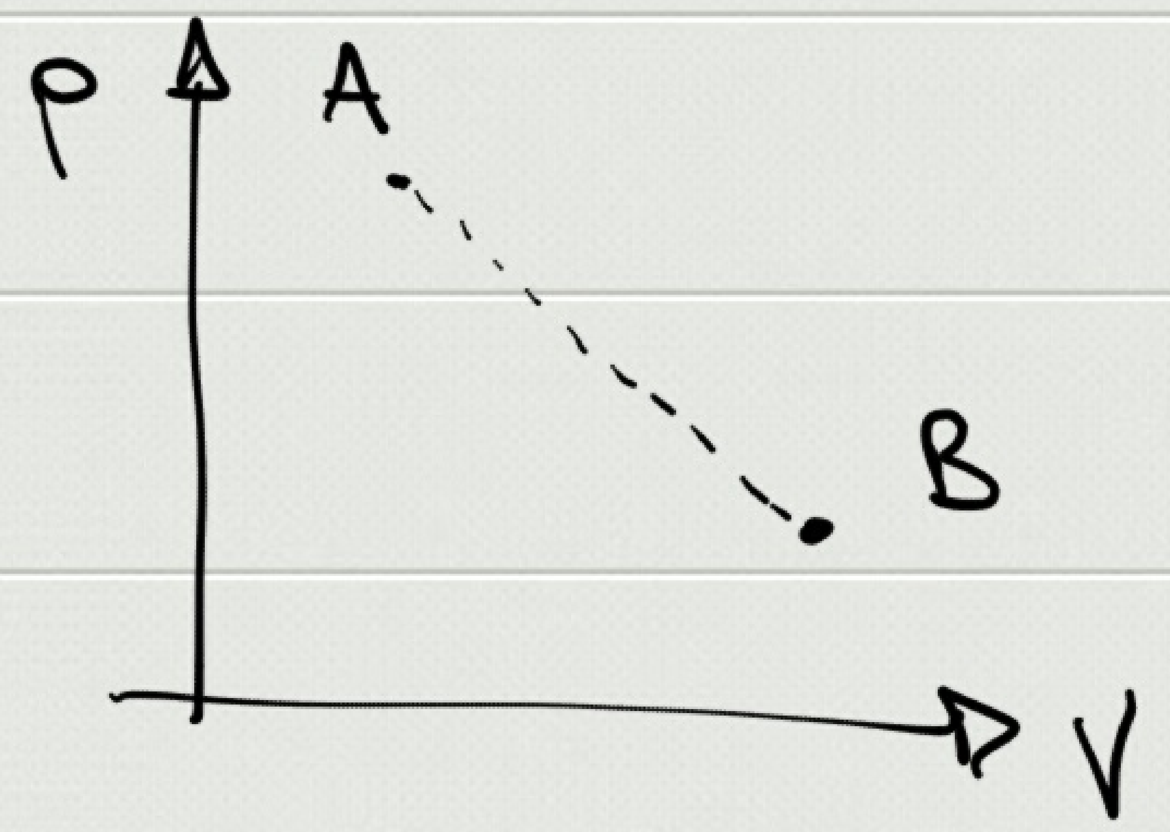
q-s

$$= \int_{V_A}^{V_B} p\, dV$$

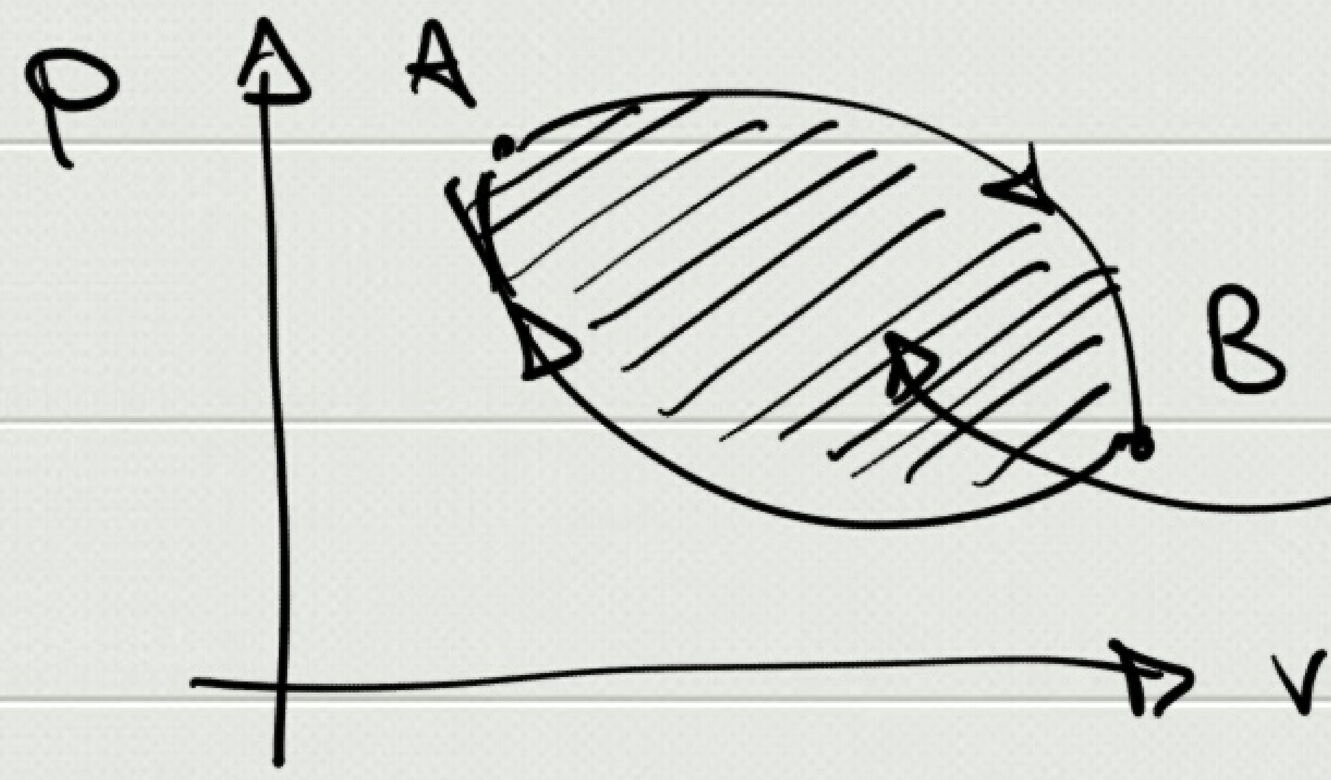
$$W_{ACB} = W_{AC} + \underbrace{W_{CB}}_{=0} = p_A \int_{V_A}^{V_C} dV = p_A (V_B - V_A)$$

$$W_{ADB} = \overbrace{W_{AD}}^{0} + W_{DB} = p_D \int_{V_D}^{V_B} dV = p_B (V_B - V_A)$$

$$W_{AB} = \frac{1}{2} (p_A + p_B)(V_B - V_A)$$

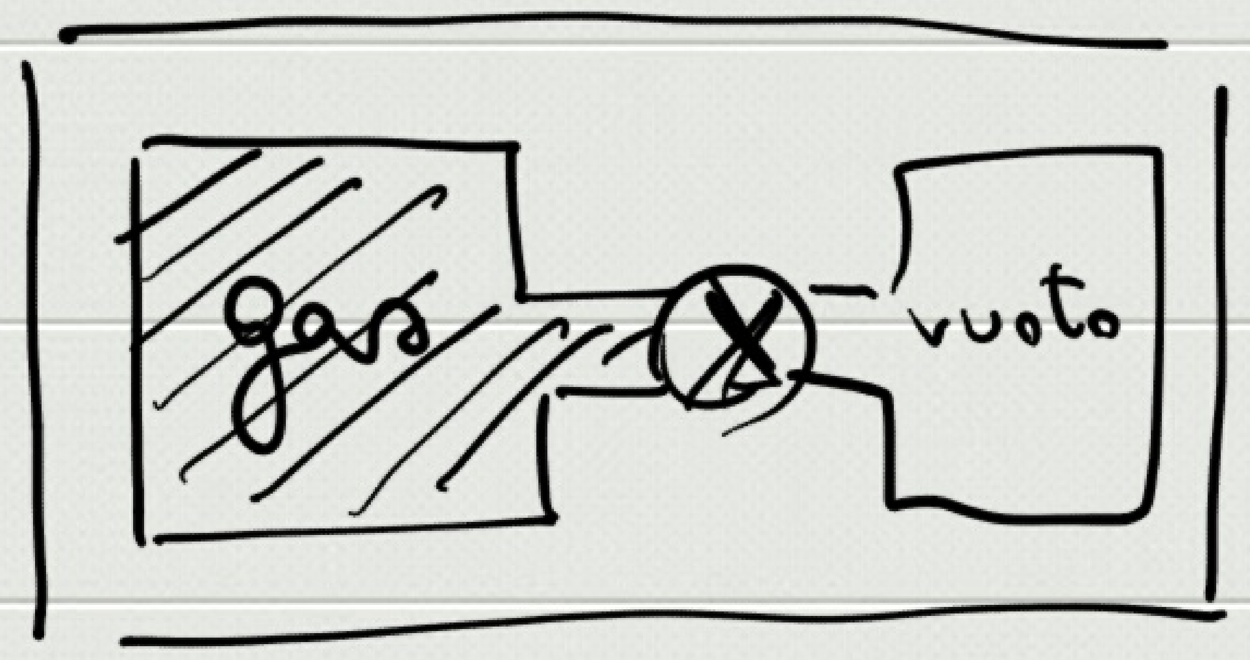


Trasf. irreversibile



$W_{A \to B \to A}$

Energia Interna



Espansione libera del gas

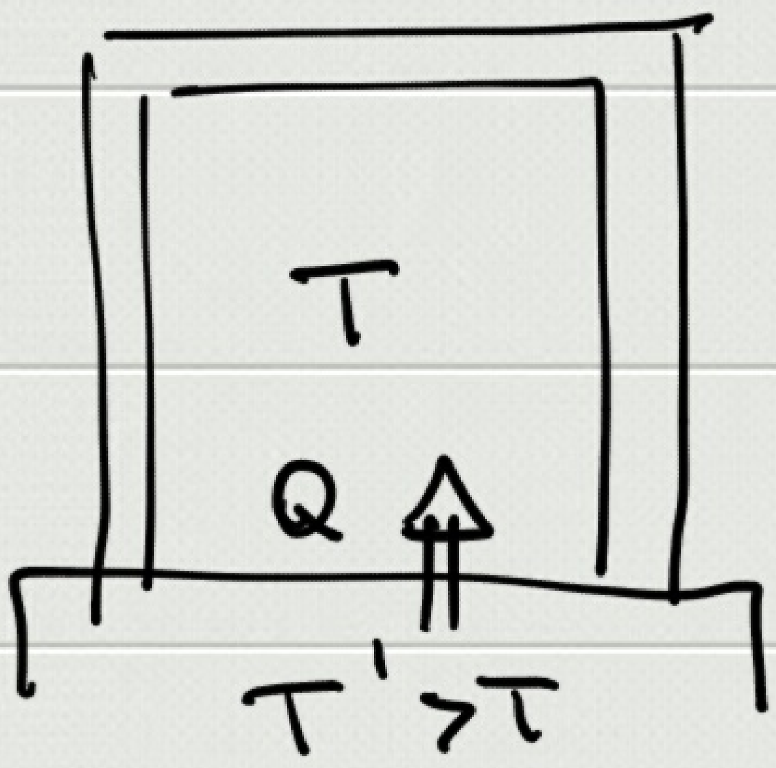
$\boxed{T = cost}$

$$Q = \Delta U + W$$
$$Q = 0, \quad W = 0 \Rightarrow \Delta U = 0$$

$\Rightarrow \boxed{U = cost}$

$U =$ funzione di stato $= U(p, T, V)$

$$\cancel{U = e^{p} + \ln T + V} \quad \Rightarrow \boxed{U = U(T)}$$



$T \to T' > 0 \qquad T \uparrow$

$$\left.\begin{aligned} Q &> 0 \\ W &= 0 \end{aligned}\right\} \Rightarrow Q = \Delta U > 0$$

$$\Rightarrow U \uparrow$$

$$\Rightarrow \boxed{U = U(T) \ \text{crescente}}$$

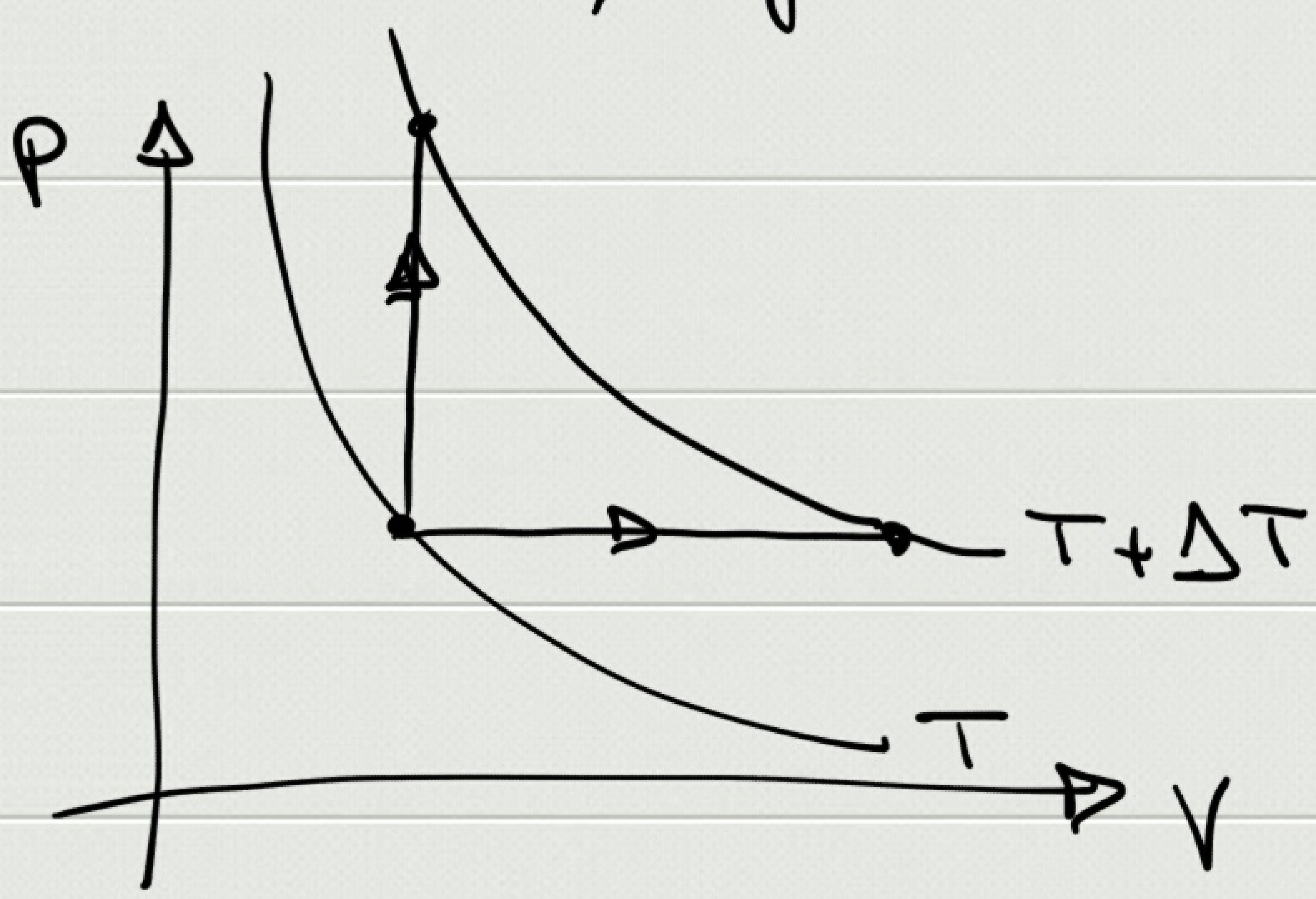
Calore

$$c_m = \frac{1}{n} \frac{\delta Q}{dT}$$ calore specifico molare

$$\Rightarrow \delta Q = n\, c_m\, dT \quad \Rightarrow \quad Q = \int_{T_i}^{T_f} n\, c_m\, dT$$

$$Q = \int_{T_i}^{T_f} m c_m \, dT \quad \underset{c_m = cost}{\overset{c_m = c_m(T)}{=}} \quad \Rightarrow \quad = m c_m (T_f - T_i)$$

$$T_i = T \quad ; \quad T_f = T + \Delta T \qquad (\Delta T > 0)$$



$V = cost$

$p = cost$

$Q = \Delta U + W$

$$\left.\begin{array}{l} Q_V \overset{W=0}{\stackrel{!}{=}} \Delta U_V \\ Q_p = \Delta U_p + W_p \\ \Delta U_V = \Delta U_p \end{array}\right\} \Rightarrow \underset{\substack{\vee \\ 0}}{Q_p} = \underset{\substack{\vee \\ 0}}{Q_V} + \underset{\substack{\vee \\ 0}}{W_p}$$

$$\Rightarrow Q_p > Q_V$$

$$Q = m c_m (T_f - T_i) \Rightarrow \begin{cases} Q_p = m c_p (T_f - T_i) \\ Q_V = m c_V (T_f - T_i) \end{cases}$$

c_p e c_v : calori specifici molari $\begin{cases} p = \text{cost} \\ v = \text{cost} \end{cases}$

$$\Rightarrow \quad Q_p = Q_v + W_p \quad \Rightarrow \qquad W_p = \int p\,dV = p\,\Delta V$$

$$n\,c_p\,(T_f - T_i) = n\,c_v\,(T_f - T_i) + p\,(V_f - V_i)$$

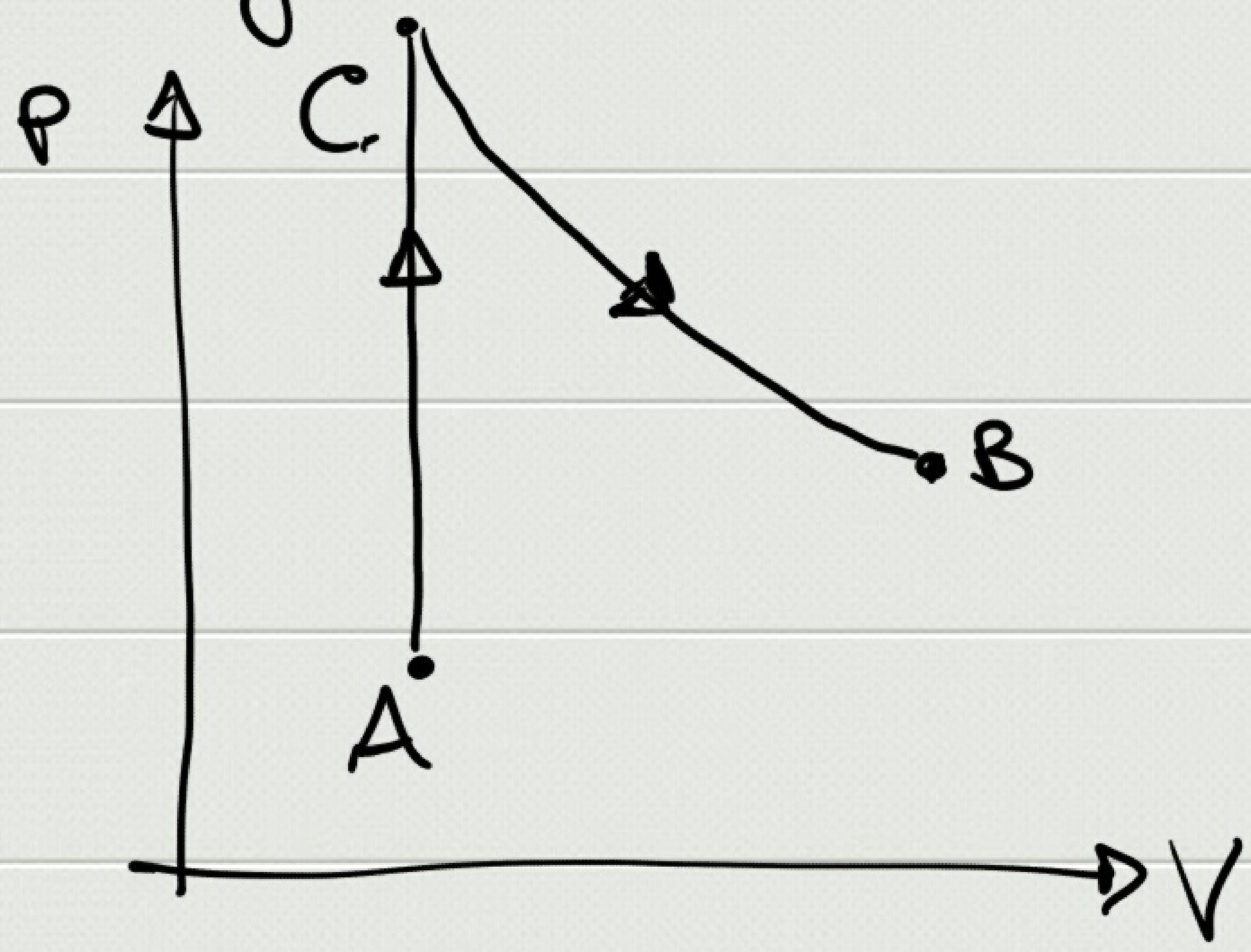
$$pV = nRT \quad \Rightarrow$$

$$n\,c_p\,(T_f - T_i) = n\,c_v\,(T_f - T_i) + nR\,(T_f - T_i)$$

$$\Rightarrow \boxed{c_p - c_v = R}$$

Relazione di Meyer

Energia interna : $U = U(T)$ crescente



$\Delta U_{AB} = U_B - U_A = ?$

$T_C = T_B$

$W_{AC} = 0$

$$\Delta U_{AB} = \Delta U_{AC} + \Delta U_{CB} = (U_C - U_A) + \underbrace{(U_B - U_C)}_{=0} =$$

$$= Q_{AC} = m c_V (\underbrace{T_C}_{=T_B} - T_A)$$

$$\Rightarrow \boxed{\Delta U_{AB} = m c_V (T_B - T_A)}$$

$$\Rightarrow dU = m c_V dT$$

$$\boxed{\delta Q = dU + \delta W}$$

<u>GAS</u> : $\boxed{\delta Q = m c_v dT + \delta W}$

$$\Rightarrow Q_{AB} = m \underset{\substack{| \\ c_v = \text{cost}}}{c_v} (T_B - T_A) + W_{AB} \quad *$$

Sempre!

Trasf. <u>quasi statico</u> $\Rightarrow \delta W = p dV$

$$\Rightarrow \delta Q = m c_v dT + p dV$$

$$\Rightarrow Q_{AB} = m c_v (T_B - T_A) + \int_{V_A}^{V_B} p(V, T) dV$$

$$\boxed{\gamma = \frac{c_p}{c_v}} > 1$$

	c_v	c_p	γ
monoatomico	$\frac{3}{2}R$	$\frac{5}{2}R$	$\frac{5}{3}$
biatomico	$\frac{5}{2}R$	$\frac{7}{2}R$	$\frac{7}{5}$

altri : $\frac{c_p}{R} = a + bT + cT^2 + \dots$

$$c_m = \frac{1}{m}\frac{\delta Q}{dT} \Longrightarrow \begin{cases} c_{adiab} \overset{\delta Q = 0}{=} 0 \\ c_{isot} \underset{dT=0}{\longrightarrow} \infty \end{cases}$$