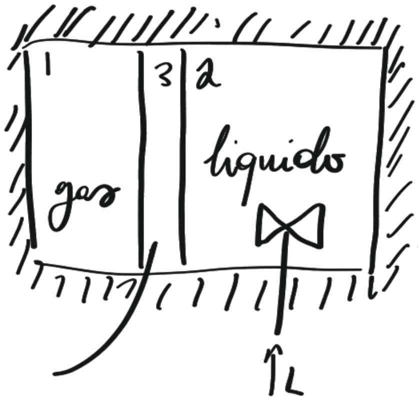
Esercitazione 3

6)



setto diabatico
↳ non adiabatico

$V_1 = 2{,}8\,dm^3 = 0{,}0028\,m^3$

$\rho_1 = 48\,kg/m^3$

$V_2 = 3 \cdot V_1 = 0{,}0084\,m^3$

$\rho_2 = 875\,g/dm^3 = 875\,kg/m^3$

$m_3 = 2{,}5\,kg \qquad c_3 = 1{,}8\,\frac{kcal}{kg\,K} \cdot 4{,}186\,\frac{kJ}{kcal}$

$= 7{,}535\,\frac{kJ}{kg\,K}$

$c_{v_1} = 1{,}674\,\frac{kJ}{kg\,K} \qquad c_2 = 5{,}023\,\frac{kJ}{kg\,K}$

$t = 45' = 2700\,s$

$\dot{L} = 300 - 0{,}06\,\tau \rightarrow [W]\ \frac{J}{s}$

? ΔU_{TOT} ? $\Delta U_1, \Delta U_2, \Delta U_3$

? Q_{13} ? Q_{32}

$TOT = 1 + 2 + 3$

$\Delta U_{TOT} = U_{FIN} - U_{IN} = \cancel{Q} - \underline{\underline{L^{\rightarrow}}}$ ← $\emptyset$ adiabatico

$$L^{\rightarrow} = -\int_{in}^{fin} \dot{L}\, d\tau = -\int_{in}^{fin} (300 - 0{,}06\,\tau)\, d\tau =$$

Perché entrante

$$= -\left[300\,\tau - 0{,}03\,\tau^2\right]_0^{2700}$$

$$= 591\,300\,J \rightarrow L^{\leftarrow}$$

$$\boxed{\Delta U_{tot} = \Delta U_1 + \Delta U_2 + \Delta U_3}$$

PROPRIETÀ ADDITIVA

gas, liquido, solido

$$\begin{cases} \Delta U_1 \overset{gas}{=} M_1 c_{v_1} (T_{1fin} - T_{1in}) \\ \Delta U_2 \overset{liq}{=} M_2 c_2 (T_{2fin} - T_{in}) \\ \Delta U_3 \overset{sol}{=} M_3\, c_3 (T_{3fin} - T_{3in}) \end{cases}$$

$$\boxed{\Delta U_{TOT} = -L^{\rightarrow} = 591{,}3\,kJ}$$

Stato iniziale è di equilibrio

$T_{1in} = T_{2in} = T_{3in}$

e anche Stato finale è di equilibrio

$T_{1fin} = T_{2fin} = T_{3fin}$

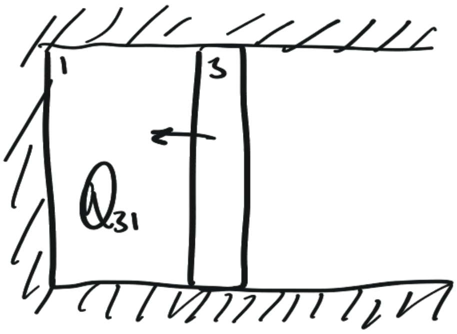
$$(\rho_1 V_1 c_{v_1} + \rho_2 V_2 c_2 + M_3 c_3)(T_{fin} - T_{in}) = 591{,}3\,kJ$$

$$\Delta T = 10{,}56\,K$$

Non possiamo sapere T_{fin} e T_{in}, ma possiamo sapere ΔT

per $\Delta U_{1,2,3}$ serve solo ΔT

$\Delta U_1 = \rho_1 V_1 c_{v_1} \cdot \Delta T = 2,38 \text{ kJ}$



$\Delta U_1 = \overset{\leftarrow}{Q_1} - \cancel{L_1}^{\to 0} = Q_{31}$

$Q_{31} = 2,38 \text{ kJ}$

$Q_{13} = -Q_{31} = -2,38 \text{ kJ}$

$\Delta U_3 = M_3 \cdot c_3 \cdot \Delta T = 199,11 \text{ kJ}$

$\Delta U_3 = \overset{\leftarrow}{Q_3} - \cancel{L_3}^{\to 0} = Q_{13} + Q_{23} \Rightarrow Q_{23} = \Delta U_3 - Q_{13} =$

$201,49 \text{ kJ}$

$\Delta U_2 = \rho_2 V_2 c_2 (\Delta T)$ $\quad \Delta U_2 = \overset{\leftarrow}{Q_2} - L_2$

$Q_2 = Q_{32}$

$\to \Delta U_2 = 390,27 \text{ kJ}$

Se il sistema è in equilibrio ΔT è uguale per ogni sottosistema.

8) (1) in

$V_A = V_B = 0,001 \text{ m}^3$

$M_m = 29 \text{ kg/kmol}$

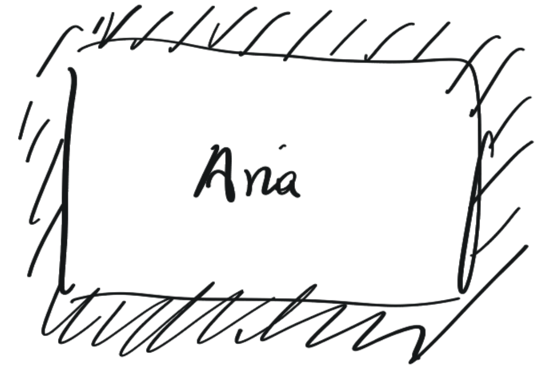
$P_1 = 1 \text{ bar} = 10^5 \text{ Pa}$

$T_1 = 293,15 \text{ K}$

Ipotesi: Adiabatico, aria gas ideale

2

Fin



$$\cancel{\Delta E_p}^{\,0} + \cancel{\Delta E_c}^{\,0} + \Delta U = \cancel{Q}^{\,0 \text{ adiabatico}} - \cancel{L}^{\,0}$$

$\Rightarrow \Delta U = 0$ (Isoenergetico)

Adiabatico e Isolato

$$M_1 = \frac{P_1 V_1}{R^* T_1} = 0{,}0012\ kg$$

$$\Delta U \underset{perf}{\overset{gas}{=}} M c_v (T_2 - T_1) = 0 \Rightarrow T_2 = T_1$$

Non compie lavoro per espansione nel vuoto ha lavoro nullo

BILANCIO ENTROPIA

$$\Delta S = S_2 - S_1 \overset{G.P}{=} M \left\{ c_v^* \cancel{\ln \frac{T_2}{T_1}}^{\,0} + R^* \ln \frac{V_2}{V_1} \right\} =$$

$$= M R^* \ln \frac{V_2}{V_1}$$

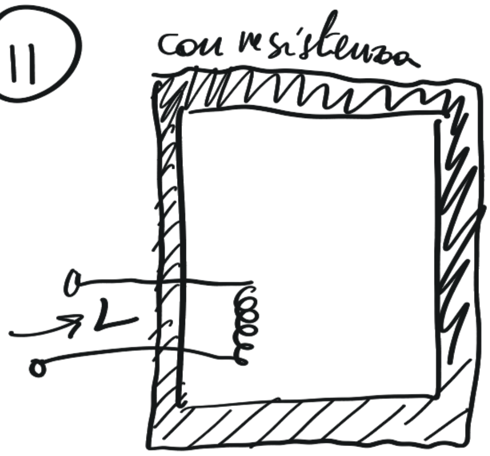
$$= 0{,}24 \ \frac{J}{K}$$

Vogliamo trovare S_{IRR}, quindi ci serve ΔS

0 perché $\delta Q = 0$ (adiabatico)

$$\Delta S = \cancel{S}^{\,0} + S_{IRR} = 0{,}24 \frac{J}{K} \Rightarrow S_{IRR} = 0{,}24 \frac{J}{K}$$

11



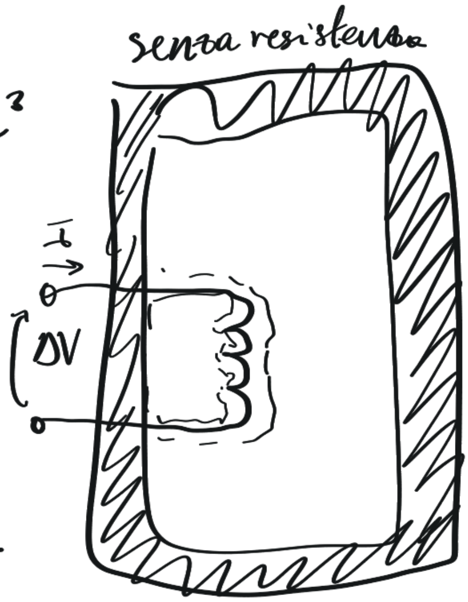
$V = 0{,}015\ m^3$

$R = 0{,}5\ \Omega$

$\Delta V = 220\ V$

$T_i = 293{,}15$

$T_f = 353{,}15\ K$



? tempo

? ΔS_{21}

$\rho = 1000\ kg/m^3$ $\quad c = 4{,}186\ \frac{kJ}{kg \cdot K}$

$$P_{el} = \Delta V \cdot I = \frac{\Delta V^2}{R} = R I^2$$

$$\Delta V = R I$$

$$L_{el} = P_{el} \cdot t$$

$$\cancel{\Delta E_p}^{0} + \cancel{\Delta E_c} + \Delta U = \cancel{Q} - L$$

operchio adiabatico

con resistenza

$$\Delta U_{H_2O} = \cancel{Q}^{0} - L^{\rightarrow}$$

$$L^{\rightarrow} = -L_{el} = -\frac{\Delta V^2}{R} \cdot t$$

$$\boxed{\Delta U_{H_2O} = \frac{\Delta V^2}{R} \cdot t}$$

senza resistenza

Adiabatico meno che contorno della resistenza

$$\Delta U_{H_2O} = Q^{\leftarrow} - \cancel{L^{\rightarrow}}^{0}$$

$$\Delta U_{res} = Q_{res}^{\leftarrow} - \underbrace{L^{\rightarrow}}_{L_{el}}$$

$$L^{\to} = -L_{el} = -\frac{\Delta V^2}{R} \cdot t$$

$$\Delta U_{res} = \overset{\to 0}{M_{res}} \cdot c_{res} (T_{2res} - T_{1res})$$

$$\simeq 0$$

$$\Delta U_{H_2O} = \frac{\Delta V^2}{R} \cdot t$$

$$\Delta U_{H_2O} \overset{LiQ}{=} M_{H_2O} \cdot c (T_2 - T_1) = \rho \cdot V \cdot c (T_2 - T_1)$$

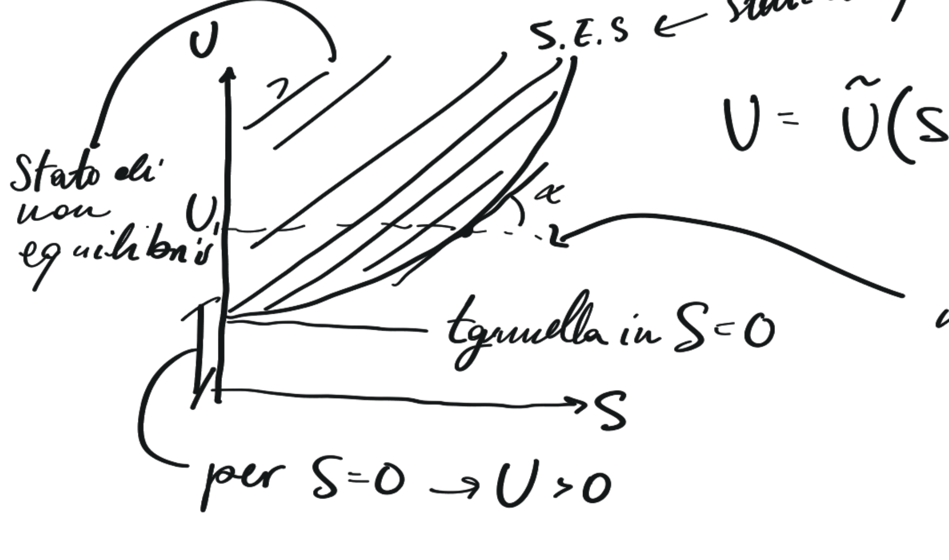
$$= 18{,}837 \text{ kJ}$$

$$t = \frac{\Delta U \cdot R}{\Delta V^2} = \frac{19460 \text{ s}}{3600 \text{ h}} \to 5 \text{ h } 24', 20''$$

$$\Delta S_{21} \overset{LiQ}{=} M_{H_2O} \cdot c \ln \frac{T_2}{T_1} = 58{,}46 \ \frac{\text{kJ}}{\text{K}}$$

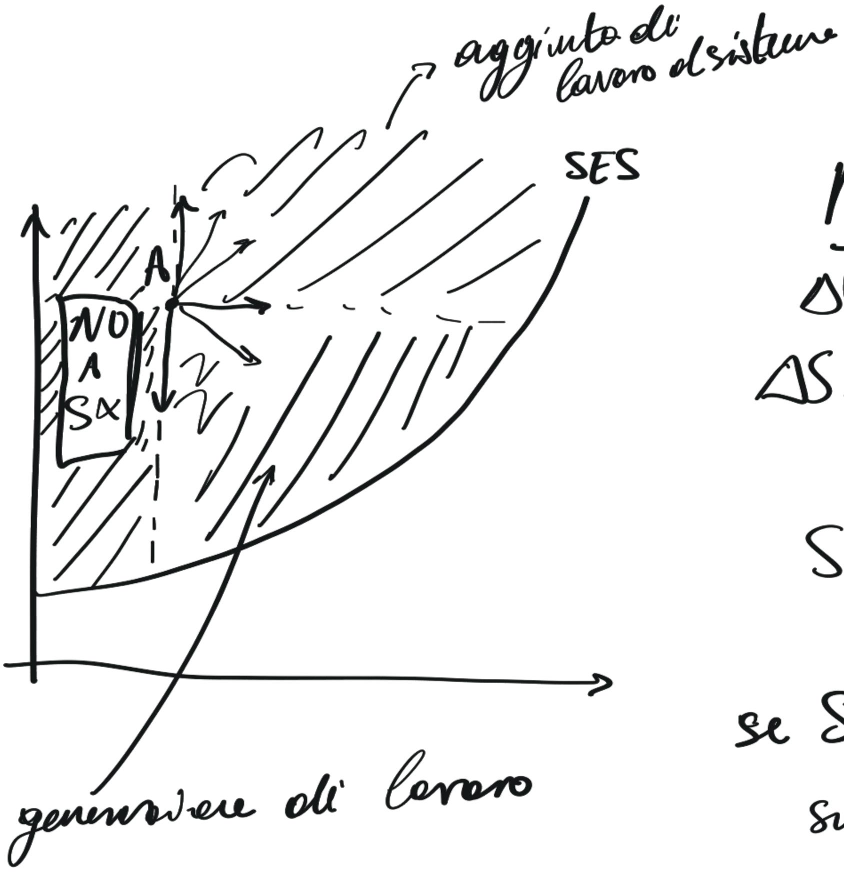
C'è un fero meno di scambio di calore, più difficile calcolare

Esercitazione 4 – Diagramma U-S



$$U = \tilde{U}(S, \underset{\text{cost}}{V}, \overset{\text{cost}}{M}) = U(S)$$

$\tan\alpha = T_1$



Processo Meccanico

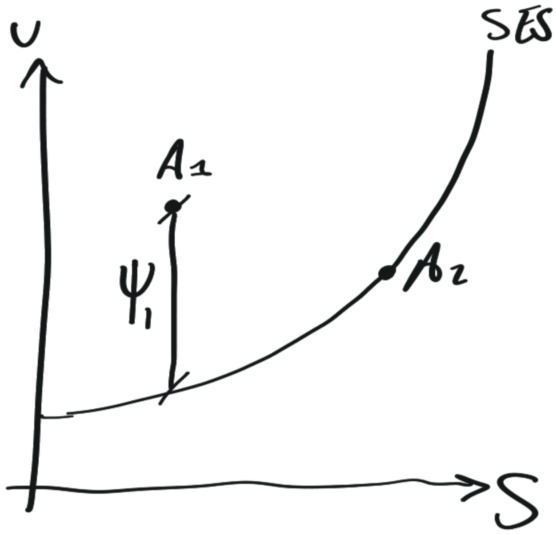
$$\Delta U = \cancel{Q}^{0} - L = U_2 - U_1$$

$$\Delta S_{21} = S_2 - S_1 = \cancel{S}^{0} + \underbrace{S_{IRR}}_{\geq 0}$$

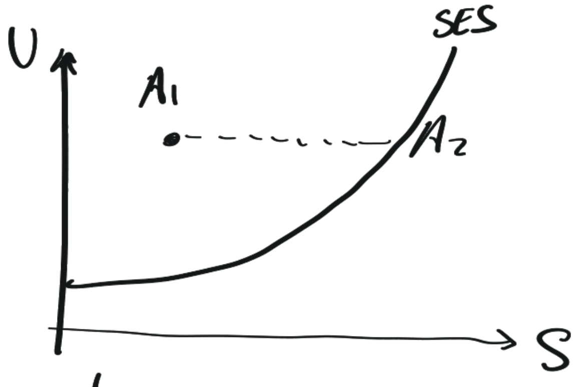
$$S_2 \geq S_1$$

se $S_{IRR} = 0$ mi muovo sulla verticale

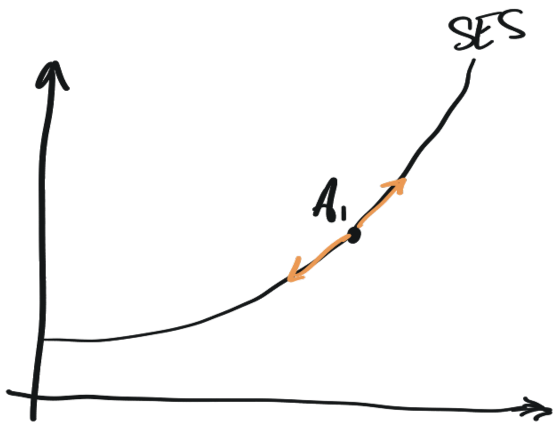
verticale → processo meccanico reversibile

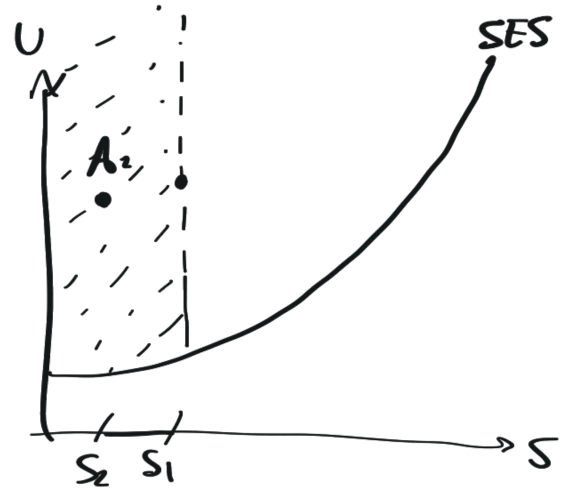


se $\Psi_2 = \phi$



in sistemi isolati





$\Delta S = S_2 - S_1 = S^{\leftarrow} + S_{irr}$

$S_2 < S_1$

È possibile avere $\Delta S < 0$

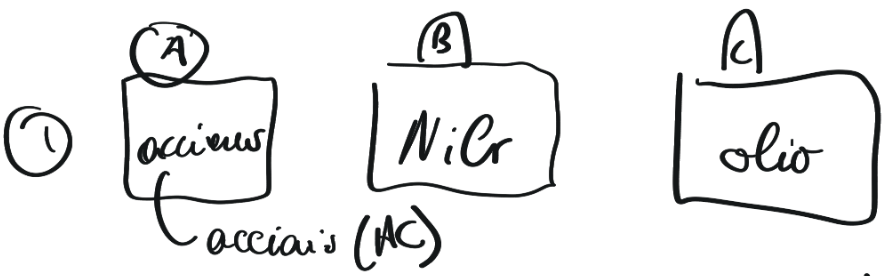
se $Q^{\leftarrow} < 0 \Rightarrow S^{\leftarrow} < 0$

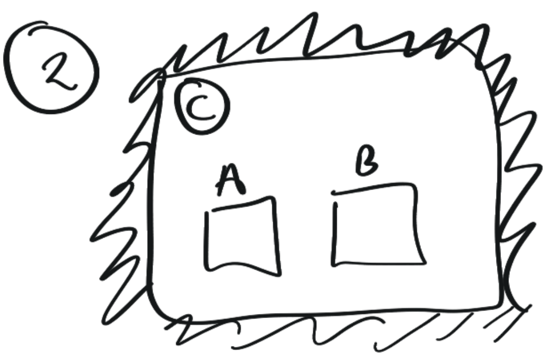
se un sistema cede calore, cede anche entropia

Esiste sempre una processo reversibile, forse non meccanico per ogni due punti A_1 e A_2

Esercitazione 3 e Esercitazione 4 cs 1)

10)





$c_{AC} = \frac{500\ J}{kg\ K}$ $\rho_{AC} = 7800\ kg/m^3$

$M_{AC} = 0{,}2\ kg$ $T_{1A} = 523{,}15\ K$

$c_{NiCr} = 400 \frac{J}{kg\ K}$ $\rho_{NiCr} = 8800\ kg/m^3$ $M_{NiCr} = 0{,}1\ kg$

$T_{1\,NiCr} = 623{,}15\,K$

$c_{olio} = 2500\,\frac{J}{kg\,K}$ $\quad \rho_{olio} = 900\,\frac{kg}{m^3}$ $\quad V_{olio} = 0{,}002\,m^3$

$T_{1\,olio} = 283{,}15\,K$ $\qquad ?\,T_{olio}$ $\quad ?\,\Delta U_{AC},\ \Delta S_{AC}$

Ipotesi - no disp. term. - no variazione volume

$\Rightarrow$ SISTEMA ISOLATO

$$\Delta U_{SIST} = \underbrace{\cancel{Q_{SIST}}}_{0\ \text{adia}} - \underbrace{\cancel{L_{SIST}}}_{0\ \text{non ci sono macchine}} = 0 \rightarrow \text{SISTEMA ISOLATO}$$

$$\Delta U_{SIST} \overset{ADDITIVA}{=} \Delta U_{AC} + \Delta U_{NC} + \Delta U_{OLIO}$$

$$\left.\begin{aligned}
\Delta U_{AC} &\overset{solido}{=} M_{AC}\, c_{AC} (T_{2AC} - T_{1AC}) \\
\Delta U_{NC} &\overset{solido}{=} M_{NC} \cdot c_{NC} (T_{2NC} - T_{1NC}) \\
\Delta U_{olio} &\overset{liq.}{=} M_{olio} \cdot c_{olio} (T_{2olio} - T_{1olio})
\end{aligned}\right\}$$

lo stato 2 è di equilibrio

$$T_{2AC} = T_{2NC} = T_{2\,olio} = T_2$$

$$T_2 = \dots = 300{,}95\,K = T_{2olio}$$

$$\Delta U_{AC} = \overset{\text{perché } T_2 < T_1}{-}2242\,J$$

$$\Delta S_{AC} \overset{liq}{=} S_{2AC} - S_{1AC} = M_{AC}\, c_{AC} \ln \frac{T_{2AC}}{T_{1AC}} = -58{,}3\,\frac{J}{K}$$

$$\Delta S_{sistema} = S_{2\,sist} - S_{1\,sist} = \cancel{\delta}^{\,0\ ad.} + \underline{S_{IRR}}$$

$$\Delta S_{sistema} \overset{ADDITIVA}{=} \Delta S_{AC} + \Delta S_{NC} + \Delta S_{olio} = 33{,}76\ \frac{J}{K}$$

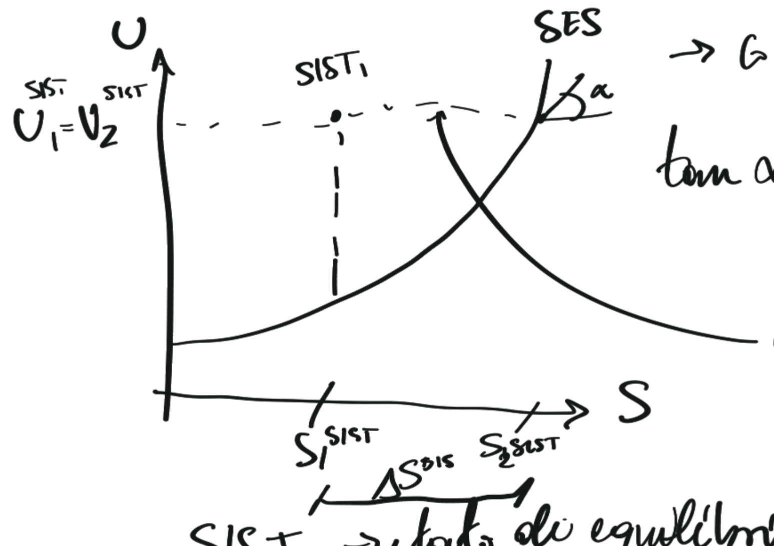
$$\Delta S_{NC} = M_{NC} \cdot c_{NC} \ln \frac{T_2}{T_1} = -29{,}11\ \frac{J}{K}$$

$$\Delta S_{olio} \overset{liq}{=} M_{olio}\, c_{olio} \ln \frac{T_2}{T_{1\,olio}} = 118{,}17\ \frac{J}{K}$$

$S_{IRR} = 33{,}76\ \frac{J}{K} > 0 \Rightarrow$ processo possibile e irreversibile

Stesso esercizio / esercitazione 4 (es 1)

$\Delta U_{SIST} = 0$ sistema isolato



→ GRAFICO U,S del sistema TOT

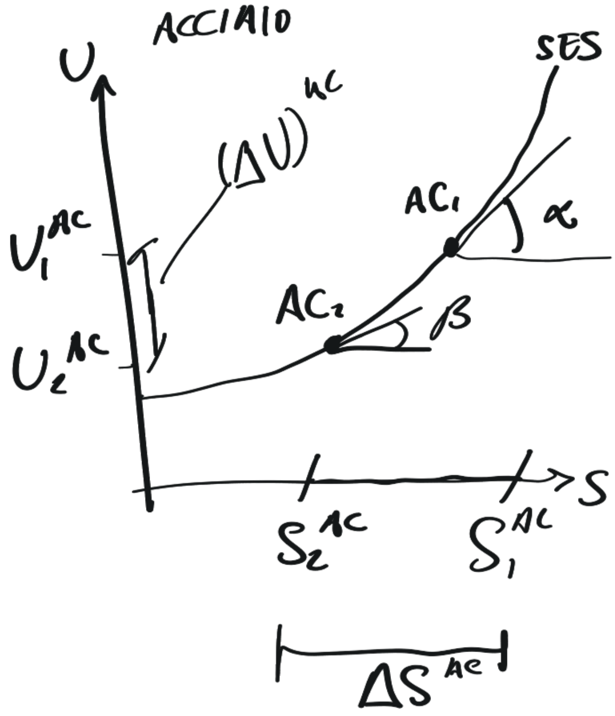
$\tan \alpha = 301\ K = T_2$

$SIST_2$ → stato di equilibrio stabile

$SIST_1$ → non è stato di equilibrio stabile

$$\Delta S^{SIST} = 33{,}76\ \frac{J}{K}$$

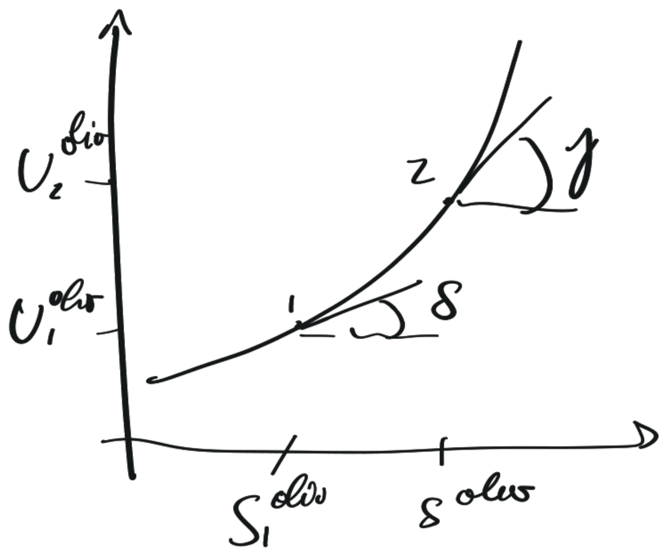
consumiamo Ψ_1 finchè siamo ad equilibrio



$\tan(\alpha) = 523{,}15\ K = T_1^{AC}$

$\tan(\beta) = 301\ K = T_2^{AC}$

NiCr è simile



$\Delta S > 0$

Si può fare un diagramma U-S il sistema intero e un diagramma per ogni elemento del sistema.