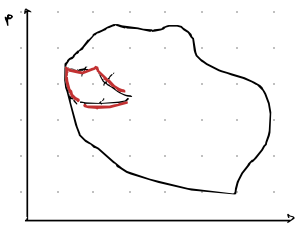
4.3 ENTROPIJA

→ mjera koliko topline se NE može pretvoriti u rad

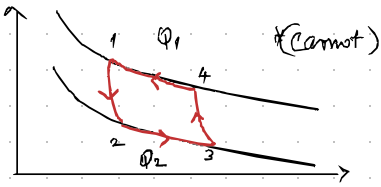
- entropija je funkcija stanja!!

Entropija: $dS = \frac{dQ}{T}$

• objasnimo preko Carnotovog (reverzibilnog) procesa



* pretpostavimo tvrdeći da se svaki proces može dokazati kao suma mnogo malih reverzibilnih Carnotovih procesa



*(Carnot)

Za Carnota vrijedi $-\frac{|Q_2|}{Q_1} = \frac{T_2}{T_1}$ * $Q_2 = -|Q_2|$

$$\Delta S = \frac{Q_1}{T_1} - \frac{|Q_2|}{T_2} = \underbrace{\frac{Q_1}{T_1}}_{S_1} + \underbrace{\frac{Q_2}{T_2}}_{S_2} = 0$$

↳ znači entropija JE funkcija stanja

$$\Rightarrow \Delta S = \oint_{rev} \frac{dQ}{T} = 0$$ Clausiusov teorem

* Za realne ireverzibilne procese efikasnost je manja nego za reverzibilne

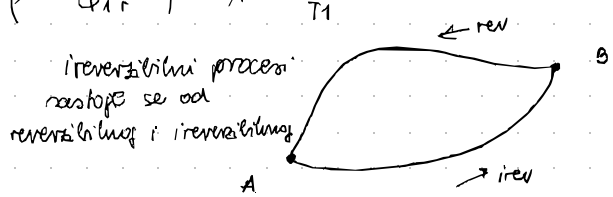
$$\eta_{ir} < \eta_{rev} \rightarrow \left(1 - \frac{|Q_{2ir}|}{Q_{1ir}}\right) < \left(1 - \frac{|Q_{2r}|}{Q_{1r}}\right) = 1 - \frac{T_2}{T_1}$$

$$\frac{|Q_{2ir}|}{Q_{1ir}} > \frac{|Q_{2r}|}{Q_{1r}} = \frac{T_2}{T_1}$$

$$\frac{|Q_{2ir}|}{Q_{1ir}} > \frac{T_2}{T_1}$$

$$\frac{|Q_{2ir}|}{T_2} > \frac{Q_{1ir}}{T_1}$$

$$\frac{Q_{1ir}}{T_1} - \frac{|Q_{2ir}|}{T_2} < 0$$



$$\frac{Q_{1ir}}{T_2} + \frac{Q_{2ir}}{T_2} < 0$$

ΔS_1 ΔS_2

$$\Rightarrow \oint_{ir} \frac{dQ}{T} < 0$$

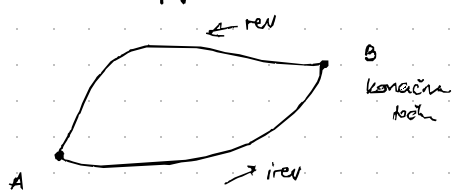
iz Clausiusov TH dobijemo Clausiusovu nejednakost: $\oint_{ir} \frac{dQ}{T} \leq 0$

=> Prirodni procesi se odvijaju tako da se povećava entropija Svemira

i) $\frac{dQ}{dT} = 0$ sustav zatvoren $dQ = 0$

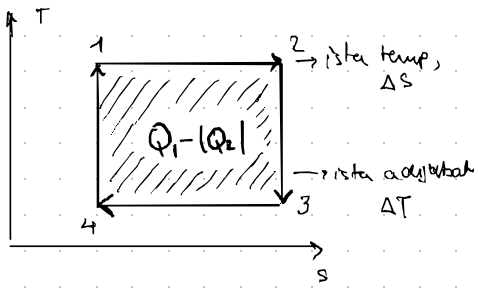
ii) $\Delta S_{rev} = S_A - S_B$

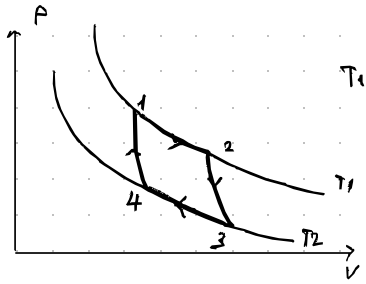
iii) $\Delta S = \Delta S_{rev} + \Delta S_{irrev} < 0$



(i) + (ii) + (iii) $\Rightarrow \underbrace{\int_{ir} \frac{dQ}{T}}_{=0} + S_A - S_B < 0 \Rightarrow S_A < S_B$ entropija se povećava

Entropija idealnog plina





$T_1 > T_2$

1) $dQ = T \cdot dS$

$dQ = 0 \Rightarrow dS = 0$

2) $T = konst.$

$$dQ = T \cdot dS = dU + pdV$$

$$\Delta S = \int \frac{dU}{T} + \int \frac{p}{T} dV = \left| \begin{array}{l} + \text{ formule} \\ dU = nC_v dT \\ pV = nRT \end{array} \right| \Rightarrow \Delta S = n C_v \ln \frac{T_2}{T_1} + nR \ln \frac{V_2}{V_1}$$

ENTROPIJA - objašnjenje

općenito za ireverzibilne procese: $\Delta S \neq \oint_{irev} \frac{dQ}{T} < 0$ ovo zapravo znači $dS \geq \frac{dQ}{T}$

(Clausiusova nejed.) $\Rightarrow S = \int_{irev} \frac{dQ}{T} + S_{gen}$

$$\Delta S_{rev} + \Delta S_{irev} < 0 \Rightarrow \int_{irev} \frac{dQ}{T} + S_A - S_B \leq 0$$

$-\Delta S_{AB} < 0$

koliko god topline doveli u ireverzibilnom procesu, entropija sustava će se promijeniti isto ili više od toga

Entropija kao funkcija stanja u izoliranom sustavu teži termodinamičkoj ravnotežnoj vrijednosti (maksimum entropije)

➤ sustavu koji nije izoliran može se smanjivati entropija u ireverzibilnom procesu, no samo ako se okolini entropija poveća za barem taj iznos

Boltzman: $S = k \ln (W)$ — termodinamička vjerojatnost stanja

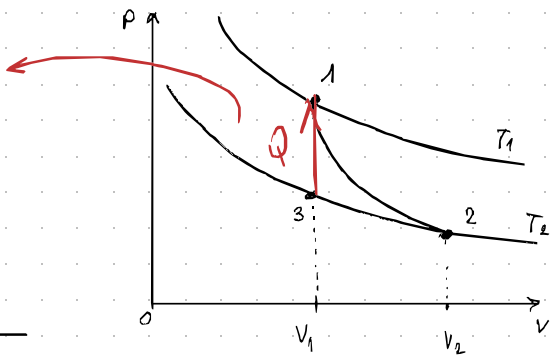
Zadatak 2012/2013)

$n = 1\,mol$ $[He_2]$ $Q = ?$

$t = 10°C \rightarrow 283K = T_1$

1) $V_1 \xrightarrow[ekspa.]{adijaba} 2V_1 = V_2$

2) $T = konst.$ $V_3 = V_1$



$He \longrightarrow i = 3$

$K = \frac{c_p}{c_v} = 1.667$

jednadžbe koje vrijede:

adijabatski proces: $T V^{K-1} = konst \rightarrow T_1 V_1^{K-1} = T_2 V_2^{K-1}$

izoterman proces: $p_1 V_1 = nRT_1$

$$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{K-1} = \frac{T_1}{2^{K-1}} \rightarrow T_2 = 178\,K$$

$\Delta Q_{31} = \Delta U_{31}$ jer $\Delta W_{31} = 0$ $(\Delta V = 0)$

$C_v = \frac{1}{n}\frac{dU}{dT} \Rightarrow dU = nC_v dT \int$

$\Delta U = nC_v (T_1 - T_3)\Big|_{T_3}^{T_2}$

$\Delta U = 1 \cdot \frac{3}{2} R \cdot (283 - 178)K$

$$\boxed{\Delta U = \Delta Q = 1309{,}46\,J}$$

$\Delta Q = nC_p \Delta T + pdV$ → ovo nije 1. ZTD!

C_v