1. Entropy is related to "losing ability to do work"

2. Only for reversible process that, $\delta Q = T \cdot ds$, $\delta W = P \cdot dV$

(ex) free expansion, state 1 : T, P_1, V_1, state 2: $T, P_2, (2V_1)$

$PV = RT$, $P_2 = \frac{1}{2} P_1$,

right side : $P \cdot dV \neq 0$

left side : $\delta W = 0$, $\longrightarrow$ $\delta W \neq P \cdot dV$ (irreversible)

3. Combined 1st, 2nd Law, TRUE for any process,

$$dU = T\,dS - P\,dV \qquad dH = T\,dS + V\,dP$$

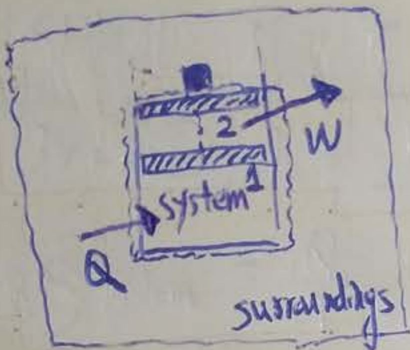
because it is a relation between "state variables"

4. 2nd Law says :

$$\Delta S_{Total} \geq 0 \text{ , where } \Delta S_{Total} = \Delta S_{sys} + \Delta S_{surrounding}$$

(ex) Isothermal reversible expansion, Free expansion, Single heat Reservoir cycle.

a) Isothermal reversible expansion.



$$\Delta S_{Total} = \Delta S_{system} + \Delta S_{sur}$$

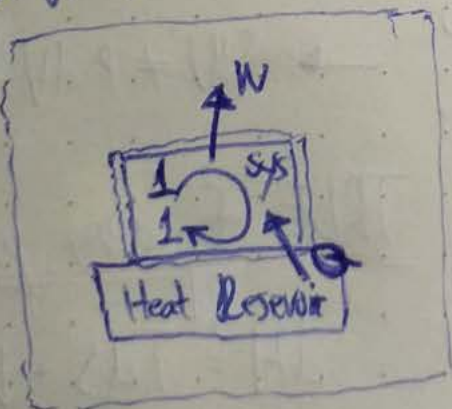
$$= \frac{Q}{T} + \frac{-Q}{T} = 0 \text{ (rev)}$$

b) Free expansion

$$\Delta S_{Total} = \Delta S_{system} + \Delta S_{sur}$$

$$= NR \ln 2 + 0 > 0 \text{ (irrev)}$$

c) Single Heat Reservoir Cycle



Because it is a cycle, gas starts from state 1 and goes back to state 1.

$$\rightarrow \Delta S_{sys,cycle} = 0$$

$$\Delta S_{sur} = \frac{-Q}{T} < 0 ,$$

$$\Delta S_{Total} < 0 \text{ (Not Possible!)}$$

5. There is a direct connection between the work needed to restore the system to the original state and the entropy change:

$$W_{restore} = T \cdot \Delta S_{2\to1}$$

The term: $T \cdot \Delta S$ has a meaning as "lost work", in the sense of work which we lost the opportunity to utilize.