2_Entropy Production Due to Heat Flow_Irreversible Thermodynamics

Link: https://www.youtube.com/watch?v=yFNj6kbILDE&list=PLdBDmcnzLC_ZMUWMdy7SmcTgnnzyiRpql&index=3

For any natural spontaneous process, Entropy is always increased. → we say here that the entropy is produced.

Entropy (S) is an extensive property.

$$dS = dS_1 + dS_2 + \cdots$$

Bulk Material dS

dS $\begin{cases} d_eS : \text{(Entropy flow due to the interaction with the exterior / environment)} \\ d_iS : \text{(Entropy contribution due to the change in the inside of the system)} \end{cases}$

$$dS = d_iS + d_eS$$

$d_iS = 0$ for a reversible Process

$d_iS > 0$ for a irreversible Process

(never be negative)

↓

This is our entropy produced

Consider the following system:

Consider the following system:

Material System : $\begin{cases} \text{Phase I} \rightarrow @ \text{ Temperature } T^{I} \\ \text{Phase II} \rightarrow @ \text{ Temperature } T^{II} \end{cases}$

They react with each other.

$$dS = \frac{dq}{T}$$

$$dS = dS^{I} + dS^{II}$$

$$d^{I}q = d_e^{I}q + d_i^{I}q$$

(Since the reaction between Phase I & II could be either exthermic or endothermic)

$$d^{II}q = d_e^{II}q + d_i^{II}q$$

$$d^{I}S = \frac{d^{I}q}{T^{I}} = \frac{d_e^{I}q}{T^{I}} + \frac{d_i^{I}q}{T^{I}}$$

$$d^{II}S = \frac{d^{II}q}{T^{II}} = \frac{d_e^{II}q}{T^{II}} + \frac{d_i^{II}q}{T^{II}}$$

$(d_i^{I}q = -d_i^{II}q)$

Thus,

$$dS = \underbrace{\frac{d_e^{I}q}{T^{I}} + \frac{d_e^{II}q}{T^{II}}}_{d_eS} + \underbrace{d_i^{I}q\left(\frac{1}{T^{I}} - \frac{1}{T^{II}}\right)}_{d_iS}$$

$d_iS \rightarrow$ Entropy Production

Arrising due to the transfer of heat from Phase I to Phase II

$$d_iS = d_i^{I}q\left(\frac{1}{T^{I}} - \frac{1}{T^{II}}\right)$$

(If $T^{II} > T^{I}$, in this case $d_i^{I}q > 0$, $\Rightarrow d_iS > 0$

If $T^{I} > T^{II}$, in this case $d_i^{I}q < 0$, $\Rightarrow d_iS > 0$)

d_iS will be equal to 0, only when the system is under thermal equilibrium. ($T^{I} = T^{II}$)

This expression can be written in the form of σ. (Entropy Production per unit time)

Written as σ_V

Entropy production per unit Volume per unit time.

$$\sigma = \frac{d_iS}{dt} = \underline{\frac{d_i^I q}{dt}}\left(\frac{1}{T^{I}} - \frac{1}{T^{II}}\right)$$

2nd term: Difference of the state function. (of our temperature)

First term: rate of heat transfer

$\frac{d_i^I q}{dt}$: Could be considered as the microscopic force or the driving force for the heat transfer

$J = LX$

X → driving force

J → Flux of the thermodynamic quantity