

Change in Entropy for Reversible Process :  $\Delta S = S_2 - S_1 = \int_1^2 \left( \frac{\delta Q}{T} \right)_{\text{rev}}$

Change in Entropy for Irreversible Process :  $\int_1^2 \left( \frac{\delta Q}{T} \right)$

Increase in Entropy :  $(S_2 - S_1) = \int_1^2 \left( \frac{\delta Q}{T} \right) + \boxed{S_{\text{generation}}}$

- For any process, there will be increase in entropy
- Physical Significance of Entropy : It denotes the degree of disorder.
- $S_{\text{generation}} \geq 0$

\* For an Isolated System, there is no work or heat-transfer

$$\therefore (S_2 - S_1) \geq 0$$

$$\therefore \boxed{S_2 - S_1 = S_{\text{generation}}}$$

- For Reversible Process, the change in entropy will be zero
- The entropy of the universe will always increase, as it is an isolated system.
- A process where entropy is constant is ~~isobaric~~ process  
Isentropic

\* Change in Entropy occurs due to two factors

- Heat Transfer
- Irreversibilities

Eg The heat removed from the refrigerator leads to decrease in entropy but the work done in removing the heat (irreversibilities) increases the entropy. Hence the net change in every process is positive.

## Isentropic Process:

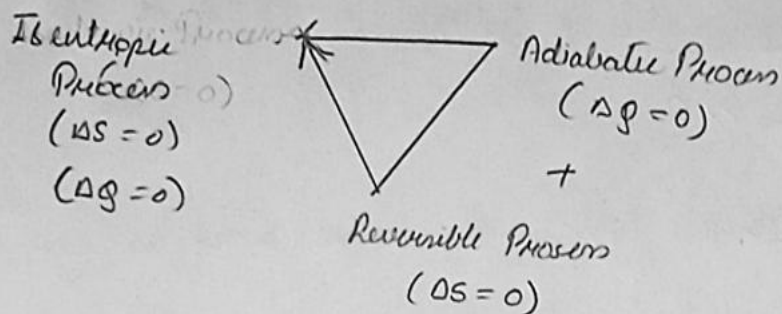
A process where entropy is constant.

$$\therefore \Delta S = 0$$

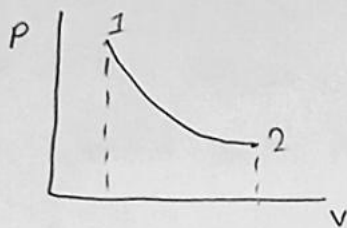
$$\therefore S_2 - S_1 = 0$$

It is only achieved as Reversible Adiabatic Process.

Isentropic Process = Reversible Adiabatic



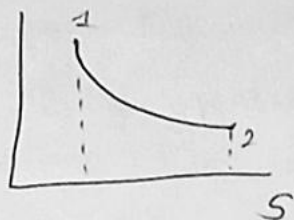
## ★ Temperature - Entropy Diagram



$$W = \int_1^2 P dv$$

$$\frac{dQ}{dT} = C_p$$

Whenever  
Phase  
Change is  
there,  
i.e. water  
and steam



$$ds = \left( \frac{\delta Q}{T} \right)_{rev}$$

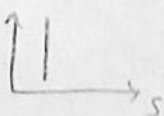
$$\delta Q = T ds$$

$$Q = \int T ds$$

→ Area under P-V diagram gives work done

→ Area under T-S diagram gives Heat Change

→ For isentropic process, ΔS = 0



Area Under the curve = 0  
Heat Change = 0

## ★ Tds Relations :

v = Volume

First Law :  $Q - W = \Delta U$

$$\therefore \delta Q - \delta W = dU \quad \text{--- (i)}$$

For Reversible Process :  $\left. \begin{array}{l} \delta Q = Tds \\ \delta W = PdV \end{array} \right\} \text{--- (ii)}$

Using eq (ii) in (i)

$$\therefore Tds - PdV = dU$$

$$\therefore Tds = PdV + dU$$

\* Per Unit Mass

$$Tds = PdV + du \quad \text{--- (iii)}$$

\* Now we know that Specific Enthalpy :  $h = u + pv$

$$\therefore dh = du + PdV + vdp$$

$$\therefore du + PdV = dh - vdp \quad \text{--- (iv)}$$

\* Putting eq (iv) in eq (iii) :

$$\therefore Tds = dh - vdp \quad \text{--- (v)}$$

\* Main Equation

eq (iii) :  $Tds = PdV + du$   
 $\therefore ds = \frac{P}{T} dV + \frac{du}{T}$

eq (v) :  $Tds = dh - vdp$

$$\therefore ds = \frac{dh}{T} - \frac{v}{T} dp$$

→ These equations follow both first and second law of thermodynamics  
→ It is applicable for both liquids and gases

\* For Liquids and Solids:

- They are incompressible, i.e.  $dv \approx 0$

$\therefore$  eq (iii) becomes  $\boxed{ds = \frac{du}{T}} \longrightarrow \text{eq (vi)}$

\* Now we know that  $u = C_{avg} T$ , where  $C_{avg}$  = Specific Heat  
 $\hookrightarrow \text{eq (vii)}$

\* Putting eq (vii) in eq (vi)

$$\therefore ds = C_{avg} \frac{dT}{T}$$

$$\therefore s_2 - s_1 = \int_1^2 ds = \int_1^2 C_{avg} \frac{dT}{T}$$

$$\therefore \boxed{s_2 - s_1 = C_{avg} \ln \left( \frac{T_2}{T_1} \right)}$$

\* For Isentropic Process, i.e.  $s_2 - s_1 = 0$

$$0 = C_{avg} \ln \left( \frac{T_2}{T_1} \right)$$

$$0 = \ln \left( \frac{T_2}{T_1} \right)$$

$$1 = \frac{T_2}{T_1}$$

$$T_1 = T_2$$

$\rightarrow$  Thus, for liquids and gases,

Adiabatic Process = Isentropic Process

\* Tds Relations For Gases :

$$\left. \begin{aligned} \text{We know that } du &= C_v dT \\ dh &= C_p dT \end{aligned} \right\} \text{--- (n)}$$

Using eq (n) in eq (iii) and (v) :

$$\therefore ds = C_v \frac{dT}{T} + \frac{P}{T} dv$$

$$\therefore ds = C_p \frac{dT}{T} - \frac{v}{T} dp$$

\* For Ideal Gases : ( $PN = RT$ )

$$ds = C_v \frac{dT}{T} + R \frac{dv}{v}$$

$$ds = C_p \frac{dT}{T} - R \frac{dp}{p}$$