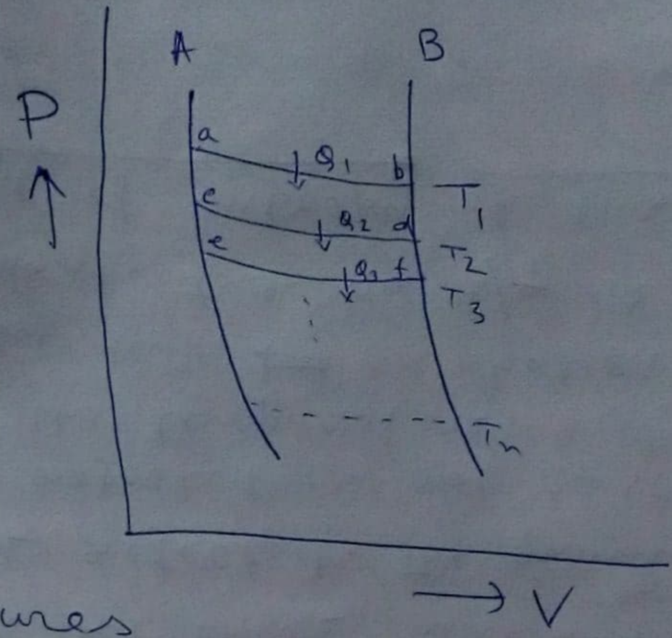
Entropy

Introduction: The concept of entropy was first ~~formulated by~~ introduced by Claussius when he was working on the formulation and application of the second law of thermodynamics. We know, in an isothermal process the temperature of a gas does not change but in an adiabatic process, as there is no exchange of heat with the surroundings, the temperature of the gas changes. When ~~that~~ the gas is adiabatically compressed, some work is done on the gas and as a result, both the heat energy and the temperature of the gas increases. Similarly, when the gas expands adiabatically, it does some work at the expense of its internal energy, resulting in the fall of both the heat energy and the temperature of the gas. This ~~tells~~ tells that in an adiabatic process, neither the heat energy nor the temperature remains constant. Both increase or decrease together. But Claussius realized that something remains constant in this process and that quantity he called as entropy and denoted by the symbol S.

The idea of entropy will be clear from the following indicator diagram.



Let A and B represent two adiabatics. Then there will be regular changes of pressure, volume and temperature along each curve. Let the isothermals ab, cd, ef at constant temperatures T_1, T_2, ~~T_3~~ and T_3 respectively intersect the two adiabatics. Then the cycles abcd, cdef form Carnot cycles. Consider the Carnot cycle abcd. When the isothermal passes from the state a to the state b isothermally at temperature T_1, it absorbs Q_1 amount of heat (say) and when it passes from the state d to the state c isothermally at temperature T_2, it rejects Q_2 amount of heat (say). Then according to Carnot's principle

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} \quad \text{--- (1)}$$

Again considering the carnot cycle edfe in which the working substance absorb Q_2 amount heat at temperature T_2 and rejects Q_3 unit heat at temperature T_3, one can write

$$\frac{Q_2}{T_2} = \frac{Q_3}{T_3}.$$

This will keep going if we consider other carnot cycles, ~~Then we can write that~~ i.e.,

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_3}{T_3} = \frac{Q_4}{T_4} = \frac{Q_5}{T_5} = \cdots$$

Then we can write

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_3}{T_3} = \cdots = \text{constant}$$

From one adiabatic to the other, heat energy is either absorbed or rejected. The quantity of heat absorbed or rejected is not constant, it depends upon the temperature. But the ratio Q/T between the two adiabatics is constant. This constant ratio Q/T is defined as the <u>change of entropy of the working substance.</u>

If the two adiabaties under consideration are very close to each other so that the quantity of heat either absorbed or given out by the working substance is dQ, at temperature then the small change of entropy ds is given by

$$\boxed{ds = \frac{dQ}{T}}.$$

- Unit of entropy : Joule/K (SI)

- Adiabatic curves are isentropic curves:

During an adiabatic process, the working substance neither absorbs ~~heat~~ nor rejects heat, i.e., $dQ = 0$ and hence, the change of entropy

$$ds = \frac{dQ}{T} = 0.$$ This means that in an adiabatic process, there is no change in entropy of the substance, i.e., the entropy of the working substance or system remains constant.

So, entropy of a system may be defined as that physical property of a system which always remains constant during an adiabatic reversible process.

- Like pressure, volume, temperature and internal energy etc. entropy is another thermodynamic variable of a system. It is a state variable.

Third law of thermodynamics (or Nernst's theorem):

The entropy of every system at absolute zero can always be taken equal to zero.

- This theorem was originally applied to condensed systems but later on it has been extended to apply to gaseous systems also.