Calculation of entropy Change for reversible and irreversible processes. : (A) Reversible Process

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Let dq_1 be the heat supplied by the working System at T_1 and dq_2 be the heat rejected by the System to the sink at T_2. All steps are reversible and therefore, in a ~~carb~~ Carnot cycle,

$$\frac{dq_1 - dq_2}{dq_1} = \frac{T_1 - T_2}{T_1}$$

OR

$$\frac{dq_1}{dq_1} - \frac{dq_2}{dq_1} = \frac{T_1}{T_1} - \frac{T_2}{T_1}$$

OR

$$\cancel{1} - \frac{dq_2}{dq_1} = \cancel{1} - \frac{T_2}{T_1}$$

OR

$$\frac{dq_2}{dq_1} = \frac{T_2}{T_1}$$

OR

$$\frac{dq_1}{T_1} = \frac{dq_2}{T_2}$$

OR

$$\frac{dq_1}{T_1} - \frac{dq_2}{T_2} = 0$$

Here $-dq$ means heat absorbed. We can rewrite the last equation in opposite sign conventions too.

$$\frac{dq_1}{T_1} + \frac{dq_2}{T_2} = 0$$

For other Carnot cycles, we have

$$\frac{dq_1'}{T_1'} + \frac{dq_2'}{T_2'} = 0 \quad \text{and so on.}$$

Thus for a complete reversible cyclic process

$$\Sigma \frac{dq}{T} = 0 \quad \text{OR} \quad \oint \frac{dq}{T} = 0$$

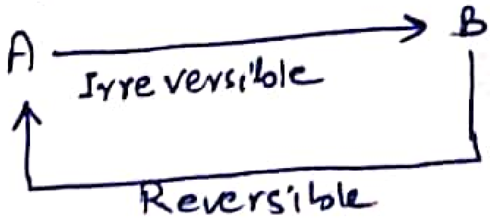
i.e. $\boxed{\oint dS = 0}$

It means that net increase in entropy of system is zero, in any reversible cyclic process.

(B) Irreversible process : Consider A ⟶ B is irreversible. No matter, what the nature of this

Now $\cancel{\oint \frac{dq_{irr}}{T}} \ngeq \cancel{\oint}$ process might be,

we can assume the reversible process B → A is carried out reversible. Then we have the following cycle.



Now
$$\oint \frac{dq_{irr}}{T} = \int_A^B \frac{dq_{irr}}{T} + \int_B^A \frac{dq_{rev}}{T}$$

we know that,
$$\oint \frac{dq_{irr}}{T} < 0$$

$$\therefore \int_A^B \frac{dq_{irr}}{T} < \int_A^B \frac{dq_{rev}}{T}$$

OR
$$\int_A^B \frac{dq_{irr}}{T} < \int_A^B ds \qquad \left[\because ds = \frac{dQ_{rev}}{T}\right]$$

OR
$$\int_A^B \frac{dq_{irr}}{T} < \Delta S_{AB} \quad \text{———} \ (1)$$

Equation ~~ΔS_{AB}~~ (1) is known as Clausius inequality which is a fundamental requirement for a real change. This is to be noted that for any change in an isolated system, $dq_{irr} = 0$ and the Clausius inequality of equation (1) becomes

$$\boxed{0 < \Delta S_{AB}}$$

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