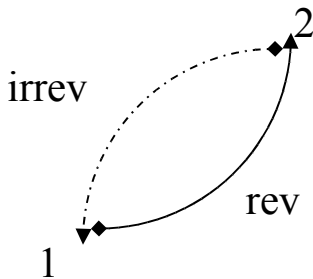


Increase in Entropy Principle

- For reversible processes, entropy of universe (system surrounding) doesn't change, it is just transferred (along with heat transfer)
- In real processes, irreversibilities cause entropy of universe to increase
- Heat reservoirs don't have irreversibility
- To simplify analysis, assume irreversibilities to exist only inside the system under study.
- Inside the system, entropy *transfer* and *generation* occur.



Irreversible cycle since one of the processes is irreversible

From Clausius Inequality;

$$\oint \left(\frac{\delta Q}{T} \right)_{irrev} < 0$$

$$\int_1^2 \left(\frac{\delta Q}{T} \right)_{irrev} + \underbrace{\int_2^1 \left(\frac{\delta Q}{T} \right)_{rev}}_{=\Delta S = S_2 - S_1} < 0$$

$$\rightarrow S_2 - S_1 + \int_1^2 \left(\frac{\delta Q}{T} \right)_{irrev} < 0$$

Rearrange

$$S_2 - S_1 < - \int_1^2 \left(\frac{\delta Q}{T} \right)_{irrev}$$

$$S_2 - S_1 > \int_1^2 \left(\frac{\delta Q}{T} \right)_{irrev}$$

Generalize for all processes

$$S_2 - S_1 \geq \int_1^2 \frac{\delta Q}{T}$$

= when rev
> when irrev
< impossible

$$S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} + S_{gen}$$

S_{gen} = entropy generated
= 0 when rev.
> 0 when irrev.
< 0 impossible

$$S_2 - S_1 = \int_1^2 \left(\frac{\delta Q}{T_b} \right) + S_{gen}$$

Change of
system
entropy

Transfer of entropy
(T where Q is
transferred, usually
at boundary

Entropy
generation

S_{gen} is the measure of irreversibilities involved during process

$$\Delta S_{total, universe} = \Delta S_{surrounding} + \Delta S_{system} \geq 0$$

ΔS surrounding or system may decrease (-ve), but ΔS total (surrounding + system) must be > 0

Entropy of universe always *increases* (Entropy increase principle)

No such thing as entropy conservation principle

For a process to occur, $S_{gen} > 0$

Entropy Generation for Closed System

$$\Delta S = S_2 - S_1 = \int \frac{\delta Q}{T_b} + S_{gen}$$

$$S_2 - S_1 = \frac{Q}{T_b} + S_{gen}$$

For multiple heat transfers at different temperatures

$$S_2 - S_1 = \sum_{j=1}^n \frac{Q_j}{T_j} + S_{gen}$$

$$\frac{dS}{dt} = \sum_{j=1}^n \frac{\dot{Q}_j}{T_j} + \dot{S}_{gen} \quad \text{In rate form}$$

$$dS = \sum_{j=1}^n \frac{\delta Q_j}{T_j} + \delta S_{gen} \quad \text{In differential form}$$

δS_{gen} - depends on the process (friction, ΔT etc.)
- not a property