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2nd LAW of THERMODYNAMICS:

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2/5: (3) EQUIVALENT FORMS of 2nd LAW;

3/5: ENTROPY DEFINED .... & ALWAYS
increases as Heat flows from HOT to COLD;

4/5: ENTROPY STATEMENT of 2nd LAW is
EQUIVALENT TO CARNOT'S STATEMENT;

5/5: ENTROPY MEASURES PROBABILITY
of STATE of SYSTEM.

CARNOT'S MAXIMALLY Efficient CYCLIC HEAT ENGINE ⇒ 2nd LAW

ACTUAL Efficiency

$$\eta_{ACTUAL} = \frac{W_{out}^{NET}}{Q_{IN}} = \frac{Q_{IN} - Q_{out}}{Q_{IN}} = 1 - \frac{Q_{out}}{Q_{IN}}$$

for any ACTUAL Heat Engine

& CARNOT proved that

CARNOT EFFICIENCY,

$$\eta_{CARNOT} = 1 - \frac{T_C}{T_H}$$

for CARNOT'S IDEALIZED Heat Engine

AND ALSO, by design of CARNOT ENGINE, that

$$\eta_{CARNOT} > \eta_{ACTUAL}$$

for any engine operating between T_H & T_C

THEREFORE

$$\frac{Q_{out}}{Q_{IN}} > \frac{T_C}{T_H}$$

AND $Q_{out} > 0$, since $T_C > 0$

(by 3rd LAW)

(3) (EQUIVALENT!) VERSIONS OF 2nd LAW of ThermoDynamics

1) A HEAT ENGINE MUST EXHAUST HEAT.

2) A REFRIGERATOR MUST CONSUME WORK.

3) ENTROPY of a closed system ALWAYS INCREASES.

CHANGE IN ENTROPY

$$\Delta S = \sum \frac{Q_i^{IN}}{T_i}$$ ← Definition of ΔS.

Eg FOR Q transferred from T_H to T_C

$$\Delta S = \frac{Q}{T_C} - \frac{Q}{T_H}$$

Clearly $\Delta S > 0$ iff $T_H > T_C$

i.e. $\Delta S > 0 \iff$ {Q flows from Higher to Lower T.}

ENTROPY STATEMENT IS EQUIVALENT TO CARNOT'S STATEMENT FOR HEAT ENGINE + SURROUNDINGS

$$\Delta S_{UNIV.} = \Delta S_{SURR} + \Delta S_{ENGINE}$$

$$= -\frac{Q_{IN}}{T_H} + \frac{Q_{OUT}}{T_C} + 0$$

because engine is same at end of cycle as at beginning.

$$\Delta S_{UNIV.} > 0 \Rightarrow \frac{Q_{OUT}}{T_C} > \frac{Q_{IN}}{T_H}$$

$$\Leftrightarrow \frac{Q_{OUT}}{Q_{IN}} > \frac{T_C}{T_H} : \text{CARNOT'S } 2^{nd} \text{ LAW}$$

$$\Delta S_{UNIV} > 0 \Leftrightarrow Q_{OUT} > 0$$

THIRD FORM of **2nd LAW** is equivalent to 1st FORM !

ENTROPY & PROBABILITY

ENTROPY $S = k(\ln W)$

k = Boltzmann's constant per molecule
$= 1.38 \times 10^{-23}$ J/particle - K

& W = probability of macroscopic state of system.

THUS INCREASE of ENTROPY in a process

$\Leftrightarrow$ movement towards a state of higher probability.