The 2nd law of thermodynamics

Lin Hsiu Hao : 热统计物理二 lecture 3

perfect heat engine $\longleftrightarrow$ perfect refrigerator

if 低温 $\rightarrow$ 高温 automatically

你可以被冷的东西烫到

$\downarrow$ modern language

For an isolated system, its entropy never decreases and it remains constant during a reversible process.

That is to say, $\Delta S \geq 0$

P240 附近, thermal physics (Kittel)

Understand entropy S better

摩擦力何只能生热，力何不能生功？

reversible

$\downarrow$

irreversible

I° Clausius: From Carnot's heat engine argument, he proved

对于循环而言

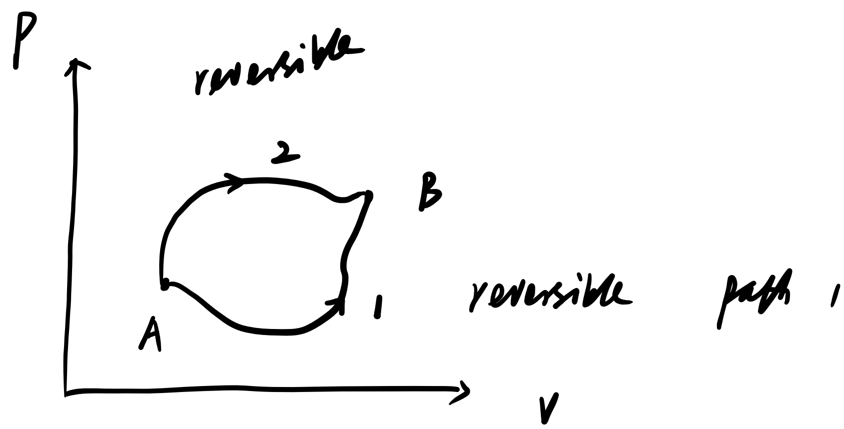
$$\boxed{\oint \frac{dQ}{T} \leq 0} \rightarrow \text{cyclic}$$

(apply calculus to carnot's cycle)

"=" holds for reversible process.

Entropy is a $\boxed{\text{state function}}$

(“误解”贡献最大)



$$\oint \frac{đQ}{T} = 0$$

$$\int_{path\ 2} \frac{đQ}{T} - \int_{path\ 1} \frac{đQ}{T} = 0$$

$$\Downarrow$$

$$\int_{path\ 2} \frac{đQ}{T} = \int_{path\ 1} \frac{đQ}{T} \equiv dS$$

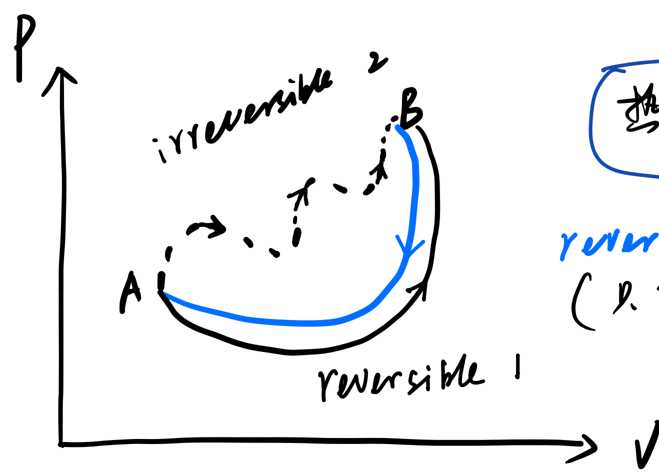
$$= S(B) - S(A)$$

$\frac{đQ}{T}$: 商 + 火 (thermal ..)

‖ 熵

(ΔS defined by reversible process) give me a state, there is a value S

what about irreversible process



热机 顺时针转

reverse 1

(只能 reverse reversible process)

$$\Delta S = \int_1 dS = \int_1 \frac{đQ}{T} = S(B) - S(A)$$

$$\oint \frac{đQ}{T} \le 0$$

$$\underset{IR}{\int_2 \frac{đQ}{T}} - \boxed{\underset{R}{\int_1 \frac{đQ}{T}}} = \oint \frac{đQ}{T} \le 0$$

$$\boxed{\Delta S \geq \int_2 \frac{dQ}{T}}$$

(如果可逆，取"=")
but，怎么对公众宣讲？

For an isolated system ($dQ = 0$)

$\rightarrow \boxed{\Delta S \geq 0}$ 报告给公众

(go back to the two reserviors T_2, T_1) 高温自动向低温放热

吸热为正 $\Delta Q_2 = -\Delta Q_1 < 0$ ($T_2 > T_1$)

$$\frac{\Delta Q_2}{T_2} + \frac{\Delta Q_1}{T_1} > 0$$

这里，两个热源合在一起当孤立系统熵增。

not a cycle
direct contact

吸热，给了能量，也给了 S（混乱度）
怎么还能协调一致地对外做功呢？

the state variable S, review Carnot cycle

$$W = Q = Q_H + Q_L$$

the "working fluid" absorbs heat from reservoir T_H

releases heat to ~ T_L

For a real heat engine:

there is a temperature differential dT

between the reservoir and the fluid while

the heat exchange takes place.

$$\Delta S_H = \int_{Q_{in}} \frac{dQ_H}{T} > \frac{Q_H}{T_H}$$

$$0 > \Delta S_L > \frac{Q_L}{T_L}$$

$$\Delta S_H + \Delta S_L = \Delta S_{cycle} = 0$$

$$\frac{Q_H}{T_H} + \frac{Q_L}{T_L} < 0 \Rightarrow \frac{Q_H}{T_H} < -\frac{Q_L}{T_L} \Rightarrow -\frac{T_L}{T_H} > \frac{Q_L}{Q_H}$$

$$\eta = \frac{W}{Q_H} = \frac{Q_H + Q_L}{Q_H} < 1 - \frac{T_L}{T_H} = \eta_I$$

"=" for the ideal heat engine

II° boltzmann :

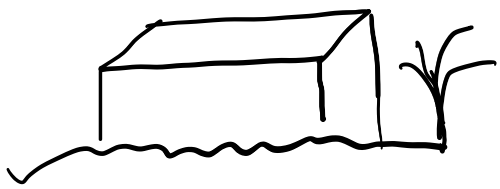
entropy → state function

skip the heat, work,

(ir) reversible processes .....

Tomb : $S = k \cdot \log W$

Q: S是广延量还是强度量?



[kittel, $\sigma = \log g$

(好老师知道洗脑要趁早)
^^]

for S

Is there the microscopic explanation ?

— a good question

Entropy of mixing

consider a mixture of N_A atom A and N_B atom B $(N = N_A + N_B)$

multiplicity : $g = \dfrac{N!}{N_A!\, N_B!}$

基础上的公式 $S = k \ln W = k \ln g$

$$= k[\ln N! - \ln N_A! - \ln N_B!]$$

$$= k[N\ln N - N - (N_A \ln N_A - N_A) - (N_B \ln N_B - N_B)]$$

$$= k[N\ln N - N_A \ln N_A - N_B \ln N_B]$$

$$= k[N_A \ln N/N_A + N_B \ln \frac{N}{N_B}]$$

$$= -k[N_A \ln \frac{N_A}{N} - N_B \ln \frac{N_B}{N}]$$

$\downarrow x \equiv \frac{N_A}{N}$ $= kN[-x\ln x - (1-x)\ln(1-x)]$

$= kN\underline{\sigma}$ (shannon entropy) stirling's approximation

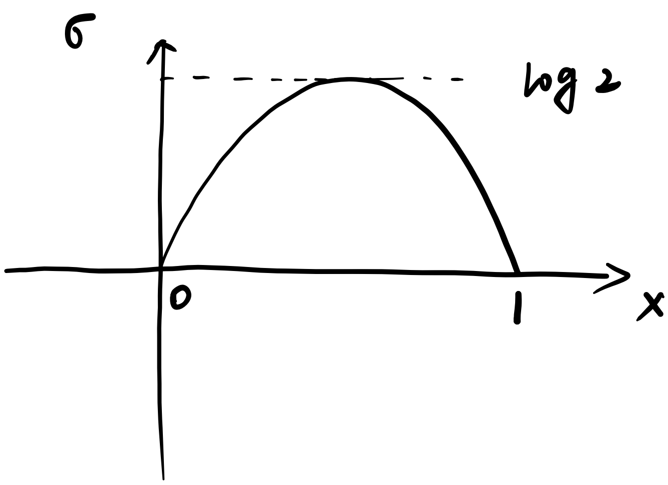
$$\ln N! = N \ln N - N$$

状态数 W → 几率 $\frac{1}{W} \to p$ （出发点）

$$\sigma = -\langle \log p \rangle$$

↓ binary

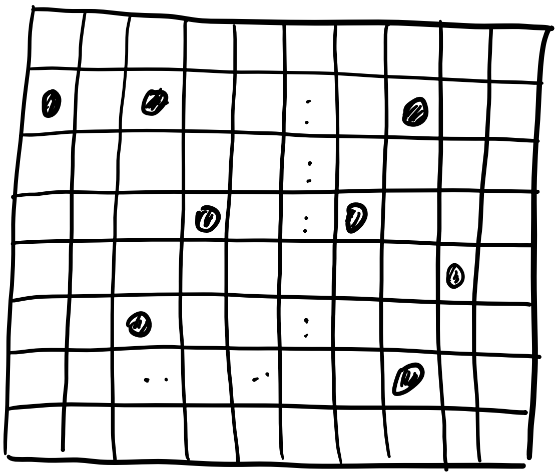
$$-\left[x \log x + (1-x)\log(1-x) \right]$$



Q：你想看一场怎样的比赛？

什么叫势均力敌？什么叫精彩？

illustration of configuration :



位置可分，粒子不可分

$C_N^{N_A}$，如果粒子可分 $P_N^{N_A}$

\# of ●: N_A 差 $N_A!$ (全排)

\# of □: N

Clausius : Entropy 的创造者

名词

Energie (能量) +

trope (转换)

以此强调这是一个描述能量转换过程的等价量。

辨析　完美热机

理想热机

实际热机

$$\sigma = -\sum_i p_i \ln p_i$$

$$S = k_B \ln W$$

讨论在不确定度的意义上，

为什么有符号差异

微观状态数与几率的关系