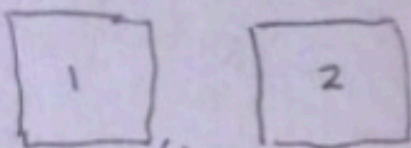
$$w_n^{(a)} = e^{-\alpha^{(a)} - \beta E_n^{(a)}} \; ; \; \beta = \frac{1}{k_B T}$$

$$E^{(a)} = \sum_n E_n^{(a)} w_n^{(a)} \quad \text{total } E$$

$$S^{(a)} = -k_B \sum_n w_n^{(a)} \ln w_n^{(a)}$$

$$S^{(a)} = S^{(a)}(E^{(a)})$$

$a = 1, 2$



$S^{(1)} \; E^{(1)} \qquad S^{(2)} \; E^{2}$

$$E^{total} = E^{(1)} + E^{(2)} \Rightarrow dE^{(1)} = -dE^{(2)}$$

$$S^{total} = S^{(1)} + S^{(2)}$$

Experimentally entropy always increases or at best is constant

In equilibrium S is a maximum

condition for eq

$$\frac{dS^{total}}{dE^{(1)}} = \frac{dS^{(1)}}{dE^{(1)}} + \frac{dS^{(2)}}{dE^{(2)}} \underbrace{\frac{dE^{(2)}}{dE^{(1)}}}_{-1}$$

$$\frac{dS^{(1)}}{dE^{(1)}} - \frac{dS^{(2)}}{dE^{(2)}} = 0$$

$$\frac{dS^{(1)}}{dE^{(1)}} = \frac{dS^{(2)}}{dE_2}$$

$$\frac{dS}{dE} = \frac{1}{T} \quad \text{definition of temperature}$$

examine rate of change of S

$$\frac{dS^{total}}{dt} = \frac{dS^{(1)}}{dE^{(1)}} \frac{dE^{(1)}}{dt} + \frac{dS^{(2)}}{dE^{(2)}} \frac{dE^{(2)}}{dt}$$

$$= \frac{dE^{(1)}}{dt} \left(\frac{1}{T^{(1)}} - \frac{1}{T^{(2)}} \right) > 0$$

energy flows from hot to cold

$H = H(p, q : \lambda(t)) \Rightarrow$ cons. action

Analog for thermodynamic syst.

$$\frac{dS}{dt} = \underset{\substack{\| \\ 0 \\ \text{entropy const. in equilib.}}}{C_0} + \underbrace{C_1 \frac{d\lambda}{dt}}_{\text{vanishes (entropy max)}} + C_2 \left(\frac{d\lambda}{dt}\right)^2 \cdots$$

$$\Rightarrow \frac{dS}{dt} = C_2 \left(\frac{d\lambda}{dt}\right)^2$$

if we go slow enough entropy will be conserved.

13