Ideal Gases (non-interacting part.

based on W_n Petit

$\rightarrow W_{nN}$ Grand

criterion for "classical" behavior

$n \equiv \frac{N}{V} \rightarrow$ seperation $a_0 \sim \frac{1}{n^{1/3}}$

for class behavior

$\bar{n}_k << 1$

assign volum to quantum state

$\overline{\frac{\Delta q \Delta p}{2\pi\hbar}} \sim \bar{n}_k << 1$

$\Delta q : a_0$; Δp thermal momentum

$a_0 >> \lambda_{dB} \longrightarrow k_B T >> \frac{\hbar^2}{2m a_0^2}$

$\sum_k \bar{n}_k = N$

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if part don't then each part can be regarded as seperate subsystem

then $\bar{n}_k = W_k = e^{-\alpha - \beta \epsilon_k}$; $e^{-\alpha} = a$

$\bar{n}_k = a e^{-\beta e_k}$ Gibbs petit

normalized $\sum_k \bar{n}_k = N$

Grand case

many body energies $E_{nN} \longrightarrow n_k e_k$ $\quad W_{nN} \rightarrow W_{n_k}$

$\sum_{nN} W_{nN} = 1$; $\sum W_{n_k}(\epsilon_k)$

Gibbs Grand ensemble

$W_{n_k} = e^{\beta(\Omega + n_k \mu_k - n_k \epsilon_k)}$

$n_k =$ integers : 0, 1, 2

$W_0 = e^{\beta\Omega}$; $W_1 = e^{\beta(\Omega + \mu - \epsilon_k)}$, $W_2 = e^{\beta(\Omega + 2\mu - 2\epsilon_k)}$

Norm

$\sum_{n_k} W_{n_k, \epsilon_k} = 1 = W_0 + W_1 \cdots$

$\bar{n}_k = \sum_k n_k W_{n_k}$ converges fast

$= 0 \cdot W_0 + 1 \cdot W_1 \cdots$ stop

$\bar{n}_k = W_1(\epsilon_k)$; $W_0 = e^{\beta\Omega} = 1$

$\bar{n}_k = e^{\beta(\mu - \epsilon_k)}$ Gibbs Grand

$\Rightarrow a = e^{\beta\mu}$

Classical particle energie

$\epsilon_k = p^2/2m + U(q)$; $U(q) \rightarrow 0$ (gravity)

$n_k \rightarrow n(\vec{p}, \vec{q})$

normalize $\int n(\vec{p}, \vec{q}) \frac{dp\, dq}{(2\pi\hbar)^3} = N$

$= V \int \frac{d^3 p}{(2\pi\hbar)^3} e^{\beta[\mu - (p_x^2 + p_y^2 + p_z^2)/2m]} = N$

home work do integral