Thermal Physics

Nov. 19th, 2014

Meeting

I Last time

II Wavefunction Symmetry

I
- $E = E(S, V, N)$

$dE = T\,dS - p\,dV + \sum_i \mu_i\, dN_i$

$\mu_j = \left(\frac{\partial E}{\partial N_j}\right)_{S,V,N}$ $\quad \mu_j = \left(\frac{\partial F}{\partial N_j}\right)_{T,V,N}$

$\mu_j = \left(\frac{\partial G}{\partial N_j}\right)_{T,p,N}$

- Phase equilibrium

$T_1 = T_2, \quad p_1 = p_2, \quad \mu_1 = \mu_2$

- Chemical equilibrium

$\sum_i b_i \mu_i = 0$

b_i ← stoichiometric coefficients

- μ_j encapsulates the tendancy of particles of species j to diffuse.

⤳ Also, like kT, it gives a typical energy scale — soon to see this.

II The quantum wavefunction of a collection of particles satisfies certain symmetry properties (these aren't derived in a 1st quantum course either — so no need to be intimidated. Just learn them here.)

Quantum wave function in abbreviated notation

coord.s of particle 1

$$\Psi_{\{s_1, s_2, \ldots, s_N\}}(Q_1, \ldots, Q_N)$$

↑ state of particle 1

Different kinds of particles have different statistics and different symmetries under exchange

Maxwell-Boltzmann: Any # of particles in any state & no symmetry requirements on Ψ.

$$\Psi(\ldots Q_j \ldots Q_i \ldots) = -\Psi(\ldots Q_i \ldots Q_j \ldots)$$

"antisymmetric under exchange"

If i and j are both in the single particle state s

$$\Psi(\ldots Q_j \ldots Q_i \ldots) = \Psi(\ldots Q_i \ldots Q_j \ldots)$$

$\Rightarrow$ together with (*) that

$$\boxed{\Psi = 0}$$

Bose-Einstein: Any # of particles in any state

Bosons: Spin of each particle is 0, 1, 2, ... integer

$$\Psi(\ldots Q_j \ldots Q_i \ldots) = \Psi(\ldots Q_i \ldots Q_j \ldots)$$

"symmetric under exchange"

Fermi-Dirac: Spin of each particle is 1/2, 3/2, 5/2, ... half integer

This implies that fermions can never be in the same state.

Truth table examples