Condensed Matter

Solids → Crystals → Conductors
Semiconductors
Insulators

$k = 8.617 \cdot 10^{-5}\ eV/K$

$T = 300\,K \Rightarrow kT \approx 26\,meV$

Heat, temperature T : $0\,K \longrightarrow \infty\,K$

Thermodynamics

$1 \ll N$ of individual objects

Each one (i) can have energy E_i

Boltzmann:

degeneracy (density of states per ΔE)

$$n(E \ldots E+\Delta E) = C \frac{g(E)\,\Delta E}{e^{E/kT}} = \frac{g(E)\,\Delta E}{e^{(E-\mu)/kT}}$$

normalization constant

$\frac{1}{C} = e^{-\mu/kT}$

defined to normalize

Ex.:

$$\frac{n(\text{1st excited})}{n(\text{g.s.})} = \frac{8\,\dfrac{1}{e^{-3.4/kT}}}{2\,\dfrac{1}{e^{-13.6/kT}}} = e^{3.4/kT}\cdot e^{-13.6/kT} = e^{-10.2\,eV/kT}$$

hydrogen: $g(-13.6\,eV) = 2$

$g(-3.4\,eV) = 8$

classical 1-atom gas

$$PV = N_{mol} R T = \left(N/\underbrace{6.022\cdot 10^{23}}_{N_A}\right)\cdot R\cdot T = N\cdot \overbrace{\frac{R}{N_A}}^{k}\cdot T$$

$g(E)\,\Delta E$ = Volume in momentum space $= 4\pi p^2 \Delta p$

$$E_{kin} = \frac{p^2}{2m} = \frac{m}{2}v^2 \quad \Big| \quad \Delta E = \frac{p}{m}\Delta p$$

$$\langle E_{kin}\rangle = \frac{3}{2}kT \qquad \langle E/d.o.f\rangle = \frac{1}{2}kT$$

Combine Thermo + QM

→ ask: identical particles

Spin 0, 1, 2 ... : Bosons → Bose-Einstein Statistic

Spin $\frac{1}{2}, \frac{3}{2}, \ldots$ Fermions → Fermi-Dirac Statistic

Bose Gas

$$n(E+\Delta E) = \frac{g(E)\,\Delta E}{e^{(E-\mu)/kT}-1}$$

T=0 : Bose-Einstein Condensate

ALL particles are in the same quantum state!

Cooper pairs = Bosons

Fermi-gas

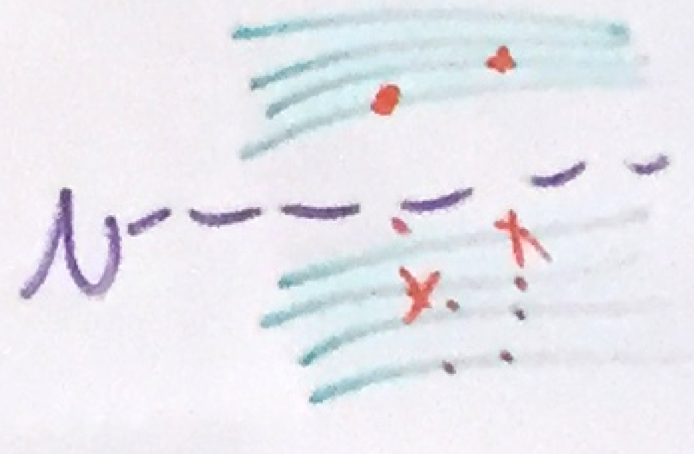
$$n(E..E+\Delta E) = \frac{g(E)\,\Delta E}{e^{(E-\mu)/kT}+1}$$

as $T \to 0$ $\mu(T)$!

$\mu(T) > E$

Conductor

Degenerate Fe



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