Lec #18: 3 OCT 2011

TODAY: Spectral Sequence Explained

- What happens if we don't have TE?
- LTE Distribution Functions
- Line Formation v. Temperature

NEXT: Atomic Physics

- The Bohr Atom
- Hydrogenic Ions
- Modifications required for >1 electron
- Atomic Structure, Selection Rules, Atomic "Terms"

TE Distribution Functions

- *Maxwell-Boltzmann Distribution:*
  $N_v/N\ (T_k)\ dv = [m/2\pi kT_K]^{3/2}\ e^{-mv^2/2kT_K}\ 4\pi v^2\ dv$
- *Boltzmann Distribution:*
  $N_b/N_a\ (T_x) = (g_b/g_a)\ e^{-(E_b-E_a)/kT_x}$
- *Saha Equation:*
  $N_{i+1}/N_i\ (T_i) = (2/n_e)\ (Z_{i+1}/Z_i)\ (2\pi m_e kT_i/h^2)^{3/2}\ e^{-\chi_i/kT_i}$
- *Planck Function:*
  $B_\nu(T_r) = 2h\nu^3/c^2\ [e^{h\nu/KT_r} - 1]^{-1}$
- **Where does this $e^{-\Delta E/kT}$ come from?**

Probability and Statistical Physics

- Probability =
  (# of ways to achieve desired result) /
  (# of ways to achieve any result)
- # of ways energy can be distributed among states with kT per degree of freedom increases exponentially with Energy (i.e. temperature)
- so # of states ~ $e^{\Delta E/kT}$
- postulate: all possible states are equally likely
- so P is # of ways to put energy in desired state divided by number of possible states ~ $e^{-\Delta E/kT}$

Maxwellian Distribution of Speeds

$$N_v/N\ dv = [m/2\pi kT_K]^{3/2}\ e^{-mv^2/2kT_K}\ 4\pi v^2\ dv$$

- each "species" establishes its own Maxwellian

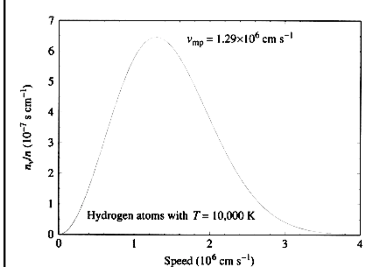
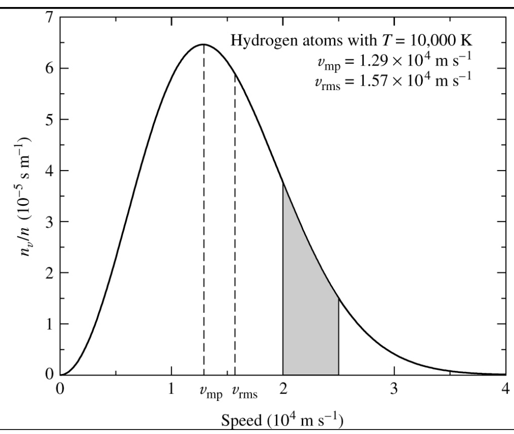


Figure 8.4 Maxwell-Boltzmann distribution function, n_v/n.

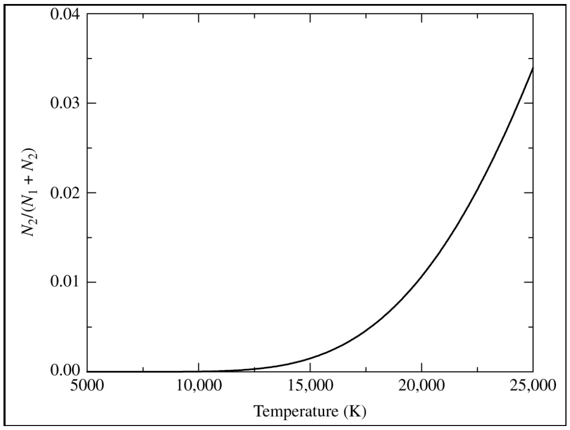
- most probable: $[2kT/m]^{1/2}$
- rms average: $[3kT/m]^{1/2}$
- velocity distribution is gaussian



Boltzmann Distribution of Excitation States

$$N_b/N_a = (g_b/g_a)\ e^{-(E_b-E_a)/kT_x}$$

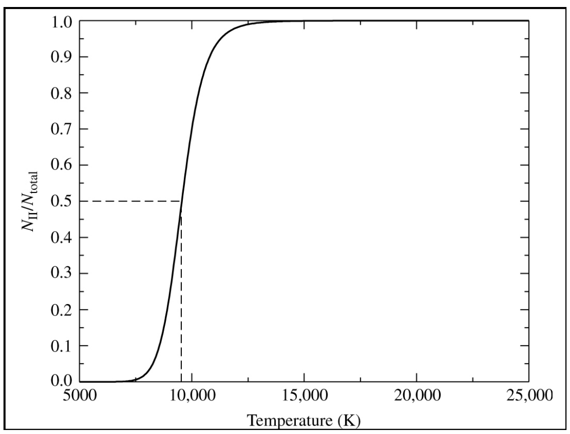
- Excitation Temperature (T_x) equals kinetic temperature in T.E.
- Example: Hydrogen n_2/n_1
  - $g_n=2n^2$ $g_1=2$ $g_2=8$
  - $E_2-E_1=10.2$ eV
  - $n_2/n_1 = N_2/N_1 = (8/2)\ e^{-10.2/kT}$

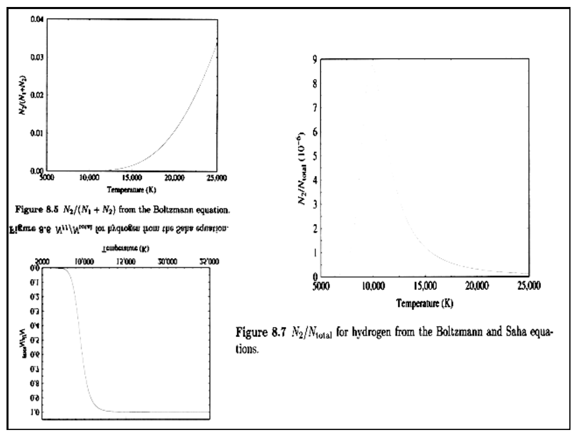


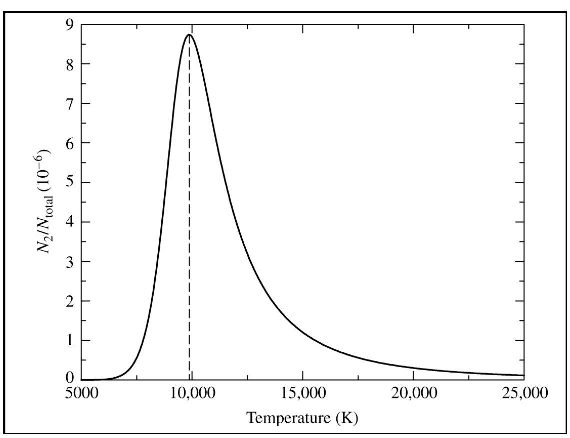
Saha Distribution of Ionization States

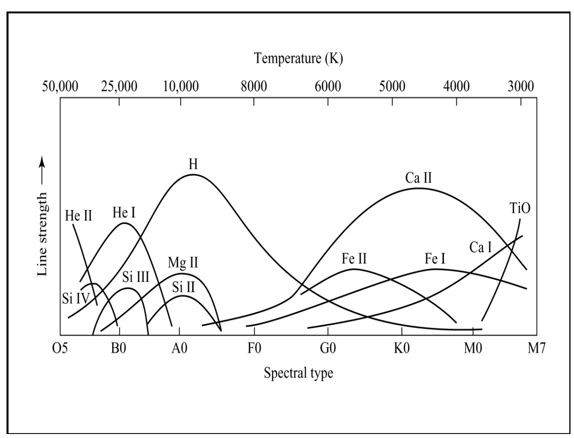
$$N_{i+1}/N_i = (2/n_e)\,(Z_{i+1}/Z_i)\,(2\pi m_e kT/h^2)^{3/2}\,e^{-\chi_i/kT_i}$$

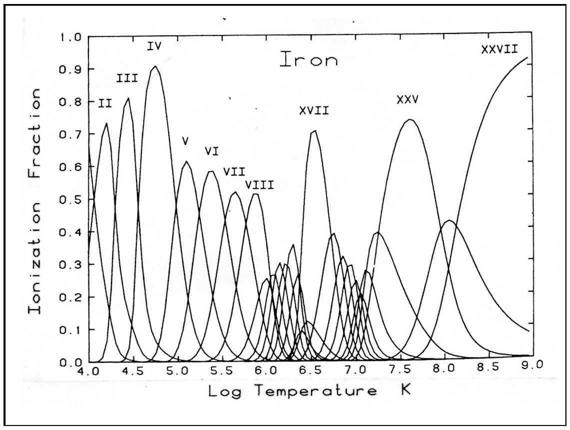
- partition functions, Z, play roll of degeneracy (number of ways to arrange electrons with same energy)
- Example: Ionized Hydrogen n_p/n_H
  - Hydrogen ion: Z = 1
  - $Z_{i+1}=g_1+\sum g_{j>2}\,e^{-(E_j-E_1)/kT} \sim g_1=2$
  - use $\chi_i = 13.6$ eV











Outside of Strict Thermal Equilibrium

- Local Thermal Equilibrium (LTE)
  - maxwellian still holds
  - boltzman holds (or real close)
  - saha holds (or real close)
  - radiation field not planckian
- Statistical Equilibrium
  - steady state $(dn_i/dt = 0)$
- Coronal Equilibrium
  - collisional excitation --> spontaneous emission
  - low density, high temperature conditions