Radiative Processes in Astrophysics
Problem Set 1

Due date: Monday, 12 March 2001

1. Maxwell distribution

What are the root mean square speeds of the electrons, hydrogen atoms and iron atoms in the Sun's photosphere? Compare this to the r.m.s. speed of oxygen molecules in the Earth's atmosphere.

Note: You will have to decide which temperature to use in each case.

2. Ideal gas law

The center of a star contains 60% hydrogen, 35% helium and 5% metals. The density is $\rho = 50$ g cm^{-3} and the temperature is $T = 1.5 \times 10^7$ K.

(a) What is the mean molecular weight of this gas?
Hint: You can assume that at this temperature, the gas is fully ionized. For the heavier elements, you can use the approximation that the atomic number is a bit less than half of the atomic weight: $Z_i + 1 \approx \frac{1}{2} A_i$.

(b) Assuming an ideal gas, estimate the gas pressure.

3. Saha equation

(a) Derive expressions for the ratio of neutral hydrogen to H^- ions, and of H^+ to neutral hydrogen, of the form

$$\frac{N(\mathrm{H})}{N(\mathrm{H}^-)} = \frac{\Phi_1(T)}{P_e}$$

$$\frac{N(\mathrm{H}^+)}{N(\mathrm{H})} = \frac{\Phi_2(T)}{P_e}$$

where $\Phi_1(T)$ and $\Phi_2(T)$ are functions of T.

(b) Compute the ratios $N(\mathrm{H}) \,/\, N(\mathrm{H}^-)$ and $N(\mathrm{H}^+) \,/\, N(\mathrm{H})$ for regions in the following stars:

- the Sun, $T = 6428$ K, $\log P_e = 1.80$
- a late A dwarf, $T = 8357$ K, $\log P_e = 2.654$

where P_e is in cgs units (dyn/cm^2).

Note: the ionization energy for H^- is $\chi = 0.754$ eV.