EE507 – Plasma Physics and Applications

Homework #3

1. Assume an electron beam with a current density of 1 A/cm^2 that is composed of 100 eV electrons collides with He atoms at a pressure of 1 Torr at room temperature.
   - Calculate the collision mean free path for ionizing collisions
   - Calculate the collision frequency
   - Calculate the density of electrons in the beam
   - Calculate the corresponding collision rate
   - Compare this collision rate to the rate of exciting collision to the 2 ^3S level of He (which one is larger?)
   - Assume the ions created live 1 microsecond before they are converted to neutrals by diffusion to the walls of the plasma container and recombination. Compute the ion density in such electron-beam created plasma.

2. For the 100 eV electrons of the problem above compute the average energy the electrons travel into the gas before they no longer have enough energy to ionize.

3. The same electron beam is now injected in a Hg lamp containing 1 Torr of Hg vapor. Calculate the collision mean free-path and collision rate for ionizing collisions. How do they compare with ones for He (problem 1?)

4. A helium plasma in a discharge tube containing a pressure of 3 Torr of He has an electron density of 1 x 10^{12} cm^{-3} and an electron temperature of 2 eV.

5. a) Compute the number of ions per second created by electron impact ionization in a 1 cm^3 volume. Hint: In computing the rate you can only need to use the rising linear ramp of the ionization cross section (why?)

6. A Hydrogen plasma is in thermal equilibrium at an electron temperature of 1 eV. The density of atoms is 1x 10^{16} cm^{-1}. Compute population the density of the first five excited states. Plot the population densities of each of these states as a function of the potential energy of the levels.

7. In the problem above, make of plot of the spectra form by the emission of each of these lines to the ground state of the atom (plot the intensity of the light emitted as a function of wavelength). Neglect re-absorption of the light. Notice you need the "oscillator strengths" or Einstein A coefficients for the lines. You can get them from the Handbook of Chemistry and Physics, or from the web.

8. Determine the electron temperature of the plasma from which the He spectrum given in the lecture notes was originated. (Same problem already given in the lecture notes). For the np ^3P Rydberg levels of He you can accurately approximate the value of the Einstein A coefficient by: A (n,q)= $2.95 \times 10^{15} / (\lambda^2 \times n^3)$ where λ is the transition wavelength and n is the principal quantum number of upper level of the transition)

9. Estimate the minimum electron density that is required for the He spectrum of problem 7 to look as it looks.

10. Continues from problem 8. Assume now the electron density is 1000 times lower than this value. Compute the relative intensities of the two shorter wavelength lines in the plot.

11. A lithium plasma is thermal equilibrium. Compute the relative ion abundance of each charge state as a function of electron temperature. (similar to what you have in the notes for Ar in the case of coronal equilibrium, but assume thermal equilibrium instead)