PHY983 - Nuclear Astrophysics - Spring 2009
Homework set 1
Due: Friday, January 23 at beginning of class

1. 1 g of an electrically neutral astrophysical plasma contains 700 mg ^{1}H, 110 mg ^{4}He, 70.0 mg ^{14}C, and 120mg ^{22}Ne. The mass density is 75.0 g/cm^3 and remains constant throughout. Feel free to submit a printout of an excel spreadsheet. However, you need to explain clearly how all the calculations are done (equations). It is not sufficient to just give numbers.
    a. [2pts] Characterize the composition using the different abundance measures used in nuclear astrophysics (you only have to worry about nuclei). In a table that gives for each constituent isotope:
        i. mass fraction
        ii. abundance ("mole fraction")
        iii. number fraction
        iv. number density
        v. abundance using the notation and units used by Grevesse & Sauval Space Sci Rev 85 (1998) 161, Table1.
    b. [2pt] Calculate mean molecular weight, Ye and electron number density for the mix.

2. For the same astrophysical plasma described in problem 1, now assume that ^{22}Ne and ^{4}He undergo a nuclear reaction. In this reaction, each ^{22}Ne nucleus fuses with a ^{4}He nucleus, and in the process neutron is emitted (a ^{22}Ne(^{4}He,n) reaction). Assume that this reaction occurs until all possible ^{4}He and ^{22}Ne pairs have been converted into reaction products. Answer all the questions from Problem 1 for the new resulting composition (include all reaction products).

3. What is the advantage of using abundance (mole fraction) to characterize a composition? (compare abundances before and after the reaction occurred)

4. Now assume that for the composition obtained in problem 2, all ^{14}C beta decays into ^{14}N (a neutrino and an electron are emitted in the process). Calculate the Y_e of the new composition.

5. Compare the initial Ye in Problem 1 with the Ye obtained in Problem 2 and 3. In general, which reactions do change Ye and which don't and why?