PHY983 - Nuclear Astrophysics - Spring 2005
Homework set 1
Due: Friday, January 26, 11:25am (beginning of class)

1. Problem: [15pts]

   It is important to understand the various ways to describe the composition of an astrophysical plasma in a star. Some people talk about abundances, some about mass fractions, some about number fractions. This is really at the basis of nuclear astrophysics. This exercise will help to become familiar with the various terms and hopefully make it clear why "abundance" is the most useful description when dealing with nuclear reactions.

   1 g of a dense electrically neutral astrophysical plasma contains 610mg ^{1}H, 150mg ^{4}He, 140mg ^{15}N, 100mg ^{14}N. The mass density is 100 g/cm^3 remains constant throughout.

   a. [2pts] make a table with mass fraction, abundance, and number fraction for each constituent nuclide. Also give the sum of the mass fractions, abundances, and number fractions for all nuclei. Also give the mean molecular weight, Ye, and metallicity Z of the mix.
   b. [1pt] Also list in the table the abundance in the notation used by Grevesse & Sauval Space Sci Rev 85 (1998) 161, Table1.
   c. [2pt] Calculate the electron density and the number of helium nuclei per cm^3 (helium number density).
   d. [2pts] First, lets assume the temperature is very high. Then ^{15}N will be destroyed by a nuclear reaction - each ^{15}N captures a proton and the resulting nucleus emits an alpha particle (2 protons and 2 neutrons). At the same time, 14N will be destroyed by a nuclear reaction - each ^{14}N captures one proton and becomes a new nucleus. Once all ^{15}N is destroyed that way, give in a table mass fractions and abundances for the new mixture. Also add a column that lists the (absolute) abundance change to the original composition.
   e. [2 pt] For problem 1.d, did Ye change? Explain why, and if it did, give the new value.
   f. [2 pts] We now assume we start with our new composition derived in 1d, but now the temperatures are low, so now the only reaction that can happen is the beta decay of 15O. In each decay, a proton in 15O is converted into a neutron and a neutrino and a positron is emitted. Once all ^{15}O is destroyed that way, give mass fractions and abundances for the new mixture by adding another column to the table created in 1d.
   g. [2 pt] For problem 1.f, did Ye change ? Explain why and if it did, give the new value ?
   h. [2 pt] Did the electron density change in any of the reactions encountered in this problem? If yes, by which process were electrons created or destroyed ?

2. Problem: [10pts]
   Using the latest table of solar abundances in Asplund et al. 2004 (astro-ph/0410214), estimate the total mass of silver in the solar system. Hint: you can use the fact that the authors give X,Y,Z on Pg. 12.

3. Print copies of
   - Grevesse&Sauval, Space Sci. Rev. 85 (1998) 161 (see website)
   - Asplund et al. 2004 astro-ph/0410214 (http://xxx.lanl.gov)
   - ApJ 649 (2006) 529 (Delhaye and Pinsonneault 2006)

   and bring them to class

   Read Grevesse&Sauval 1998 and Asplund et al. 2004. You don't have to understand everything. Read the sections that pertain to your assigned elements especially carefully and try to understand those so that you are prepared for the group quiz.

   Also have a look at ApJ 649 (2006) 529 for an interesting alternative view. You might be interested in reading the paper, but look at least at the abstract and know what the alternative view is.