PHY983 - Nuclear Astrophysics - Spring 2009
Homework Set 4
Due: Feb 13, 2009 at beginning of class
Key words: reaction rates, half-life, branching

1. [10pts] By comparing todays hydrogen abundance in the center of the sun with the pre-solar hydrogen abundance, calculate how many years the sun has been burning hydrogen.

Also, provide a plot showing hydrogen abundance as a function of time for a period that is at least twice as long as the time you find.
Instructions:

- Find the current composition and conditions in the sun using the standard solar model BS2005-AGS,OP, which can be found on John Bahcall's home page at http://www.sns.ias.edu/~jnb/ (go to "Solar Neutrinos" and "Solar Models").
- Assume temperature and density have stayed constant
- Use reaction rates from the JINA reaclib database
- Use the pre-solar hydrogen abundance from Lodders
- Write down the equation that describes the hydrogen abundance as a function of time. A numerical solution is ok - but please explain how you found the solution (code printout is fine).

2. a. [8pts] The deuterium abundance in the sun reaches very quickly an equilibrium abundance where dY/dt=0 (equilibrium condition). Write down the equation describing the rate of change of the deuterium abundance and calculate the deuterium to hydrogen abundance ratio in equilibrium in the center of the sun using the same sources of information as in problem 1 on solar model and reaction rates.

2.b [2 pts] Give a rough time for how long it takes for deuterium to be in equilibrium (you can use the graphs provided in the text book "Nuclear Physics of Stars") - no calculation needed.

3. An important "stepping stone" in the pp-chain burning hydrogen in stars like the sun is ^{7}Be. How the "reaction flow" towards the synthesis of ^{4}He proceeds depends on the dominant destruction mechanism for ^{7}Be in the sun. All questions refer to the conditions at the center of the sun as determined by the standard solar model BS2005-AGS,OP (see problem 1).

a. [2 pt] The 7Be decay lifetime (partial lifetime) under solar condtions is 0.33 yrs. Compare that to the terrestrial lifetime. Why is it different ?

b. [10 pt]Use the NACRE reaction rate compilation to calculate the reaction flow branchings (the fraction of 7Be that ends up in the respective destruction channel) into decay, proton capture and alpha capture at solar conditions. Compare your result to the branching into the ppIII chain in the lecture notes. What is the total lifetime of 7Be in the sun?

c. [2 pt] Why is the alpha capture rate so much smaller than the other rates?