PHY983 - Nuclear Astrophysics - Spring 2007
Homework set 3
Due: Friday, February 9, 2007, before class
Key words: Lifetime, Reaction rate, Half-life, Branchings, Q-values

1. [10 pt] The p+p reaction is the slowest reaction in the pp-chains responsible for most of the sun's luminosity. From the currently observed solar luminosity (4e33 erg/s) and the (calculated) stellar reaction rate for the p+p reaction given in the NACRE reaction rate compilation (see website), estimate the temperature at which hydrogen burns in the sun (this must be the temperature near the center). Assume you have a rough estimate for the density of 100 g/cm^3 and the size of the solar core (about 0.2 solar radii) and that the 1H and 4He mass fractions in the core are both 50%.

   This is an example of how one can use in nuclear astrophysics the understanding of the nuclear physics, for example from calculations or experimental determinations of stellar reaction rates, to constrain astrophysical conditions that are otherwise not accessible by observations (in this case however, there is another constraint from helioseismology)

2. An important "stepping stone" in the pp-chain burning hydrogen in stars like the sun is 7Be. How the "reaction flow" towards the synthesis of 4He proceeds depends on the dominant destruction mechanism for 7Be in the sun. All questions refer to the conditions at the center of the sun as determined by the standard solar model at http://www.sns.ias.edu/~jnb/SNdata/Export/BS2005/bs05op.dat (this is one recent version).
   a. [5 pt] 7Be is unstable. Determine its main decay mode using the nuclear mass table.
   b. [2 pt Bonus] The 7Be decay lifetime (partial lifetime) under solar condtions is 0.33 yrs. Compare that to the terrestrial lifetime. Why is it different ?
   c. [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?
   d. [5 pt] Why is the alpha capture rate so much smaller than the other rates?