Exercises for Nuclear Astrophysics I
WS 2011/12 - Prof. Shawn Bishop
Sheet 8

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Problems will be discussed in exercises on 1/26/2012 at 13:00.

17 The proton-proton reaction

In low mass main sequence stars like our sun energy is generated primarily via the proton-proton (p-p) chain. The first reaction in this cycle is given in equation (1). For this exercise problem, you will need the non-resonant reaction rate formulas (see e.g. exercise sheet 6).

(a) Show that the reaction

$$\mathrm{p} + \mathrm{p} \rightarrow d + \beta^+ + \nu_e \tag{1}$$

provides a total of 1.442 MeV in the form of kinetic energy and gamma rays. However, not all of this energy can be converted to local heat, why?

(b) Assuming that the energy for the sun's luminosity is provided by the conversion of $4\mathrm{H} \rightarrow \mathrm{He}^4$ ($Q = 26.7$ MeV) and that the neutrinos carry off only about 3 percent of the energy liberated, how many neutrinos are liberated each second from the sun? What is the neutrino flux at the earth from the sun?

(c) Use the values $S(0) = 3.78 \cdot 10^{-22}$ kev·b and $\frac{dS}{dE} = 4.2 \cdot 10^{-24}$ b to show that the thermonuclear reaction rate of the p-p-reaction can be written as

$$r_{pp} = 11.05 \cdot 10^{10} \rho^2 X_H^2 T_6^{-2/3} \exp(-33.71\ T_6^{-1/3}) \cdot (1 + 0.011\ T_6^{2/3}) \tag{2}$$

where X_H is the hydrogen fraction and ρ is the density in the star.

(d) Calculate the lifetime of protons against the p-p-reaction at a temperature of $T_6 = 15$, density $\rho = 100$ g/cm^3, and composition $X_{\mathrm{He}} = X_{\mathrm{H}} = 0.5$. Comment on this value in relation to the total lifetime of our sun.

18 The Hertzsprung-Russel Diagram

Review what you have learned about the HR-Diagram. Draw one for yourself, mark interesting regions and describe the stars that occur in them. Also, trace out the path of an arbitrary low mass star (you can of course use our sun) in the diagram and discuss.