PHYSICS 160: Stellar Structure

Instructor: Dr. A. M. Wolfe (phone: 47435)
Homework no. 6
Due: Tues. Nov. 24

1

Consider the production of solar neutrinos during the ppI cycle.

(a) How many neutrinos are released during the production of one ${}_2\mathrm{He}^4$ nucleus and what is their maximum energy?

(b) Assuming the ppI chain releases 26 Mev of enrgy during the production of one ${}_2\mathrm{He}^4$ nucleus and this accounts for the solar luminosity, how many ppI reactions must occur per second?

(c) Compute the number of neutrinos released per second.

(d) What is the maximum energy flux of these neutrinos at earth?

2

In class we worked out the effective energy E_0 at which fusion reactions in the solar interior occur. Consider the reaction

$${}_1\mathrm{H}^1 \ + \ {}_6\mathrm{C}^{12} {\rightarrow} {}_7\mathrm{N}^{13} \ + \gamma$$

Compare E_0 to the mean thermal energy of a proton for a central temperature, T_c=1.5$\times$10^7 K.

3

Compute the amount of energy released or absorbed in the following reactions (answers should be expressed in Mev).

$${}_6\mathrm{C}^{12} +_6 \mathrm{C}^{12} {\rightarrow} {}_{12}\mathrm{Mg}^{24} + \gamma$$

$${}_6\mathrm{C}^{12} +_6 \mathrm{C}^{12} {\rightarrow} {}_8\mathrm{O}^{16} + 2{}_2\mathrm{He}^4$$

$${}_9\mathrm{F}^{19} +_1 \mathrm{H}^1 {\rightarrow} {}_8\mathrm{O}^{16} +_2 \mathrm{He}^4$$

The mass of ${}_6\mathrm{C}^{12}$ is 12.000u by definition, and the masses of ${}_8\mathrm{O}^{16}$, ${}_9\mathrm{F}^{19}$, and ${}_{12}\mathrm{Mg}^{24}$ are 15.9949u, 18.9984u, and 23.98504u respectively. Are these reactions exothermic or endothermic. Note, 1u=931.494013 Mev/c^2.

4

During its main sequence phase the nuclear energy production rate $\mathcal{L}_{\rm nuc} > \mathcal{L}_{\rm rad}$.

(a) Explain what the response of the radius of the H-burning core is to this energy balance (hint: use the virial theorem to back up your results).

(b) How does the temperature of the core respond?

(c) How does the nuclear reaction rate respond.

(d) Does the star get back to global thermal equilibrium equilibrium? If so, how?

5

In class we derived energy production rates for the pp and CNO cycles.

(a) Compare the ratios of these rates for interior of the sun assuming the central temperature T_c=1.57$\times$10^7 K, H abundance X=0.7, and metal abundance Z=0.02

(b) Repeat this exercise for a more massive star in which T_c=5$\times$10^7 K

(c) At what value of Z/X would the pp chain dominate the CNO cycle for the star in (b)?