Stellar Evolution – Hints to exercises – Chapter 6

6.1 **Conceptual questions: Gamow peak**

(a) $e^{-b/E^{1/2}}$ is the energy dependence of the tunnelling probability; $e^{-E/kT}$ is the tail of the Maxwell-Boltzmann distribution.

(b) See Figure 6.4.

(c) See Figure 6.4.

(d) The Coulomb barrier is lower for hydrogen burning (smaller Z and smaller A).

(e) Hint: the neutron has no charge.

6.2 **Hydrogen burning**

See Table 6.1 for the atomic masses of the nuclei involved.

(a) $m_u c^2 = 931.49\,\mathrm{MeV}$.
Energy release per reaction in each step of the pp1 chain: 1.44, 5.49 and 12.85 MeV.

(b) $2 \times (1.44 - 0.263) + 2 \times 5.49 + 12.85 = 26.21\,\mathrm{MeV}$.

(c) $26.21\,\mathrm{MeV}/(4m_\mathrm{H}) = 3.91 \times 10^{24}\,\mathrm{MeV/g} = 6.3 \times 10^{18}$ erg/gram H.

6.3 **Relative abundances for CN equilibrium**

$X_{^{15}\mathrm{N}} : X_{^{13}\mathrm{C}} : X_{^{12}\mathrm{C}} : X_{^{14}\mathrm{N}} = \tau(^{15}\mathrm{N}) : \tau(^{13}\mathrm{C}) : \tau(^{12}\mathrm{C}) : \tau(^{14}\mathrm{N})$

6.4 **Helium burning**

To produce ^{12}C you need 3 α's: 7.28 MeV per reaction = 3.65×10^{23} MeV/gram ^{12}C.

To procuce ^{16}O you need 4 α's:

$$\begin{array}{rcll} 3\alpha & \to & ^{12}\mathrm{C} & 7.28\,\mathrm{MeV} \\ \alpha + {}^{12}\mathrm{C} & \to & ^{16}\mathrm{O} & 7.16\,\mathrm{MeV} \\ \hline 4\alpha & \to & ^{16}\mathrm{O} & 14.44\,\mathrm{MeV} = 5.44 \times 10^{23}\,\mathrm{MeV/gram}\ ^{16}\mathrm{O} \end{array}$$

Assume equal mass fractions of ^{12}C and ^{16}O, so that

$$\begin{aligned} \frac{1}{2}(3.65 \times 10^{23} + 5.44 \times 10^{23}) &= 4.55 \times 10^{23}\mathrm{MeV/g} \\ &= 7.29 \times 10^{17}\mathrm{erg/g} \\ &\approx \frac{1}{10} \text{ of that for H burning} \end{aligned}$$

6.5 **Comparing radiative and convective cores**

Hand-in exercise.