CHAPTER 14: Supernovae

14.2 For a uniform sphere the gravitational energy is

\[ E_G = -\frac{3}{5} \frac{GM^2}{R} = 1.584 \times 10^{54} \left( \frac{M}{M_\odot} \right) \left( \frac{R}{\text{km}} \right) \text{erg}. \]

For the uncollapsed core \( M \simeq 1.32M_\odot \) and \( R = 500 \text{ km} \), which gives a gravitational energy of \(-5.52 \times 10^{51} \text{ erg}\). After collapsing this mass to a radius of 10 km the gravitational energy is \(-2.76 \times 10^{53} \text{ erg}\). The difference is the gravitational energy released, which is about \(2.7 \times 10^{53} \text{ erg}\). For the full star before collapse insertion of \( M = 15M_\odot \) and \( R = 2 \text{ AU} \simeq 3 \times 10^8 \text{ km} \) gives a gravitational energy of \(-1.19 \times 10^{48} \text{ erg}\).

14.4 Since the velocity-averaged cross section varies only with the square root of the temperature, we may use the result obtained in Exercise 9.3 for the s process as a rough estimate. There we found that for cross sections of order 100 mb the neutron number density \( n_n \) required to give a capture mean life \( \tau_n \) is approximately

\[ n_n = \frac{1}{\tau_n \langle \sigma v \rangle} \simeq \frac{3 \times 10^{16}}{\tau_n} \text{s cm}^{-3}. \]

Inserting \(10^{-6} \text{s}\) for the capture mean life gives a neutron number density of order \(10^{22} - 10^{23} \text{ cm}^{-3}\) required to sustain this r-process capture rate. This may be compared with a neutron number density of order \(10^9 \text{ cm}^{-3}\) estimated in Exercise 9.3 for the s process and of order \(10^7 \text{ cm}^{-3}\) for a typical fission power reactor.