

**Ay 127 – Homework #2**  
**Posted on Apr.17, due on Friday, Apr. 24**

1. **Carbon (non)-production in BBN.** The isotope  $^{12}\text{C}$  is produced in stars by the “triple alpha” process:



The rate of carbon production by this mechanism, neglecting electron screening, is given by:

$$\dot{X}_{\text{C}} = 2 \times 10^{-57} \frac{e^{-4.294/T_9}}{T_9^3} \left( \frac{n_b}{\text{cm}^{-3}} \right)^2 X_{\text{He}}^3 \text{ s}^{-1}, \quad (2)$$

where  $T_9$  is the temperature in GigaKelvin. Assuming that the  ${}^4\text{He}$  abundance is negligible until  $T_9 = 0.8$ , and is 0.24 thereafter, compute the final abundance of primordial carbon produced by the triple alpha process. (An order-of-magnitude answer will suffice for this problem.)

2. **Helium recombination.**

- (a) Write down the Saha equation for the equilibrium of He I, He II, and He III.
- (b) Assuming the hydrogen is fully ionized, estimate the redshift  $z_2$  at which 50% of the helium recombines from He III to He II, and the redshift  $z_1$  at which 50% of the helium recombines from He II to He I.