Mini-Problem Set XVII: BBN: Deuterium and Carbon *due 6 Apr 2009*

We continue with looking at the expected abundance of Deuterium, for three cases of the baryon-to-photon ratio, $\eta = 0.06$, 6, and 600×10^{-10}. You need the reaction rates mentioned in the previous problem set, as well as the ages at which deuterium becomes present in significant amounts: $t = (343, 257, 183)\,\mathrm{s}$ for $\eta = (6 \times 10^{-12}, 6 \times 10^{-10}, 6 \times 10^{-8})$.

1. Calculate the Deuterium mass fraction X_{D} for which the time scale $\tau_{\mathrm{D:D}}$ for one Deuteron to fuse with another Deuteron is the same as the ages you calculated in item 3 of the previous problem set. Compare with Fig. 16.2.
2. This time the estimates fail worst for $\eta_{10} = 600$. To see why this might be the case, calculate for a Deuteron the timescale $\tau_{\mathrm{D:p}}$ for it to meet and fuse with a proton. Does this help to understand the discrepancy?
3. Use Eq. 8.21 to estimate the mass fraction of carbon formed during nucleosynthesis, for $\eta = 6 \times 10^{-10}$. Given your result, can Carbon be ignored for, say, the first stars? Check by comparing the energy generation rates by the p-p and CNO cycles at $7 \times 10^{7}\,\mathrm{K}$ (which is the temperature where we found the first stars could generate C themselves).