IntroCosmo24

Homework problems #2

Due October 31, 2024

1. Estimate the temperature at which protons that are moving with the most probable velocity according to the Maxwell-Boltzmann distribution can get as close as 10^{-15} m of each other.

2. At what temperature the ^3He nuclei can get as close as 10^{-15} m of each other, if the are moving with the most probable velocity according to the Maxwell-Boltzmann distribution.

3. Estimate the density of a hydrogen gas at which the average distance between protons is comparable to twice the characteristic size of the hydrogen atom.

4.Estimate the density of hydrogen gas in the center of the Sun ($T_c = 12 \cdot 10^6$ K) at which the average distance between electrons is comparable to their de Broglie wavelength $\lambda = h/p$, $p = mv$.

5. Estimate the density of hydrogen gas in the center of the Sun ($T_c = 12 \cdot 10^6$ K) at which the average distance between protons is comparable to their de Broglie wavelength.

6. Protons can be transformed into helium nuclei in the following cycle of reactions (so called PPIII cycle)

$^1H +^1 H \rightarrow {}^2H + e^+ + \nu_e$
$^1H +^2 H \rightarrow {}^3He + \gamma$
$^3He +^4 He \rightarrow {}^7Be + \gamma$
$^7Be +^1 H \rightarrow {}^8B + \gamma$
$^8B \rightarrow {}^8Be + e^+ + \nu_e$
$^8Be \rightarrow 2 \cdot {}^4He$

Estimate how much energy is released in one full cycle of these reactions. Two neutrinos that are created carry correspondingly 0.263 MeV and 7.2 MeV of energy.