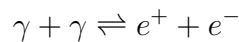


Stellar Astrophysics, Fall 2024

PROBLEM SET III

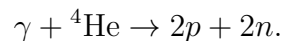
Deadline: 5PM OF THURSDAY, NOVEMBER 7, 2024

1. **The Saha equation (15%).** A stellar atmosphere consists almost entirely of hydrogen. Assume that 50% of the hydrogen molecules are dissociated into atoms and that the pressure is 10^3 dyn cm^{-2} . Estimate the temperature given that the binding energy of the hydrogen molecule is 4.48 eV and the ratio of degeneracy to be $g(\text{H}_2)/g(\text{H}) \sim 1$.
2. **Equilibrium of pair production (15%).** In the hot central regions of an evolved star, the gas is considered to form with dilute, classical positrons and dense, degenerate electrons. Consider the electron-positron production



in such a degenerate electron gas with Fermi energy ϵ_F .

- (a) (5%) Find the chemical potential for a classical gas of non-relativistic positrons as well as that for a *degenerate* gas of non-relativistic electrons.
 - (b) (5%) Derive an expression for the equilibrium concentration of positrons using $\mu_{e^+} + \mu_{e^-} = 0$.
 - (c) (5%) Make a numerical estimate for n_{e^+} in stellar matter at $T = 10^9 \text{ K}$ and $\rho = 10^7 \text{ g cm}^{-3}$.
3. **Photodisintegration of ${}^4\text{He}$ (15%).** When the core of a massive star exceeds the Chandrasekhar limit, it collapses. During this collapse, energy is absorbed by the photodisintegration of ${}^4\text{He}$ via the reaction



The energy required for this reaction is $Q = 28.30 \text{ MeV}$. Assume that this reaction is in equilibrium with its inverse. Estimate the temperature at which 50% of the ${}^4\text{He}$ is dissociated into nucleons when the density is 10^9 g cm^{-3} .