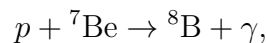


Stellar Astrophysics, Fall 2024  
**PROBLEM SET VII**

**Deadline:** 5PM OF THURSDAY, DECEMBER 5, 2024

1. **Temperature dependence of fusion reactions (10%).** The flux of energetic neutrinos from  ${}^8\text{B}$  decay in branch III of the proton-proton chain is very dependent on the central temperature of the Sun. Show that the rate of the reaction producing  ${}^8\text{B}$ ,



is approximately proportional to  $T^{14}$ , when the temperature  $T$  is near to  $1.2 \times 10^7$  K.

2. **Photodisintegration of nuclei (15%).** The photodisintegration of nuclei plays an increasingly important role as a star evolves and as the temperature at its center increases.

- (a) (10%) Derive an expression for the number density of photons with an energy above 9.98 MeV in a gas at temperature  $T$ . Recall the Planck's formula for the photon flux density in the frequency range  $\nu$  to  $\nu + d\nu$

$$F_\nu d\nu = \frac{2\pi\nu^2}{c^2} \frac{h\nu}{e^{h\nu/kT} - 1} d\nu,$$

and assume that  $kT \ll 9.98$  MeV, the minimum energy needed to eject a  ${}^4\text{He}$  nucleus from a  ${}^{28}\text{Si}$  nucleus.

- (b) (5%) Estimate the fractional change in the number of such photons that occurs when the temperature rises from  $10^9$  K to  $4 \times 10^9$  K.