885.

Problem 55.42 (RHK)

At the central core of the Sun the density is $1.5\times10^{5}\ \text{kg m}^{-3}$ *and the composition is essentially* 35% *hydrogen by mass and* 65% *helium*. (a) *We have to find the density of protons at the Sun's core*. (a) *We have to find the ratio of this to the density of particles for an ideal gas at standard conditions of temperature and pressure*.

Solution:

(a)

At the central core of the Sun the density is $1.5\times10^{5}\ \text{kg m}^{-3}$ and the composition is essentially 35% hydrogen by mass and 65% helium. Therefore, the contribution to the mass density by hydrogen will be

$$\rho_{\text{p}} = 1.5\times10^{5}\times0.35\ \text{kg m}^{-3}$$
$$= 0.525\times10^{5}\ \text{kg m}^{-3}.$$

The mass of proton $m_{\mathrm{p}} = 1.67 \times 10^{-27}$ kg. Therefore, the number density of protons at the central core of the Sun will be

$$n_{\mathrm{p}} = \frac{0.525 \times 10^{5}\ \mathrm{kg\ m^{-3}}}{1.67 \times 10^{-27}\ \mathrm{kg}} = 3.14 \times 10^{31}\ \text{protons per m}^{3}.$$

(b)

The number density of particles in an ideal gas is determined by its pressure and temperature. The ideal gas equation of state is

$$P = nkT,$$

where k is the Boltzmann constant. The standard conditions of pressure and temperature are

$$P = 1.01 \times 10^{5}\ \mathrm{Pa},\ T = 273\ \mathrm{K}.$$

Therefore,

$$n = \frac{1.01 \times 10^{5}}{273 \times 1.38 \times 10^{-23}}\ \text{particles per m}^{3}$$
$$= 2.68 \times 10^{25}\ \text{particles per m}^{3}.$$

And

$$\frac{n_{\mathrm{p}}}{n} = \frac{3.14 \times 10^{31}\ \text{protons per m}^{3}}{2.68 \times 10^{25}\ \text{particles per m}^{3}} = 1.17 \times 10^{6}.$$