890.

Problem 55.48 (RHK)

After converting all its hydrogen to helium, a particular star is 100% *helium in composition. It now proceeds to convert the helium to carbon via the triple alpha process*

$$^4\mathrm{He} + {}^4\mathrm{He} + {}^4\mathrm{He} \rightarrow {}^{12}\mathrm{C} + \gamma,$$

$Q = 7.27$ MeV. *The mass of the star is* 4.6×10^{32} kg, *and it generates energy at the rate of* 5.3×10^{30} W. *We have to calculate the time in which all helium will be converted into carbon.*

Solution:

Helium is converted by fusion in a star to carbon via the triple alpha process

$$^4\mathrm{He} + {}^4\mathrm{He} + {}^4\mathrm{He} \rightarrow {}^{12}\mathrm{C} + \gamma,$$

$Q = 7.27$ MeV. The mass of the star is 4.6×10^{32} kg. It generates energy at the rate of 5.3×10^{30} W.

The mass of a $^4\mathrm{He}$ atom is 4.002603 u. The total number of $^4\mathrm{He}$ atoms in the star will be

$$N_{^4\text{He}} = \frac{4.6\times10^{32}\ \text{kg}}{4.002603\times1.6605\times10^{-27}\ \text{kg}}$$

$$= 6.92\times10^{58}.$$

Three ^4He nuclides undergo fusion to form a ^{12}C atom by releasing 7.27 MeV energy. Therefore, the total energy that will be released by conversion of all helium of the star will be

$$E = \frac{N_{^4\text{He}}Q}{3} = \frac{6.92\times10^{58}\times7.27\times1.6\times10^{-13}}{3}\ \text{J}$$

$$= 2.68\times10^{46}\ \text{J}.$$

The star is generating energy at the rate of $5.3\times10^{30}\ \text{W}$. Therefore, the time in which all its helium will be converted into helium will be

$$t = \frac{2.68\times10^{46}\ \text{J}}{5.3\times10^{30}\ \text{W}} = 5.056\times10^{15}\ \text{s}$$

$$= \frac{5.056\times10^{15}}{3.156\times10^{7}}\ \text{y} = 1.60\times10^{8}\ \text{y}.$$