Kilic

PROBLEM 3

a) (3 points) Describe the burning process on the main sequence. Explain the difference of the sun on the main sequence and a $1.5 M_{sun}$ star.

b) (3 points) Describe He burning in the lower mass stars and intermediate mass stars. What is the mass range for each approximately? Compare the timescale of helium burning (lifetime on the helium main sequence) to that of hydrogen burning (lifetime on the main sequence).

c) (4 points) Describe the following burning stages in stars: carbon burning, neon burning, oxygen burning, silicon burning.

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Astro #3

a) For a star on the main sequence, it is burning hydrogen to helium. For stars less than 1.3 $M_\odot$, they perform the nuclear fusion via the PP chain, while stars more massive than 1.3 $M_\odot$ use the CNO cycle. The reaction chains are shown below

P-P Chain:

$$\left.\begin{array}{l} 2H_1^1 \rightarrow H_1^2 + \nu_e + e^+ + \gamma \\ H_1^2 + H_1^1 \rightarrow He_2^3 + \gamma \end{array}\right\rangle \times 2$$

$$2He_2^3 + \quad \rightarrow He_2^4 + 2H_1^1$$

CNO Cycle:

$$C_6^{12} + H_1^1 \rightarrow N_7^{13} + \gamma$$

$$N_7^{13} \rightarrow C_6^{13} + e^+ + \nu$$

$$C_6^{13} + H_1^1 \rightarrow N_7^{14} + \gamma$$

$$N_7^{14} + H_1^1 \rightarrow O_8^{15} + \gamma$$

$$O_8^{15} \rightarrow N_7^{15} + e^+ + \nu$$

$$N_7^{15} + H_1^1 \rightarrow C_6^{12} + He_2^4$$

b) He-burning is done via the triple-α rxn in stars, and produces carbon ash. In low mass stars, the He-core contracts to the point of degeneracy before He fusion begins, resulting
$<2M_\odot$ in He flashes lifting the degeneracy before stable fusion starts. In higher mass stars, this is not necessary as the required central temperature can be reached simply via core $<8M_\odot$ contraction. He burning lasts for $\sim 10\%$ of time of H-burning (~ 120 Myr v 10 billion yr for $1 M_\odot$ star).

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#3 (cont.)

c) Carbon burning: $C_6^{12} + He_2^4 \rightarrow O_8^{16} + \gamma$

$T \approx 5 \cdot 10^8 K$

$2C_6^{12} \rightarrow Mg_{12}^{24*} \rightarrow Ne_{10}^{20} + \alpha$

$\rightarrow Na_{11}^{23} + p$

Neon burning: $Ne^{20} + \gamma \leftrightarrow O^{16} + \alpha$

$Ne^{20} + \alpha \leftrightarrow Mg^{24} + \gamma$ $\quad T \approx 1.5 \cdot 10^9 K$

$\Rightarrow 2Ne^{20} \rightarrow Mg^{24} + O^{16}$

Oxygen burning: $2O_8^{16} \rightarrow S^{32} \rightarrow Si^{28} + \alpha$

$T \approx 2 \cdot 10^9 K$

Silicon burning: * combination of photodisintegration chain to generate α particles and successive fusions w/ α-particles from Si^{32} to Ni^{56} which decays to Fe^{56}

$T \approx 3 \cdot 10^9 K$