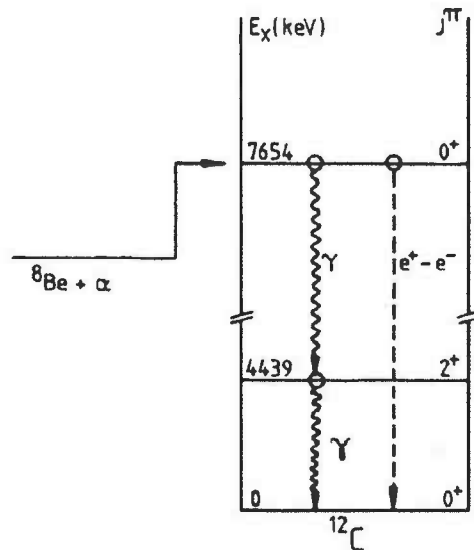


The exam comprises 3 problems. The total number of points is 34. The final grade is obtained by dividing the number of points by 3,4.

Problem 1 (12 pts)

The second step of the triple α -process proceeds through a resonance at $E_r = 7654 \text{ keV}$ in $^{12}_6\text{C}$, as shown in the figure below.



- Determine the temperature of the star at which the production of $^{12}_6\text{C}$ is activated through the reaction $^8_4\text{Be} + ^4_2\text{He} \rightarrow ^{12}_6\text{C} + \gamma$, knowing that the energy of the Gamow peak is $E_0 = 287 \text{ keV}$. (4 pts)
- The temperature of the Sun is currently about $1.5 \times 10^7 \text{ K}$. Does helium-burning occur in the sun at present? (2 pts)
- On which branch of the Hertzsprung-Russell diagram would you find a star burning helium? (4 pts)
- Which nucleosynthesis process produces the isotope $^{13}_6\text{C}$? (2 pts)

Problem 2 (12 pts)

- Give the main stellar nuclear reaction and the corresponding burning-stage for the following isotopes: ^4He , ^{12}C , ^{28}Si and ^{56}Ni . For example, ^{16}O is created by the main reaction $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ in stars undergoing He-burning. (8 pts)
- The core of a massive star goes through all fusion burning stages. What is the main end product and why does fusion end up at this element? (4 pts)

Problem 3 (10 pts)

Short answer questions (1 to 2 sentences)

- Explain why each successive burning stage in a massive star requires a higher temperature. (2 pts)

- Explain why a massive star does not experience a Helium flash at the end of the Red Giant Branch. (2 pts)
- Which principal element is produced in the helium flash? (2 pts)
- When does a star leave the main sequence? (2 pts)
- What happens to the core of a large mass star when it can no longer fuse hydrogen? (2 pts)

Formula and other useful stuff

- Gamow energy: $E_G = 2\mu c^2 (\pi\alpha Z_1 Z_2)^2$
with $\alpha = 1/137$, μ the reduced mass and $c^2 = 931.494 \text{ MeV}/u$
- Energy of the Gamow peak:

$$E_0 = \left[E_G \left(\frac{kT}{2} \right)^2 \right]^{1/3} = 0.122 (Z_1^2 Z_2^2 \mu T_9^2)^{1/3} [\text{MeV}]$$

with $k = 8.617 \cdot 10^{-5} \text{ eV/K}$

- Periodic table

PERIODIC TABLE OF ELEMENTS

Chemical Group Block

The periodic table displays elements from Hydrogen (H) to Oganesson (Og). Each element cell includes its symbol, atomic number, and name. The table is color-coded by groups: alkali metals (blue), alkaline earth metals (orange), transition metals (green), post-transition metals (yellow), metalloids (purple), nonmetals (pink), and noble gases (light blue). The Lanthanide and Actinide series are shown at the bottom, separated from the main body of the table.