PHY983 - Nuclear Astrophysics - Spring 2007
Homework set 7
Due: Friday, **March 23**, 2007, in my mailbox
Keywords: rp-process

1. [10pts] Make a graph showing the temperature and mass density conditions needed for breakout of the CNO cycles via a) the 15O(a,g) reaction and b) via the 18Ne(a,p) reaction assuming a proton abundance of 0.66 and a helium abundance of 8.4e-2. Mark typical peak conditions for X-ray bursts on the graph (see lecture notes). Document the rates you are using and all equations.

15O(a,g) rate: Use the latest results from the JINA measurement at Notre Dame http://pos.sissa.it//archive/conferences/028/023/NIC-IX_023.pdf. Use their alpha branching and the total width of the resonance corresponding to the 4.03 MeV state and use the narrow resonance formalism to calculate the reaction rate. Neglect the higher lying resonances to keep it simple - they matter a little bit. For the total width, there is a value from previous work and from the new work - use the better value with the smaller error (for simplicity don't need to average).

18Ne(a,p) rate: Use our new JINA reaction library database to obtain that rate. Go to http://www.nscl.msu.edu/~nero/db/ and search for the 18Ne(a,p) rate. Click on "View" Data Points and you can copy the values into a spreadsheet or any other program you are using (and calculate additional values with the calculator on the page if needed - for some reason it doesn't display the small numbers ...).

2. [15 pts] Derive a simple estimate for the mass number of the endpoint of the rp-process in X-ray bursts by using the initial hydrogen and helium abundance and the number of (a,p) reactions in the (a,p) process as free parameters. Make the following assumptions:

- In a first step, the burst burns instantaneously all the helium via the triple alpha reaction and the alpha-p process along a SIMPLE alpha-p process reaction chain (alternating (alpha,p) and (p,g) reactions starting at 18Ne). Neglect the additional proton capture at 12C in this chain - assume you have only alpha-p process and triple alpha.
- Assume all helium is converted into the nucleus at the endpoint of this alpha-p process instantaneously.
- Assume that only then the hydrogen burning via the rp-process starts
- Assume that the burst burns all the hydrogen and that the final composition is a single nucleus at the end of the rp-process.
- Assume there are no cycles.

Hint: the critical quantity is the proton to seed nucleus ratio at the onset of the rp-process.

2.a. Go through all assumptions in the previous sub-problem and write one sentence about why you think this is a good or a bad assumption.

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2.b Calculate the endpoint for a proton abundance of 0.66 and a helium abundance of 8.4e-2, a peak temperature of 1.5GK, and a density of 1e6 g/cm^3.

The peak temperature and density determine the endpoint of the ap-process and therefore the number of (a,p) reactions occuring. The endpoint of this alpha-p process is determined by the (a,p) reaction rate becoming slower than the burst rise timescale of ~1s (use the He abundance from problem 1). For this you need to go through the a,p reaction rates in the JINA reaction rate database (see previous problem) step by step along the ap process and check the rates at 1.5 GK.

2c   By how much does the endpoint shift (and in which direction) when the peak temperature would be higher such that the alpha-p process can proceed further by exactly one single (alpha,p)-(p,g) sequence. What would that peak temperature have to be?

3. [10pts] List all the parameters that you can think of that in nature determine the light curve of X-ray bursts. These would be the free parameters of an X-ray burst model, and variations in these parameters might be responsible for the variations in burst properties that is observed.

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