FYSN440 Nuclear astrophysics

Final exam 8.2.2013

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1. Are the following sentences true or false? If a sentence is false, explain shortly why.

   a) The r process proceeds close to stable nuclei. [2 p]

   b) The νp process takes place in core-collapse supernovae. [2 p]

   c) Uranium isotopes are produced via s process. [2 p]

   d) ^{12}C is not consumed in the CNO cycle. [2 p]

2. a) Consider the direct capture reaction ^{15}N(n,γ)^{16}N. Assume only direct capture into the ground (2^-) and the first three excited states at 120.42 keV (0^-), 298.22 keV (3^-) and 397.27 keV (1^-) in ^{16}N plays a role. What is the dominant direct capture reaction mechanism in terms of orbital angular momentum of the neutron (s-wave, p-wave,...) and multipolarity of the emitted gamma ray (E1, M1, E2,...)? The groud-state spin of ^{15}N is $1/2^+$. [5 p]

   b) Above which minimum excitation energy would a state in ^{16}N have to be located to serve as a resonance in the ^{15}N(n,γ) reaction? [3 p]

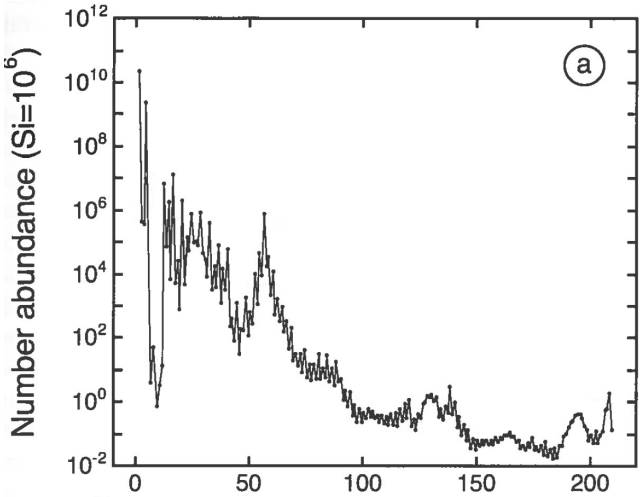
3. a) Explain the different steps of the ppI chain. [3 p]

   b) What is the bottleneck reaction (the slowest reaction) in the ppI chain? [1 p]

   c) How much energy is released in the ppI chain? You can use the attached mass tables to calculate that. [1 p]

   d) Assuming that the ppI chain is totally responsible for the production of solar neutrinos, estimate the flux of solar neutrinos on Earth. The distance from Earth to Sun is about $1.5 \cdot 10^8$km.[3 p]

4. The following picture (Iliadis, Fig. 1.2.a) shows the solar abundance pattern as a



function of mass number A. Write a short essay to explain the main features of this distribution. [8 p]

5. a) Estimate a cross section for the reaction ^{44}Ti(α,p)^{47}V. You have detected 10 protons with your detector setup which has an efficiency of 20 %. A 2-cm-long helium gas target with a target thickness of about 20 μg/cm^2 has been bombarded by a ^{44}Ti^{13+} beam with an intensity of 6.0 pA (electrical current) for 8 hours. [6 p]

   b) Was the cross section for the reaction ^{44}Ti(α,p)^{47}V discussed in a) measured in normal kinematics or in inverse kinematics? [1 p]

   c) Why some reactions are measured in inverse kinematics instead of normal kinematics? [1 p]

6. a) About 3 s after the onset of the Big Bang, the neutron-proton ratio became frozen when the temperature was still as high as 10^{10} K. About 250 s later, fusion reactions took place converting neutrons and protons into ^{4}He. Essentially all neutrons were converted to ^{4}He. Calculate the abundances of ^{1}H and ^{4}He after the primordial nucleosynthesis. The neutron half-life is 10.24 min and the neutron-proton mass difference is 1.29 MeV/c^2. [4 p]

   b) Xenon has nine stable isotopes between A=124-136. Which of these isotopes are produced by (i) p process, (ii) s process and (iii) r process? Note that some of the isotopes can be produced both via s and r process. Half-lives are given for the nuclei. "+" indicates β^+ decay, otherwise β^- decay for the non-stable nuclei. [4 p]?

Xe	+123 2 h	124	+125 17 h	126	+127 36 d	128	129	130	131	132	133 5 d	134	135 9 h	136	137 4min
I	+122 4 min	+123 13 h	+124 4 d	+125 59 d	+126 13 d	127	128 25 min	129 10^7a	130 12 h	131 8 d	132 2 h	133 21 h	134 52 min	135 7 h	136 84 s
Te	+121 17d	122	123	124	125	126	127 9 h	128	129 70 min	130	131 25 min	132 76h	133 13 min	134 42 min	135 19 s
Sb	+120 16 min	121	122 3 d	123	124 60 d	125 3 a	126 12 d	127 4 d	128 9 h	129 4 h	130 6 min	131 23 min	132 3 min	133 3 min	134 0.75s