22.01 Fall 2015, Quiz 1

October 13, 2015

Answers should be given symbolically or graphically, no calculation should be necessary. Define any intermediate variables which you need to complete the problems. Partial credit will be given for methodology.

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1 (40 points) Short Answers, 10 points each

1.1 Graph the mass per nucleon of a nucleus as a function of nucleons ($\frac{\mathbf{M(A)}}{\mathbf{A}}$ vs. A), for the full range of A=1 to A=250.

1.2 Explain why most heavy element fission products undergo β^- decay.

1.3 Write a necessary and sufficient condition for a nuclear reaction to occur in terms of its Q-value and the incoming particle's kinetic energy (KE). What does this say about the combined KEs of the outgoing particles?

1.4 Draw a graph showing the intensities of antineutrinos vs. energy from a given β^- decay reaction. Comment on the absolute probabilities of finding β^-s vs. antineutrinos.

2 (30 points) Fusion Reactor End Products

Fusion reactors can be used to generate tritium $\left({}^3_1H\right)$ in their first walls by bombarding lithium-7 $\left({}^7_3Li\right)$ with 14 MeV neutrons produced from fusion [Rxn 1], generating their own fuel. However, ${}^3_1H$ also decays to ${}^3_2He$ [Rxn 2], a very useful and very expensive gaseous neutron detector (currently valued at $53,000/gram). However, ${}^3_2He$ and ${}^3_1H$ also absorb neutrons [$Rxns\ 3-4$], so they get destroyed as they are created. Key data for this problem include:

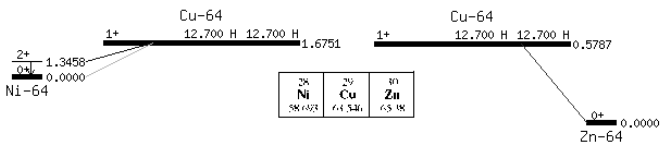
$$\sigma_{c,7-Li} = 10^{-4}b \qquad \sigma_{c,3-H} = 10^{-10}b \qquad \sigma_{c,3-He} = 10^{-5}b \qquad \lambda_{^3H} = 1.8 \cdot 10^{-9}\left[\tfrac{1}{s}\right]$$

2.1 (8 points) Write the complete nuclear reactions for each step [$Rxns\ 1-4$] above.

2.2 (22 points) Draw a graph of the concentration of ${}^3_2He$ in the fusion reactor, assuming it turns on at time $t = 0$ and shuts off 50 years later.

3 (30 points) Decay Chain Diagrams

For these problems, consider the decay of ${}^{64}_{29}$Cu, which decays by multiple paths as shown below:



3.1 (8 points) Write the complete nuclear reactions for all possible decays shown, assuming that Ni-64 and Zn-64 are stable isotopes.

3.2 (16 points) Draw complete photon and electron spectra which would be observed from the decay of Cu-64.

3.3 (6 points) Give an energetic argument why nuclei like Cu-64 can decay by either of the mechanisms shown here, while most isotopes only have one mode of decay.

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