Queen Mary
University of London

Nuclear Physics & Astrophysics
Homework – 2

Proton mass m_p = 1.00727647 u
Neutron mass m_n = 1.00866501 u
Avogadro's number N_A=6.022 x 10^{23} mol^{-1}

1) The deuteron has a mass of 2.014102 u. Calculate its binding energy in MeV. Explain why the fusion reaction $^1H + {}^1H \rightarrow {}^2He$ does not occur and so direct proton fusion can only proceed through the reaction $^1H + {}^1H \rightarrow {}^2H + e^+ + \upsilon_e$. In the solar fusion cycle why is this step known as a bottleneck? The hydrogen burning fusion process can occur through three distinct routes (in the absence of carbon), each involving one of the following partial steps:

i. $^1H + {}^1H \rightarrow {}^2H + e^+ + \upsilon_e$

ii. $^7Be + e^- \rightarrow {}^7Li + \upsilon_e$

iii. $^8B \rightarrow {}^8Be + e^+ + \upsilon_e$

Which earth based observations allow researchers to distinguish reaction (ii) from the others? **[7]**

2) In some extensions to standard particle physics theories the proton is unstable and decays to a positron and a pion. If all the energy in such decays is deposited in the body, and assuming that an absorbed dose of 5Gy per year is lethal for humans, what limit does the existence of life place on the proton lifetime? **[6]**

[hint: assume all energy is deposited within the body, i.e. pion and positron decay too. Consider the number of protons in an average 70kg human]

3) Compare the advantages and disadvantages of using photons (X-rays), electrons and protons to treat cancer tumours inside the body. **[6]**

4) What is brachytherapy, and what type of radioactive isotopes would be ideal in this form of treatment? **[3]**