Nuclear Physics & Astrophysics
Exercises – 5

Hand in on 1st floor by Friday 5th November 4pm

Proton mass m_p = 1.00727647 u **Hydrogen mass ^{1}H = 1.007825 u**
Neutron mass m_n = 1.00866501 u
Avogadro's number N_A=6.022 x 10^{23} mol^{-1}
$e^2/4\pi\varepsilon_0$ = 1.439976 MeV fm

Assume the ordering of nuclear shells is:
$1s_{1/2}$; $1p_{3/2}$; $1p_{1/2}$; $1d_{5/2}$; $1d_{3/2}$; $2s_{1/2}$; $1f_{7/2}$; $2p_{3/2}$; $1f_{5/2}$; $2p_{1/2}$; $1g_{9/2}$; $1g_{7/2}$; $2d_{5/2}$

1. A certain decay scheme shows the following gamma energies in keV: 32.7, 42.1, 74.8, 84.0, 126.1, and 158.8. Coincidence studies reveal two features of the decay: only one of the gamma energy peaks is in coincidence with three of the others. The gammas are preceded by a beta decay that is known to populate only one single excited state of the daughter nucleus. From this information suggest a possible level scheme. (note: there are two different arrangements of the energy levels that are consistent with the information given above.) [14]

2. Write down the complete reaction equations and determine the Q value for the following beta-decay processes. You should use atomic masses from Krane, and recall that using atomic masses modifies the standard equation for Q:
   a) $^{65}Ni \rightarrow {}^{65}Cu$
   b) $^{11}Be \rightarrow {}^{11}B$
   c) $^{193}Os \rightarrow {}^{193}Ir$ [6]

3. Explain the difference between a "thermal" neutron and a "fast" neutron. [2]
   Why are moderating materials typically made of light nuclei e.g. ^{12}C [2]

4. Considering a mother nucleus X with atomic mass number A and atomic number Z, give four reaction equations for the processes of internal conversion, electron capture and beta decay (+ and -). Briefly explain the different origin of the emitted electron (or positron) in each case. [8]

5. Explain why neutrons are a dangerous source of "radiation damage" to humans. Suggest two processes by which neutrons will interact with human tissue and cause damage. [6]

No need to turn over