Queen Mary University of London — PHYSICS department

Nuclear Physics & Astrophysics
Exercises – 3

Hand in on 1st floor by Friday 22rd October 4pm

Proton mass m_p = 1.00727647 u **Hydrogen mass ^1H = 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
$1s_{1/2}$; $1p_{3/2}$; $1p_{1/2}$; $1d_{5/2}$; $1d_{3/2}$; $2s_{1/2}$; $1f_{7/2}$; $2p_{3/2}$; $1f_{5/2}$; $2p_{1/2}$; $1g_{9/2}$; $1g_{7/2}$; $2d_{5/2}$

1. Give the shell model spin and parity assignments for the ground states of the following nuclei using the shell ordering given above:
   (a) ^7_3Li (b) $^{11}_5B$ (c) $^{15}_6C$ [6]

2. The Q value for the reaction:
   $$^9Be + p \rightarrow {}^8Be + {}^2H$$
   is 559.5 KeV. Using this value and the accurately known masses of ^9Be, ^2H, and ^1H (see the Table of Nuclear Properties on the NPA homepage) to find the mass of ^8Be in MeV [5]

3. Use the Semi Empirical mass formula to estimate the kinetic energy of an α particle emitted from the decay of ^{242}Cf to ^{238}Cm, where B is given by
   $$B(Z,A) = a_V A - a_S A^{2/3} - a_C \frac{Z^2}{A^{1/3}} - a_A \frac{(A-2Z)^2}{A} \pm \delta \text{ and } \delta(Z,A) = a_P / A^{1/2}$$
   and a_V=15.56, a_s=17.23, a_c=0.697, a_A=23.285 and a_p=12. Should the δ term be positive, negative, or zero? Show all steps in your working. Start by calculating the masses of all three particles involved. [10]

4. Given the ordering of nuclear energy levels as above, estimate the separation of the $1p_{1/2}$ and $1d_{5/2}$ energy levels for nuclei with A~16 using the following information:
   The total binding energy for the oxygen isotopes is: ^{15}O……111.96 MeV
   ^{16}O……127.62 MeV
   ^{17}O……131.76 MeV
   [4]

5. The Bethe-Bloch formula describes the mean energy loss of a heavy charged particle per unit distance for a given material. The formula is modified to describe the energy loss of electrons which, at relativistic energies undergo strong bremsstrahlung processes. Sketch a graph of the expected energy loss from very low to very high momenta and show the bremsstrahlung losses. Indicate where on the graph the minimum ionising electrons would be located. [4]