

Nuclear Physics & Astrophysics Exercises – 3

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

Proton mass $m_p = 1.00727647$ u

Hydrogen mass ${}^1\text{H} = 1.007825$ u

Neutron mass $m_n = 1.00866501$ u

Avogadro's number $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

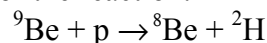
$e^2/4\pi\epsilon_0 = 1.439976 \text{ MeV fm}$

$1s_{1/2}; 1p_{3/2}; 1p_{1/2}; 1d_{5/2}; 1d_{3/2}; 2s_{1/2}; 1f_{7/2}; 2p_{3/2}; 1f_{5/2}; 2p_{1/2}; 1g_{9/2}; 1g_{7/2}; 2d_{5/2}$

1. Give the shell model spin and parity assignments for the ground states of the following nuclei using the shell ordering given above:

(a) ${}^7_3\text{Li}$ (b) ${}^{11}_5\text{B}$ (c) ${}^{15}_6\text{C}$ [6]

2. The Q value for the reaction:



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

3. Use the Semi Empirical mass formula to estimate the kinetic energy of an α particle emitted from the decay of ${}^{242}\text{Cf}$ to ${}^{238}\text{Cm}$, 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 $A \sim 16$ using the following information:

The total binding energy for the oxygen isotopes is: ${}^{15}\text{O} \dots \dots 111.96 \text{ MeV}$

${}^{16}\text{O} \dots \dots 127.62 \text{ MeV}$

${}^{17}\text{O} \dots \dots 131.76 \text{ MeV}$

[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]