Problem Solving Class: Van Quark tot Biomaterie

Problem Set 10: Nuclear Structure
Hand-in on paper Monday 17 November (before 12:00 h)
in Mailbox Madhu Talluri (Mailboxes W&N building)
Hand-in digitally, email to: m.t.talluri@vu.nl;
All documents in a single file [file: YourName-WC-P2]
All answers in English

Numbers: 1 u = 1.660538921 x 10^{-27} kg = 931.494061 MeV/c^2; M(^{1}H)=1.00782503 u; M_n= 1.008665 u. R_0=1.2 fm.

1) The α-particle

A) Calculate the mass of a bare a-particle given the "atomic mass" of 4He as given in Appendix F (in units of MeV/c^2).
B) Show that this is much less than the masses of its constituting particles.
C) Calculate the radius of an α-particle given the radius of nuclear matter scaling with R_0 and $A^{1/3}$.

Suppose now that two α-particles are placed like two balls touching at each other's surface.
D) Calculate their repulsive force.
E) Calculate the acceleration these particles undergo.

2) Binding in Na-nuclei

a) Calculate the binding energy in $^{23}Na_{11}$.
b) Calculate the binding energy in $^{24}Na_{11}$.
c) Compare the average binding energy per nucleon in these two Sodium nuclei.

3) Mirror nuclei and density of nuclear matter

Consider the mirror nuclei $^{12}B_5$ and $^{12}N_7$ of mass M(^{12}N)=12.018613196 u and M(^{12}B) = 12.014352104 u. Note that $^{12}B_5$ has 12 nucleons, of which 5 protons, etc.

a) Explain how and why the masses of these nuclei can help in calculating the density of nuclear matter; explain explicitly what assumptions are made and can be made.

b) The Coulombic repulsive energy of a homogenously charged sphere of radius R is:

$$V_C = \frac{3}{5}\frac{Z^2 e^2}{4\pi\varepsilon_0 R}$$

What is then the radius R of these nuclei and the characteristic size R_0 of nuclear matter: $R = R_0 A^{1/3}$.

4) Are the following decays possible or not possible ?

a) ${}^{233}_{92}U \rightarrow {}^{232}_{92}U + n$

b) ${}^{40}_{19}K \rightarrow {}^{39}_{19}K + n$