Homework 11 PS405

Due: Monday, November 28, 2016

Some of the problems are from "The Physics of Nuclei and Particles," by Richard A Dunlap

Chapter 4

4.2 Modified

Use Equation 4.10 to calculate the binding energy/nucleon (B/A) for ${}^{4}_{2}He$, ${}^{56}_{26}Fe$, and ${}^{197}_{79}Au$. Compare these to the Wolfram Database for Isotope Data.*

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IsotopeData[{2, 4}, "BindingEnergy"]
  .   .   .   etc.
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Determine the percent difference between the *calculated* B/A (using the semiempirical mass formula) and the *database* B/A.

4.4 (a) Using measured atomic masses *m* calculate the binding energies of ${}^{13}C$ and ${}^{13}N$. These nuclei are referred to as mirror nuclei.

Use Eq. 4.2 to calculate B (ignore *b* the binding energy of the electrons).

$B({}^{13}_{6}C)$ = __________ *MeV*

$B({}^{13}_{7}N)$ = __________ *MeV*

(b) On the basis of the liquid drop model, describe the reason(s) for the differences observed in part (a).

(c) From these results, calculate $A^{1/3}$ from the coulomb term and calculate the radius of the ${}^{13}_{6}C$ nucleus.

R_o = ____________ *MeV*

4.8 Modified

Using the semiempirical mass formula, calculate the most stable value of *Z* for nuclei having the following number of nucleons: A = 10, 50, 100, 200.

Z = _____ *Z* = _____ *Z* = _____ *Z* = _____

Problem 4

The ground-state wave-function of a lepton of mass m in a Coulomb potential $-\frac{Ze^2}{4\pi\epsilon_o r}$ is

$$\psi(r) = \frac{1}{\sqrt{\pi}}\left(\frac{Z}{a}\right)^{3/2} e^{-Zr/a}$$

where *a* is the Bohr radius ($\hbar/(m\alpha c)$), and the corresponding binding energy *E* is $Z^2\hbar^2/2ma^2$. The finite size of the nucleus modifies the Coulomb energy for $r < R$, the nuclear radius, by adding a term of the approximate form

$$V(r) = -\frac{Ze^2}{4\pi\epsilon_o R}\left[\frac{3}{2} - \frac{r^2}{2R^2} - \frac{R}{r}\right]$$

(a) Show that the volume integral ($0 \to R$) of this potential energy is $\int V(r)d^3r = \frac{Ze^2R^2}{10\epsilon_o}$.

(b) Show that the first-order correction to the binding energy due to this term, $\Delta E = \int \psi^*(r)V(r)\psi(r)d^3r$, is

$$\Delta E \approx \frac{e^2}{10\pi\epsilon_o}\frac{Z^4R^2}{a^3}$$

(Note that the lepton wave-function can be taken to be constant over nuclear dimensions.)

(c) For the nucleus ${}^{66}_{30}Zn$ show that:

$\frac{\Delta E}{E} \approx 5 \times 10^{-6}$ for electrons,

$\frac{\Delta E}{E} \approx 0.2$ for muons.

Problem 5

In an experiment using 14 g of selenium containing 97% by weight of ${}^{82}_{34}Se$, 35 events associated with the double β-decay

$${}^{82}_{34}Se \to {}^{82}_{36}Kr + 2e^- + 2\bar{\nu}_e$$

were counted over a period of 7960 hours. Assuming a detector efficiency of 6.2%, estimate the mean life for this decay.
(See S. R. Elliott, A. A. Hahn, and M. K. Moe, *Phys. Rev. Lett.* **59**, 2020 – Published 2 November 1987)

*IsotopeData Source Information

IsotopeData is based on a wide range of sources, with enhancement at the Wolfram Research Companies by both human and algorithmic processing.
Among principal sources for IsotopeData are:

Atomic Mass Data Center. "NUBASE." 2003. »
Firestone, R. B. "The Berkeley Laboratory Isotopes Project's: Exploring the Table of Isotopes." 2000. »
Raghavan, P. "Table of Nuclear Moments." *Atomic Data and Nuclear Data Tables* 42, no. 2 (1989): 189–291.
Sansonetti, J. E. and W. C. Martin. "NIST Handbook of Basic Atomic Spectroscopic Data." 2005. »
United States National Institute of Standards and Technology. "Atomic Weights and Isotopic Compositions Elements." 2005. »
United States National Nuclear Data Center, Brookhaven National Laboratory. "Nuclear Wallet Cards." 2007. »
United States National Nuclear Data Center, Brookhaven National Laboratory. "NuDat 2.3." 2007. »