Name(s): PHY-222 (Fall 2018), 11/26/18

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Homework Assignment #7

(*Due Date*: Wed, 12/05, 04:10 pm, in class; Show all your work for full/partial credit)

7.1 *Nuclear Sizes, Binding and Shell Structure* *(1+2+2+1 pts.)*
Consider the elements $^{7}_{3}$Li(7.016), $^{40}_{20}$Ca(39.963), $^{56}_{26}$Fe(55.935), $^{62}_{28}$Ni(61.928) and $^{197}_{79}$Au(196.967) with their measured atomic masses in units of u=931.5 MeV/c^2 in parentheses (use m_p=938.3 MeV/c^2, m_n=939.6 MeV/c^2 and m_e=0.5 MeV/c^2).

(a) Caclulate their nuclear radii.

(b) Calculate their nuclear binding energies per nucleon, E_B/A, from the above data.

(c) Calculate the total nuclear mass per nucleon *including* the nucleon rest masses (but not the electrons) for the Fe-56 and Ni-62 nuclei (use improved accuracy, u=931.494 MeV/c^2 and m_e=0.511 MeV/c^2). Is the hierarchy the same as in part (b)?

(d) Calculate the binding energy predicted by the liquid-drop model (see equation (1) in problem 7.2 below) for Li-7, Fe-56 and Au-197, and quantify the percentage deviation from the measured values obtained in part (b).

(e) Classify all nuclei above according to the nuclear shell model as either non-magic, magic (in N or Z) or doubly magic (in N and Z).

7.2 *Liquid Drop Model of Nuclei* *(2 pts.)*
The empirical Weizsäcker formula for the binding energy of nuclei is given by

$$E_B = C_1 A + C_2 A^{2/3} + C_3 \frac{Z(Z-1)}{A^{1/3}} + C_4 \frac{(A-2Z)^2}{A} \tag{1}$$

with A: nuclear mass number, Z: nuclear charge in units of e, C_1=−15.75 MeV, C_2=17.8 MeV, C_3=0.71 MeV and C_4=23.7 MeV.

(a) Derive the value Z^* for the charge which minimizes the binding energy for a given A. Sketch the resulting “valley of stability”, $Z^*(A)$, in a plot.

7.3 *Radioactivty* *(2 pts.)*
In a nuclear reactor, several radioactive elements are produced, including Pu-239 (with a half-life of 24110 years) and Cs-137 (with a half-life of 30.17 years).

(a) What is the predominant kind of radiation that the decays of these nuclei emit? (*hint: consult the internet*)

(b) What is the activity (in Ci) of 10 kg of (i) Pu-239, (ii) Cs-137?
(Assume a molar weight of 239 g and 137 g, respectively; N_A=$6 \cdot 10^{23}$)