Assignment # 3

The Following page summarized the SEMF.

http://en.wikipedia.org/wiki/Semi-empirical_mass_formula

For numerical

- Compute the binding energy and the binding energy per nucleon for, (a) ^{7}Li (b) ^{56}Fe (c) ^{235}U. using the SEMF. Compare this with the experimental binding energies given on the http://www.nndc.bnl.gov web site.

  1. On the web site the binding energies are given in terms of the mass excess

  $$\Delta(Z,N) = (M(Z,N)/\text{amu} - A) \times \text{amu} \tag{1}$$

  with

  $$1\text{amu} = 931.494088 MeV/c^2 \tag{2}$$

  2. The binding energy is defined as

  $$M(Z,N) = \underbrace{Zm_H}_{Zm_p+Zm_e} + Nm_N - B(A,Z) \tag{3}$$

  A couple of lines of MATHEMATICA can help with this excercise. I wrote a function to convert Δ in amu to Binding Energy in MeV/c^2.. Also I used mathematic to evaluate the SEMF

- Use a plotting program to plot B/A from the semi-empirical mass formula. Plot

  1. The volume term by itself
  2. The volume + surface terms.
  3. The volume + surface + coulomb term
  4. The volume + surface + coulomb + symmetry

- Starting with the definition of binding energy given above, explain using a lot of words why

$$S_{2n}(A, Z) = B(A, Z) - B(A - 2, Z) \tag{4}$$

is the energy required to remove two neutrons from a a nucleus.

- Using the semi-empirical mass formula to obtain an expression for the two neutron separation energy for large A. Use differential methods rather than algebraic methods and recall that the two neutron separation energy is

$$S_{2n}(A, Z) = B(A, Z) - B(A - 2, Z) \tag{5}$$

- The purpose of this excercise is to familiarize you with the web site `http://www.nndc.bnl.gov` as well as to understand basic decay modes of nuclei.

  - Look at ^{102}Rh. Find the two neutron separation energy on the figure on the next page. The two neutron separation energy can be related Check that this number agrees with the data that you can find at the `nndc` web site.
  - Draw a graph of $M(Z, A)$ (taken from the web site) on the y axis and and Z on the x-axis for fixed $A = 102$ and changing Z. Indicate the β and β^+/electron capture decay modes and the isotopes. See lecture `nuc1` page 3 for examples. Note the mass excess $\Delta(Z, A)$ is useful here since A is fixed. Again Mathematica can help here.

- Briefly describe how we did the following :

  1. Estimated kinetic energy contribution to the volume term of the semi-empirical mass formula.
  2. From the kinetic energy contribution and the volume term itself, we estimated the potential contribution to the volume term. Explain.
  3. How did we estimate the symmetry energy?
  4. How did we estimate the Coulomb term?

5. How did we understand the ratio of protons to neutrons in nuclei?
6. How did we estimate where nuclei becom unstable to spontaneous fission?

- Consider ^{15}O and ^{15}N which have the same number of nucleons but differ only in the number of protons relative to neutrons. Given that nuclear forces are nearly independent of wether we have protons are neutrons what is the dominant contribution to the binding energies in these so called "mirror" nuclei. Estimate the radii of these nuclei from the mass difference. Use the fact that the electrostatic energy of a sphere of charge Q and radius R is

$$U = \frac{3}{5} k_e \frac{Q^2}{R} \tag{6}$$

- In the lecture `nuc1` starting on page 9, I determined the minimum potential depth to have at least one bound state. What would the potential depth have to be (in one dimension) in order to have two bound states.