Physics 203
H. W. Assignment 6

1.) The semi-empirical mass formula (with coefficients in MeV) is

$$E_b(MeV) = 16A - 18A^{2/3} - .71\frac{Z(Z-1)}{A^{1/3}} - 23\frac{(A-2Z)^2}{A} + \frac{\Delta}{A^{1/2}}$$

with $\Delta = +11$ MeV for even-even nuclei, $\Delta = 0$ MeV for odd-even nuclei and $\Delta = -11$ MeV for odd-odd nuclei. Use this formula to calculate the binding energy per nucleon vs. A for stable nuclei for $A = 1 - 200$. Sketch the resulting curve and determine **THE** most stable nucleus. [Hint: use the above formula to find stable nuclei by identifying for a given A what value of Z gives the largest binding energy].

2.) Use the Fermi Gas Model to determine the fourth term in the semi-empirical mass formula (Prob. 1). You should be able to determine both the dependence on A and Z as well as the coefficient.

3.) Use the semi-empirical mass formula (in Prob. 1) to investigate the stability of ^{235}U against emission of (a) a proton, (b) a neutron, (c) an α particle (the α particle is a ^{4}He nucleus; Note - don't use the semi-empirical formula to calculate the mass of the α!). For any of these cases where the decay is possible calculate the kinetic energy of the emitted particle.

4.) The single particle shell model can be used to calculate the magnetic moments of odd-even nuclei (by assuming that the magnetic moment is due to the odd nucleon only). Using the formula for magnetic moment we derived for the deuteron, we can write the magnetic moment operator for a heavy nucleus A as

$$\hat{\mu}^n_A = \underbrace{2\mu_n\hat{s}_3}_{\hbar}\ ;\ \text{for an odd neutron} \qquad (\hat{s}_3 = \tfrac{1}{2}\hbar\sigma_3)$$

$$\hat{\mu}^p_A = \underbrace{2\mu_p\hat{s}_3}_{\hbar} + \mu_N\hat{L}_3\ ;\ \text{for an odd proton}$$

Use these operators and the Clebsch-Gordan coefficients (see CG PDF) to derive the shell model predictions:

$$\hat{\mu}^n_A = \mu_n\ ;\ \text{for } j = l + \frac{1}{2}$$

$$\hat{\mu}^n_A = -\mu_n\left(\frac{j}{j+1}\right)\ ;\ \text{for } j = l - \frac{1}{2}$$

$$\hat{\mu}^p_A = \mu_p + \mu_N(j - \frac{1}{2})\ ;\ \text{for } j = l + \frac{1}{2}$$

$$\hat{\mu}^p_A = \left(\frac{j}{j+1}\right)\left[-\mu_p + \mu_N\left(j + \frac{3}{2}\right)\right]\ ;\ \text{for } j = l - \frac{1}{2}$$