Nuclear Physics
Assignment # 1

Use $m_p = 938.28MeV,\ m_n = 939.57MeV,\ a_v = 15.56MeV,\ a_s = 17.23MeV,\ a_c = 0.72MeV,$ $a_a = 23.28MeV,\ \delta_p = 12MeV,\ \hbar = 1.055 \times 10^{-34}J - s,\ e = 1.6 \times 10^{-19}C,\ B_\alpha = 28.32MeV,$ $\hbar c = 197MeV\ fm,\ e^2/(4\pi\epsilon_0) = 1.44\ MeV\ fm,\ 1\ a.m.u. = 931.5MeV,\ g_s^p = 5.586\mu_N,$ $g_s^n = -3.826\mu_N$

The standard masses of the nuclei can be found at the end of the book by Krane.

1. Evaluate the density of nuclear matter, nucleon concentration, and volume density of electric charge in a nucleus.

2. Assuming constant density of nucleus, show that mean-square charged radius of a uniformly charged sphere is $\frac{3}{5}R^2$.

3. Using nuclear density formula, calculate skin thickness of a nucleus. If the diffuseness parameter 'a' is 0.52 fm, calculate its value.

4. Using single particle model, predict ground state spin and parity of the following nuclei (i) ^{7}Li (ii) $^{11}_{5}$B (iii) $^{15}_{c}$C, (iv) $^{23}_{12}$Mg (v) $^{17}_{9}$F (vi) $^{14}_{6}$C

5. The low-lying levels of ^{13}C are ground state, $\frac{1}{2}^-$; 3.09 MeV, $\frac{1}{2}^+$; 3.68 MeV, $\frac{3}{2}^-$; 3.85 MeV, $\frac{5}{2}^+$. The next states are about 7 MeV and above. Interpret these four states according to the shell model.

6. The maximal kinetic energy of positron being emitted in the β^+ decay of ^{13}N amounts to 1.24 MeV. After the beta decay, no γ ray is emitted. Calculate nuclear radius of atomic nucleus with mass A=13. Compare the so derived with the radius calculated as root mean square for a nucleus of A=13.

7. Compute the values of the magnetic dipole moments expected from the shell model, and compare with the experimental values. You may consult books for single particle levels.

Nuclide	J^π	$\mu(\exp)(\mu_N)$
^{75}Ge	$\frac{1}{2}^-$	+ 0.510
^{87}Sr	$\frac{9}{2}^+$	-1.093
^{91}Zr	$\frac{5}{2}^+$	-1.304
^{47}Sc	$\frac{7}{2}^-$	+ 5.34
^{147}Eu	$\frac{11}{2}^-$	+ 6.06

8. Given that the quadrupole moment of the nucleus $^{127}_{53}$I in the $J^\pi = 5^+$ state is -0.705 eb. Assuming an ellipsoidal charge distribution, calculate its axes ratio.

9. Compute the expected shell-model quadrupole moment of ^{209}Bi $(\frac{9}{2}^-)$ and compare with the experimental value, - 0.37 b.

10. Calculate the total binding energy and the binding energy per nucleon for ^{7}Li, ^{20}Ne, ^{56}Fe and ^{235}U. Compare the values.

11. For each of the following nuclei, use the semiempirical mass formula to compute the total binding energy and the Coulomb energy: (a) ^{21}Ne; (b) ^{57}Fe;(c) ^{209}Bi; (d) ^{256}Fm.

12. Compute the mass defects of (a) ^{32}S;(b) ^{20}F; (c) ^{238}U.

13. Given the following mass defects, find the corresponding atomic mass: (a) ^{24}Na: - 8.418 MeV; (b) ^{144}Sm: - 81.964 MeV; (c) ^{240}Pu :+ 50.123 MeV.

14. Calculate the binding energy of a neutron in a ^{14}N nucleus, if the binding energies of ^{14}N and ^{13}N nuclei are known to be equal to 104.66 and 94.10 MeV.

15. Find the energy required to split an ^{16}O nucleus into an α-particle and ^{12}C nucleus, if the binding energies of ^{16}O, ^{12}C, and ^{4}He nuclei are known to be equal to 127.62, 92.16, and 28.30 MeV.

16. Find the energy liberated on the formation of two alpha particles as a result of fusion of ^{2}H and ^{6}Li nuclei, if B/A in ^{2}H, ^{4}He and ^{6}Li are known to be equal to 1.11, 7.08 and 5.33 MeV, respectively.

17. Evaluate (a) the neutron separation energies of ^{7}Li, ^{91}Zr and ^{236}U; (b) the proton separation energies of ^{20}Ne, ^{55}Mn and ^{197}Au. What variation do you see with mass number?

18. Use the Bethe-Weizsäcker mass formula to find neutron dripline location for the nucleus Sn (Z=50). What will be the mass number of Sn on proton drip line? [on neutron(proton) dripline $S_n(S_p)$ is zero]

19. Determine separation energy of alpha particles from $^{21}_{10}$Ne nucleus.

20. Compute the energy release (Q value) of:
(a) ^{235}U + $\rightarrow$ ^{90}Kr +^{144}Ba + ?;
(b) ^{252}Cf $\rightarrow$ ^{106}Nb + ?+ 4n

21. In the fission of ^{236}U into two fragments A_1 and A_2 = 236 - A_1, plot the Coulomb repulsion energy of the two fragments if they are formed just touching at their surfaces. Consider all values of A_1 from 50 to 150, and assume each fragment has the same Z / A ratio as ^{236}U. You can use excel sheet or write a program to calculate.