INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS

Homework Set 6

March 16, 2016

1. This problem relates to magic numbers.

   (a) What is Z for the lightest element with *three* stable isotopes? [*Hint:* Use the handout (Appendix C) from homework Set 2.] List the stable isotopes with the same N as this Z.

   (b) What is Z for the lightest element with *six* stable isotopes? List the stable isotones with the same value N as this Z.

   (c) The element with the *most* (10) stable isotopes is tin (Sn), with $Z = 50$. List the stable isotones with $N = 50$.

   (d) The nuclei with the *most* stable isotones are those with $N = 82$. List the *seven* stable isotones with $N = 82$.

   (e) The lightest nuclei with *five* stable isotones are those with $N = 20$ and $N = 28$. List the stable isotones with $N = 28$.

2. (a) Draw a simplified shell-model diagram for the 0^+ ground state of ^{12}C.

   The lowest excited states of ^{12}C are a 2^+ state at 4.44 MeV and a 0^+ state at 7.65 MeV. The lowest 1^+ state does not occur until 12.71 MeV. Draw a diagram (or diagrams) showing a likely shell-model interpretation for these low-lying 0^+ and 2^+ excited states.

   (b) The low-lying states of ^{13}C include the $\frac{1}{2}^-$ ground state, a $\frac{1}{2}^+$ excited state at 3.09 MeV, a $\frac{3}{2}^-$ excited state at 3.68 MeV, and a $\frac{5}{2}^+$ excited state at 3.85 MeV. All other excited states have energies above about 7 MeV. Draw diagrams that give a likely shell-model interpretation for each of these four states.

3. (a) The low-lying negative-parity states in ^{43}Ca, ^{45}Ca, ^{51}V, and ^{53}Mn have similar three-particle or three-hole configurations. Identify the dominant configuration for each nucleus. [For example, the low-lying positive-parity states in ^{18}O have a dominant two-particle configuration given by $(1d^{\nu}_{5/2})^2$.]

(b) Each of these nuclei has a $\frac{7}{2}^-$ ground state. Determine what other negative-parity states are allowed by Fermi symmetry. [*Hint*: Use the fact that the three-particle (or three-hole) wave function must be antisymmetric under particle (or hole) interchange.]