MODELLING THE ANGULAR MOMENTUM J OF 1s, 1p, 1d, 2s, AND 1f NUCLEONS

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Norman (1), (2) has shown that if alpha particles are densely packed as spheres then not only are nuclide sizes, densities, quadrupole moments and binding energy data satisfied but so too are the requirements of the energy levels of the `shell models of nuclear structure.

The magnitude of the angular momentum J of a nucleon is defined as $\sqrt{j(j+1)}\ h/2\pi$ where j is the quantum number and h is the Planck constant. It will be assumed that J = mvr where m = 1.67×10^{-27} kg is the nucleon mass, v = nucleon velocity about the nuclide centre of mass distant r from the nucleon. For each 1s nucleon in an alpha particle $r_1 = 0.86$ fm and $J_1 = 0.86\ h/2\pi$ so that $v_1 = 0.21$ c.

In the liquid drop model of 4 alpha particles representing an oxygen 16 nuclide. each 1p nucleon is distant $r_2 = 2.18$ fm from the centre of the nuclide. Because $J_2 = 1.94\ h/2\pi$ it follows that $v_2 = 0.19\ c \sim v_1$.

By using the liquid drop model of 14 alpha particles representing a nickel 56 nuclide it can be shown that the mean distance of each of the 1d and 2s nucleons is $r_3 = 2.85$ fm from the nuclide centre. Because $J_3 = 2.96\ h/2\pi$ it follows that $v_3 \sim v_2 \sim v_1$. A similar situation holds for the 1f7/2 nucleons for which $r_4 = 3.95$ fm and $J_4 = 3.96\ h/2\pi$ so that $v_4 \sim v_1$. That is, the velocity of all nucleons is the same and is independent of the energy level.

This implies that the de Broglie wavelength of all nucleons is $w = h / m v = 6.3$ fm $\sim 2\pi$ fm . Therefore for $r_1 \sim 1$ fm there is one w per orbit; for $r_2 \sim 2$ fm there are 2 w per orbit and so on. This implies that in the first magic number closed shell of nucleons there are 2 orbits each containing 2 standing wave maxima representing 1 proton and 1 neutron. The second closed shell consists of 3 orbits each containing 2 proton and 2 neutron standing wave maxima. While the third closed shell consists of 4 orbits each containing 3 protons and 3 neutrons the fourth closed shell consists of only 2 orbits each containing 4 protons and 4 neutrons.

The Bernal liquid drop alpha particle models of nuclear structure appear to accord quite well with the quantum mechanical prescriptions of nucleon angular momentum and de Broglie wavelength.

References:

(1) Norman P.D. (1993) "Models of the meson bond structure of the most abundant products of stellar nucleosynthesis" Eur. J. Phys. 14,36.

(2) Norman P.D. (1995) "Liquid drop alpha particle models of some common nuclides" Proc. A.N.A. 95, 125.