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Letter to the Editor

Electrodynamic Model of the Nucleus

Nuclear engineers are well aware of the importance of the closed nuclear shell "magic numbers" to nuclear engineering. Magic numbers are responsible for double-hump fission curves, the existence of delayed neutrons, and for xenon poisoning and xenon-induced power oscillations in reactors. Engineers are also aware of the binding energy per nucleon curve, and the fact that fusion is energetically possible for low-A nuclides while fission and alpha decay are energetically possible for high-A nuclides. All of this information came from experimental data. The magic numbers were inferred by noting discontinuities in nuclear systematic studies.[1] The binding energy data were qualitatively fit by the semiempirical mass equation, which was an attempt to combine the liquid drop model and the quantized nuclear shell model. For more than 40 years, no theory was put forward that could quantitatively explain why all of these ideas worked.

Based upon experimental and theoretical work done by Compton[2–4] and his student Bostick,[5] a new explanation for these phenomena has been obtained. Protons and neutrons are each represented by small charged ring magnets, as suggested by X-ray scattering experiments on electrons,[6] and these nucleons are then arranged as symmetrically as possible in three-dimensional space so that the electrodynamic forces between them attain static balance. Geometrical packing follows some electrodynamic constraints, so the pattern is not completely arbitrary. The neutron is known to have an internal charge distribution, so it can polarize and orient its positive and negative ends to a position of torque balance.

With this model, Lucas[7] predicts all the magic number shell closings for neutrons and protons and explains why they have the values we know. Using a similar model for atoms, he also predicts the periodic table[8] and shows why nuclear shells are different from atomic shells. For ^{208}Pb, as shown in Fig. 1, the protons occupy the outermost two rings of 32 and 50, giving the magic number of 82, while the neutrons occupy five different rings of 8, 18, 18, 32, and 50 that add up to 126. The protons get as far away from each other as possible, which is why they occupy the outer shells. Between these two proton shells lies a neutron shell, where the neutrons are polarized sideways. That shell acts like a force decoupler and gives the nucleus its liquid drop properties. The rest of the neutrons polarize away from the protons, and the innermost shell is left empty as the positive ends of the neutrons also get as far away from each other as possible. It is the rearrangement and emptying of inner shells when outer shells can be completed that accounts for the difference between nuclear magic numbers and the atomic magic numbers that correspond to the noble gases.

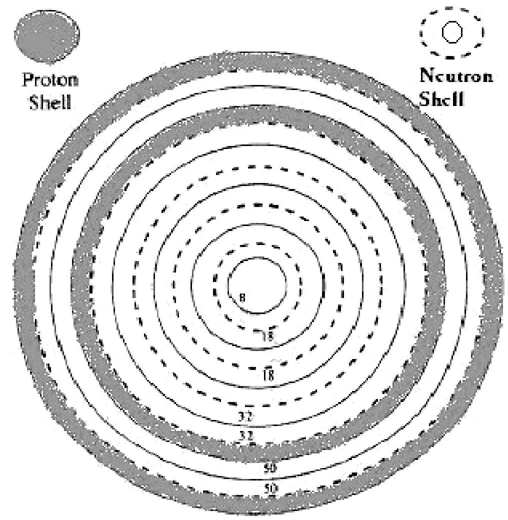

Fig. 1. Cross-sectional view of the electrodynamic shell model of ^{208}Pb.

Using this basic model, Lucas formed rules to assign shell positions for all 3000+ nuclides in the Chart of the Nuclides. He then derived his own semiempirical mass formula, using new definitions for the terms, as shown below. Specifically, the surface term only uses the outermost proton and neutron shells, asymmetry and magic are determined by pairing, and spin is determined by failure to pair.

$B/A = K_1$	(Volume)
- K_2 (#Neutrons + #Protons in outermost shell)/A	(-Surface)
- $K_3\, Z(Z\text{-}1)A^{-4/3}$	(-Coulomb)
- K_4 (#paired Neutrons − #paired Protons)^2/A	(-Asymmetry, Magic)
- K_5 (#unpaired Protons + #unpaired Neutrons)/A	(-Pairing)

The fit, shown in Fig. 2, matches all the masses to a fraction of a percent, including all the experimental low-A peaks shown in Evans' book,[1] *The Atomic Nucleus*. This means that the magic effects, surface effects, spin-pairing effects, and asymmetry effects are now correctly included in a phenomenological manner. Using the rule that odd numbers of neutrons and/or protons in a shell link together like ring dipole magnets in a line to form the nuclear spin or magnetic moment by merely

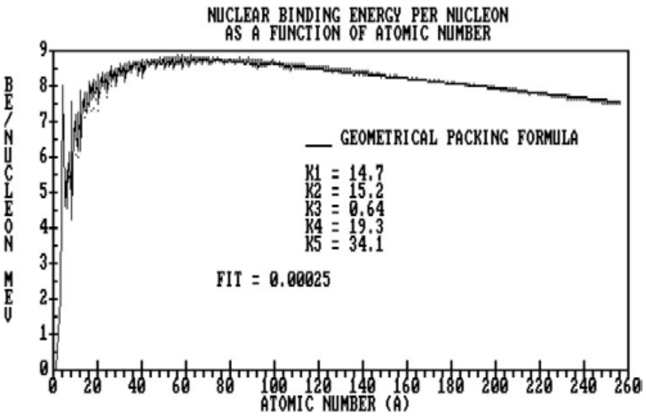

Fig. 2. New semiempirical binding energy fit from the electrodynamic model.

adding their intrinsic nucleon spins or moments together allows the spin of all known nuclides (stable or unstable) to be predicted. Lucas correctly predicts the experimentally measured spins of all nuclides, while the standard model gets about half of the nonzero spins wrong.

It should be emphasized that this very successful phenomenological nuclear model is based solely on classical electrodynamics. Instead of having the nucleons move around the nuclear volume in curved orbits at high speeds, where according to Ampere's law and Faraday's law in electrodynamics they should radiate energy continuously, they are placed in stable static positions where they at most vibrate back and forth. Such vibratory motion is similar to that invoked in the liquid drop model of fission. Unstable vibratory oscillations also offer a physical explanation for alpha decay, where loosely bound protons and neutrons in the outer shells can easily form an alpha particle that then splits off. Thus, perhaps it is not necessary to invoke quantum mechanics to explain why the nucleus behaves as it does.

Charles W. Lucas, Jr.

Church Computer Services
29045 Livingston Drive
Mechanicsville, Maryland 20659
bill.lucas001@gmail.com

Roger A. Rydin

University of Virginia
Charlottesville, Virginia 22901
rarydin@earthlink.net

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