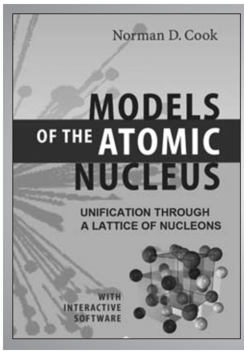

Models of the Atomic Nucleus: Unification Through a Lattice of Nucleons

Norman D. Cook
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Review by George Egely

There might have been another equally fitting subtitle for this book: "All You Wanted to Know About Nucleons, but Never Dared to Ask."

A fundamental need for LENR studies is to get to know the shape of the nuclei, the real nature of interaction between nuclei. Therefore this book is highly recommended for both theorists and experimenters in the field of LENR, a.k.a. "cold fusion," or transmutation in general. If the shape of nuclei and their interaction were known, half of the work toward a rough understanding of LENR would already be done, and it would be of immense practical importance. Then abundant, inexpensive, sustainable, pollution-free energy would be a reality, not just a dream. But there is a stiff resistance on behalf of mainstream physicists to extend the realm of nuclear physics. Why? Because there are skeletons in the nuclear cupboard. We ought to know each of them.

This book is a serious contribution towards this goal. Even the most "skeptical" but objective researcher will find the issues raised by this work are important, getting to the heart of the problems.

The bottom line: Despite nearly unlimited funding and decades of research, the shape and structure of the nuclei are still unknown. The competing mainstream models—shell and liquid drop models—frequently yield mutually exclusive predictions. Though both of them have some practical merits, their applicability is fragmented at best.

The main statement of the book is that there is a third possible model, a better and unifying one: the nucleons are placed side by side, like ions in the sodium chloride lattice, or in this model in a close-packed, face-centered lattice. (See Figure 1 as an example.)

To establish a good, practical model of nuclear shape and interaction is a tough problem, as it is the smallest collective object of nature, where even the best electron microscope is useless. Consequently only second-hand indirect information could be collected—like from the usual scattering experiments.

Can we determine the internal structure of a bird if we can dissect it only with a blast from a shotgun while in mid-flight? Is it good enough to observe the fragments of flesh, bones, feathers and pieces of guts to imagine the sophisticated interconnections of the organs of a live bird?

The scattered fragments of millions of experiments with the nucleus have not yielded enough practical details so far about the shape of different isotopes of the elements in the periodic table.

After decades of frustrating failed attempts, we are left with two "half baked" mainstream ideas, and the field was practically abandoned to a handful of some rear guard researchers, to comb through the pieces that do not fit this jigsaw puzzle.

Cold fusion (LENR) threw a stone into this lukewarm pond in 1989. These observations challenged the mainstream in a hard hitting, painful way, unbearable for the orthodox view. Norman Cook is unorthodox in a double way.

He clearly challenges and describes the severe shortcomings and controversies of mainstream models, and at the same time admits the possibility of nuclear transmutations. He states in the introduction, "The so-called transmutation results are among the most unambiguous empirical findings indicative of nuclear effects in 'tabletop' experimental setups."

Although Cook is a theorist, and apparently he is not aware of the plasma-based LENR phenomena, his interpretation of LENR is also worth looking at, *i.e.* the role of the palladium lattice.

The book consists of four parts. The first part deals with the fundamentals and the author has a captivating style to describe the essentials of complex problems, to show the parallel between the atom (electron shell) and the nuclear shells. A brief historical review helps the reader put the field into context. He explains how the rival models were conceived and when they were fashionable, etc.

There is a brief summary about the merits and shortcomings of the shell and liquid drop models including Linus Pauling's spheron model (nuclei made of soft close-packed rubber balls), which is an especially insightful idea.

Part II on the "Long Standing Problems" is a strength of the book, which makes this work essential for the diligent LENR researcher. Cook took an amusing and thought provoking approach to confront different authors on a given subject, like the mean free path of nucleons in nuclei, nuclear size and shape, nuclear force and super heavy nuclei, nuclear fission and finally LENR in about ten pages. It is obvious that there are internal contradictions in this field and there are some rare admissions of the lack of knowledge on behalf of textbook writers. He concludes that mainstream

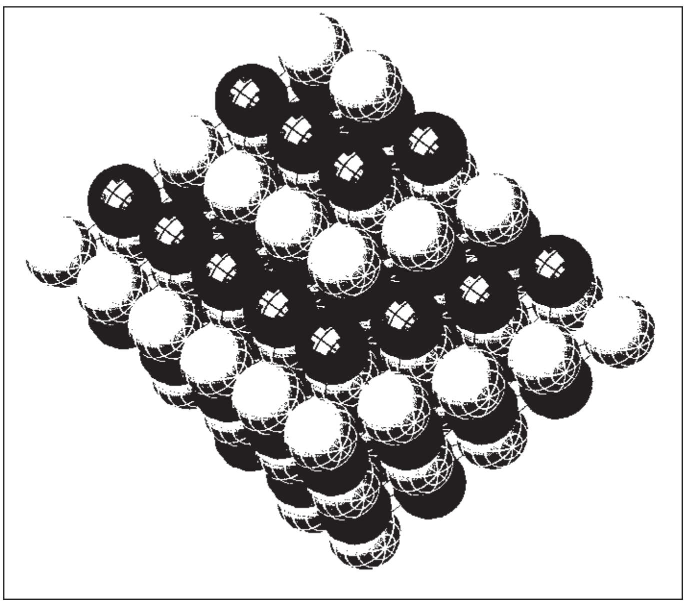

Figure 1. A closed packed, crystal-like nucleon. The isotopes of a given element might be different depending on the number of their neutrons.

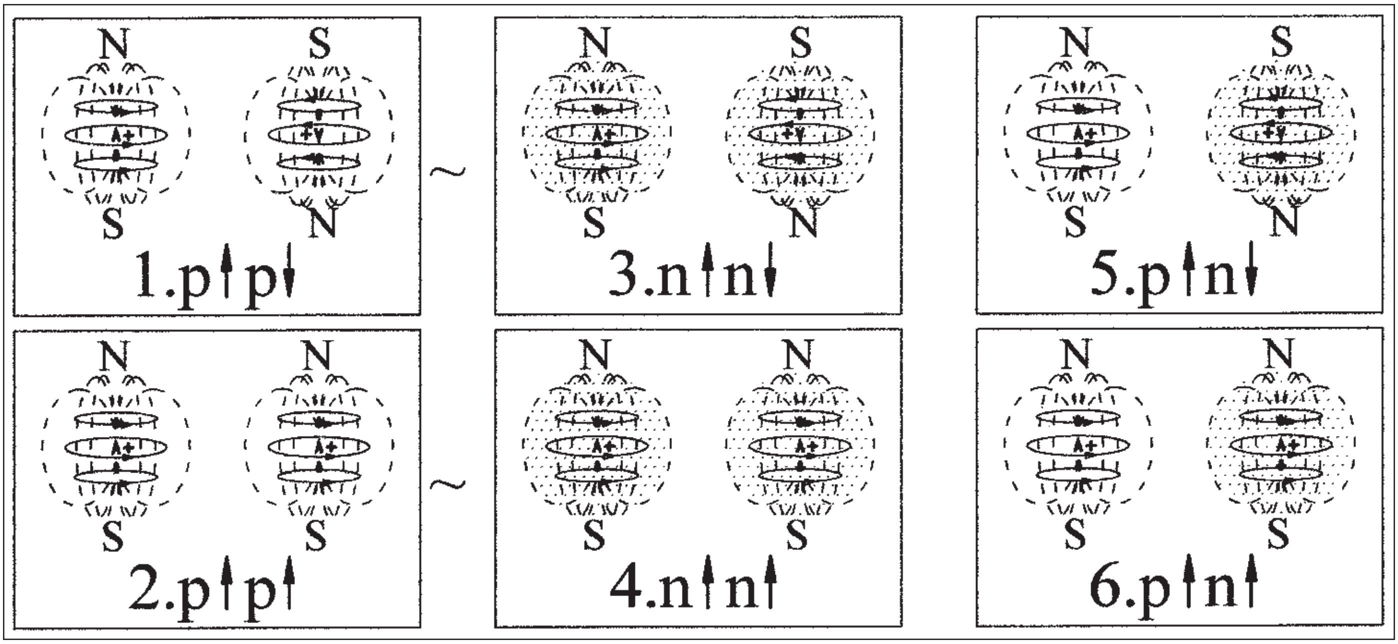

Figure 2. Magnetic interaction may take place between protons and neutrons instead of strong force. There are six possible interactions between them. Some of them are strongly attracting, some are weakly attracting, others are repelling.

nuclear science is full of skeletons in the closet. There is a brief summary at the end of each chapter to help the reader muse about these problems.

Part III deals with the author's main subject: the lattice model. If one is not prejudiced against the idea of this type of a nucleus, this is the most useful part.

The idea is that the nucleus as a collection of closely packed nucleids is relevant to possible applications and therefore it is worth having a deeper look (see Figure 1).

The shell model (independent particle model) has been the mainstream idea for the last 40 odd years. This model requires a lengthy mean free path between nuclei, an assertion that is flatly contradicted by experiments. Though shell models explain quite well a vast amount of experimental data about γ radiation frequencies, nuclear spins, etc., they don't explain all of the test data at the same time; hence the need for a close-packed model, the result of Cook's work.

Even the early electron scattering tests indicated that atomic nuclei were extremely dense, and their size is not more than 10^{-13} m. Although there is a 5-10% uncertainty in test data, the size of the nucleus and its density must be a non-negotiable fact for any theorist. Related to this shape problem is the very nature of nuclear interaction. What sort of force keeps this dense nuclei together? How are nucleids able to interact to overcome Coulomb forces? What is this mighty, strong interaction? Is it a separate kind of force (as claimed by the mainstream), or some tricky kind of electromagnetic force? Finally, are neutrons somehow able to cluster to form some rare exotic but stable sort of nuclei? (Mainstream models don't give us answers for the last question raised by the tests of Fisher and Oriani.)

Cook's model is based on a high density internal core of nucleons with a less dense periphery that is like a crystal, but closely packed neutrons and protons are stacked into this unique crystal. The higher the number of protons, the more neutrons are needed to glue this tightly-packed cluster together. Cook believes that the nature of nuclear forces is not described correctly by "strong interactions." There cannot be even modestly long range forces up to ~10 femtometers as demanded by both shell and loose cluster models. This is a daring statement, but there is a truth to it to be explained later. Again there is another twist in this story.

Nuclear fission (the bread and butter of nuclear physics) is not interpreted correctly by those loose mainstream models. But the close-packed crystal model of Cook has a more plausible explanation. For example: closed shell and liquid drop models yield a symmetrical split between daughter nuclei after fission—contrary to established observations. So mainstream models which are used to deny the feasibility of LENR can't describe even the most established fact, hence the need for a better model of nuclei.

There is a hidden advantage to the solid, close-packed, model that binding forces (strong interaction) can be derived from the known magnetic properties of nucleons. If proven to be correct, this idea will be a second revolution not only in nuclear theory, but in the industry as well. This part of the work (pp. 217-223 with co-authors Valerio Dallacasa and Pablo Di Sia) is extremely useful, though it is short. Essentially, Cook and the co-authors believe that the known magnetic forces of the nucleons keep the nuclei together, as bar magnets (or spherical magnets) may be self-organized together. (This is a sort of Ising model of magnetic domains; see Figure 2.)

Though fusion of light nuclei is not elucidated at all in the context of the model, readers might start thinking along this line, too. The mutual positions of protons and neutrons allow only six possible geometric interactions. Three of them are strongly attractive, one is attractive but weak and the rest are repulsive. So far to commence LENR the problem to be solved is how to arrange and align nucleons to help the strongly attractive versions. Vacuum-based (hot fusion) solutions are therefore less likely to take advantage of this possibility than surface-based LENR solutions, when there is enough time for the proper attractive alignment.

There have been some efforts to explore simple, cubic packed models (scp), but Cook took a step beyond by exploring the properties of face-centered cubic (fcc) packing. The combination of scp and fcc yields an amazingly good fit between theory and experiments.

Early pioneers—like Hungarian E.P. Wigner in 1937, German Friedrich Everling in 1959 and American Linus Pauling in 1965—noticed the merits of this approach, but their ideas were not absorbed by the mainstream theorists of independent particles (shells).

Lattice models of the nucleus have a good agreement with observations and were easy to visualize. The "magic numbers"—the pride of shell models—are also inherent attributes of the lattice model, due to the symmetries of the fcc or scp layouts. The author states: "If spheres of equal size are assembled to yield structures of the highest symmetry, the result is a series of 4, 16, 40, 80, 140, etc. spheres. The first three agree in their particle numbers with the mass numbers of the four double magic nuclides of 4 He2, 16 O8, 40 Ca20 found in nature...A second series of highest symmetry structures correspond to the double magic self conjugate nuclides of 28 Si14, 56 Ni28, 100 Sn50 which are found in nature. The numbers 104 and 252 relate to the known magic proton number 82, and magic neutron number 126 in 208 Pb126 where the excess of neutrons over protons became important."

A further advantage of fcc-scp lattice models is the correct prediction of binding energies already noted by Everling.

The giant resonances observed by experiments are also the inherent properties of lattice models. Subclusters of α particles on the surface of nucleons are also featured in lattice models.

There are more advantages of the lattice model over the shell model, not touched here. The lattice does not have to be always densely packed because there may be "vacancies." Several heavy ion collision test results were adequately simulated by these physical models. The calculations yielded realistic results for the density of bulk nuclear density, temperature, Coulomb effects and kinetic energy levels.

The sparsely populated "simple cubic packing" model is also a realistic tool to describe nuclei.

The plague of all theoretical models ("fudging" by empirical parameters) can be applied to all models, but face-centered cubic lattice models require less "adjustment" than rival models. The formation of such a nucleus starts with strong magnetic interactions with the nearest neighbors, in the order of 2 femtometers. Thus there is good description of both the core and the edge of a nucleus, for most of the nuclei. Nuclear spin and parity is also properly described: "Among 274 isotopes...there were only two examples where an fcc structure with correct spin and parity was not evident—indicating either experimental error or possibly an insufficient search among fcc permutations" (p. 249).

Cook explains the excess heat from the electrolysis of heavy water to LENR in terms of nuclear fission of the Pa electrode, which is yet another interesting idea in this field.

Theoretical nuclear physics has attracted over 10,000 researchers from all over the world since the 1930s. It is strange that liquid, gas and cluster models were widely (and unsuccessfully) scrutinized and explored, but solid state lattice models were not seriously considered during all these decades.

A further strength of the book is the freely downloadable software at extras.springer.com, developed by Cook. An appendix is helpful to master the application of the software.

The book is written with clarity and elegance and sometimes with a bittersweet humor. This work is highly recommended, and especially worthy of reading for the LENR community.