The Electromagnetic Considerations of the Nuclear Force: Part III
An Analysis of the Electromagnetic Contributions to Nuclear Behavior

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Abstract:
This theory discusses the role of the electromagnetic force inside the atomic nucleus. Previous nuclear theories have relegated the electromagnetic force as being a relatively minor component, considering only the Coulomb force of the protons. These previous models usually make the incorrect and outdated assumptions of a homogeneously-charged proton and a homogeneously-neutral neutron. With the understanding that quarks are the centers for both the electric charge and magnetic dipole moments within a nucleon, such outdated assumptions are no longer valid. Because of the strong electromagnetic interaction between the internucleon quarks, electromagnetism can, indeed, be the force that holds the nucleons together in an atomic nucleus. Thus, these changes in the understanding of the electromagnetic forces within the atomic nucleus require a more significant role of electromagnetism with regards to the understanding of nuclear behavior. Part III of this series of papers describes how the electromagnetic forces and energies affect the nuclear behavior. New insights and understandings are gained by applying the laws of electromagnetics to the nuclear structure inside an atomic nucleus. In this paper, explanations of bond formation and bond breakage are given in detail, as well as how these processes relate to nuclear fission and nuclear particle decay.

Keywords—electromagnetics, nuclear binding energies, nuclear force, quarks, and nuclear particle decay.

1. Introduction

The concepts discussed in this paper describe how the electromagnetic principles can be used to analyze nuclear behavior. Electromagnetic behavior is well understood and experimentally verified. The ideas presented in this paper are not speculative physics, but rather the application of standard electromagnetics to nuclear physics. The electromagnetic forces within the atomic nucleus should not be ignored, minimized, or invalidated.

This paper is organized as follows:

Section 1—Introduction
Section 2—A Brief Review of Part I.
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Section 4—A Brief Review of Previous Models of the Nuclear Force.
Section 5—Quarks and the Copenhagen Interpretation of the Heisenberg Uncertainty Principle.
Section 6—Calculations of the Energies within the Atomic Nucleus.
Section 7—The Segments.
Section 8—Applying Electromagnetic Principles to Bond Formation.
Section 9—Applying Centrifugal Energy Principles to Bond Breakage.
Section 10—Applying Electromagnetic Principles to Bond Breakage.
Section 11—Energy Considerations of the Beta Decay Modes.
Section 12—Summary of the Electromagnetic Behavior for the Various Nuclear Configurations.

There are historical objections and misconceptions about the concept of the Electromagnetic Force being the force that holds nucleons together; these are answered in Section 2. Historical objections and misconceptions regarding quarks and quantum uncertainty principles are answered in Section 5.

The development of a proper theory of the Nuclear Force has occupied nuclear physicists for over eight decades and has been one of the main topics of physics research in the 20th and 21st centuries. The focus of this paper is the role of electromagnetic energies within the nucleus and how electromagnetics affect nuclear behavior. The emphasis of this series of papers is electromagnetics, since this topic has been largely disregarded in previous models of the Nuclear Force. However, this paper does not contradict quantum physics in any way. The concepts of quantum physics are properly included in this paper.

Currently, there is no one singular model of the Nuclear Force that can explain the majority of nuclear behaviors [1, 2, 3]. Here is a brief list of the more salient nuclear behaviors that a successful model of the Nuclear Force should address:

- The shape of binding energy curve
- Particle decay
- Large quadrupole moments
- Excited energy states.

This model asserts that the electromagnetic properties of the quarks hold the protons and neutrons together in an atomic nucleus, binding the nucleons together with an internucleon quark-to-quark bond. Using the Electromagnetic Model, the ground state configurations of hundreds of atomic nuclides, from ^{2}H to ^{283}Cn, have been determined and computer simulated. The calculated binding energies agree with the experimental binding energies to within a few percent. These computations are done by using only one selected parameter. No previous theoretical model of the Nuclear Force has been able to demonstrate such an accurate prediction of binding energy with only one parameter, such as this model is able to achieve. This is an unprecedented success and strongly indicates the correctness of the Electromagnetic Model. The Electromagnetic Forces inside a nucleus, when fully considered, can explain many aspects about nuclear behavior. The Electromagnetic Forces, applied to the internal configurations of the atomic nuclides, are what control and dictate the majority of their observable nuclear behaviors.

In Part III of this series of papers, electromagnetic principles are used to analyze nuclear behavior, using numerous examples, calculations, and illustrations. The laws of electromagnetics, as applied to the nuclear structure, are able to explain much about nuclear behavior—without needing convoluted calculations, complex mathematics, non-intuitive concepts, theoretical conjecture, or magic numbers. This model uses exact mathematical expressions, rather than the estimated equations, perturbation mathematics, and numerous empirical parameters that are used in other models. This model is able to explain many aspects of nuclear behavior with far more clarity than any previous model of the Nuclear Force. By considering the Electromagnetic Forces within the atomic nuclide, a stronger understanding of nuclear behavior can be gained.

1.1. Definition and Clarification of Terms

The "Nuclear Force" is that force which binds together the protons and neutrons in the nucleus. Historically, the Nuclear Force was called the "Strong Nuclear Force", and it was considered to be one of the four forces of nature, along with the Gravitational Force, the Electromagnetic Force and the Weak Nuclear Force. Soon after the discovery of quarks, a new force was needed to hold the quarks together inside of a nucleon; this force was called the "Chromodynamic Force". Several years later, the Chromodynamic Force was renamed as the "Strong Nuclear Force"; thus the "Strong Nuclear Force" is now considered to be a force responsible for binding the sub-nucleon particles together inside of a nucleon. Concurrent with that change, the force which holds the nucleons together in a nucleus was renamed as the "Nuclear Force".

To add to this unfortunate confusion even more, there is a model of the Nuclear Force called the "Residual Chromodynamic Force", which is also known as the "Residual Strong Force". Because of this model and its association with chromodynamics, it was presumed that the Nuclear Force is simply a subset of the Chromodynamic Force. Thus, it was claimed that there are still only four forces in Nature: The Strong Nuclear Force, the Electromagnetic Force, the Gravitational Force, and the Weak Nuclear Force. Now, however, due to these changes, the Strong Nuclear Force is considered to have two parts--the Chromodynamic Force, which is the force holding the quarks inside of a nucleon, and the Nuclear Force, which is the force holding the nucleons together in an atomic nucleus.

To avoid any confusion about these forces, the term "Strong Nuclear Force" will not be used in this paper. Rather the term "Quantum Chromodynamic Force" will be used to reference that force which holds together the quarks inside a nucleon. The term "Nuclear Force" will be used to describe that force which holds the nucleons together inside an atomic nucleus. The term "Residual Color Force" will be used to describe the Residual Chromodynamic Force.

Many of the smaller atomic nuclides exhibit an instability due to the Nuclear Force, defined as a change in the mass number A. For the smaller atomic nuclides, the half-life of this instability is on the order of zepto-seconds. Such near instantaneous instabilities can occur either in the ground state of the atomic nuclide or when the atomic nuclide is in a high energy state. Instabilities due to the Weak Nuclear Force include β- decay, β+ decay, and electron capture. The instabilities due to the Weak Nuclear Force generally have a longer half-life, much longer than a zepto-second. An instability due to the Nuclear Force should not be confused with an instability due to the Weak Nuclear Force. Although both forces can cause an instability of the atomic nucleus, they are due to two completely different forces and mechanisms.

2. Brief Review of Part I

It is recommended that the first two papers regarding the electromagnetic considerations of the Nuclear Force [4, 5] be read and understood prior to continuing with the information presented in this paper. However, as a convenience, a brief review is given here. (Readers who are familiar with these first two parts can proceed to section 5.)

In part I of this series, the electromagnetic considerations of the binding energy of the atomic nucleus is calculated mathematically. Using accurate and clear explanations, the historical misconceptions and falsehoods regarding electromagnetics inside a nucleus are debunked and discredited.

2.1. Quarks

In 1964, the concept of quarks was revealed by Gell-Mann and Zweig [6, 7, 8], clarifying the proton and neutron as being non-elementary particles with electrical inhomogeneity. A proton is made up of three quarks, two up quarks and one down quark. A neutron is made up of two down quarks and one up quark. Up quarks have an electrical charge which is 2/3 of an elementary charge. Down quarks have an electric charge that is -1/3 of an elementary charge. The electrical charge and magnetic moments of a nucleon are confined to the quarks, rather than being homogeneously distributed throughout the nucleon. The quarks are confined inside the proton and neutron by the Quantum Chromodynamic Force. Quarks have the attributes of mass, spin, electric charge, magnetic moments, and a quantum attribute called "color", which is unrelated to actual visual color.

Illustrated in Fig. 1 are shorthand symbolic representations of the proton and neutron, showing the up and down quarks, and the electric charges associated with them. In this representation, the up quarks, in red, have a "++" charge (2/3 of an elementary charge), and the down quarks, in blue, have a "-" charge (-1/3 of an elementary charge). Please note that the colors in these illustrations do not relate to the colors of the Quantum Chromodynamic Force. The colors are used merely to distinguish between the up and down quarks. The dots do not represent the relative quark size. Rather, the dots are simply sized to be easily seen. The magnetic moments of the up quarks are out of the page, and the magnetic moments of the down quarks are into the page; these magnetic moments are not shown.

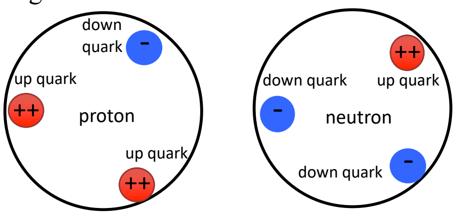


Fig. 1. Shorthand simplified representations of a proton and neutron.

Gell-Mann believed that quark charges could be localized, and Richard Feynman asserted that high energy experiments showed that quarks are indeed real particles. Feynman surmised the quarks have a distribution of position and momentum, like any other particle, and he correctly believed that the diffusion of quark momentum explained diffractive scattering. James Bjorken proposed that point-like partons would imply certain relations in deep inelastic scattering of electrons and protons, which were verified in experiments at SLAC in 1969 [9].

These deep inelastic scattering experiments indicate that the quarks have a confined three-dimensional spatial distribution for their position. In other words, the quarks are not moving with a simple random motion throughout the entire three-dimensional volume of the nucleon. The quarks are not mixing together to form one merged or blended charge. Rather there is a physical separation of the probability distribution of the quarks, as illustrated in Fig. 2.

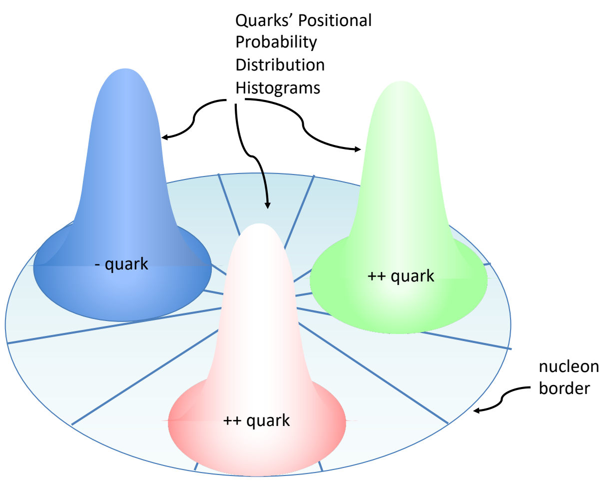


Fig. 2. This is an illustration of histograms for the probability distributions of three quarks. The probability distributions are not superimposed on one another. Rather the quark colors and electric charges are distinct and separate. The colors in this figure represent the RGB colors of the chromodynamic force.

The quarks exist as individual and definitive particles confined within the nucleons, with each quark having a relative charge distribution in three-dimensional space, separate and distinct from the other quarks. When considering the quantum wave-like qualities of a quark inside a nucleon, this means that the potential energy well of a quark is not coincident with the boundaries of the nucleons. Instead, the energy well of a quark is believed to confine each quark in a more restrictive manner.

The quarks do not give the proton or neutron the characteristic of homogeneous charge. Similarly, the quarks do not blend together to form a neutral chromodynamic "color" inside a nucleon. They do not move in pure random motion throughout the entire volume of the nucleon. This false hypothetical situation is illustrated in Fig. 3, as a comparison to Fig. 2.

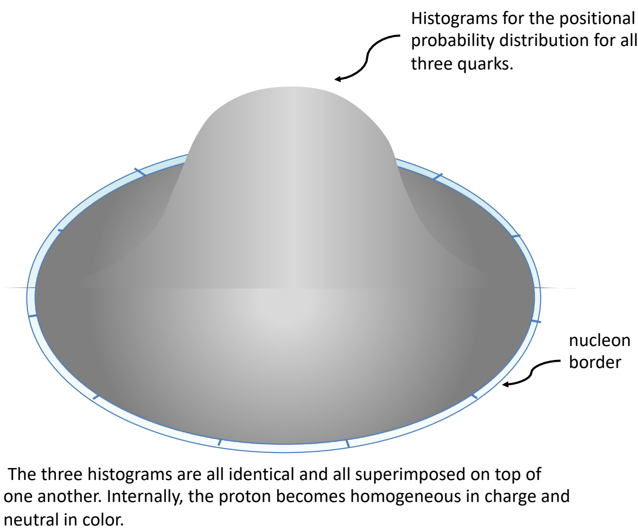


Fig. 3. This is an illustration of incorrect and unrealistic probability distributions of the three quarks, all superimposed on one another, and coincident with the boundary of the nucleon. The nucleon would become homogeneous in charge and neutral in color. This hypothetical situation is known to be incorrect experimentally.

The three quarks are <u>not</u> uniformly distributed within the confines of the nucleon boundary, and this is an experimentally confirmed fact [10].

> "The neutron's non-zero mean charge radius is a direct consequence of the asymmetric distribution of the positively-charged (up) and of the negatively-charged (down) quarks in the system, a consequence of the non-trivial quark gluon dynamics of the strong force."

Thus, the quarks are <u>not</u> as shown, hypothetically, in Fig. 3. Otherwise the neutron would have a charge radius of zero. Experimentally, it does not. The three quarks are not homogeneously and symmetrically distributed inside a nucleon.

2.2. Comparing and Contrasting the Quantum Chromodynamic Force, Nuclear Force, and Electromagnetic Force

The Quantum Chromodynamic Force is much stronger than the Nuclear Force, by several orders of magnitude. However, an actual definitive measurement of the strength of this force has not been made, because particle physicists have been unable to separate the quarks from a nucleon. The Quantum Chromodynamic Force is thought to be similar to the force of a spring—the further it is stretched or compressed from its neutral point, the stronger it pulls back toward its neutral position. Presently there are numerous models of what comprise the mass of a nucleon. These models of the nucleon attempt to describe the number of quarks inside a nucleon, what components comprise the mass of a nucleon, and what components give a nucleon its spin. Some models claim there are several hundred non-valence quarks and gluons inside a nucleon. For the Electromagnetic Model of the Nuclear Force, only the three valence quarks are considered. The Quantum Chromodynamic Force is the force <u>inside</u> of the protons and neutrons, and it confines and contains the quarks therein.

The Nuclear Force is defined to be the force <u>outside</u> of the protons and neutrons, and it holds the protons and neutrons together in an atomic nucleus. The Residual Color Force is one of the many models of the Nuclear Force, and it is somewhat related to the Quantum Chromodynamic Force, in that they are both based on quark color. Other characteristics, however, are different for these two forces. The Residual Color Force and the Quantum Chromodynamic Force have different mediating particles, different ranges, different magnitudes of strength, and different regions—inside or outside the nucleon—for their active domains.

The Quantum Chromodynamic Force of the quarks and the Electromagnetic Force of the quarks have different characteristics as well, described below.

The Quantum Chromodynamic Force is dependent upon the color of the quarks. The Quantum Chromodynamic Force is a very confining and powerful force, and it controls and confines the positions of the quarks. The Quantum Chromodynamic Force abruptly neutralizes itself, falling to zero near the edge of the nucleon. Therefore, inside a neutron or proton, the color of a quark strongly affects the other quarks inside that same proton or neutron. However, the color of a quark does <u>not</u> affect quarks that are contained within <u>other</u> protons or neutrons.

Conversely, the Electromagnetic Force is a long range force, and it does not abruptly neutralized itself at the edge of the nucleon. Rather the Electromagnetic Force continues outside of the nucleon, completely unaffected by the nucleon boundary. The Electromagnetic Forces of the quarks, therefore, continue to have an influence on all of the other quarks within the entire atomic nucleus. The electromagnetic charges of the quarks <u>do not</u> contain and control the quarks <u>inside</u> the proton or neutron. The electromagnetic charges of the quarks are felt <u>outside</u> of the proton and neutron. Therefore, the Electromagnetic Forces can attract or repulse the other quarks in the atomic nuclei. That attractive or repulsive force depends on the polarity of the associated electric charges and magnetic dipoles of the quarks involved.

As a result, a quark inside of one nucleon feels the electromagnetic influences of a quark from another nucleon, via an internucleon quark-to-quark electromagnetic force. Those two quarks are contained and confined within their two different respective nucleons by the Quantum Chromodynamic Force. However, outside of their respective nucleons, these same two internucleon quarks are influenced by each other due to the electromagnetic forces.

2.3. The Deformation Parameter

The deformation parameter is a measure an atomic nuclide's non-spherical shape. Fig. 4 shows all the experimentally known deformation parameters. If the Shell Model were correct, then all of the deformation parameters seen in Fig. 4 should be less than one, indicated by the blue line. However, they are much higher. (All data for Fig. 4 was extracted from reference [11].)

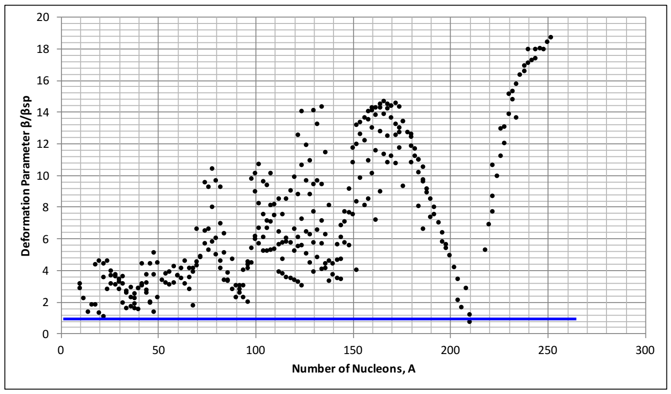


Fig. 4. The ratio of the experimental nuclear deformation parameter divided by the predicted deformation parameter of the Shell Model, indicated by the blue line at the value 1.

The deformation parameters are much larger than the Shell Model can explain, as shown in Fig. 4. This is true of electric quadrupole moments as well. The distortion from a spherical shape does not appear in just a few isolated regions of the nuclear table; rather it covers the entire range of the table. These large experimentally-measured deformation parameters for the vast majority of atomic nuclides invalidates the concept of spherical atomic nuclides, in direct conflict with any model that pre-assumes a spherical shape.

When researchers interpret the scattering data from an experimentally probed atomic nucleus, the shape of the atomic nucleus is pre-assumed to be a spherical shape. Then, for this pre-assumed spherical shape, the best value of its radius is forced-fit to the data, without any consideration of a possibly different shape [12, 13]. The interpretation of the electron scattering data only considers the electric monopole moment of the target—in other words, it considers only a point-like electric charge of the target. This monopole scattering data is then normalized to force-fit the charge of the atomic nuclide into the shape of a sphere, based on the densest packing radius of spherical protons and neutrons. A Gaussian curve is added to the sphere as the "skin" of the atomic nuclide. Thus, regardless of the actual shape or density of the atomic nuclide, the manipulated forced-fit normalized data makes the nucleus appear to be a dense spherical shape with a Gaussian skin. Even the so-called "model-independent" interpretations of scattering data still assume a spherical shape [14]. The experimental data is force-fit to be spherical--to match the models. And most of the nuclear models assume a spherical shape--to match this manipulated data. The misconception of a spherical atomic nucleus is thus perpetuated.

2.4. The Concept of a Nuclear Bond Similar to an Atomic Bond

For the Electromagnetic Model, the nuclear bond is between two quarks forming the bond, an up quark from one nucleon and a down quark from another nucleon. This bond between the quarks lowers the overall energy of the nucleus. The concept of a nuclear bond is similar to the electronic bonds between the atoms of a molecule. In electronic bonding of atoms, one atom cannot bond to an indefinite number of other atoms. Similarly, one nucleon cannot bond to an indefinite number of other nucleons. Rather the number of bonds is limited by the number of quarks available for bonding. Thus with only three valence quarks, each nucleon can bond only to three other nucleons.

2.5. The Limitation of the Electromagnetic Force

Prior to the 1960's, the proton was incorrectly thought to be homogeneously charged and to have a radius of about 1.2 femto-meters. As a result, the strongest electrical energy between two such protons was thought to be 9.62×10^{-14} joules. The experimental energy required to free a single nucleon from an atomic nucleus is much larger than 9.62×10^{-14} joules. For this reason, the Nuclear Force was believed to be much stronger than the Electromagnetic Force. As a result, this incorrect concept of a homogenously charged elementary proton created an erroneous limitation for the maximum strength of the Electromagnetic Force. Unfortunately, this incorrect concept is still often perpetuated.

Mathematically, in the limit as the distance goes to zero, the electromagnetic energy goes to infinity. Hence, the electromagnetic energy can be extremely large if the quarks are close enough to each other. Since the charge of the nucleons resides within the quarks, a quark from one nucleon can bond electromagnetically with a quark in another nucleon, and the resulting force between two such quarks can be extremely large—indeed, large enough to be the Nuclear Force.

If the minimum internucleon quark-to-quark distance (defined as the minimum distance of one quark in one nucleon to another quark in another nucleon) is 0.2111 femtometers, and if the magnetic force between the quarks is also properly included into the calculation, the value for the energy of an electromagnetic bond is 1.18014 x 10^{-12} joules, which is 7.36584 MeV.

2.6. Nuclear Bonds and the Quantum Hard-core Repulsion

The Pauli Exclusion principle states that nucleons cannot overlap in their physical dimensions; this is also known as the hard-core repulsion. For this reason, a pair of double-bonded nucleons, defined as two nucleons bonded twice to each other, is not allowed. Similarly a triple-quark bond, defined as three quarks attempting to bond together, is not allowed. These conditions are illustrated in Fig. 5.

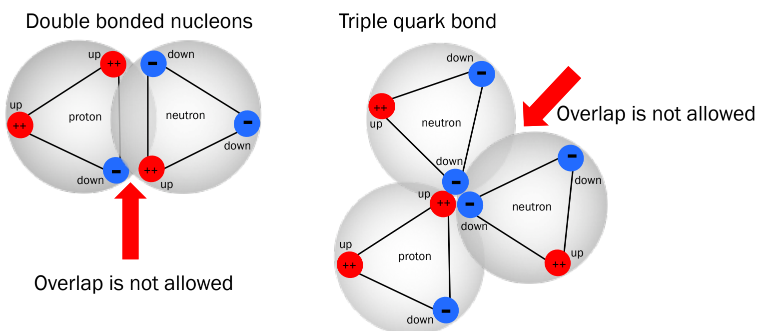


Fig. 5. Left is an illustration of a proton double-bonded to a neutron. Right is an illustration of a triple-quark bond.

2.7. Summary of the Electromagnetic Force within the Nucleon

- The electromagnetic force is valid inside the atomic nucleus.
- The electric charge and the magnetic moment of the protons and neutrons are contained within the quarks.
- Within a single nucleon, the three quarks have a spatial quantum probability distribution relative to each other. (An equilateral triangle is assumed for simplicity.)
- There are three possible bonds per nucleon, one for each quark.
- An up quark and a down quark, one from two different nucleons, are needed for one bond.
- The lowest electromagnetic energy configuration is assumed for the ground state.
- The kinetic energy of the quantum angular momentum of the nucleus [15, 16] is also properly taken into account.
- There is a minimum distance between two quarks of two different nucleons, consistent with the hard core repulsion.
- The hard core repulsion of the nucleons prevents a nucleon from bonding more than once to another nucleon. Two nucleons bonded twice to each other are a "double-bonded nucleons". Double-bonded nucleons are not allowed.
- A quark that attempts to bond to more than one other quark is engaged in a "triple-quark bond". This triple-quark bond is not allowed.

Once the lowest energy configurations are determined, there remains only one parameter to be selected for the best fit to the binding energy data--namely, the "minimum quark-to-quark distance". This model has only one variable to determine, whereas the Weizsäcker formula uses five empirically-fit parameters and a conditional logic statement to achieve its mathematical curve-fitting. The electromagnetic model of the Nuclear Force is able to get comparable results with only one parameter.

Over a thousand different configurations for different atomic nuclides have been computer modeled using this method to calculate the binding energy based on electromagnetics. These include stable and unstable atomic nuclides; large, medium, and small atomic nuclides; and ground and excited states. These detailed calculations have been done for every atomic nuclide shown in Fig. 6. Each atomic nuclide is placed in the lowest energy configuration; then the electromagnetic energy of the configuration is calculated, and the binding energy is determined.

The value for the minimum distance between quarks is 2.11082 x 10^{-16} meters. The resulting binding energy curve is shown in Fig. 6. The top pane shows all the points from A=2 to A=208. The lower pane shows only the points from A=2 to A=60, for ease of viewing the details. As can be seen, there is excellent agreement in the reproduction of the experimental data.

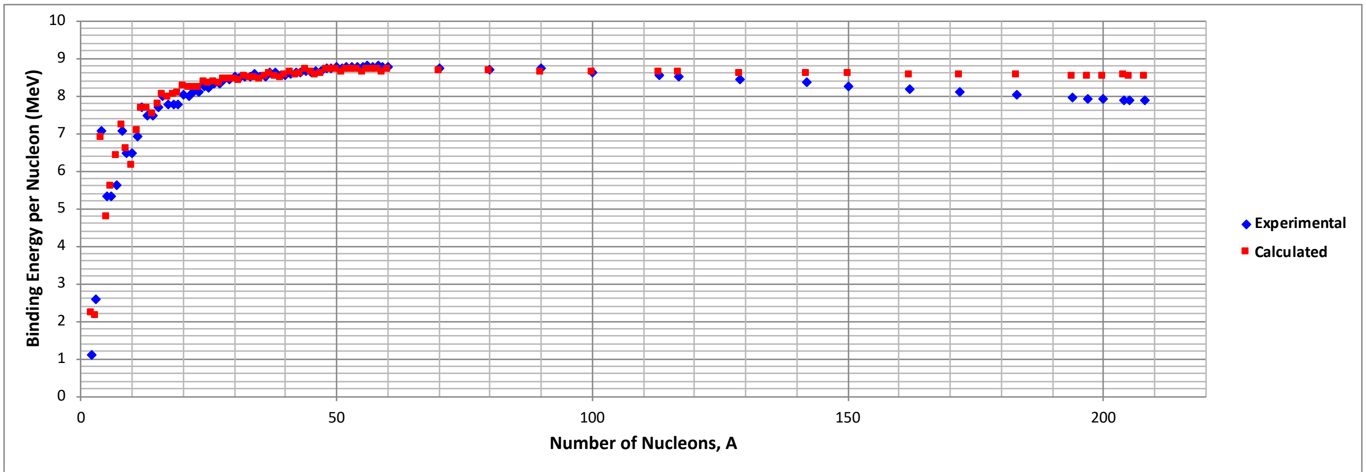


Fig. 6a. Binding energy per nucleon versus A, for both calculated and experimental data, from A=2 to A=208.

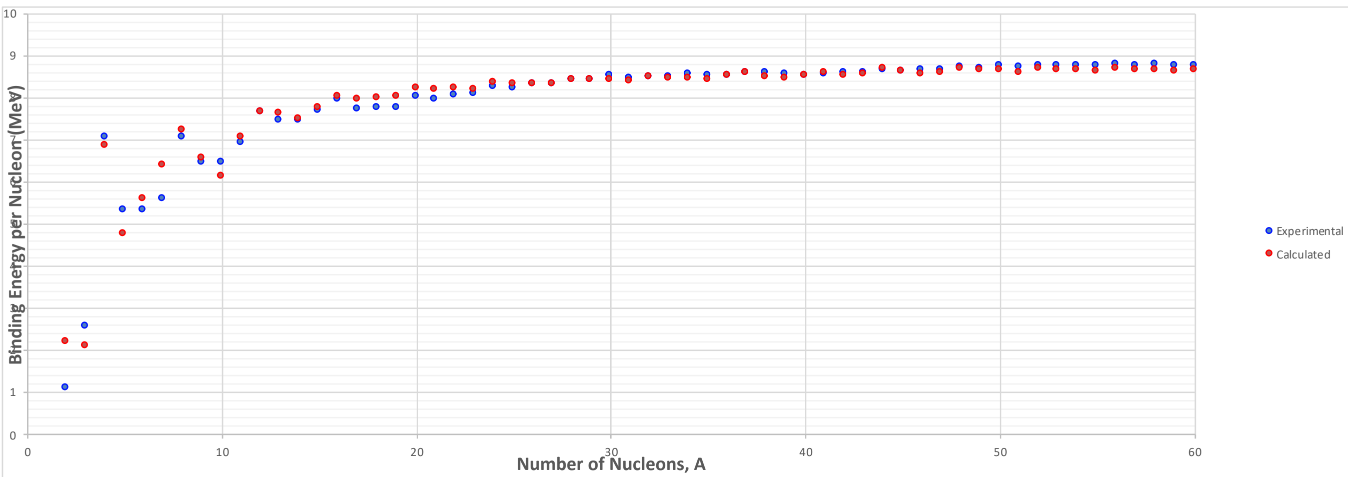


Fig. 6b. Binding energy per nucleon versus A, for both calculated and experimental data, showing detail for the smaller atomic nuclides, from A=2 to A=60.

Most of the atomic nuclides fall within a one or two percent error. For the atomic nuclides with large A, the predicted downward slope is not as severe as is experimentally observed. For these larger atomic nuclides, the worst error is 8.32% for ^{204}Pb.

No other theoretical model has been able to achieve such a tight prediction of binding energy with only *one* parameter. This is an unprecedented success for the Electromagnetic Model in obtaining such results. The numbers for the calculated binding energy are generated from the computer simulation of each atomic nuclide using the electromagnetic equations. (Experimental data is extracted from reference [17].) Using electromagnetic equations, atomic nuclides as large as copernicium ^{283}Cn have been easily modeled.

This model asserts that the electromagnetic attraction of the up-to-down quarks is the force that holds the protons and neutrons together in an atomic nucleus. This electromagnetic energy and the specific configurations of the atomic nuclides are what give the atomic nuclides certain behaviors--such as binding energy, large quadrupole moments, excited states, and particle decay. Thus, the Nuclear Force is actually an Electromagnetic Force.

3. Brief Review of Part II

In the part II of this series, the lowest energy configurations of the atomic nuclei are mathematically determined, using the electromagnetic properties of the quarks. A pattern emerges for the ground state of atomic nuclides. Both stable and radioactive atomic nuclides are examined. (Readers who are familiar with part II can proceed to section 5.)

3.1. The Assumed Shape of the Protons and Neutrons

In order for the energy of the internucleon up-to-down quark bond to be calculated, the distance and angle between the two bonded quarks must be determined. To make this determination, the general shape of the proton and neutron must be known. Unfortunately, particle physicists do not know the exact intrinsic shape of the proton or neutron. Experimentally and theoretically, there are several conflicting concepts about their shapes, but the overall consensus is that protons and neutrons are not spherical.

The most likely shape is an oblate ellipsoidal [18, 19, 20].

As a result, some assumptions about the shape are necessary in order to proceed. For this paper, these assumptions will be as few as possible and as simple as possible. Consistent with the observations, an oblate ellipsoid shape for the proton and neutron is assumed, with the quarks in an equilateral triangle inside that ellipsoid. This is shown in Fig. 7.

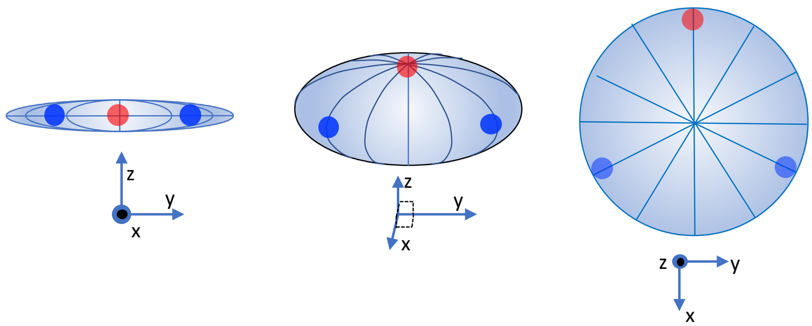


Fig. 7. An oblate ellipsoidal neutron, with three quarks in an equilateral triangle, shown in three different viewpoints.

A different kind of triangle could be assumed, such as an isosceles triangle or a scalene triangle; however, those are not the simplest assumption, since they involve more variables to specify the shape. Should it be determined, in the future, that the Expectation Value of the positional probability function of the quarks are arranged in a different type of triangle, it would cause only minor variations in the calculated binding energy curve. In this series of papers, an equilateral triangle is used, to reduce both the number of assumptions and the complexity of the assumptions. It is assumed that the proton and neutron are disk-shaped with a finite thickness (in other words, a non-infinitesimal thickness). This finite thickness prevents double-bonded nucleons, triple-quark bonds, and also the stacking the nucleons one atop of another. No other assumptions are made concerning the intrinsic shape of the protons and neutrons.

3.2. The Cause of Clustering

Clustering is caused by the Electromagnetic Force putting the atomic nucleus in its lowest energy configuration. The lowest energy configuration is one that:

- Maximizes the number of up-to-down quark bonds. This is because the Electromagnetic Forces within the nucleus will attempt to make as many bonds as possible and allowable.
- Spreads out the net positive charge as far as possible, while still maintaining the bonds. This will reduce the Coulomb energy.
- Situates any negative charge, such as an unbonded down quark, in a position what would otherwise be the highest concentration of positive charge. Again, this will reduce the Coulomb energy.

When these three considerations are taken into account, the resulting nuclear shape is a chain-like structure of segments. A chain-like structure utilizes the maximum number of allowed quark-to-quark bonds, and also allows the charge to be spread out as much as possible, while maintaining the bonds. Any excess negative charges are inserted into the chain-like structure to mitigate and spread out the net positive charge.

3.3. The Determination of the Lowest Energy Configurations

The lowest energy configurations of the atomic nuclei are determined by using the laws and equations for electromagnetics and angular momentum, as applied to the quarks within a structured nucleus.

For every atomic nucleus in this paper, the position of each quark is defined in a matrix with xyz spatial coordinates and an electric charge value of either -1/3 or +2/3 of an elementary charge. The value of the magnetic moment, for either the up or down quark, and the three-dimensional vector direction of each magnetic moment are also included in the matrix. Based on the physical constraints of the configuration, a determination is made as to whether the magnetic bond is stacked, angled, or side-by-side.

The various possible lowest energy configurations are tested to determine which configuration is the lowest state. As a result, every atomic nucleus in this paper is in its lowest energy state, in accordance with the rules for electromagnetic and spin energies. Also, the configurations are in accordance with the quantum considerations that double-bonded nucleons or triple-quark bonds are not allowed.

The atomic nuclides from hydrogen ^{2}H up to capernium ^{283}Cn are examined for the lowest energy state of the atomic nuclides, including radioactive nuclides. For this lowest energy configuration, a pattern emerges from ^{12}C upwards.

The protons and neutrons bond together to form the various basic segments; these segments subsequently bond together to form the larger atomic nuclides. For the lowest energy configuration, the basic segments bond together in a chain-like configuration, in strong agreement with the findings of the Cluster Model.

For stable atomic nuclides, the alpha segment predominates. This predilection for the alpha segment is due to the three possible internucleon up-to-down quark bonds that each proton or neutron can form. When there are only three possible bonds per nucleon, the alpha segment is the lowest energy configuration for two protons and two neutrons.

For stable atomic nuclides with $A \geq 12$, a star segment, which has two unbonded down quarks, is in the center of the configuration. The triton segment is included in all stable nuclides with odd Z. For stable atomic nuclides with $N > Z$, the extra neutrons are positioned in the location that would otherwise have the highest positive electric charge density. This allows the extra neutrons, with their negatively-charged unbonded down quarks, to help mitigate and spread out the net positive charge of the nucleus. For stable atomic nuclides smaller than bismuth ^{209}Bi, the excess neutrons are positioned between the alpha segments.

For radioactive atomic nuclides larger than ^{209}Bi, the extra neutrons are forced to double up between the alpha segments. There are no stable nuclides with doubled-up neutrons in their configuration. For radioactive nuclides above the nuclear drip line, the net positive charge of the nuclide is spread out as much as possible, in the lowest energy state. For radioactive nuclides below the nuclear drip line, the excess neutrons, with their negatively-charged unbonded down quarks, are spread out as much as possible, for the lowest energy state. The chain-like configurations may also curve or curl—to form a helix shape, for example—depending on the exact shape of the oblate ellipsoid of the protons and neutrons.

4. Brief Review of Other Models of the Nuclear Force

A brief review of other pertinent models of the Nucleon Force is given here. For a more comprehensive review of Nuclear Force Models, see [21].

4.1. Overview of Other Models

At present, there is no complete model that can describe all of the complexities of the Nuclear Force. Indeed, this missing theoretical explanation is listed as being one of the most important unanswered questions of physics. For example, the near instantaneous instability due to the Nuclear Force, which is on the order of zepto-seconds, cannot be adequately explained by the previous theories of the Nuclear Force. The previous theories are not able to provide a clear answer of why such an extreme instability occurs, especially in the smaller nuclides. There are a number of models of restricted validity, each of which can explain only a limited range of nuclear behavior. A successful model of the Nuclear Force should be able to give a reasonable account of the more salient nuclear behaviors; however, the current state of the theory for the Nuclear Force is simply a study of the various models, with no one single model being able to explain the many complexities of nuclear behavior.

4.2. Liquid Drop Model

The Weizsäcker formula [22] is a mathematical equation used to curve-fit the experimental binding energy data. This formula is also known as the semi-empirical mass formula. It uses five parameters and conditional logic to obtain the best fit to the experimental binding curve. Although this curve-fitting formula is not a model *per se*, it is used in conjunction with the Liquid Drop Model.

In the Liquid Drop Model, which was developed in 1929, the nucleons bind to their closest neighbors, as in a drop of liquid. This concept is based on the empirical data of the binding energy curve, for which the binding energy per nucleon is relatively constant—a behavior that is caused by the limited number of times a nucleon can bond to other nucleons. The Liquid Drop Model assumes the nucleus is spherical. When using the curve-fitting Weizsäcker formula, the Liquid Drop Model can predict the experimental binding energies to within a few percent. The Liquid Drop Model does offer a conceptual description for the behavior of spontaneous fission, but it cannot offer a mathematical explanation. The Liquid Drop Model does not consider excited states, large quadrupole moments, or other types of nuclear particle decay.

4.3. Shell Model

The nuclear Shell Model was first hypothesized in 1932 and further developed in 1949 [23, 24]. It is a concept that mimics the electronic shell structure of atoms. The model attempts to explain the minor deviations that were observed, in the 1940's, between experimental data and the Weizsäcker formula. At that time, when the limited amount of experimental data were compared to the Weizsäcker formula, inconsistencies were observed at the so-called "magic" numbers. However when utilizing the current up-to-date data, these inconsistencies are revealed to be minor or related to relatively obscure behavior [25].

To get these same "magic" numbers theoretically, the Shell Model starts from a potential energy well called the "Woods-Saxon" potential. A spin-orbit coupling term is then added, with a number of parameters empirically set in order to duplicate the observed magic numbers.

The Shell Model uses the Pauli Exclusion Principle to predict spins of the various atomic nuclides; however, it can only do this accurately if the Nilsson terms are included [26]. The Nilsson terms are often referred to as "spaghetti plots" due to their complicated natures. From the Nilsson terms, two or three different parameters are selected for each individual nuclide. Only when these empirically-selected terms are included is a prediction of the nuclear spins achieved [27]. The Shell Model does not explain any type of particle decay or large quadrupole moments.

4.4. Independent Particle Models

There are several Independent Particle Models [28] of the Nuclear Force. These models hypothesize that nucleons are confined inside a three-dimensional potential energy well, and that the nucleons do not interact with each other. It assumes, rather, that the nucleons move independently of one another, with no collisions or interacting forces between nucleons. This concept is employed to make the mathematics of the Schrödinger equation easier to solve. However, it is an unrealistic concept for a densely-packed spherical nucleus.

Depending on the atomic nuclide being studied, the Independent Particle Models alter the shape of the three-dimensional potential energy well, by using numerous empirically selected variables, thereby allowing the models to predict the excited states of the nuclide. If the potential energy well is modeled to be a three-dimensional ellipsoid, then these models can also replicate large quadrupole moments. However, these Independent Particle Models do not attempt to explain the binding energy curve, nor do they attempt to explain any form of particle decay.

4.5. Collective Model

The Bohr-Mottelson model is also known as the Collective Model [29, 30]. This model is a combination the Liquid Drop Model and the Shell Model. The Bohr-Mottelson model is a general description of nuclear structure that considers the total state of motion as a superposition of two basic components of motion. Such a description is regarded as a generalization of the Shell Model, in which the nuclear field is no longer considered to be time independent. Rather the nuclear field is considered to be a dynamic variable, in that the net nuclear potential undergoes deformations away from a spherical well. This variation of the nuclear field is linked with the vibrating shape of the nucleus. By using this dynamically-variable nuclear field, the Bohr-Mottelson model can more closely estimate magnetic dipole moments and large electric quadrupole moments.

4.6. Collective-Motion Model

The Collective-Motion Model [31] is more of an experimental observation than a model. Experimentally-measured spin energies of the nucleus indicate that the nucleus is not a collection of independent particles moving randomly with respect to each other, but rather the rotational moment of inertia of the nucleus is similar to a rigid structure. This behavior is referred to as the apparent collective motion of the nucleus.

4.7. Alpha Cluster Model and the Clustering Model

The Alpha-Cluster Model was developed in 1938 [32] to explain the stronger binding energy that is experimentally observed for nuclei with an integer number of alpha segments. When used in conjunction with the Alpha Decay Model [33], a mechanism can describe the alpha decay half-life seen in the largest nuclides.

The Alpha-Cluster Model [34] was extended beyond the alpha nuclei, and renamed the Clustering Model, with much recent research occurring in the field of a cluster-type structure. These clusters can be thought of as building blocks or segments, linked together to form a chain-like structure. Recently, there has been much experimental and theoretical evidence that atomic nuclides are indeed made of clusters of alpha particles, as well as other building blocks. The recent research regarding the Clustering Model has shown that clustering structures exist within nuclei, confirming the concept of nuclear structure [35, 36, 37, 38, 39].

These chain-like nuclear structures are illustrated graphically in Ikeda diagrams [40], as shown in Fig. 8.

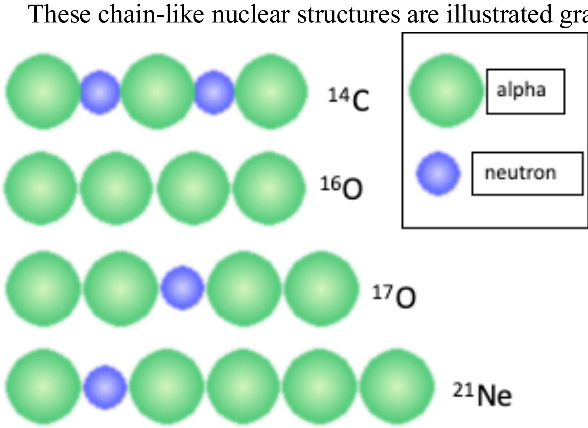


Fig. 8. Ikeda diagrams of four simple atomic nuclides

As can be seen from the Ikeda diagrams, the nuclear segments form chain-like configurations to create the atomic nuclides.

4.8. Residual Color Model

The Residual Color Model (also known as the Residual Chromodynamic Model or the Residual Strong Force Model) is a theoretical model of the Nuclear Force, which postulates that the exchange of virtual pi-mesons is the binding force between nucleons [41]. In this model, the Nuclear Force is thought to be related to the Quantum Chromodynamic Force, but with four notable exceptions--it acts outside the nucleons rather than inside the nucleons, it is a short range force, it has different mediating particles, and it has a significantly lower strength. The Quantum Chromodynamic Force is the force that acts inside the nucleons to confine the quarks. Conversely, the Residual Color Force is theorized to occur outside the nucleons. This Residual Color Force bonds a quark in one nucleon to another quark in another nucleon, thereby binding the two nucleons together. In other words, the Residual Color Force is an internucleon quark-to-quark bond between two quarks of different colors in two different nucleons. When a bond is made between these two different quarks in two different nucleons, the two nucleons themselves are thus bonded. The Residual Color Model asserts that each nucleon is bonded to its nearest neighbors, similar to the Liquid Drop Model. This model is one of the few models of the Nuclear Force that takes quarks into consideration, making it consistent with the "Standard Model" of particle physics.

The Residual Color Model uses the Schrödinger equation and the wave-like properties of the quarks, combined with Lattice Quantum Chromodynamics and chiral perturbations. It is mathematically difficult to derive this residual Nuclear Force, even for a system of only two nucleons [42]. This difficulty arises because each nucleon consists of three quarks, such that the system of two nucleons is a six-body problem, with each quark affecting the potential energy wells of other quarks. Only the smallest atomic nuclides have been simulated with the Residual Color Model; however, those simulated results had significantly large errors. Thus, this model does not answer questions regarding nuclear behavior--such as particle decay, excited states, binding energy, or quadrupole moments.

It should also be noted that in the computer simulations for the Residual Color Model, the mass of the quarks is inflated to extremely large values, several orders of magnitude larger than the theoretical mass of a quark. This extreme mass inflation of the quarks is done in order to aid in the convergence of the computer simulations, since simulations with small quark masses do not converge to a solution. Only when the larger inflated quark masses are used will the simulations converge. (Note: computational non-convergence is often times an indication that the system being simulated is itself unstable; implying that if the simulated system were to be created in physical form somehow, then it would similarly be unstable in its physical reality.) Also, the use of extremely inflated quark masses side-steps what would otherwise be a violation of Copenhagen interpretation of the Heisenberg uncertainty principle.

Fortunately, there is some validity to this extreme mass inflation of the quarks, related the quantum Constituent Quark Model--a model not of the Nuclear Force, but of what constitutes the internal structure of the protons and neutrons.

4.8.1. The Residual Color Model and the Constituent Quark Model

In the Constituent Quark Model, the protons and neutrons consist of three constituent quarks, that are "dressed" with gluons and quark-antiquark pairs, thereby significantly increasing the mass of the quarks. This analysis is based on estimates for binding energy of the quarks inside the nucleon. In order to calculate the constituent quark masses, the quantum chromodynamic binding energy of the quarks is added to the rest mass of the nucleon; this would give the actual masses of the quarks, if they could be isolated from each other.

Unfortunately, the quantum chromodynamic binding energy of the quarks inside a nucleon is unknown; however, it is at least as large as the amount of energy required to make the nucleon spontaneously emit a meson. (The actual binding energy could be much larger.) From this known minimum estimate of binding energy, the minimum value for the constituent-quark mass can then be determined, giving the results that each "dressed" quark has a mass between 300 and 400 MeV/c^2 (between 5.3E-28 kg and 7.13E-28 kg.) The model-dependent estimates for the up and down quarks are 336 MeV/c^2, (6.0E-28 kg) and 340 MeV/c^2 (6.06E-28 kg), respectively. [43]. A simple calculation, not model dependent, shows that the minimum mass of the quarks is 359 MeV (6.4E-28 kg) [44]. Thus, the inflated quark masses used for the Residual Color Model are actually consistent with the minimum values calculated for a dressed quark.

4.8.2. Indistinctive Nucleons Inherent in the Residual Color Model

The Residual Color Force postulates that the Nuclear Force is a residual effect of the color of quarks. The Residual Color Force is postulated to be an exchange of pi-mesons between the quarks of different nucleons, creating an internucleon force between two quarks. However in terms of color, there is no difference, for the theoretical Residual Color Model, between a proton and a neutron. Unfortunately, this is a significant problem for the Residual Color Model, a problem which has been revealed in the complex simulations that have been done on this model. Since there is no difference between a proton and a neutron in terms of color, any set of isobars would have the same binding energy and behavior. Experimentally, this is a completely erroneous concept. However, these are the results from the complex computer simulations of the theoretical Residual Color Model [45].

4.8.3. Slight Conceptual Change to the Internucleon Quark-to-Quark Bonding

One simple conceptual improvement to the hypothesis of the Residual Color Model makes an extremely interesting difference in the understanding of the Nuclear Force. If the Nuclear Force is dependent upon the up/down flavor of quarks, rather than on the color of the quarks, then many problems are resolved, and many questions can immediately be answered [46].

The concept is that a down quark is attracted to an up quark, but not to another down quark. Similarly, an up quark is attracted to down quark, but not to another up quark. The Nuclear Force is then simply the attraction of the up quark in one nucleon to the down quark in another nucleon—an internucleon force between two quarks. As with the theoretical Residual Color Model, when a bond is made between these two different quarks in two different nucleons, the nucleons themselves are thus bonded, and the nucleus is at a lower overall energy (higher binding energy) than the sum of the constituent parts.

This simple change of concept, that the Nuclear Force is dependent upon the up/down polarity rather than the color of the quark, easily explains why a system of 6 protons and 6 neutrons is at a lower energy (and at a higher binding energy) than 5 protons and 7 neutrons. It is because 6 protons and 6 neutrons can form one bond for every pair of up-down quarks. There are 18 up quarks and 18 down quarks in the system of 6 protons and 6 neutrons, thus there could be 18 pairs of up-down quarks, and 18 bonds. However, for 5 protons and 7 neutrons, there are 19 down quarks and 17 up quarks, thus only 17 bonds could be formed. The nucleus with 5 protons and 7 neutrons would be at a higher overall energy (and at a lower binding energy) than the system of 6 protons and 6 neutrons. With this simple change, we can also now understand why a nucleon can only bond to its nearest neighbors. Specifically, a nucleon can only bond to three other nucleons because it only has three quarks available for bonding. The quarks involved in the bonding must be of opposite up/down polarity.

This concept also explains the first term of the Weizsäcker formula; it is because there is a limited number of bonds for each nucleon in the atomic nuclide. Also, this simple change of concept immediately explains the asymmetry force of the Weizsäcker formula, because the greatest number of bonds occurs when there are equal numbers of up quarks and down quarks, which in turn means an equal number of protons and neutrons. The Coulomb energy term of the Weizsäcker formula is also easily explained as being related to the electrical energy of the net positive charges of the up and down quarks.

Furthermore, due to the internucleon up-to-down quark bonding with only three possible bonds per nucleon, there is a predilection for the alpha segment, made of two neutrons and two protons, to form. This predilection for alpha segment formation, then, explains the pairing term in the Weizsäcker formula, which gives a higher binding energy (meaning a lower overall energy) when N and Z are even. The highest binding energy occurs when there are even numbers of protons and even number of neutrons, forming into alpha segments. The "surface" term of the Weizsäcker formula is related to the two unbonded up quarks on the ends of the chain-like configuration, as well as the two unbonded down quarks in the middle star segment.

Thus, for this one simple change—that the internucleon quark-to-quark bond is related to up/down flavor rather than color—we can now understand the five terms of the Weizsäcker formula as being a direct results of the internucleon up-to-down quark bonding. The simple and quick calculations for this [46] show that this concept of internucleon up-to-down quark bonding reproduces the binding energy curve surprisingly well. Such good replication, achieved with very straightforward and simple mathematics, points toward the correctness of this concept of internucleon up-to-down quark bonding.

Recall that an up quark has a positive electromagnetic charge, and that a down quark has a negative electromagnetic charge. When the attractive force is assumed to be the electromagnetic force between the up and down quarks, as is done in Parts I and II of this series, then a more rigorous and detailed calculation can be done, as previously shown in Fig. 6, with excellent results. Using the concept of up-to-down quark bonding, the Electromagnetic Model conceptually explains all of the five terms of the Weizsäcker formula. This is indeed why the Electromagnetic Model is able to duplicate the binding curve so accurately.

5. Quarks and the Copenhagen Interpretation of the Heisenberg Uncertainty Principle

The original derivation of the Heisenberg uncertainty principle states that if the two variables, position and momentum, are measured simultaneously, then the uncertainty of the measurement must be greater than $\hbar/2$, shown in Eq. (1).

$$\sigma_x \eta_p \geq {}^{\hbar}/_{2} \tag{1}$$

where σ_x is the noise in the error of the measurement of position, and η_p is the resultant disturbance in the momentum as a result of the measurement [47]. This equation and these definitions of the variables represent the original form for Heisenberg uncertainty principle. More advanced and accurate uncertainty principles, such as the Osawa uncertainty principle [48] and the Robertson-Schrödinger uncertainty principles [49, 50] have since refined this equation, and are considered to be more accurate than the Heisenberg uncertainty principle.

The Osawa uncertainty principle is best described by a quote from Osawa [48].

> The Heisenberg uncertainty principle states that the product of the noise in a position measurement and the momentum disturbance caused by that measurement should be no less than the limit set by Planck's constant, hbar/2, as demonstrated by Heisenberg's thought experiment using a gamma-ray microscope. Here I show that this common assumption is false: a universally valid trade-off relation between the noise and the disturbance has an additional correlation term, which is redundant when the intervention brought by the measurement is independent of the measured object, but which allows the noise-disturbance product much below Planck's constant when the intervention is dependent.

In the Robertson-Schrödinger Uncertainty Principle, the noise-disturbance product in Eq. (1) can be stricter than originally conceived by Heisenberg, if there are strong correlations in the movements of the quarks. This increased strictness of the Robertson-Schrödinger Uncertainty Principle allows for much larger fluctuations than does the Heisenberg uncertainty value for uncorrelated paths. The same circumstance is also important for the so-called "squeezed" quantum states, in which the fluctuations cannot be smaller than Heisenberg's uncertainty estimate.

Both the Osawa uncertainty principle and the Robertson-Schrödinger uncertainty principle relate to laboratory measurements. As was originally derived and stated by the Heisenberg uncertainty principle, the quantum particle exists in an exact quantum state, but the influence of a measurement causes an uncertainty in the precision of that measurement of that state.

The Copenhagen interpretation, however, does not involve laboratory measurements; rather, it takes the observer out of the situation. Thus according to the Copenhagen interpretation, the influence of an observer or of a measurement is not necessary in order for an uncertainty to exist. The Copenhagen interpretation claims that the existence of a quantum system—whether observed or not—cannot exist in a state that is more precise than the Heisenberg limit. It cannot be known, it cannot be modeled, and it can not exist. Philosophically, this changes the original Heisenberg uncertainty principle from that of Eq. (1) to that of Eq. (2).

$$\sigma_x \sigma_p \geq \hbar/2 \tag{2}$$

where the variables are defined differently. For Eq. (2), σ_x is the standard deviation of the position probability distribution of the particle, and σ_p is the standard deviation of the momentum probability distribution of the particle.

The Copenhagen interpretation of the Heisenberg uncertainty principle is both disputed and controversial [51], with its most famous critics being Einstein and Schrödinger, the two founding fathers of quantum physics. It is not the intent of this paper to debate the veracity of the Copenhagen interpretation of the Heisenberg uncertainty principle. *Rather, it is shown in this paper that there is no violation, and the concepts described in this paper are within the allowable confines of the Copenhagen interpretation of the Heisenberg uncertainty principle.*

An example calculation, Calc. 1, is done to show that there is no violation. First some definitions, explanations, and equations are discussed.

There is a probability distribution of position and a probability distribution of momentum for each quark. These quantum probability distributions are the important considerations for the uncertainty principles. Associated with these probability distributions are the quantum Expectation Values for position and momentum, which are essentially the mean position and mean momentum of a quark. These Expectation Values are used for calculating the energy of the configuration.

The mean value for the position x is a summation of all the possible values that x can take, with each value being weighted according to the probability P(x) of that value occurring. This is then divided by the total number of events, which is the summation of P(x). For a smooth distribution, the summation is replaced by an integral. This is shown in Eq. (3):

$$Mean\ of\ x = \frac{\int_{-\infty}^{\infty} xP(x)dx}{\int_{-\infty}^{\infty} P(x)dx} \tag{3}$$

To relate this to a quantum mechanical calculation, the wave function $\Psi(x,t)$ of the particle must be found by solving the Schrödinger equation with the appropriate boundary conditions. The probability P(x) of the particle is the complex conjugate of the wave function times the original wave function. For the Expectation Value of position, this probability distribution is then multiplied by x, and then integrated within the appropriate boundaries. Given that the overall probability of the particle's position within infinity is unity, the integral in the denominator of Eq. (3) is defined to be one. Thus, the Expectation Value of the position x is shown in Eq. (4):

$$Expectation\ Value\ of\ x = \int_{-\infty}^{\infty} \Psi^*(x,t)\ x\ \Psi(x,t)dx \tag{4}$$

where the denominator, being defined as one, is no longer explicitly necessary for the equation. A similar operation is done to find for the Expectation Value of momentum.

The Expectation Value can be interpreted as the mean value of x, the value expected from a large number of measurements or as a time averaged position. This could also be viewed as the average value of the position for a large number of particles which are described by the same wavefunction. (For example, the Expectation Value of the radius of the electron in the ground state of the hydrogen atom is the average value expected from making the measurement for a large number of hydrogen atoms.)

As mentioned previously, in the computer simulations of the Residual Color Force Model, the mass of "naked" quarks were inflated to avoid non-convergence and to avoid the inherent violation of the Copenhagen interpretation of the Heisenberg uncertainty principle. However, when considering "dressed" quarks, the quantum uncertainty principles are not inherently violated.

That mass inflation is thought to be due to either relativistic speeds or to an additional quantum energy associated with the quarks or gluons. (Note: this inherent quantum energy inside a nucleon is not to be confused with the binding energy of the quarks [44]). If relativistic speeds are involved, then the dressed quarks would also have a significant uncertainty in their momentum probability distribution as well. The Quantum Chromodynamic Force is considered strong enough to confine the quarks inside the nucleus, despite relativistic speeds.

Due to their vibrations and quantum fluctuations, the quarks have a quantum probability distribution in three-dimensional space with respect to each other, as previously discussed in Section 2.1. The quarks also have a quantum probability distribution in their three-dimensional momentum. Thus, the quarks are not in a fixed or static position, relative to each other. Rather there are three-dimensional probability distributions for their relative positions and relative momentums. When the positions are averaged over spacetime, the Expectation Value of the three quarks appear to be in point-like spatial positions, relative to each other. This is shown in Fig. 9.

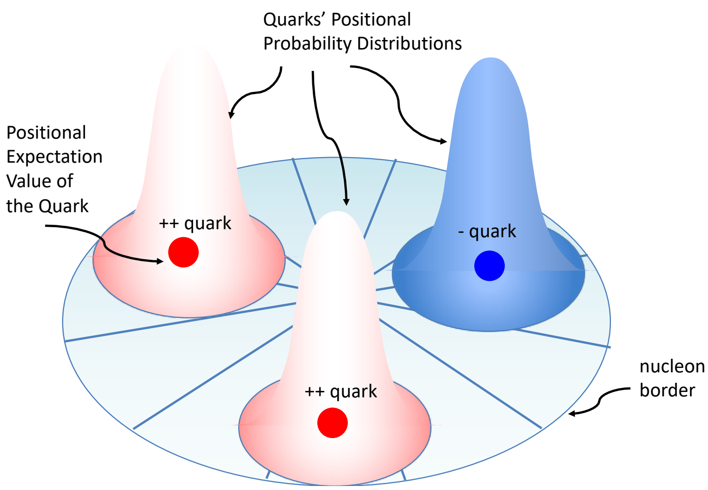


Fig. 9. The positional Expectation Values of the quarks appear to be point-like. (These colors do not relate to the colors of the Chromodynamic Force.)

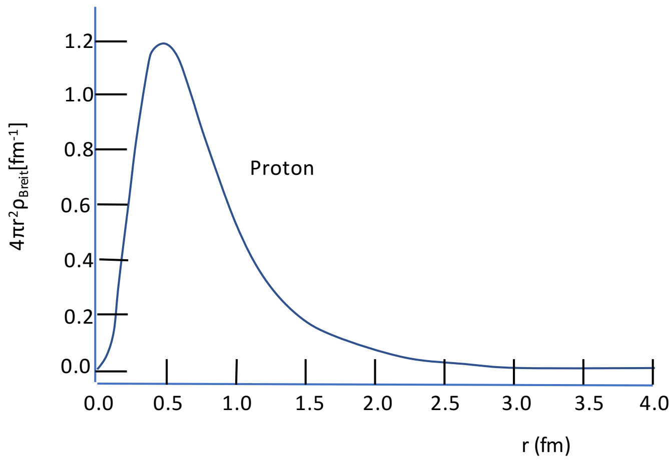
This is an important concept to understand: the Expectation Value of the three-dimensional spatial positions of the three quarks inside a nucleon can be modeled as point-like positions with respect to each other. At any given instant in time, there is an uncertainty in the position of the quarks, and there is an uncertainty in the momentum of the quarks. Although the spatial and momentum probability distributions are not point-like, the positional Expectation Values do appear as point-like fixed positions. Furthermore, the three positional Expectation Values of the three quarks are not centered atop one another in the very center of the nucleons.

Consistent with this concept, here is a quote about the Laureates who won the 1990 Nobel Prize for their experiments, which were completed in 1973, at the Stanford Linear Accelerator.

> "Earlier investigations of the proton at low energies had shown that this ought to be "soft" with a relatively even internal distribution of its electrical charge. This year's Laureates therefore had reason to believe there would be a decline in the probability of photon absorption (low number of events). But they found instead a high probability level (many events), i.e. there seemed to be something small and "hard" inside the proton.
>
> "**Thus the new investigations gave the surprising result that the electrical charge within the proton is concentrated to smaller components of negligible size.**
>
> "This unexpected discovery by the 1990 Laureates was noted immediately by certain skilled theoreticians, chiefly R.P. Feynman and J.D. Bjorken. The result was first interpreted within the framework of what is termed the parton model, which, however, soon came to be identified with the **quark** model."

Thus, the charge is not homogeneously distributed, as hypothetically and incorrectly shown in Fig. 3. Rather the charges, and the quark distributions, are concentrated into smaller and distinct distributions.

Several experimental studies have been conducted to measure the radial charge distribution inside a proton and neutron [52, 53, 54], The resulting radial charge densities are shown in Fig. 10.



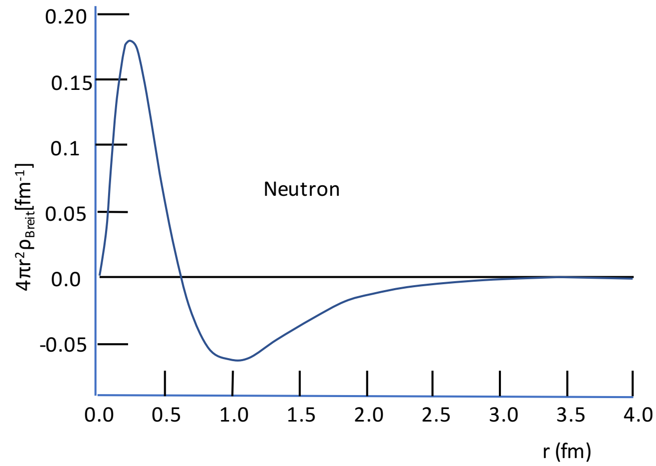


Fig. 10. Experimental data for the radial charge symmetry of the proton and neutron. Note the difference in the vertical axis. The horizontal axis is in fm.

As seen in the Fig. 10, these experiments indicate that there is zero charge density at the center of both the proton and neutron—which is consistent with the quarks having a probability distribution situated more toward the periphery. Using these experimentally determined charge distributions, the quark probability distributions can be found by solving for the up and down probability distributions that are necessary in order to achieve these same charge distributions [55]. These up and down quark probability distributions are shown in Fig. 11.

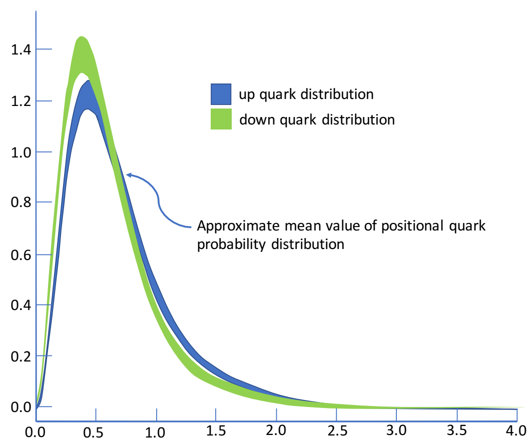


Fig. 11. Up quark and down quark orbital radial distributions. The mean value of the quarks position is roughly at 0.8 fm from the center.

As can be seen, the quarks are not homogeneously distributed through out the entire volume of the nucleon. Their mean position, (i.e. the Expectation Value) is approximately 0.8 fm from the center, in agreement with the calculations of this paper. (Bear in mind, these distributions are orbital densities.)

For the quarks inside a nucleon, the exact standard deviations of the position and momentum distributions are not known. Thus, it is not possible to definitively calculate the combined uncertainty in space and momentum. That being said, however, some estimates can be made to determine if reasonable values for these vibrational standard deviations do, indeed, fit within the confines of quantum uncertainty principles.

As previously discussed in section 4.8.1, if the quarks inside a proton cannot be unbound by the addition of 139.6 MeV of energy, then the binding mass is at least this 139.6 MeV/c^2. The binding mass is subtracted from the mass of the isolated constituent particles. This means that the mass of the bound system is the sum of the masses of the isolated constituent particles minus the binding mass. Hence, in the bound system, this same binding mass decreases the sum of the masses of the three isolated constituent quarks. This information gives us a lower limit to the mass of the constituent quarks. The calculation is shown in Calc. 1.

$$\sum Mass_{consituent\ parts} \geq 938.3\frac{MeV}{c^2} + 139.6\frac{MeV}{c^2} \geq 1077.9\ \frac{MeV}{c^2} \qquad (Calc.1)$$

Assuming there are no other massive particles, as yet undiscovered, inside the proton, this gives the sum of the masses of the three quarks to be at least 1077.9 MeV/c^2. This indicates that each of the masses of the constituent quarks are *at least* 350 MeV/c^2 = 6.4 x 10^{-28} kg in mass. And most likely, they are more massive than this. Regardless of whether this constituent quark mass is either the rest mass of the three "dressed" quarks or a relativistically-inflated mass of the "naked" quarks, this value of 6.4 x 10^{-28} kg is a reasonable estimate for the lower limit of the quark mass. Also this value is in good agreement with the Constituent Quark Model, for the estimated quark mass.

A reasonable estimate for the standard deviation of the quark vibrational velocity distribution is about 0.8 times the speed of light. Thus, σ_v= 0.8c=2.4 x 10^8 m/sec. This gives, σ_p, the standard deviation for the quark momentum as: σ_p=(2.4 x 10^8 m/sec)(6.4 x 10^{-28} kg)=1.54 x 10^{-19} kg m/sec. A reasonable estimate for the standard deviation of the spatial distribution, σ_x , is about ¼ the diameter of the nucleon. Thus, σ_x= ¼ x (1.68 fm) = 0.42 x 10^{-15} m.

Using these reasonable estimates and the lower limit of the quark mass, the product of the two standard deviations falls within the limits of the Heisenberg uncertainty principle, as shown in Calc. 2.

$$\sigma_x\sigma_p = (0.42 \times 10^{-15}\ m)(1.54 \times 10^{-19}\ kg\ m/sec) = 6.45 \times 10^{-35}\ \geq\ \hbar/2 \qquad (Calc.2)$$

Thus, these reasonable estimates for the product of the two uncertainties in the conjugate variables is above the Heisenberg limit. There is no violation of the Copenhagen interpretation of quantum uncertainty principles in this model. As mentioned previously, the binding mass is very likely to be more than 139.6 MeV/c^2, which means that the product of the uncertainties is even larger. Also, the vibrational speed of the quarks could easily exist well within the realm of relativistic speeds, again making the product of the uncertainties even larger. Both of these considerations make a violation of Copenhagen interpretation of the quantum uncertainty principles even more unlikely.

Also, the positional probability distribution may not be a symmetric Gaussian curve in three-dimensions, but could well be spatially skewed, situating the Expectation Value closer to the edge. These understandings allow the concept of a quark that "appears" to be a point-like electric charge and a point-like magnetic dipole moment. Thus, the point-like positions of the spatial Expectation Values used in this series of papers are, indeed, valid conceptual representations for the calculations of the Electromagnetic Force, without violations of the Copenhagen interpretation of the Heisenberg uncertainty principle.

6. Calculations of the Energies within the Nucleus

The energies within the nucleus that must be taken into consideration are the centrifugal energy, electric energy, and magnetic energy. The electrical charges and magnetic dipole moments of the nucleons are contained in the quarks, a fact that must be considered for any realistic model of the Nuclear Force. With the understanding that the electric charges and magnetic dipole moments reside in the quarks, it can readily be realized that the electromagnetic forces between an up quark and a down quark are strong enough to bind the two nucleons together. No other force, different from the electromagnetic force, is needed to account for the strong bond between nucleons. Fig. 12 shows this electromagnetic bond.

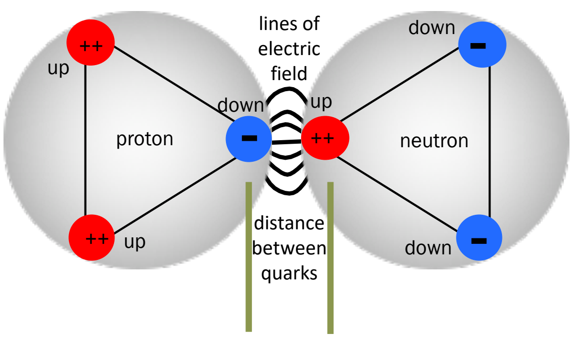


Fig. 12 The electromagnetic bond between quarks

In other words, the force binding these two nucleons need not be anything other than the electromagnetic forces between the up and down quarks. Clearly stated, *the Nuclear Force is electromagnetic*. The Nuclear Force is *directly* unified to the Electromagnetic Force.

6.1. The Electric Energy

The electric energy [56] between two electrically charged particles is shown in Eq. (5):

$$Energy_{12} = \frac{q_1 q_2}{(4\pi\varepsilon_0)(distance_{12})} \qquad (5)$$

where $distance_{12}$ is the distance between particles 1 and 2, and q_1 and q_2 are the electric charges on particles 1 and 2.

For additional charges, the total electrical energy is the double summation over all pairs of charges, as shown in Eq. (6).

$$E_{electric\_total} = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \frac{q_i q_j}{(4\pi\varepsilon_0)(distance_{ij})} \tag{6}$$

6.2. The Magnetic Energy

The magnetic energy [57, 58] between two magnets has vector and positional dependence. Given two magnets, with magnetic moments μ_1 and μ_2, the magnetic field of $magnet_1$ is determined at the location of the $magnet_2$. This vector field is symbolized as B_{12}, shown in Eq. (7).

$$\overrightarrow{B_{12}} = \frac{\mu_0}{4\pi}\left\{\frac{3(\overrightarrow{\mu_2}\cdot\overrightarrow{r_{21}})\overrightarrow{r_{21}} - r_{21}^2(\overrightarrow{\mu_2})}{r_{21}^5}\right\} \tag{7}$$

The resultant energy, $U_{magnetic12}$, is the negative dot-product of the vector of the magnetic moment μ_2 with the vector of B_{12}, as shown in Eq. (8).

$$U_{magnetic12} = -\overrightarrow{\mu_2}\cdot\overrightarrow{B_{12}} \tag{8}$$

For a collection of magnets, the total magnetic energy is the double summation over all pairs of magnets, as shown in Eq. (9).

$$U_{magnetic\ total} = \sum_{i-1}^{n-1} \sum_{j=i+1}^{n} -\overrightarrow{\mu_\iota}\cdot\overrightarrow{B_{\iota\jmath}} \tag{9}$$

where $\overrightarrow{B_{\iota\jmath}}$ is the vector magnetic field established by the i[th] magnet at the location of the j[th] magnet.

Combining equations (6), (7), and (9), the total electromagnetic energy of a distribution of charges and magnets is shown in Eq. (10):

$$U_{EM\ total} = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \frac{q_i q_j}{(4\pi\varepsilon_0)(r_{ij})} + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \frac{\mu_0}{4\pi}\left\{\frac{3(\overrightarrow{\mu_\jmath}\cdot\overrightarrow{r_{\jmath\iota}})(\overrightarrow{\mu_\iota}\cdot\overrightarrow{r_{\jmath\iota}}) - r_{ji}^2(\mu_i\cdot\mu_j)}{r_{ji}^5}\right\} \tag{10}$$

Due to the vector properties of this energy, the lowest energy configuration for two magnets is a stacked bond, in which the magnetic moments of the magnets are parallel, with the magnets are stacked one atop the other, and as close as physically possible. A side-by-side bond is with anti-parallel magnetic moments, with the magnet oriented side-by-side, and as a close as physically possible. An angled bond is in between a stacked and a side-by-side bond, and it will give intermediate results. From quantum field theory it is known that quarks behave as point-like Dirac particles, each having their own inherent magnetic moment [59].

6.3. The Centrifugal Energy

The kinetic energy of a spin must be properly included in the total energy of a nucleon. A rotating rigid object is comprised of numerous individual particles that orbit about a central axis of rotation. The kinetic energy of this orbital movement, $E_{orbital}$, is related to the angular velocity, ω, and to the moment of inertia, $I_{orbital}$, shown in Eq. (11):

$$E_{orbital} = ½I\omega^2 = ½\,L^2/I_{orbital} \tag{11}$$

where L is the orbital angular momentum of the object. Note that $L = \omega I_{orbital}$. Putting these concepts into the quantum realm of nuclear physics [60], the equation for the quantum orbital angular momentum, L, is shown in Eq. (12):

$$L = \hbar\sqrt{\ell(\ell+1)} \tag{12}$$

where the lower-case script ℓ is the value of the quantum number for the orbital angular momentum. Combining equations (11) and (12) yields Eq. (13).

$$E_{orbital} = \frac{\frac{1}{2}L^2}{I_{orbital}} = \frac{\frac{1}{2}(\hbar^2[\ell(\ell+1)])}{I_{orbital}} \tag{13}$$

For one particle, the orbital moment of inertia, $I_{orbital}$, is the arm radius squared, and then multiplied by the mass of the nucleon, (where the arm radius is the closest distance of the particle to the axis of rotation). To get the total orbital moment of inertia for the entire nucleus, the orbital moment of inertia of each nucleon is summed for all nucleons in the nucleus, as shown in Eq. (14).

$$I_{orbital\_total} = \sum m_i r_{arm\_i}^2 \tag{14}$$

For this equation, m_i is the mass of the i^{th} particle, and r_{arm_i} is the closest distance of the i^{th} particle to the axis of rotation. In order to calculate the arm radius, r_{arm}, the center of mass must be known. For a freely spinning object, the axis of rotation is assumed to go through the center of mass of the configuration of particles. Thus the center of mass of the configuration of particles must be calculated first, as shown in Eq. (15):

$$X_{cm} = \frac{1}{M}\sum_{i=1}^{n} m_i x_i$$

$$Y_{cm} = \frac{1}{M}\sum_{i=1}^{n} m_i y_i$$

$$Z_{cm} = \frac{1}{M}\sum_{i=1}^{n} m_i z_i \tag{15}$$

where M is the total mass of the object and m_i is the mass of the i^{th} particle. Also x_i is the x-position of the i^{th} particle in any xyz orthogonal reference frame, and similarly for y_i and z_i. X_{cm}, Y_{cm}, and Z_{cm} are the three-dimensional coordinates for the center of mass.

Once the center of mass is known, the arm radius r_{arm}, can be found for each nucleon in the configuration. Using simple trigonometry, this arm radius is shown in Eq. (16).

$$r_{arm\_i} = \sqrt{\Delta x_i^2 + (\Delta y_i Sin\theta)^2 + (\Delta z_i Cos\theta)^2} \tag{16}$$

where Δx_i is the difference between x_i and the X_{cm}, for the i^{th} nucleon. Similar definitions pertain to Δy_i and Δz_i.

The arm radius is used in Eq. (14) to determine the orbital angular inertia $I_{orbital}$. This orbital angular inertia can be found for the entire nucleus, as well as for each nucleon in the nucleus. By combining equations (11), (12) and (14), the formula for the quantum centrifugal energy of a rotating nucleus is found, shown in Eq. (17):

$$E_{orbital} = \frac{½(h^2[\ell(\ell+1)])}{\sum m_i r_{arm\_i}^2} \tag{17}$$

In the calculations for this paper, a matrix is made of the xyz position of every nucleon in the configuration. This positional data is then used to calculate the center of mass in three dimensions. In order to calculate the arm radius for each nucleon, the angle of the axis of spin must be set to a specific angle. It is set to be 45° for a nominal calculation. (For the larger atomic nuclides, this assumption of a 45° angle has a minor effect, since this orbital energy term becomes negligibly small for the larger nuclides. However, for the smaller atomic nuclides, the angle of the axis spin has a larger effect, due to the inverse mass dependence of the orbital energy.)

6.4. The Total Binding Energy

The total binding energy can be calculated using these equations. There is only one parameter that must be set, and that is the minimum distance between the internucleon quarks, as shown in Fig. 12, between two bonded quarks of two different nucleons. The value of 2.11082×10^{-16} meters is used to match the experimental data. This value gives excellent matching to the experimental binding energy, as seen previously in Fig. 6. The calculated binding energy is the difference of the total energies of the configuration and the total energies of the isolated constituent parts. This is shown in Eq. (18).

$$U_{binding\ energy} = U_{total\ of\ configuration} - U_{total\ of\ constituent\ parts} \tag{18}$$

In these calculations, the mass of the electrons is taken into consideration, as is the binding energy of the electron to the atom. Any difference in the before-and-after energy of the angular momentum is also taken into consideration.

Note that a positive binding energy lowers the total energy and mass of the configuration, compared to the total energy and mass of the individual constituent parts. In other words, the bonded configuration of nucleons will be at a lower total energy and lower total mass than the isolated parts. Detailed step-by-step calculations are shown in part I of this series.

7. The Segments

As explained in Parts I and II of this series, the atomic nucleus is made of segments, which are bonded together to form a chain-like structure within an atomic nuclide. In this section, the various segments are briefly reviewed.

7.1. The Segment Names and Their Representations

For some of the drawings of the various atomic nuclides, several different viewpoints are shown for a better understanding of the three-dimensional shape. These different viewpoints do not change the atomic nuclide in anyway and should not be misconstrued to mean that a nuclide seen in one viewpoint is somehow physically different from the same nuclide seen in another viewpoint. The drawings of the nucleons are sized to be easily viewed; similarly, the dots are sized to be easily viewed. The nucleons size and dot size are not meant to represent of the relative size of the nucleons or quarks within a nucleus. These are short-hand symbolic representations, not intended to be accurate physical representations. The dot colors for the quarks are not related to the colors of the Quantum Chromodynamic Model.

The three short-hand simplified graphic representations for the proton and neutron are shown in Fig. 13.

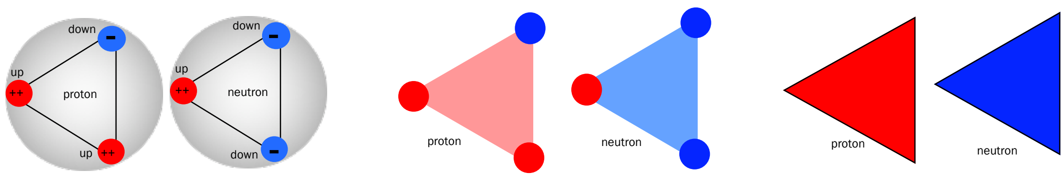


Fig. 13. Short-hand symbolic representations of a proton segment and neutron segment.

For most of the diagrams in this paper, the middle representation in Fig. 13 will be used. The reader should remember that the protons and neutrons are oblate ellipsoids in shape, even though that ellipsoid shape is not drawn in the more simplified representations.

An alpha segment, with two neutrons and two protons, is shown in Fig. 14, with several viewpoints to show its three-dimensional structure.

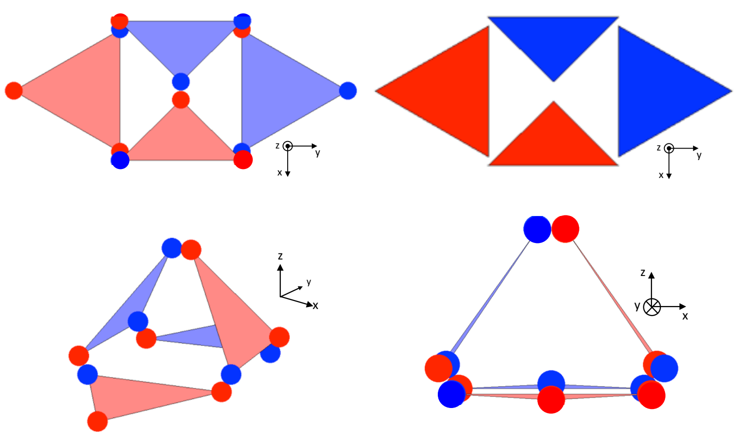


Fig. 14. Short-hand symbolic representations of an alpha segment, in several viewpoints

A star segment, with two neutrons and two protons, is shown in Fig. 15.

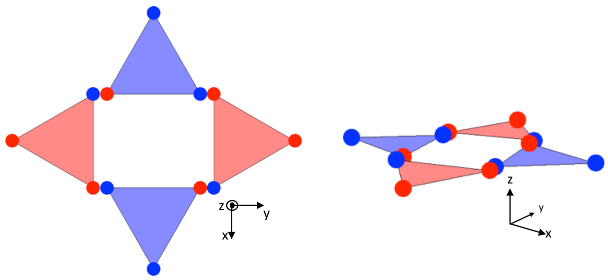


Fig. 15. Short-hand symbolic representations of a star segment, in two viewpoints.

Fig. 16 shows a Li4 segment, with one neutron and three protons. Note the additional unbonded up quark as compared to the alpha segment. Its three-dimensional shape is similar to that of the alpha segment. This segment is rare and only exists in unstable atomic nuclides or excited states.

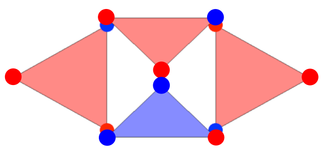


Fig. 16. Short-hand symbolic representations of a Li4 segment

Shown in Fig. 17 is an H4 segment, with three neutrons and one proton. Note the additional unbonded down quark as compared to the alpha segment. Its three-dimensional shape is similar to that of the alpha segment and the Li4 segment.

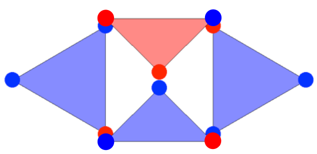


Fig. 17. Short-hand symbolic representations of a H4 segment

Fig. 18 is a triton segment, with two neutrons and one proton. This is shown from several different viewpoints for better understanding of its three-dimensional shape. The position of the proton can be at any one of the three nucleon sites. Similarly, the position of the side-to-side magnetic bond can be between any of the two nucleons, it need not be at the bottom as drawn here.

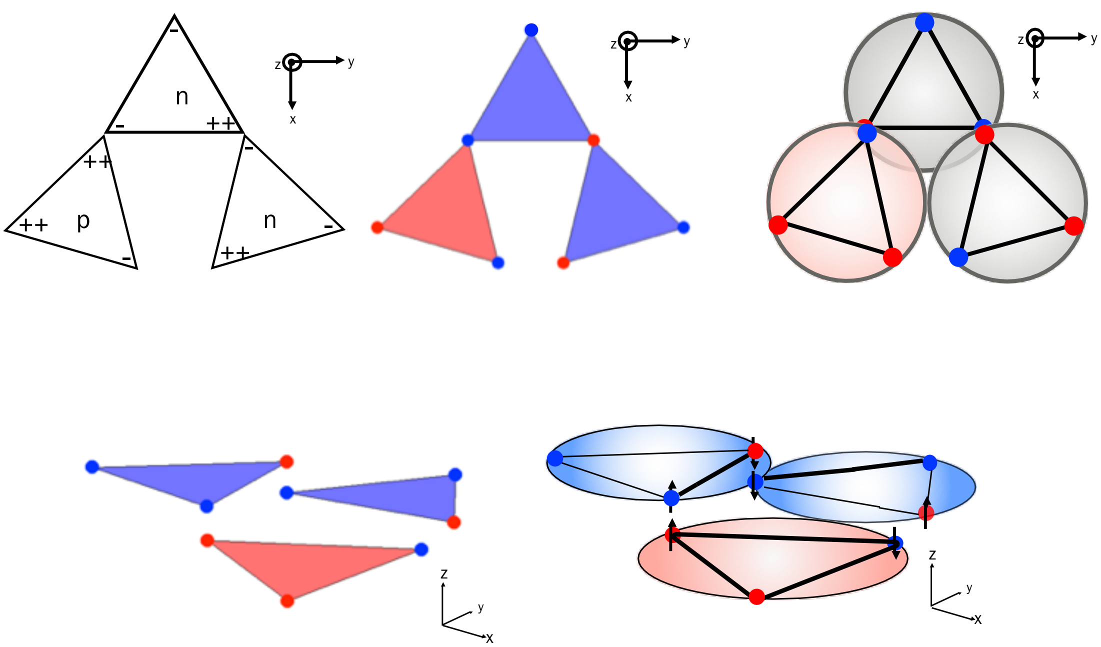


Fig. 18. Five short-hand symbolic representations of a triton segment

Fig. 19 is an He3 segment, with one neutron and two protons. Note the additional unbonded up quark as compared to the triton segment. This is shown in four different representations for better understanding of its three-dimensional shape. The position of the neutron can be at any one of the three nucleon sites. Similarly, the position of the side-to-side magnetic bond can be between any of the two nucleons; it need not be at the bottom, as drawn here.

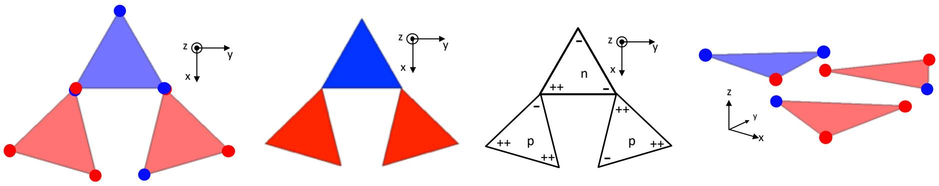


Fig. 19. Four short-hand symbolic representations of a He3 segment.

For this paper, when the various configurations are described, the segments are listed in order from left to right in the configuration, with a comma between each of the segments. There is parenthesis around the entire configuration name to separate it from the rest of the sentence. The bond between two segments is called the "link" bond. (Because the link bonds are stacked-magnetic bonds between the two quarks, it is hard to see the lower quark beneath the upper quark. The reader should be aware that both quarks are present in the bond.) For example, in Fig. 20 is Boron ^{11}B in a (triton, star, alpha) configuration, shown in two graphic representations.

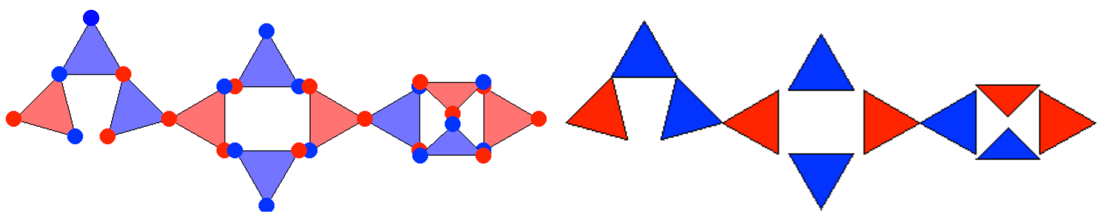


Fig. 20. Short-hand simplified representations of ^{11}B.

7.2. The Computer Calculations

For every atomic nuclide in this paper, the position of each quark is defined in a matrix, with xyz spatial coordinates. The value of the electric charge of each quark also entered into the matrix, being either -1/3 or +2/3 of an elementary charge (1.60217657 x 10^{-19} coulombs). The spin for each atomic nuclide is also included in this file. The best estimated values are used for the magnetic moments of the quarks, which are 1.85 nuclear magnetons for an up quark and -0.97 nuclear magnetons for a down quark. This matrix file, which contains the position and electromagnetic values of each quark in the atomic nuclide, is then run through the computer program to analyze the data, using to the equations for spin energy, electrical energy, and magnetic energy. The difference in energy is then compared to the individual isolated parts of the atomic nuclide—comprised of the same number of protons, electrons, and neutrons. From this difference in energy, the binding energy is calculated.

7.3. Understanding Redundant Configurations

There are several ways in which the protons and neutrons can combine and still be the essentially the same configuration. This is illustrated in Fig. 21, using an alpha segment as an example, with variations of the locations of the up and down quarks. These six configurations of the alpha segment are essentially redundant. In all of these configurations shown in Fig. 21, the unbonded quarks on the end are all the same, the number of protons and neutrons are the same, the number of bonds is the same, and all bonds are properly made.

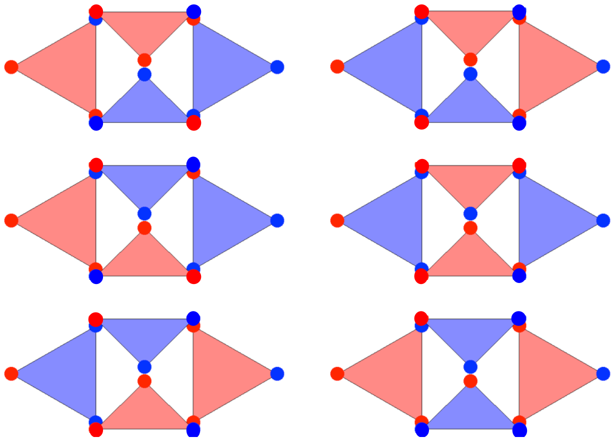


Fig. 21. Six short-hand symbolic representations of an alpha segment, with different positions of the *bonded* quarks.

The important considerations are that all the bonds are correctly formed and that the unbonded quarks are in the correct place. With these considerations in mind, all of these redundant configurations for the alpha segment, shown in Fig. 21, are essentially the same. In subsequent drawings, all of the redundant configurations are not shown, since this would be an unreasonably large and unnecessary number of figures.

8. Applying Electromagnetic Principles to Bond Formation

The energy considerations of bond formation will be considered first.

If a mass were to fall a certain distance on Earth, it would experience a lowering of its potential energy, as it falls from a higher height to a lower height. As the object is falling, pulled down by the gravitational force, this potential energy is converted to kinetic energy. Just before the moment of impact, the kinetic energy is fully equal to this change in potential energy. This is the "energy of the impact." The moment just after the impact, assuming a non-elastic collision, the kinetic energy is again zero, and the energy of the impact is radiated out as heat, for a non-elastic collision. The total of mass-energy is conserved at all times, and momentum is conserved as well. A gravitational bond is formed between the Earth and this mass.

In electromagnetics, a similar situation occurs. For example, consider a system made up of two oppositely-charged particles. As the distance between these two particles decreases, this system of two oppositely-charged particles experiences a lowering of its potential energy and, at the same time, an equal increase in its kinetic energy. The kinetic energy is fully equal to the change in potential energy just before the moment of impact. After the impact, again assuming a non-elastic collision, the kinetic energy is zero in the center of mass reference frame, and the energy of the impact is radiated out as heat or light. The total of mass-energy, momentum, and charge are all conserved at all times. An electromagnetic bond is formed between the two oppositely charged particles.

In nuclear physics, it is essential to understand the behavior of the electromagnetic force of two oppositely-charged particles coming together, as described above. This is because a similar behavior occurs inside the atomic nucleus. In other words, if two oppositely-charged particles move to a lower electrical energy, this system of particles would experience a lowering of its potential energy, as the distance between these two particles decreases. For example, if there are two oppositely-charged quarks, one in a neutron and one in a proton, and they move closer together, the potential energy is converted to kinetic energy as they move toward one another. The change in kinetic energy is equal to the change in potential energy, and as before, this is true at the moment of impact. After the impact, assuming a non-elastic collision, the kinetic energy is again zero for center of mass coordinates, and the energy of the impact is radiated out as gamma radiation. The total of mass-energy, momentum, baryon number, and electric charge are all conserved at all times. An electromagnetic bond is formed between the two quarks and between the two associated nucleons.

An example of this type of behavior is the specific case of an He3 segment and a neutron segment that are next to each other and able to form an electromagnetic bond. For example, consider a high energy state of Boron ^{11}B, in the (He3, neutron, star, triton) configuration, as shown in Fig. 22. (From this viewpoint, some of the lower quarks are hidden from view, beneath the upper quarks; the reader should be aware that they are present.) If a bond is formed between the unbonded up quark and the unbonded down quark, circled in green in the upper illustration of Fig. 22, then an alpha segment is formed. Also circled in green in that figure is the side-by-side bond in the He3-segment. This bond goes to a lower energy bond, forming the center bond in the alpha segment. Thus, not only is there an electric force pulling the He3 and neutron segment together, there is also a contribution from the magnetic force as well. After the bond is formed, the result is shown in the lower illustration of Fig. 22, in an (alpha, star, triton) configuration. The newly formed bond is circled in green, as is the lower energy angled bond that was formed from what was initially the side-by-side bond.

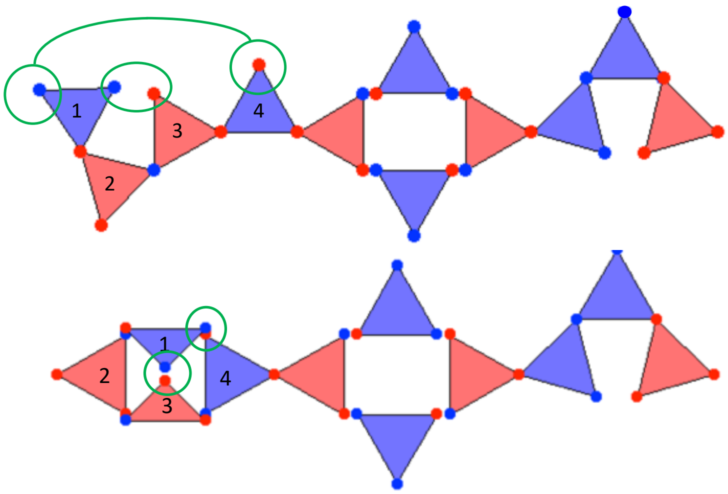


Fig. 22. The top graphic shows a high energy state of boron ^{11}B, in an (He3, neutron, star, triton) configuration, before bond formation. The lower graphic shows boron ^{11}B in an (alpha, star, triton) configuration, after bond formation.

The binding energies of the two ^{11}B nuclei in Fig. 22 are the total energy difference between the configuration and the individual constituent protons, electrons, and neutrons. This energy difference, ΔE, is the sum of the differences in the electric, magnetic, and orbital energies, as shown in Eq. (19).

$$\Delta E_{total} = \Delta E_{total\ electric} + \Delta E_{total\ magnetic} + \Delta E_{orbital} \tag{19}$$

For the top configuration in Fig. 22, the binding energy is 64.2977 MeV. For bottom configuration in Fig. 22, the binding energy is 74.3179 MeV (assuming identical spins). Therefore, the binding energy is higher, meaning that the overall total energy of the bottom configuration in Fig. 22 is lower than the overall total energy of the upper configuration. Thus, the high energy state of Boron ^{11}B falls to the lower energy state of Fig. 22, due to the electromagnetic forces that form the bond, resulting in approximately 10.02 MeV of released energy (again assuming identical spins). Boron ^{11}B has numerous high energy states that might be the energy state represented in the top panel of Fig. 22.

(Since it may be of interest to determine which particular excited state of ^{11}B this excited state shown in the figure might be, this is done here. Experimental data for the high energy levels of ^{11}B show there are numerous states that are approximately 10 MeV higher than ground, but they have a different spin than the ground state. The best estimate for this excited state is the one at 11.89 MeV above ground, with a spin of 5/2. With that higher spin of 5/2, the excited state shown in the top pane of Fig. 22 would be 11.67 MeV above that ground state, giving a very close 1.8% error for the binding energy.)

When an atomic nuclide falls to a lower potential energy configuration, there is a decrease in the potential energy of the configuration. As the atomic nuclide moves from one configuration to the other, this decrease in potential energy is converted to an increase in kinetic energy as it is moving from one configuration to another. The instant before the impact, the increase in kinetic energy is fully equal to the decrease in the potential energy. After the impact, the bond is formed and this change in the energy is radiated out as gamma radiation. The total of mass-energy, momentum, baryon number, and charge are all conserved at all times. An electromagnetic bond is formed.

Such bond formation can occur in any configuration similar to that of boron ^{11}B, one with an He3 segment and a neutron segment next to each other on the very end. For example, similar behavior is seen in numerous high energy states of ^{15}N, ^{19}F and ^{23}Na, wherein a high energy level drops directly to the ground state, releasing about 10 MeV of energy. The formation of a bond is able to explain this large energy drop in the high energy states.

9. Applying Centrifugal Energy Principles to Bond Breakage

The energy considerations behind the bond breakage of a nuclear bond will be examined next. The examination of centrifugal energy will be considered first. If the centrifugal force on the endmost alpha segment is greater than the link bond holding it, then alpha decay results. This centrifugal effect could also possibly affect a proton or a neutron; however, most likely it would affect an alpha particle, simply because alpha particles are four times more massive. An alpha segment on the very end is connected to the rest of the atomic nuclide with only one bond--the link bond--and it has a mass of four nucleons. Thus, is it particularly susceptible to the situation wherein the energy of the orbital angular momentum is greater than the energy of the link bond.

For the calculation of centrifugal energy on the endmost particle, the kinetic energy due to the orbital angular momentum of the nucleus is of interest. It is assumed that the nucleus moves as a rigid non-spherical structured object. (Historically, a sphere has assumed for the shape of the atomic nucleus. Because the calculations for the angular momentum of a non-spherical object were difficult to do without a computer, a spherical shape was assumed for ease of computations.) It is a well known experimental fact that atomic nuclei are not spherical in shape, but rather they have large electric quadrupole moments and deformation parameters—indicating prolate ellipsoidal shapes (cigar shaped), consistent with the chain-like shapes in this model.

If the centrifugal energy, as determined with Eq. (17), for the endmost particle is greater than the energy strength of the link bond, then particle decay will result. The mechanism for this type of particle decay might be initiated when an atomic nuclide exhibits β decay and changes its spin as a result. This behavior of bond breakage due to centrifugal force would normally be seen for smaller atomic nuclides, wherein even a relatively low spin, such as spin 2, could have enough centrifugal energy to break the bond.

9.1. Centrifugal Energy of the End-Most Segment

Of particular interest for the smaller atomic nuclides is the question of how much the centrifugal energy pulls outward on the endmost segment. If the centrifugal energy is larger than the electromagnetic energy holding that segment on, then the centrifugal energy would be able to pull off that endmost segment. To find the centrifugal energy of the endmost segment, the quantum angular velocity ω must be determined. This is shown in Eq. (20):

$$\omega = \frac{L}{I} = \frac{\hbar\sqrt{(\ell)(\ell+1)}}{\sum m_{endmost}\, r_{arm}^2} \tag{20}$$

where $m_{endmost}$ is the mass of the endmost particle. The velocity of the endmost segment, $v_{endmost\ segment}$, can then be determined, which is the angular velocity times the arm radius, r_{arm}, for the endmost segment. This is shown in Eq. (21).

$$v_{endmost\ segment} = (\omega)(r_{arm\_endmost}) \tag{21}$$

Once the velocity of the endmost segment is known, the centrifugal energy of the end-most segment can be calculated, shown in Eq. (22).

$$Energy_{centrifugal} = (\tfrac{1}{2})(mass_{endmost\ segment})(v_{endmost\ segment})^2 \tag{22}$$

The calculated centrifugal energy of the end-most segment is then compared to the electromagnetic energy of the link bond. If the centrifugal energy is greater than the energy of that bond, then the centrifugal energy has the ability to break that electromagnetic bond. Thus, a determination can be made whether or not the centrifugal energy is sufficient to break the electromagnetic bond, and this calculation gives us information as to how the centrifugal energy might affect the nuclear behavior of particle decay.

10. Applying Electromagnetic Principles to Bond Breakage

When an atomic nuclide transitions from one configuration to another, the kinetic "energy of the impact" must be taken into consideration. To better understand this, consider the classical case of a mass, call it mass1, that is bonded to a second mass, mass2. Assume the bond between mass1 and mass2 has an energy associated with it, namely: $Energy_{bond\_m1\text{-}to\text{-}m2}$. Define the kinetic energy of a third mass, mass3, as $Energy_{kinetic\_m3}$. This will be the energy of impact when the third mass, mass3 hits mass1. As an example, consider a magnet (mass1) that is magnetically bonded to a piece of steel (mass2), and it is hit with a sideways glancing blow with a third mass (mass3).

If the bond energy is greater than the kinetic energy of the impact, such that $Energy_{bond\_m1\text{-}to\text{-}m2} > Energy_{kinetic\_m3}$, then the bond between mass1 and mass2 will not break. In this example, if the magnet is barely touched with a feather, then nothing happens. However, if the energy of the bond is less than the energy of the impact, $Energy_{bond\_m1\text{-}to\text{-}m2} < Energy_{kinetic\_m3}$, then the bond between mass1 and mass2 will break. If the magnet is hit very hard with the hammer, it unbonds from the mass2. Some heat will be radiated, depending on the elasticity of the collision. The total of mass-energy and the momentum are conserved at all times. Basically, if a bond is hit hard enough, it will break.

Taking this into the nuclear realm, a similar situation occurs inside the nucleus. For example, consider an existing electromagnetic bond between quark1 and quark2, which are in two different nucleons. When a third quark, quark3, attempts to triple bond to this existing bond, the bond between quark1 and quark2 will break if the kinetic energy of the impact exceeds the energy of the bond. Assume the bond energy between quark1 and quark2 is $Energy_{bond\_q1\text{-}to\text{-}q2}$. Assume that quark3 impacts this bond with an energy $Energy_{kinetic\_q3}$. If $Energy_{bond\_q1\text{-}to\text{-}q2}$ is less than $Energy_{kinetic\_q3}$ then the bond will break. After the bond breaks, particle decay results, and some gamma radiation also occurs. Basically, if a nuclear bond is hit hard enough, it will break. If this energy of the impact is higher than the energy of the bond, roughly 6 to 7 MeV, then the bond will break. The total mass, energy, momentum, baryon number, and charge are all conserved at all times. An electromagnetic nuclear bond is broken.

10.1. Bond Breakage due to Double-Bonded Nucleons

Double-bonded nucleons may be attempted if there is an unbonded down quark on the very end of a configuration. The unbonded down quark is attracted to the positive charge of the rest of the atomic nuclide, and it attempts to form a double-bonded nucleon.

If the atomic nuclides were perfectly flat triangles, as shown in the short-hand symbolic representations, then double-bonded nucleons might actually be allowed. However, the triangle drawings are merely a short-hand symbolic representation, rather than the actual nucleon shape. Assuming the nucleons are oblate disk-shaped ellipsoids with a non-infinitesimal thickness, then the shape of the nucleons would prevent double-bonded nucleons from forming. Instead, the bond between the nucleons breaks, and a nucleon is ejected.

For example, consider an excited state of lithium ^{8}Li, shown in Fig. 23. The negative charge of the unbonded down quark on the end neutron is attracted to the positive charge of the unbonded up quark. Both are circled in green in Fig. 23.

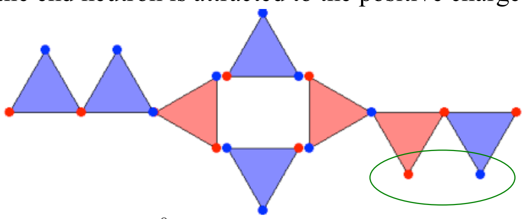


Fig. 23. Lithium ^{8}Li in an excited state (neutron, neutron, star, proton neutron) configuration.

The electromagnetic attraction between the unbonded up quark and unbonded down quark will attempt to form double-bonded nucleons. However as the two nucleons attempt to form a double bond, the two nucleons are instead pried apart, due to their disk-like ellipsoidal shape and their thickness. This is shown in Fig. 24.

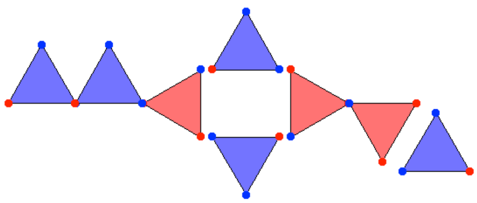


Fig. 24. Lithium ^{8}Li in an attempted double-bonded nucleon configuration.

The kinetic energy of the neutron attempting to form a double bond is 7.18 MeV at its maximum, as calculated from the difference in the energies of these two configurations. This energy is greater than the energy of a bond. Thus, the initial bond would break as a result, and the neutron becomes unbonded, carrying away any excess kinetic energy. Thus, once the bond is broken, the neutron will be ejected from the nucleus, as shown in Fig. 25.

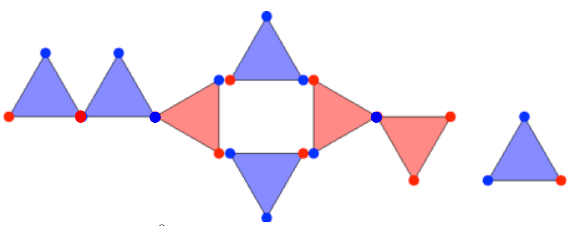


Fig. 25. Lithium ^{8}Li immediately after ejecting a neutron, after an attempt to form double-bonded nucleons.

No other model of the Nuclear Force can explain the behavior of particle ejection—not the Shell Model, not the Liquid Drop Model, not the various Independent Particle Models, not the Residual Chromodynamic Model, not the Standard Model. The behavior of particle ejection is an unexplained behavior for the previous models of the Nuclear Force. However, it is very easily explained by the Electromagnetic Model—the electromagnetic forces within the nucleus cause the nucleons to attempt to form double-bonded nucleons, which is not allowed by the hard core repulsion properties of the nucleons. A nucleon is ejected as a result.

For an atomic nuclide with more positive charge than ^{8}Li in a similar configuration—that of a single nucleon segment with unbonded down quarks on the very end—there will be even more potential energy than in this example. Therefore, similar to this example, a bond will break and the atomic nuclide will exhibit particle decay. The level scheme data in the nuclear table verify this behavior, especially for the smaller elements in high energy states. If there is a configuration with a single nucleon segment on the very end of an atomic nuclide, and the unbonded quarks of that single nucleon segment are electrically attracted to the unbonded quarks in the nucleon next to it, then an attempt to form a double-nucleon bond occurs. This attempted double bond results in a violation of the hard core repulsion. Bond breakage and nucleon ejection results. The Electromagnetic Model provides a very understandable explanation for the behavior of nucleon ejection.

Another example of an attempt to form double-bonded nucleons is the configuration of an excited state of boron ^{8}B in a (He3, alpha, proton) configuration, as shown in Fig. 26. Since the ground state of boron ^{8}B is in an (He3, proton, alpha) configuration, the energy difference between the ground state and this excited state is relatively small. Thus, this (He3, alpha, proton) configuration shown in Fig. 26 is a low-level excited state, slightly above the ground state. The single proton segment on the very end has an unbonded down quark. This negatively charged unbonded down quark would be attracted to the positive charges of the rest of the atomic nuclide, circled in green in the figure. Thus, this proton and neutron would attempt to form double-bonded nucleons, and simultaneously there is an attempt to form a triple-quark bond. Thus, proton decay occurs 100% of the time for this configuration of boron ^{8}B, even though the excited state is just slightly above the ground state. Experimentally, this state is at 0.769 MeV above the ground state. Using the electromagnetic calculations, the calculated difference between this excited-state configuration and the ground state is very close to this, predicting only 0.565 MeV, just a slight fractional difference from what is seen experimentally.

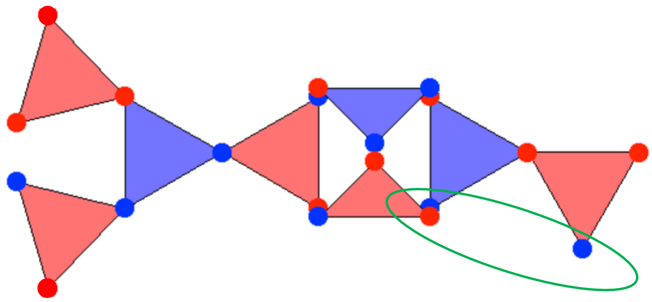


Fig. 26: Boron ^{8}B in a low-level excited state with a (He3, alpha, proton) configuration.

This is an example of a very low-level excited state that exhibits proton decay. This behavior of a low-level excited state exhibiting p-decay is not only seen in boron ^{8}B, but it is seen in ^{12}N and ^{16}F as well. No other model of the Nuclear Force can explain this behavior.

10.2. No Bond Breakage When Similar Quarks Are Not Electrically Attracted.

If the unbonded quarks are not electromagnetically attracted to each other, such as two up quarks or two down quarks next to each other, then no attempt to form double-bonded nucleons occurs. Fig. 27 shows a high energy state of Lithium ^{6}Li, in an (alpha, neutron, proton) configuration with two unbonded down quarks next to each other.

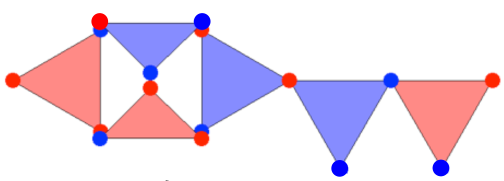


Fig. 27. Lithium ^{6}Li in an (alpha, neutron, proton) configuration, with the two unbonded down quarks next to each other.

The two unbonded down quarks are electrically repelled from each other, and the unbonded up quark on the very end is electrically repelled from the net positive charge of the rest atomic nuclide. Also, the magnetic bond between the single neutron segment and single proton segment is a stacked bond, which is the strongest alignment for the magnetic bond. Thus, the magnetic bond will not allow the nucleons to flip around to a side-by-side magnetic bond. In order for double-bonded nucleons to form in this configuration, calculations show that an increase the overall energy of the atomic nuclide, of 3.68 MeV, is required. Therefore, no double-bonded nucleons will be attempted. This very minor difference in the way that the two end-most nucleons are arranged makes a major difference in the nuclear behavior of the atomic nuclide. One configuration will eject a nucleon, but the other will not. This is why some high energy states may sometimes exhibit particle decay and other times the same high energy state will not. Thus, when there are two single nucleon segments on the very end of an atomic nuclide, this configuration may or may not be stable with respect to particle decay, depending on the electromagnetic forces involved.

10.3. Bond Breakage Due to Triple-Quark Bond

Another way that alpha particle decay might occur is with an attempted triple-quark bond. Typically this occurs when a star segment or an open-H4 segment is on the very end of an atomic nuclide configuration.

10.3.1. Example of Lithium ^{7}Li and an Attempted Triple-Quark Bond

An example of a triple-quark bond is shown in Fig. 28, with an excited state of lithium ^{7}Li. This excited state is in an (He3, open-H4) configuration.

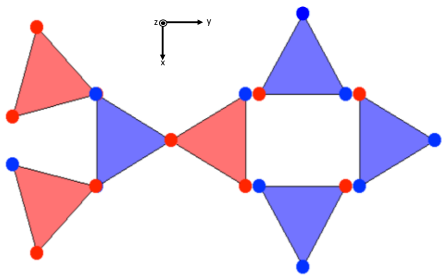


Fig. 28. An excited state of Lithium ^{7}Li in an (He3, open-H4) configuration.

This configuration will attempt to reconfigure itself, since the unbonded down quark on the far right end is electrically attracted to the net positive charge of the rest of the configuration. Also, the four side-by-side bonds of the open-H4 segment will try to move to a lower energy magnetic state. This lowering of energy occurs when the star segment curls inward to bring the unbonded down quark closer to the net positive charge of the rest of the configuration. Simultaneously, the magnetic bonds go from side-by-side bonds to lower energy angled bonds. Thus, there is a lowering of both the electric and magnetic energies, and together, this drives a curl-in behavior of this configuration.

An illustration of this curled-in configuration is shown, in Fig. 29, in several viewpoints for better understanding of its three-dimensional form. The attempted triple-quark bond is circled in green.

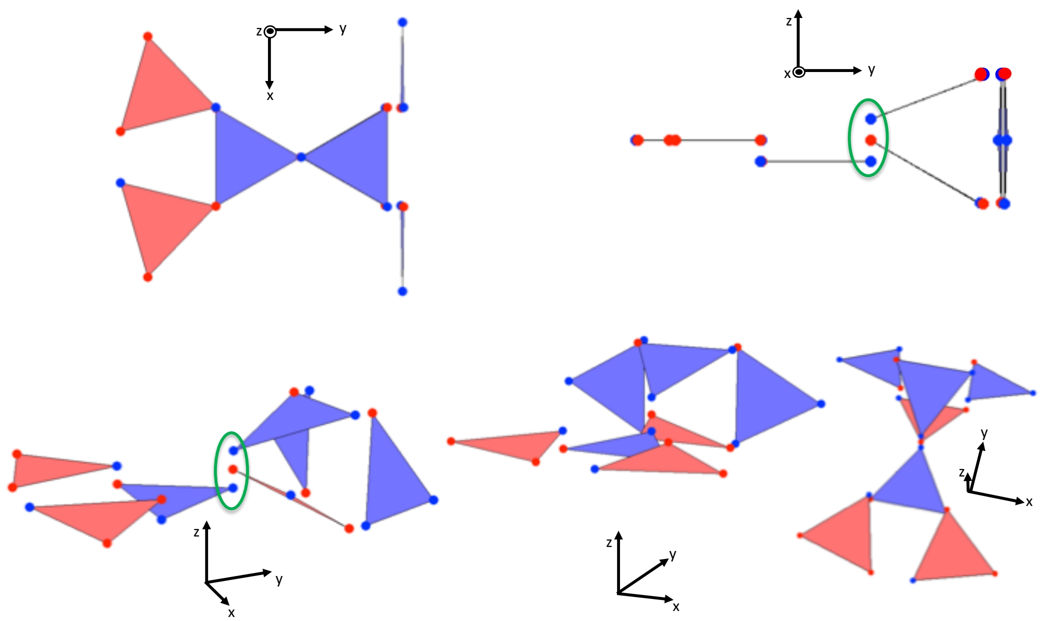


Fig. 29: Several viewpoints of an excited state of ^{7}Li, with an attempted triple-quark bond and a curled-in H4 segment.

Recall that the nucleons are not flat triangles, rather they are disk-shaped oblate ellipsoids, with a finite thickness. Although the oblate ellipsoidal shapes of the nucleons are not shown in this simplified graphic representation, it can easily be appreciated that the non-infinitesimal thicknesses of the nucleons would not allow a triple-quark bond to form. If the energy of impact exceeds the link bond strength, the link bond will break, and alpha decay will result.

The configuration in this illustration is an example of how particle decay might occur in an excited state of ^{7}Li. For this illustration, the excited state of the atomic nuclide ^{7}Li would fission into an H4 segment and an He3 segment when the triple-quark bond is attempted. However, the H4 segment decays, on the order of zepto-seconds, into a ^{3}H and a neutron. This exact behavior of ^{3}H decay simultaneous with neutron emission is seen in two excited states of ^{7}Li, at 7.459 MeV and at 9.670 MeV levels. Similarly, this behavior of excited states simultaneously exhibiting ^{3}H and neutron emission is also seen in several excited states of boron ^{11}B and Nitrogen ^{15}N. Such behavior is easily understood as being due to the electromagnetic forces within the structure of the nucleus, attempting to violate the hard core repulsion of the nucleons.

10.3.2. Example of Beryllium ^{8}Be, Folded-star, and an Attempted Triple-Quark Bond

Another type of an attempted triple-quark bond occurs when a star segment, which has two neutrons and two protons, is on the very end of an atomic nuclide. This behavior is a fold-in behavior rather than a curl-in behavior. Magnetically, the side-by-side magnetic bonds of the star attempt to go into a lower energy state. Electrically, the plus and minus charges of the unbonded quarks attempt to bond. An example of this is seen in the ground state of ^{8}Be, shown in Fig. 30.

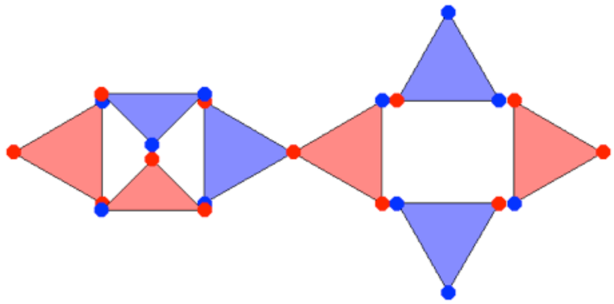


Fig. 30: The ground state of beryllium ^{8}Be.

The star segment will attempt to fold-in, in order to lower the electromagnetic energy of the configuration. The resultant folded-in shape is shown in Fig. 31, in several different viewpoints.

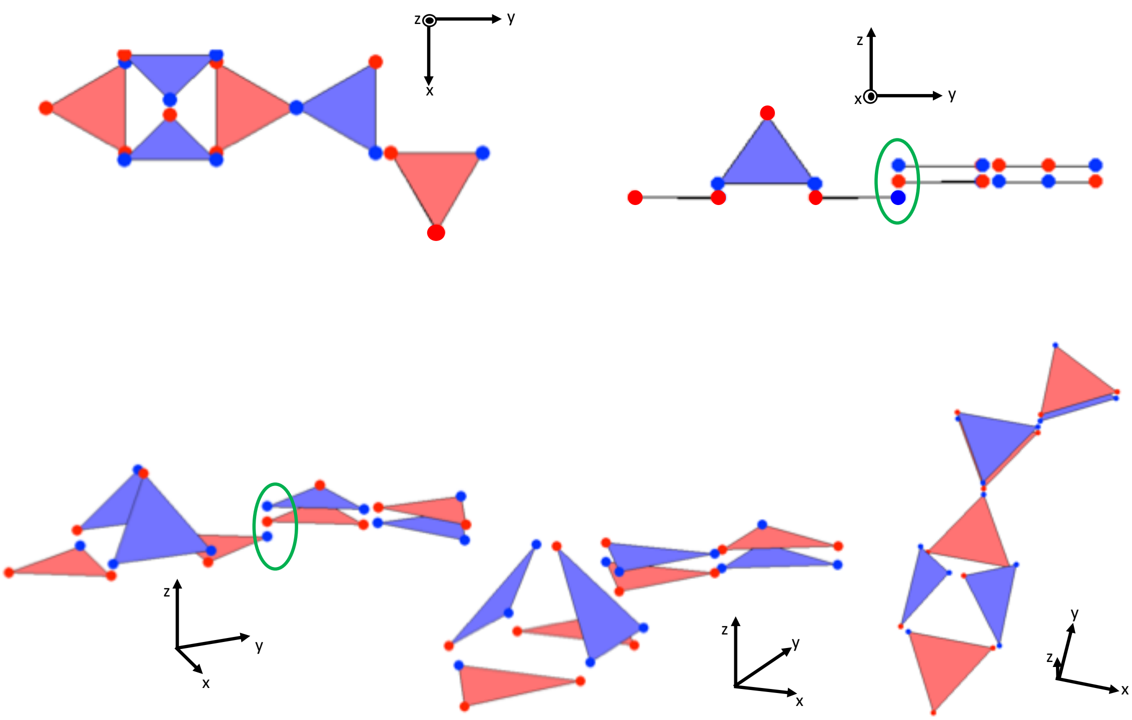


Fig. 31. Beryllium ^{8}Be in an (alpha, curled-in-star) configuration, attempting to triple bond.

Recall that the nucleons are not flat triangles, but rather disk-shaped oblate ellipsoids, with a non-infinitesimal thickness. Although the oblate ellipsoidal shapes of the nucleons are not shown in this simplified graphic representation, the thicknesses of the ellipsoidal nucleons would not allow a triple bond to form, as is attempted in this folded-in configuration. This type of configuration is not allowed due to the hard core repulsion. When a triple-quark bond is attempted, if the energy of impact exceeds that of the initial bond strength, the link bond breaks, and particle decay results.

When the end star segment goes into this folded configuration, there is a large increase in the binding energy—due to the side-by-side magnetic bonds changing into stacked magnetic bonds, and due to the unbonded quarks bonding together. The total energy of the configuration is lowered. Thus the impact energy, which is the energy available to break the initial bond between the alpha and the star, is the difference between the energies of the initial and final configurations, shown in Fig. 30 and Fig. 31. That energy difference is over 20 MeV, which is more than enough to break the 6.5 MeV of the bond. Experimentally, it is known that beryllium ^{8}Be is extremely unstable with a half life on the order of atto-seconds.

For atomic nuclides larger than ^{8}Be, a similar behavior is the most likely cause of alpha decay in the excited states, especially if there is no spin in those states. For example, in ^{12}C there are two spin-zero excited states, one at 7.654 MeV and one at 10.300 MeV above ground. Both of these states exhibit alpha decay 100% of the time. A star segment on the very end of the configuration, which would attempt to fold in, could well be the explanation for this behavior. A similarly particle decay behavior—wherein an excited state with zero spin exhibits 100% alpha decay—is seen for several excited states of ^{16}O and ^{20}Ne. A star segment on the very end of a configuration, which attempts to fold-in in violation of the hard core repulsion, can easily explain this type of decay for these excited states.

10.3.3. Applying Electromagnetic Principles to Isomeric Transitions

The transition process from a high energy state to a lower energy state is known as an "isomeric transition". Such a process emits gamma radiation. Isomeric transitions are the reconfigurations of an atomic nuclide from a higher energy configuration to a lower energy configuration, with no baryonic particle decay involved. Two simple reconfigurations have already been discussed: when a triton segment and a proton segment reconfigure into an alpha segment, and similarly when an He3 segment and a neutron segment reconfigure into an alpha segment. If an atomic nuclide is in a high energy state, the atomic nuclide reconfigures itself to go to a lower energy state, either by lowering the magnetic energy of the bonds, or by lowering the electric energy of the electric charges, or both. A change in the spin energy usually accompanies a change in the configuration.

If several reconfiguration steps are required to go from the high energy state to the ground state, then there could easily be an intermediate state that is unstable with respect to particle decay. If so, then it would exhibit particle decay instead of going to its ground state.

11. Energy Considerations of the Beta Decay Modes

11.1. Energy considerations of β- decay

Energy considerations indicate that β radiation will not occur if it makes the configuration go to a higher energy state. In other words, β radiation, whether β- or β+, will not occur if the child isotope is at a higher energy level than the parent isotope. The β decay always lowers the resultant total energy of the atomic nuclide.

This simple observation indicates something very important about the occurrence of β- decay. If the β- decay were to break a bond, the overall energy of the resulting child isotope would go up, due to the broken bond and also due to the increase in Coulomb energy. In other words, if a bond were to be broken when β- decay occurs, the overall energy of the atomic nuclide would go up, due to the broken bond and due to the increased Coulomb energy. Energetically, this energy increase is not allowed. Thus, β- decay can only occur at the unbonded quarks within the configuration. (Note that the particular mechanism and/or theories behind β- decay are not discussed or questioned here. Furthermore, this observation about β decay and energy is completely consistent with current theories about the Weak Nuclear Force and the experimental data regarding β decay.)

A second interesting observation regarding β- decay relates to the overall energy of the child nuclide after the β- decay occurs. When there is a large drop in the overall energy of the nuclide—more than about 7 MeV or so—this is a strong indication that a new bond has been <u>formed</u> in this process. When the β- decay occurs, a down quark changes into an up quark, a neutron changes into a proton. (Any changes in the Coulomb energy, the spin energy, and the mass difference between a neutron and a proton must also be taken into account.)

For example, consider a single neutron segment and a triton segment that are next to each other, such as in the (alpha, star, neutron, triton) configuration of boron ^{12}B. When the β- occurs, it must occur on an unbonded down quark. If it occurs on the unbonded down quark of the neutron segment, then the neutron segment becomes a proton segment, and a new bond will form between that proton segment and the triton segment, forming an alpha segment. The atomic nuclide is now ^{12}C. As a result of the new bond formation, there will be a large lowering of the overall energy of the child nuclide, even though the Coulomb energy went up slightly. Also, the spin changes from 1 to 0, which lowers the kinetic energy. Thus, due to the bond and the change in spin energy, the overall energy of the child nuclide is lower than that of the parent nuclide. Experimentally, when this β- decay occurs for ^{12}B, the overall energy is lowered by 13.37 MeV. When β- decay occurs and there are large jumps in the energy, such as in this example, it is a strong indication that a new electromagnetic bond was formed within the configuration.

11.2. Energy considerations of β+ decay

Similar to β- decay, when β+ decay occurs, the overall energy of the atomic nuclide must go down. For β+ decay, if a bond is broken, the energy of the configuration would go up, due to the broken bond. However, the Coulomb energy goes down due to the reduction of the net positive charge in the configuration. Changes in the spin energy will also contribute, as well as the mass difference between a neutron and a proton. Thus, the resulting net energy change may be either higher or lower depending on these other changes as compared to the bond energy. The difference in the initial and final energies, however, would be relatively small, since that difference is a subtraction of these two opposing energies, rather than an addition of two similar energies. It is well known that if the change in energy, between initial and final states, is less than two times the mass energy of an electron (1.022 MeV), then β+ decay is not allowed. Thus β+ decay cannot break a bond since the net change from initial to final energy would be too small. Thus as with β- decay, β+ will not break a bond.

A second interesting observation regarding β+ relates to the overall energy of the child nuclide after the β+ decay occurs. Similar to what was seen with β- decay, when there is a large drop in the overall energy of an atomic nuclide after the β+ decay, this is a strong indication that a bond is formed. For example, consider ^{12}N exhibiting β+ decay and going to ^{12}C; the drop in the overall energy after the β+ decay is over 15 MeV. This energy lowering is due to a bond formation. Also, the Coulomb energy is lowered, and the spin energy is lowered as well. Large energy drops after β+ decay, such as that seen in this example, are a strong indication that a bond was formed after the β+ decay.

11.3. Energy considerations of Electron Capture

Similar to β+ decay, electron capture may occur if the child nuclide is at a lower total energy than the parent nuclide. However for electron capture, the change in the energy from parent to child may be smaller than the requisite 1.022 MeV required for β+ decay. Decay by electron capture will lower the Coulomb energy. If the changes in both the Coulomb energy and spin energy go down enough to compensate for the energy of the broken bond, <u>then a broken bond *may* occur due to electron capture.</u> In such circumstances, electron capture would be the only allowed decay mechanism, and β+ decay would not occur. For example, when ^{44}Ti decays to ^{44}Sc, the only decay mode is electron capture. In this example, the overall energy drop between parent and child is only 0.267 MeV. However, the predicted estimated change due to Coulomb energy and spin energy would be a drop of roughly 5.24 MeV. Since only a drop of 0.267 MeV is seen experimentally between the parent and child, this is a strong indication that a broken bond occurred. The broken bond raises up the overall energy, which then counteracts the estimated 5.24 MeV drop that occurs due to spin and Coulomb energy. A bond can be broken by electron capture.

11.4. β Decay and Particle Decay in High-Energy States

Another consideration about β decay is that β decay does not typically occur in the high energy states of an atomic nuclide, unless that high energy state is classified as a "metastable isomeric" state. This lack of β decay for high energy states is because high energy states of an atomic nuclide typically fall into a lower-energy state too quickly for β decay to occur. If the lifetime for falling to a lower energy state exceeds about one nanosecond, then the excited nucleus is defined to be in a "metastable isomeric" state. In other words, due to the short half-lives of the high energy states (usually measured in femtoseconds or shorter) compared to the longer half-life of most β decay processes (milliseconds to years), the high energy state reconfigures to a lower state long before the β decay process takes place—unless that high energy state is classified as a metastable isomeric state.

12. Review of the Electromagnetic Contributions to Nuclear Behavior

Listed below are the rules and observations from this analysis of the electromagnetic contributions to nuclear behavior. The rules are strict rules due to the laws of physics, and cannot be violated. These rules should be considered as the rules of stability for the Nuclear Force. The observations are interesting observations that are a direct result of the rules.

12.1. Rules and Observations Due to the Pauli Exclusion Principal and Hard Core Repulsion

Because the nucleons are oblate ellipsoidal shapes—rather than being infinitesimally thin with perfectly flat edges between the quarks—the following three rules prevent the violation of the hard core repulsion of nucleons.

<u>Rule 1</u>: No triple-quark bonds. Triple-quark bonds are defined as three quarks attempting to bond to each other. Triple-quark bonds are not allowed, and if attempted, the bonds will break. Particle decay results.

<u>Rule 2</u>: No double-bonded nucleons. Double-bonded nucleons are defined as two nucleons attempting to bond twice to each other. Double-bonded nucleons are not allowed, and if attempted, the bonds will break. Particle decay results.

<u>Observation 1</u>: A single neutron segment on the end of a configuration with two unbonded down quarks is unstable and will attempt to form double-bonded nucleons. Neutron emission will result.

<u>Observation 2</u>: If there is a single nucleon segment—either a neutron segment or a proton segment—on the very end of a configuration, with one unbonded up quark and one unbonded down quark, the unbonded down quark will attempt to bond with the nearby net positive charge. The result is an attempt to form double-bonded nucleons with an adjacent nucleon. The bonds will break, and nucleon decay will result, either in the form of neutron emission or proton emission.

<u>Observation 3</u>: A single proton segment with two unbonded up quarks will not try to form a double-bonded nucleon, and no baryonic particle decay will result. (However, any configuration with two unbonded up quarks on the end-most proton would either exhibit β+ decay or it would reconfigure itself to a lower energy state. Thus, a single proton segment with two unbonded up quarks on the very end of a configuration is not allowed for the ground state of stable atomic nuclides.)

<u>Observation 4</u>: If there are two single neutron segments next to each other on the very end of a configuration, and the charges of the unbonded quarks are electromagnetically repulsed from each other, they will not exhibit neutron emission.

12.2. Rules and Observations Regarding Alpha formation

<u>Rule 3</u>: If a single proton segment and a triton segment are next to each other, and are electromagnetically attracted to each other, then they will bond and form an alpha segment. Similarly, if a neutron segment and an He3 segment are next to each other, and are electromagnetically attracted to each other, then they will bond and form an alpha segment. If the segments are next to each other, but not electromagnetically attracted to each other, then no alpha segment formation will occur.

<u>Observation 5</u>: A proton segment adjacent to and electrically attracted to a triton segment cannot be in the ground state of a nuclide.

<u>Observation 6</u>: A neutron segment adjacent to and electrically attracted to an He3 segment cannot be in the ground state of a nuclide.

12.3. Rule and Observation Due regarding Star Segments and open-H4 Segments

Rule 4: A star segment or an open-H4 segment on the very end of a configuration will either curl-in or fold-in, in order to lower its electromagnetic energy. Particle decay results.
Observation 7: A star segment or an open-H4 segment is not allowed as the end-most segment for the ground state of a stable nuclide.

12.4. Rules and Observations Concerning Particle Decay by Centrifugal Force

Rule 5: If the centrifugal energy of the end-most segment in a configuration is more than the energy of the bond, the bond will break.
Rule 6: Particle decay due to centrifugal force can only happen when there is a non-zero spin.
Observation 8: Particle decay due to centrifugal force will be more prevalent in the smaller atomic nuclides, wherein the centrifugal force is stronger for a given quantum spin value.

12.5. Rule and Observation Regarding Isomeric Transitions and Reconfiguration.

Rule 7: Isomeric transitions (AKA reconfiguration) will occur in order to lower the energy of an atomic nuclide. The process of reconfiguration does not allow the atomic nuclide to go to a higher energy state. During this reconfiguration process, particle decay may result if a configuration violates one of the stability rules for the Nuclear Force.
Observation 9: No reconfiguration can have a net bond breakage from the initial to the final state. This is because a net bond breakage would raise, rather than lower, the overall energy.

12.6. Rules and Observations about β decay

Rule 8: There can be no bond breakage due to β- or β+ decay.
Rule 9: There may be bond breakage due to electron capture if this is the only mode of decay.
Observation 10: After the event of β- decay, β+ decay, or electron capture, if there is a large drop in the overall energy of the child atomic nuclide, then this is a strong indication that a new bond has been formed.

12.7. A Brief Summary of All Rules and Observations

In a more concise form, the rules and observations are summarized here.

- Rules:
  - Rule 1: No triple-quark bonds.
  - Rule 2: No double-bonded nucleons.
  - Rule 3: Alpha formation occurs when a triton segment and a single proton segment are next to each other in a configuration. Similarly for a He segment and a single neutron segment.
  - Rule 4: A star segment or an open-H4 segment on the very end of a configuration will particle decay.
  - Rule 5: If the centrifugal energy of the end-most segment in a configuration is more than the energy of the bond, the bond will break.
  - Rule 6: Particle decay by centrifugal force can only occur with a non-zero spin.
  - Rule 7: Isomeric Transitions can only lower, not raise, the energy of an atomic nuclide. If the transition violates one of the stability rules for the Nuclear Force, particle decay may result.
  - Rule 8: There can be no bond breakage due to β- or β+ decay.
  - Rule 9: There may be bond breakage due to electron capture if this is the only mode of decay.

- Observations:
  - Observation 1: A single neutron segment with two unbonded down quarks is not stable and will particle decay.
  - Observation 2: A single neutron or proton segment, on the very end of a configuration, with one unbonded down quark and one unbonded up quark, is not stable and will particle decay.
  - Observation 3: A proton segment with two unbonded up quarks will not particle decay. (However, it will either reconfigure or β+ decay.)
  - Observation 4: Two neutron segments next to each other on the very end of a configuration, wherein the charges of the unbonded quarks are electromagnetically repulsed from each other, will not exhibit neutron emission.
  - Observation 5: A configuration with a proton segment and a triton segment that are electrically attracted to each other cannot be in the ground state of a nuclide.
  - Observation 6: A configuration with a neutron segment and an He3 segment that are electrically attracted to each other cannot be in the ground state of a nuclide.
  - Observation 7: A star segment or an open-H4 segment is not allowed as the end-most segment for the ground state of a stable nuclide.
  - Observation 8: Particle decay by centrifugal force is more prevalent in the smaller atomic nuclides, wherein the

centrifugal force is stronger for a given quantum spin value.

- Observation 9: No reconfiguration can have a net bond breakage from the initial to the final state.
- Observation 10: After the event of β decay or electron capture, if there is a large drop in the overall energy of the atomic nuclide, this is a strong indication that a new bond has been formed.

12.8. Conclusions

By applying the electromagnetic forces to the quarks and nucleons within a nucleus, new insights about the behavior of the Nuclear Force have been achieved. By examining the electromagnetic forces and energies in detail within the nucleus, this model is able to explain the nuclear behaviors of neutron emission, proton emission, and alpha emission for the small atomic nuclides. (Alpha decay for the larger atomic nuclides, characterized by long half lives, will be discussed in a subsequent paper.) Also, this model provides insight regarding the nuclear behaviors of excited energy states and isomeric transitions, in a clear and understandable manner. No other *one* previous model is able to explain all of these nuclear behaviors.

Historically, the explanation for the various modes of particle decay (defined as a change in the mass number A) have been extremely difficult for previous models of the Nuclear Force to explain. Previous models of the Nuclear Force can only observe that these decay modes are allowed energetically, but they offer no theoretical explanation or understanding as to why or how these particle decays occur. Indeed, it is difficult to explain such behavior without the concept of an internal structure inside the atomic nucleus, and without the concept of a force that can be both attractive and repulsive, depending on that structure. It is the inclusion of structure and a bipolar force within the atomic nucleus that makes the Electromagnetic Model of the Nuclear Force so powerful in being able to explain and understand the various complex behaviors of atomic nuclides. Previous concepts of an atomic nucleus—such as liquid drops, shells with magic numbers, or independent particles inside an energy well—are not able to explain why the Nuclear Force should suddenly eject a particle within a few zepto-seconds.

The explanations and insights that are discussed in this paper, Part III, can now be used to understand the nuclear behaviors seen in the smaller and medium-sized atomic nuclides, and specifically this will be done in Part IV of this series. Compared to other previous models of the Nuclear Force, the Electromagnetic Model is unique, because it acknowledges the electromagnetic forces of the quarks that exist inside of an atomic nucleus. Also, since this model acknowledges the existence of quarks, it is more closely aligned with the concepts and principles of The Standard Model.

The Electromagnetic Force may not be the only force holding the nucleons together in a nucleus; however, the electromagnetic force is able to account for and explain a large portion of the behaviors of the Nuclear Force. This series of papers acts as an introduction and a starting point for other researchers to consider the electromagnetic behaviors inside the atomic nucleus. Being an introduction for this topic, the concepts discussed in this series of papers may indeed need refining and perfecting, especially since the Nuclear Force and the Electromagnetic Force are both complicated forces. However, rather than disregarding the electromagnetic forces and energies of the quarks, when taken into full account and understanding, the electromagnetic forces inside a nucleus can explain much about nuclear behavior. Only the slight decrease in binding energy per nucleon that is seen for the largest nuclides is not explained by the electromagnetic force. It is the intent of this series of papers to show that the role of electromagnetics within the nucleus is a research field that deserves further analysis and serious consideration by other theoretical nuclear physicists. This paper serves as the introduction to such theoretical investigations into the electromagnetic considerations of the nuclear force.

The outdated concepts and obvious misconceptions, which existed prior to the discovery of quarks, have dominated the field of nuclear physics. However, such outdated concepts and misconceptions should no longer continue to dominate and restrain the progress of this field. Electromagnetism *can,* indeed, be the force that holds the nucleons together in an atomic nucleus. With the understanding provided by this model, the behavior of the Nuclear Force is no longer mysterious or complex. The Nuclear Force can be easily be understood by applying the laws of electromagnetism and quantum angular momentum to the structure of the nucleus. The Electromagnetic Forces of the quarks create the Nuclear Force and hold the atomic nucleus together. Furthermore, if the Electromagnetic Forces cause a violation of the stability rules for the Nuclear Force, these same Electromagnetic Forces can cause particle decay. Nuclear behaviors are a direct consequence of the Electromagnetic Forces acting within the nuclear structure. The Electromagnetic Forces and the specific configurations of the atomic nuclei are what control nuclear behavior. By recognizing the Electromagnetic Forces within the nuclear structure, a better understanding of nuclear behavior is obtained. This model has directly unified the Nuclear Force to the Electromagnetic Force.

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