The Structure of the Nucleus

Assumptions:
The structure of the nucleus must be simple (belief that nature is inherently simple)
Only the two quarks with like charge rotate in nucleons (assumption of this model, helps explain the magnetic moment of the neutron.)
Frequency of rotation for proton and neutron are the same (assumption of this model)
Spherical shape of nucleus is an apparent shape due to a flat structure viewed from all possible angles or precessing at a high rate of spin.
The Structure of the Nucleus

Requirements:
The structures must agree with the stability of known nuclei.

The Nucleus must have a periodic structure to explain the “fuzzy” diffraction patterns.

A nucleus may have more than one structure (isomer).
The structure must be able to logically explain alpha, beta, and gamma decay.
The Structure of the Nucleus

GIVEN,

MAGNETIC MOMENTS:

Proton = \(1.41060761(47) \times 10^{-26}\) Joules/Tesla

2.7928473(37) + 29 Bohr Magnetons

(PDG 2000)

Neutron = -\(0.96623707(40) \times 10^{-26}\) Joules/Tesla

-1.913042(7) ± 5 Bohr Magnetons

(PDG 2000)
The Structure of the Nucleus

Given,
Masses of Proton and Neutron: * = PDG 2000

Proton = 1836.15(3) mass electrons
1.672623 × 10^{-27} Kg *
938.327200(0) + 4 MeV *
1.007276466(88) + 13 AMU *

Neutron = 1838.683(7) mass electrons
1.6749286 × 10^{-27} Kg *
939.5653(3) + 4 MeV *
1.008664915(78) + 55 AMU *

Electron = 9.1093897(54) × 10^{-31} Kg
The Structure of the Nucleus

Given:

**CONSTANTS:**
- Electron/Proton charge = 1.602095 \( \times \) 10\(^{-19}\) coul.
- Speed of light “c” = 2.997925 meters / sec
- Plank’s constant “h” = 6.62618 \( \times \) 10\(^{-34}\) J s

**Equations used in this theory:**

- Magnetic Moment:
  \[ \mu = I(A) = ef (\pi \ r^2) = 1/2 \ (e \ v \ r) \]

- Einstein:
  \[ m_v = m_o \ (1 - v^2/c^2)^{-1/2} \]

- DeBroglie:
  \[ \lambda_v = h / m_v v \]
The Structure of the $^4\text{He}$ Nucleus

Basic Principle:

- Protons
- Neutrons
- Up Quark: $+\frac{2}{3}$
- Down Quark: $-\frac{1}{3}$

$^4\text{He}$
The Structure of the $^4$He Nucleus

Basic Principle refined

- Proton
  - Spin down
  - Dn Quark
  - $-1/3\,Q$

- Neutron
  - Spin down
  - Up Quark
  - $+2/3\,Q$

- Proton
  - Spin up

- Neutron
  - Spin up
The Structure of the He Nucleus
Basic Principle refined

Proton spin Up  Neutron spin Up

Neutron spin Down Proton spin Down
The Structure of the Nucleus

Known Charge Distribution of the Neutron
Agrees with assumed structure of this theory

Charge Distribution for the neutron as determined by electron scattering

Reference:
Pg 687, Figure 14.19, Fujia Yang and Joseph H. Hamilton, “Modern Atomic and Nuclear Physics, McGraw- Hill, 1996.

Quote from that text: “The neutron charge distribution with an inner positive charge and outer layer of negative charge is consistent with its negative magnetic moment”

The Structure of the Nucleus

Two examples of nuclear mirror nuclei:

3
He
2

3
H
1

7
Be

7
Li
3

Proton
Neutron
The Structure of the Carbon Nucleus

Abundance = 98.89%

half life = 5715 years

Proton

Neutron
The Structure of the Nucleus

Two stable isomers of Oxygen 16.

The Nuclear Cluster Model, which predicts linear structures such as Oxygen 16 and Mg 24 is described in the Handbook of Nuclear Properties, D.N. Peonaru and W. Greiner pg 103.

The Structure of the Nucleus

Only stable forms of odd proton-odd neutron.
The Structure of the Nucleus

Stable structures from Oxygen 16 to Fluorine 19.

2 - Alpha Particles

Neutron

Proton
The Structure of the Nucleus

Neutrons

\[ \text{spin down} \quad \text{Spin up} \]

\[ \text{n} \quad \text{u} \]

Protons

\[ \text{spin down} \quad \text{spin up} \]

\[ \text{d} \quad \text{p} \]
The Structure of the Nucleus

Stable structures of Neon, 5 alpha particles

spin = 0

20 Ne 10
90.48%

spin = 3/2+

21 Ne 10
0.27%

spin = 0

22 Ne 10
9.25%

Alpha Particle: Neon 22 has 8 additional neutron sites that could be populated, resulting in Ne 30. To date the heaviest isotope of Ne that has been...
Most abundant form of Ca, 96.94%. Double mirror symmetrical.
Double Magic number Nuclei.
The Structure of the Nucleus

These 4 nuclear structures all follow the same pattern / symmetry. They all have double mirror symmetry. Two of these structures are double magic. The other two have high abundance's.
The Structure of the Nucleus

These 3 nuclear structures all have double mirror symmetry and are key nuclei for their abundance and stability. Fe 56 has the highest binding energy of any nucleus.
The Structure of the Nucleus

Starting with Ca 48 and filling six additional non-structural neutron sites gives Ca 54. To date the heaviest isotope of Ca that has been found is Ca 53 with a half-life of 0.09 seconds.
The Structure of the Nucleus

2 - Alpha Particles

O 24, Mg 34, Cr 64, Ni 74, are significantly more stable than the next heavier isotope. The above structures have a number of protons that is divisible by 4. Ca 54 would fit this model, to date only Ca 53 (90 msec) has been found.
The Structure of the Nucleus

Most abundant form of Fe, 91.75%. Double mirror symmetry.
The Structure of the Nucleus

Different Forms of stable Iron nuclei

Half life = 1.5 \times 10^6 \text{ years}

54^{26}_{\text{Fe}} 5.84\%  
56^{26}_{\text{Fe}} 91.75\%  
58^{26}_{\text{Fe}} 0.282\%  
60^{26}_{\text{Fe}}
Fe 68 and Fe 69 are the last two isotopes of Fe. Notice that the structure of Fe 68 (or Ti 58) is a repeating structure of 3 neutrons followed by 2 protons. The structure at the bottom of Fe 69 above would also explain the nuclei of Ne 29, Si 39, Zn 79, and Se 89. Similarly if the splitting occurred at both ends that would explain Zn 80 and Se 90. Also the Fe 68 structure would predict that Ar 48 will eventually be found. All the above nuclei have one thing in common: their number of protons are $4(n + 1/2)$. 

$68 \text{ Fe}$
$26 \text{ Fe}$

half life = .10 sec

half life > 150 nsec
The Structure of the Nucleus
The Structure of the Nucleus

- 70 Ge 21.23%
- 72 Ge 27.66%
- 74 Ge 35.94%
- 84 Ge 0.947 sec
- 76 Ge 7.44%

- 2- Alpha Particles
- Non structural Neutron
- Neutron
- Proton
Sn 120 is the most abundant form of Sn. Subtract two non structural neutrons and you get Sn 118, 24.22% abundance. Subtract two more non structural neutrons and you get Sn 116, abundance 14.54%. Subtract the last two non structural neutrons = Sn 114, abundance .65%.
Sn 124 is the last stable nuclei of Sn. This structure has mirror symmetry. This structure has 4 more neutron sites so that nuclei up to Sn 128 can be explained.
Xe 132 is the most abundant stable nuclei of Xe. This structure has 27 alpha particles arranged in 9 rows of 3 alphas each. 9X3 is the only way you can factor 27. If you remove the 8 non structural neutrons from Xe 132 you get Xe 124, which is the lightest stable nuclei of Xe.
The Structure of the Nucleus

- Neutron
- Proton
- Non Structural Neutron
- 2- Alpha Particles

138
Xe
54
14.08 min
Gd 164 is the heaviest unstable isotope of Gd with a half-life.
32 Alpha structures, plus 30 additional structural neutrons and six non-structural neutrons. If you remove the 6 non-structural neutrons from Gd 164, you get Gd 158, the most
The Structure of the Nucleus

208 Pb

Note: This structure does not agree with the currently accepted size of Pb 208. This structure is about 3X as large as currently accepted. This structure better explains the large quadrupole moments for nuclei over 50 > A > 90. If we drop the single bonded neutrons (2 at a time) we get Pb 206 and Pb 204, both stable nuclei.
The Structure of the Nucleus

O 26, F 29, Mg 38, Si 43, P 46, also fits this pattern and all except Carbon are the heaviest known isotope. Only Al 41 and S 49 have not yet been found.
He 6, He 8, Li 11, Be 12 and Be 14 are known as the Halo Nuclei, it is known that two loosely bound neutrons are tied to the core of the nuclei. In these nuclei, mass and charge radii may differ by large amounts. The density distribution shows an extended neutron tail at low density. Li 11 extends farther out than current models can explain. B 17, also believed to be a halo nuclei, fits this pattern.

Reference: D.N. Poenaru and W. Greiner pg 139. and proceedings of ENAM 98.
The Structure of the Nucleus

<table>
<thead>
<tr>
<th>Element</th>
<th>8 He</th>
<th>11 Li</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Stability</td>
<td>119 ms</td>
<td>8.7 ms</td>
</tr>
</tbody>
</table>
The Structure of the Nucleus

Semi-stable structures along the proton drip line

- half life = 53.29 days
- half life = 8.58 ms
- half life = 19.255 seconds
- half life = 6 ms

Ne 16 and Mg 19 exists and fit this pattern, their half lives should be between 6-8 ms.
The Structure of the Nucleus

Very unstable structures that decay by double proton emission:

- Be (6) with half-life: \(5.0 \times 10^{-21} \text{ sec}\)
- C (8) with half-life: \(2.0 \times 10^{-21} \text{ sec}\)
- O (12) with half-life: \(1.0 \times 10^{-8} \text{ sec}\)
The Structure of the Nucleus

He\textsubscript{10} does not have a bound state. B\textsubscript{19} is the last isotope of Boron.

Predictions: Hydrogen 6 will be found to be an unbound nucleus.

\begin{align*}
\text{He} & \quad \text{half life} = 2 \times 10^{-21} \text{sec} \\
\text{B} & \quad \text{half life} = ?? \\
\text{H} & \quad \text{half life} = 1 \times 10^{-21} \text{sec}
\end{align*}
Ni 76 is believed to have a half life > 150 ns. Ni 78 half life is not known.

Mg 34 is known to have a half life of 20 ms. Ni 35 and Ni 36 have half lives > 200 ns.

Ni 76 is believed to have a half live > 150 ns. Ni 78 half life is not known.
The Structure of the Nucleus

\[ \mu = I(A) = (e_q f) \pi r^2 = 1/2 (e_q v_q r) \]

\[ \mu_{\text{proton}} = I(A) = 2(2/3)f \pi r_p^2 \]

\[ \mu_{\text{neutron}} = I(A) = 2(-1/3)f \pi r_n^2 \]

Since this model assumes the frequency of rotation of the proton and neutron are the same, we get.

\[ \mu_{\text{proton}} / \mu_{\text{neutron}} = -2 (r_p/r_n)^2 \]

\[ r_n/r_p = \{2(.96623707)/1.41060761\}^{1/2} \]

\[ r_n = 1.1704523 \; r_p \]

Therefore the velocity of the down quark in the neutron is 1.17045 the velocity of the up quark in the proton.
The Structure of the Nucleus

It is generally accepted that the Binding energy difference between the mirror nuclei of $^3$He and $^3$H is due to Coulomb repulsion between the two protons. Blatt, Weisskoff, Theoretical Nuclear Physics, 52, p 204

$$\text{BE}(^3\text{H}) = \text{mass}(^3\text{H}) - m_e - m_p - 2m_n = 8.48183 \text{ Mev}$$

$$\text{BE}(^3\text{He}) = \text{mass}(^3\text{He}) - 2m_e - 2m_p - m_n = 7.71809 \text{ Mev}$$

$$\text{BE}(^3\text{H}) - \text{BE}(^3\text{He}) = 0.76374 \text{ Mev}$$

Coulomb energy in $^3$He $= \Delta \text{BE} = 0.76374 \text{ Mev} = \frac{6e^2}{5R_c}$

$R_c$ = separation distance between the two protons in $^3$He. $R_c = 2.262$ fm. If we assume the structure is linear, and the neutron is between the two protons and 1.1704523 times larger, we get $r_p = 0.5211$ fm and $r_n = 0.6099$ fm.
Structure of the Nucleus

\[ \mu_{\text{proton}} \equiv \frac{2e_{\text{quark}} \cdot v_{\text{up, quarks}} \cdot r_{\text{proton}}}{2} \]

\[ v_{\text{up, quarks}} \equiv \frac{2\mu_{\text{proton}}}{2e_{\text{up, quark}} \cdot r_{\text{proton}}} \]

\[ v_{\text{up, quarks}} \equiv \frac{2(1.41060761 \times 10^{-26} \text{ J} / \text{T})}{2(2/3)(1.602095^{-19} \text{ C}) \cdot 0.5211 \text{ fm}} \]

\[ v_{\text{up, quark, in, proton}} \equiv 2.53447 \times 10^8 \text{ m/s} \equiv 0.8454c \]

\[ v_{\text{dn, quarks, in, neutron}} \equiv 1.1704523 \cdot v_{\text{up, quarks}} \equiv 0.9895c \]
Plugging \( v_{up} = 0.8454c \) and \( v_{dn} = 0.9895c \) into the above 2 equations, we get two equations with two unknowns (mass of up and down quarks). This gives a mass of the up quark of 463.8 mass electrons and the down quark of 99 mass electrons. This results in the up quark having a DeBroglie wavelength of 3.30 fm, which when divided by \( 2\pi \) corresponds to a radius of .526 fm, which is 1% different than the .5211 fm initially estimated.
The Structure of the Nucleus

Iterating until the DeBroglie wavelength of the up quark in the proton exactly matches the radius of the proton we get:

Radius:
- Proton = $0.519406 \times 10^{-15}$ meters
- Neutron = $0.6079394 \times 10^{-15}$ meters

Velocity:
- 2 - Up Quarks in Proton = .848123 speed of light
- 2 - Down Quarks in Neutron = .992685 speed of light

Mass:
- Up Quark mass = 464.41 electron masses
- Down Quark mass = 82.958 electron masses
The Structure of the Nucleus

Known Charge Distribution of the Neutron

Size of the Neutron in this model agrees with the peak of the negative charge distribution.

Charge Distribution for the neutron as determined by electron scattering

Reference:
Pg 687, Figure 14.19, Fujia Yang and Joseph H. Hamilton, "Modern Atomic and Nuclear Physics, McGraw-Hill, 1996.

Quote from that text: “The neutron charge distribution with an inner positive charge and outer layer of negative charge is consistent with its negative magnetic moment”

The Structure of the Nucleus

Unit cell size = 1.12735 fm
“diameter” of He nucleus = 2.255 fm

This model predicts a size and charge distribution of the neutron that agrees with electron scattering, pg 687 Modern Atomic and Nuclear Physics, F. Yang and J.H. Hamilton, 1996 McGraw Hill. (see text)
This model predicts a size of the proton that agrees with many nuclear physics texts, namely 0.45 fm to 0.65 fm. Note that the linear extrapolation of the 3D model predicts a size of 1.23 fm for the proton, which is too large.
Notice that the above diamond structures give consecutive magic numbers. The Sn structure is stable because square structures of Sn are stable, on the other hand the above structure of Pb is not as stable. Since this model has derived the size of a Helium nucleus as 2.255 fm this can be used to calculate the size of the
Notice that the above structures of O 16, Ca 40, and Fe 56 give good agreement to the accepted size of these structures. This model has derived the size of a Helium nucleus as 2.255 fm and this can be used to compare against the accepted size of these nuclei.
The Structure of the Nucleus

<table>
<thead>
<tr>
<th>Mass Mev</th>
<th>Electric Charge</th>
<th>Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Quarks</td>
<td>+2/3</td>
<td>Up M=237.31</td>
</tr>
<tr>
<td></td>
<td>-1/3</td>
<td>Down M=42.392</td>
</tr>
<tr>
<td>Leptons</td>
<td>+</td>
<td>Electron M=.51100</td>
</tr>
</tbody>
</table>

This model predicts that the Up quark will be heavier than the down quark. In the other two families the +2/3 quark is heavier than the -1/3 quark. The first generation now is similar to the others. The ratio of the mass of the Up quark to the down...
Gamma emission is represented by a shift of one lattice position by an even number of nucleons. Beta (-) emission is the shift of a proton becoming a neutron and shifting over one lattice position.
Structure of the Nucleus

What reasons can account for the different structures above and below Pb?

If the Uranium nuclei are really linear, then they are shorter by a factor of \( \sqrt{2} \) than they would be if they were diagonal. This would mean the structure has extra stored up potential energy in the form of repulsion of those protons. Because the structure has just as many bonds (4) at any point along the structure, it should be just as strong a structure as Pb, just that potential energy of all the repelling protons. Therefore it is like an elastic spring waiting for an alpha decay to make the structure unstable resulting in it expanding to the diagonal size of the Pb nuclei. It would be expected that this would explain the back bending of the \( I \) vs \( \omega \) for the yrast states of Dy, and other such nuclei. Also it would explain why each emission is the same in energy and why the number of steps in these spectrum is approximately the same number as the number of steps in this model.
The Structure of the Nucleus
The Pi Meson is known to be composed of a dn and an anti up quark. An anti up has the same mass as an up quark. The sum of the mass of up plus the dn quark in this model is:

279.70 Mev.

The accepted value of the pi meson is 139.5675 + - .0004 Mev.* This means that this model predicts a mass of the Pi meson almost exactly (a difference of 0.2%) twice as large as the accepted value. In a pi meson dn quark and an anti-up quark must be held together by some amount of binding energy. If 1/2 of the rest mass of the quarks go into the binding of the Pi meson, this would explain the rest mass of the Pi meson.

* Pg 234, G.D. Coughlan and J.E.Dodd “The Ideas of Particle Physics“
The Structure of the Nucleus

Mass difference of the Phi(1020) and W(782)

The mass difference between the Phi (1020) meson and the W (782) meson is 237.47 ± 0.13 MeV based upon the latest data from the Particle Data Group. What is interesting is that this difference is almost exactly that of the predicted mass of the up quark in the CBM model.

Why these two mesons are significant is that since they are the lowest excited state of the Pi meson, we know their masses better than the higher excited states and we know that all the quantum numbers of both mesons are the same and they are composed only of up and down quarks. It must be more than just coincidence that this mass difference is in agreement with this model's mass of the up quark.
The Structure of the Nucleus

Binding Energy Per Nucleon

Most abundant isotope

BE/nucleon = %1 bond (1.122) + %2 bonds (7.074) + %3 bonds (8.13) + %4 bonds (9.53) MEV
The Structure of the Nucleus

The CBM Model of the Nucleus Explains

- Central Force term (center quarks) and the Stronger Tensor Term (rotating quarks)
- Why the volume of the nucleus is mostly empty (flat structure)
- Why the force is repulsive at $r < 0.5$ fm (size of the proton, incompressible)
- Why there is a neutron skin of about 0.1 fm on many nuclei (see structure)
- Saturation of the binding energy (at most only 4 nearest neighbors)
- Explains the exact magnetic moments of the nucleons, especially the neutron
- Why the nucleus can have only half integer spins (flat; up or down)
- Prime number proton nuclei have only one stable form (2X operator)
- Why the nucleus can produce a diffraction pattern (it is periodic)
- The size of key square nuclei agree well with accepted values (not Pb)
- Explains Gamma and Beta emission as nucleon lattice movement
- Does a good job of explaining most of the Magic numbers (4, 8, 50, 82)
- Thermal neutrons react with nuclei (better able to align to flat structure)
- It explains the linear alpha chains recently discovered such as Mg 24
- It explains the large Electronic Quadrupole Moments of rare earth and