Understanding nuclear stability and binding energy with Up and Down quarks via 5 terms having single energy coefficient

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Introduction

Recently, N. Ghahramany and team members tried to explore nuclear binding energy and magic numbers in terms of quarks [1]. Very interesting point of their study is that - nuclear binding energy can be understood with two terms having a single variable energy coefficient of the order of 10 MeV. In this context, with reference to three atomic gravitational constants, in our recent publication [2], we tried to understand nuclear stability and binding energy. With further study, nuclear stability and binding energy can be understood with Up and Down quarks and coupling constants.

5 terms with single energy coefficient

In our approach, there exists only one binding energy coefficient with five terms. It can be expressed as, for $Z \geq 3$,

$$B_A \cong \begin{Bmatrix} A - 0.00189A\sqrt{ZN} - A^{1/3} \\ -(Z/N) - \left[(A_s - A)^2 / A_s \right] \end{Bmatrix} 10.09 \text{ MeV} \quad (1)$$

where

$$\begin{cases} A_s \cong \text{Estimated mass number close to} \\ \quad \text{actual stable mass number} \\ \quad \cong Z + N_s \cong 2Z + 0.0064Z^2 \\ \text{where, } k_s \cong 0.0064 = \text{Nuclear stability coefficient} \end{cases}$$

Inference of relation (1)

Based on the proposed semi empirical relation (1) and with reference to the recommended Up and down quark masses [3], we propose that,

1) Nuclear binding energy coefficient is,
$B_0 \cong \left[(2m_u + m_d)c^2 + (m_u + 2m_d)c^2 \right] / 2$
$\cong (3m_u + 3m_d)c^2/2 \cong 10.275 \text{ MeV} \approx 10.1 \text{ MeV}$
2) For increasing (Z, A), all nucleons will not involve in nuclear binding energy scheme.
3) Nucleons that are not involving in nuclear binding energy scheme can be called as 'free nucleons' and can be represented by $A_f \cong k_f A\sqrt{ZN}$ where the coefficient $k_f \cong 0.00189$ can be called as 'Free nucleon number coefficient'. With reference to the semi empirical mass formula, quantitatively, $k_f \cong 2(a_c/a_a)^2 \cong 0.0018753$ where $a_c = 0.71$ MeV and $a_a = 23.21$ MeV.
4) Nucleons that involve in nuclear binding energy scheme can be called as 'active nucleons' and can be represented by $A_a \cong A - A_f \cong A\left(1 - 0.00189\sqrt{ZN}\right)$.
5) Nuclear binding energy decreases with increasing radius in the form of $A^{1/3}$.
6) Nuclear binding energy depends on (Z/N).
7) Stable mass number close to beta stability line, plays a vital role in estimating the binding energy of other stable and unstable isotopes in the form of $\left[(A_s - A)^2 / A_s \right]$.It needs further study.

To fit the Fine structure ratio

we noticed that,

$$\frac{m_u c^2 + m_d c^2}{m_n c^2} \cong \frac{2.15 + 4.7}{938.918664} \quad (2)$$
$$\cong 0.007295627 \cong 0.00297352533$$

where m_n = average mass of nucleon.

Based on this coincidence, it is possible to say that,

$$\alpha \cong \left(\frac{m_u + m_d}{m_n} \right) \quad (3)$$

To fit the free nucleon number coefficient

We noticed that, the product of fine structure ratio and strong coupling constant seem to play an interesting role in estimating the two proposed coefficients. Free nucleon coefficient can be fitted with a relation of the form,

$$k_f \cong \left(\frac{m_d}{m_u} \right) \alpha\alpha_s \cong 0.00184 \quad (4)$$

where, α_s = Strong coupling constant = 0.1181

In terms of quark masses, qualitatively,

$$k_f \cong \alpha_s \left[\frac{m_d + \left(m_d^2 / m_u \right)}{m_n} \right] \quad (5)$$

To fit the nuclear stability coefficient

One can find the historical form of k_s in Ref. [4,5]. Close to beta stability line,

$$N - Z \cong 0.006 A^{5/3} \quad (6)$$

Quantitatively, we noticed that,

$$k_s \cong \alpha - (\alpha\alpha_s) \cong \alpha(1 - \alpha_s) \cong 0.0064355 \quad (7)$$

In terms of quark masses, qualitatively,

$$k_s \cong (1 - \alpha_s) \left(\frac{m_u + m_d}{m_n} \right) \quad (8)$$

To understand the ratio of k_s and k_f

Based on relations (5) and (8),

$$\frac{k_s}{k_f} \cong \left(\frac{1}{\alpha_s} - 1 \right) \left(\frac{m_u + m_d}{m_d + \left(m_d^2 / m_u \right)} \right) \cong 3.416 \quad (9)$$

Discussion and conclusion

We would like to appeal that,

a) $A_s \cong 2Z + 0.0064 Z^2$ is a direct relation by using which, stable nucleon number can be addressed directly. It can also be applied for super heavy elements.
b) Even though relation (1) is semi empirical, it can be given some consideration in understanding and estimating nuclear binding energy with respect to up and down quarks.
c) Relation (3) seems to play an interesting role in understanding the origin of fine structure ratio.
d) Proposed relations (4) and (7) can be given some consideration in understanding the coefficients k_s and k_f.
e) With further study, at nuclear scale, actual role of up and down quarks can be understood.

References

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