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On the Role of Squared Neutron Number in Reducing Nuclear Binding Energy in the Light of Electromagnetic, Weak and Nuclear Gravitational Constants – A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Author UVSS designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Author SL managed the analyses of the study in all aspects. Both authors read and approved the final manuscript.

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ABSTRACT

With reference to authors recently proposed three virtual atomic gravitational constants and nuclear elementary charge, close to stable mass numbers, it is possible to show that, squared neutron number plays a major role in reducing nuclear binding energy. In this context, Z=30 onwards, 'inverse of the strong coupling constant', can be inferred as a representation of the maximum strength of nuclear interaction and 10.09 MeV can be considered as a characteristic nuclear binding energy coefficient. Coulombic energy coefficient being 0.695 MeV, semi empirical mass formula - volume, surface, asymmetric and pairing energy coefficients can be shown to be 15.29

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MeV, 15.29 MeV, 23.16 MeV and 10.09 MeV respectively. Volume and Surface energy terms can be represented with $(A-A^{2/3}-1)*15.29$ MeV. With reference to nuclear potential of 1.162 MeV and coulombic energy coefficient, close to stable mass numbers, nuclear binding energy can be fitted with two simple terms having an effective binding energy coefficient of [10.09-(1.162+0.695)/2] = 9.16 MeV. Nuclear binding energy can also be fitted with five terms having a single energy coefficient of 10.09 MeV. With further study, semi empirical mass formula can be simplified with respect to strong coupling constant.

Keywords: Three virtual atomic gravitational constants; nuclear elementary charge; nuclear stability; binding energy; squared neutron number; screened mass number.

1. INTRODUCTION

Considering neutrons and protons as microscopic molecules, the liquid drop model treats the atomic nucleus as a drop of incompressible nuclear fluid of very high density bound by strong nuclear force. The residual effect of the strong nuclear force plays a crucial role in understanding nuclear binding. Mathematical analysis of the model delivers a formula to predict the binding energy of any atomic nucleus in terms of its number of protons and neutrons with five different energy terms and five different energy coefficients. Energy coefficients of the formula are chosen in such a way to fit the wide range of nuclear binding energy data partly based on theory and partly based on empirical measurements. Hence 'liquid drop formula' is generally called as 'Semi empirical mass formula (SEMF). Even though, many scientists reviewed the formula in different ways, as on today, the syntax of the formula almost remains the same with very minor changes [1-6].

In this context, authors would like to emphasize the fact that, physics and mathematics associated with fixing of the energy coefficients of SEMF are neither connected with residual strong nuclear force nor connected with strong coupling constant. Since nuclear force is mediated via quarks and gluons, it is necessary and compulsory to study the nuclear binding energy scheme in terms of nuclear coupling constants. In this direction, N. Ghahramany and team members have taken a great initiative in exploring the secrets of nuclear binding energy and magic numbers [7-11]. Very interesting point of their study is that - nuclear binding energy can be understood with two or three terms with single energy coefficient.

Now days a lot of progress is taking place in the fields of fluid mechanics at atomic and nano scales [12-17]. As the origin of SEMF was 'Fluid Mechanics', authors hope that, by considering a combined study on the residual nuclear force, ground sate quarks, strong coupling constant and atomic scale fluid mechanics, it may be possible to understand nuclear binding energy in a unified picture.

Objective of this paper is to review, simplify and establish the concepts proposed in authors' recent papers and conference proceedings [18-38] pertaining to nuclear stability and binding energy connected with three virtual atomic gravitational constants.

The most desirable cases of any unified description are:

a) To implement gravity in microscopic physics and to estimate the magnitude of the Newtonian gravitational constant (G_N).
b) To simplify the complicated issues of known physics. (Understanding nuclear stability, nuclear binding energy, nuclear charge radii and neutron life time etc.)
c) To predict new effects, arising from a combination of the fields inherent in the unified description. (Understanding strong coupling constant, Fermi's weak coupling constant and radiation constants etc.)
d) To develop a model of microscopic quantum gravity.

1.1 History of the Three Atomic Gravitational Constants

(1) Since 1974, K. Tennakone, Abdus Salam, C. Sivaram, K.P.Sinha, Dj. Sijacki, Y. Ne'eman, J.J. Perng, J. Strathdee, Usha Raut, V. de Sabbata, E. Recami, T.R. Mongan, Robert Oldershaw and S.G. Fedosin like many scientists proposed the existence of 'Nuclear' or 'strong' gravitational constant with a magnitude approximately (10^{35} to 10^{39}) times the Newtonian gravitational constant. In this

context, one can see a detailed discussion by F. Akinto and Farida Tahir in their arXiv preprint [39].

(2) In 2010, 2011 and 2012, in a series of papers, authors proposed the existence of 'electromagnetic' gravitational constant [23,24,25]. In 2016 Franck Delplace also proposed its existence [14].

(3) In 2013, Roberto Onofrio proposed the existence of 'weak' gravitational constant [40].

(4) In 2016, Tüzemen, S. described a possible microscopic model for gravitational interaction [41].

1.2 To Estimate the Newtonian Gravitational Constant in a Theoretical Approach

According to Rosi et al. [42]: There is no definitive relationship indeed between G_N and the other fundamental constants and no theoretical prediction for its value to test the experimental results. Improving the knowledge of G_N has not only a pure metrological interest, but is also important for the key role that this fundamental constant plays in theories of gravitation, cosmology, particle physics, astrophysics, and geophysical models.

To estimate the value of G_N in a theoretical approach, authors would like to suggest the following points.

(1) Interaction constants are connected both with global phenomena of physics and with phenomena at small distances, such as quantum gravity. Therefore, the search for relations among the constants of the four types of interactions is important, relevant and necessary. At present, there exist no basic formulae or mechanisms using by which one can develop at least models with ad hoc relations. In a unified approach, one can see a great initiative taken by J. E. Brandenburg [43]. It would be important to consider in detail such theories as microscopic quantum gravity and a combination of the fields inherent in the unified description of the four interactions.

(2) As there is a large gap in between nuclear and Planck scales, with currently believed notion of unification paradigm, it seems impossible to implement gravity in atomic, nuclear and particle physics.

(3) G_N is a man created empirical constant and is having no physical existence. Clearly speaking, it is not real but virtual. For understanding the secrets of large scale gravitational effects, scientists consider it as a physical constant.

(4) In the same way, each atomic interaction can be allowed to have its own virtual gravitational constant.

(5) With a combined study of the four gravitational constants, their magnitudes can be refined for a better fit and understanding of the nature.

1.3 Scope of This Work

(1) Current nuclear physical models and String theory models [44-46] are failing in implementing gravity in nuclear physics. In this context, authors proposed concepts can successfully be implemented in nuclear physics.

(2) Nuclear charge radii, nucleon magnetic moments, nuclear stability, nuclear binding energy, magic proton numbers [5,6,34], nucleons kinetic energy [35] and atomic radii can be understood in terms of gravity. Super heavy elements can also be studied in this direction.

(3) Hadronic mass spectrum and melting points of quarks can be understood [36].

(4) Strong coupling constant, Fermi's weak coupling constant, Newtonian gravitational constant and Avogadro number can be studied in a unified manner [37,38].

(5) Astrophysical mass units like Chandrasekhar mass limit [47] and neutron star mass limit [48,49] can be understood.

(6) Recently observed astrophysical emission line of 3.5 keV [38,50,51] can be understood.

1.4 Four Basic Semi Empirical Reference Relations

With reference to our recent publications and conference presentations [18-38], authors propose the following set of four semi empirical 'reference' relations. Let,

Electromagnetic gravitational constant = G_e

Nuclear gravitational constant = G_s

Weak gravitational constant = G_w

$$\frac{m_p}{m_e} \cong 2\pi\sqrt{\frac{4\pi\varepsilon_0 G_e m_e^2}{e^2}} \cong \left(\frac{G_e m_e^2}{\hbar c}\right)\left(\frac{G_s m_p^2}{\hbar c}\right) \quad (1)$$

$$\hbar c \cong \left(\frac{m_p}{m_e}\right)^2 \left(G_e^2 G_N\right)^{1/3} m_p^2 \quad (2)$$

$$G_F \cong \left[\left(G_e m_p^2\right)^2 \left(G_N m_p^2\right)\right]^{\frac{1}{3}} \left(\frac{2G_s m_p}{c^2}\right)^2 \cong \frac{4G_w \hbar^2}{c^2} \quad (3)$$

$$\frac{G_w}{G_N} \cong \left(\frac{m_p}{m_e}\right)^{10} \quad (4)$$

Based on relation (1), magnitudes of $\left(G_e, G_s\right)$ can be estimated. Based on relation (2), magnitude of G_N can be estimated. Based on relation (3), magnitudes of $\left(G_F, G_w\right)$ can be estimated [40,52]. Again, based on relation (4), G_N can be estimated. Estimated values seem to be:

$$\begin{array}{|l|}\hline G_e \cong 2.374335\times10^{37}\ \text{m}^3\text{kg}^{-1}\text{sec}^{-2} \\ G_s \cong 3.329561\times10^{28}\text{m}^3\text{kg}^{-1}\text{sec}^{-2} \\ G_w \cong 2.909745\times10^{22}\ \text{m}^3\text{kg}^{-1}\text{sec}^{-2} \\ G_N \cong 6.679855\times10^{-11}\ \text{m}^3\text{kg}^{-1}\text{sec}^{-2} \\ G_F \cong 1.44021\times10^{-62}\ \text{J.m}^3 \\ \hline \end{array}$$

Even though our approach is speculative, role played by the four gravitational constants seems to be fairly natural. This kind of approach may help in producing a variety of such relations by using which in near future, an absolute set of relations can be developed. Proceeding further, estimated absolute theoretical value of G_N can be considered as a standard reference for future experiments. In a verifiable approach authors developed many interesting relations and working on deriving them from basic principles.

2. THREE SIMPLE ASSUMPTIONS PERTAINING TO NUCLEAR PHYSICS

1) There exists a strong elementary charge in such a way that,

$$\frac{e_s}{e} \cong \left(\frac{G_s m_p^2}{\hbar c}\right) \cong \left[\frac{G_s m_e^2}{\left(G_e^2 G_N\right)^{1/3} m_p^2}\right] \quad (5)$$

$$\frac{e_s^2}{e^2} \cong \left(\frac{G_s m_p^2}{\hbar c}\right)^2 \cong \left(\frac{G_s m_p^3}{G_e m_e^3}\right) \text{ and}$$
$$\frac{m_p}{m_e} \cong \left(\frac{e_s^2}{4\pi\varepsilon_0 G_s m_p^2}\right) \Big/ \left(\frac{e^2}{4\pi\varepsilon_0 G_e m_e^2}\right) \quad (6)$$

$$\frac{e_s G_s}{e G_w} \cong \left(\frac{m_p}{m_e}\right)^2 \quad (7)$$

2) Strong coupling constant [52] can be expressed with,

$$\alpha_s \cong \left(\frac{e}{e_s}\right)^2 \cong \left(\frac{\hbar c}{G_s m_p^2}\right)^2 \cong \left(\frac{G_e m_e^3}{G_s m_p^3}\right) \quad (8)$$

3) Nuclear charge radius can be addressed with,

$$R_0 \cong \frac{2G_s m_p}{c^2} \quad (9)$$

Based on relations (5) to (9),

$$\begin{array}{|l|}\hline e_s \cong 2.9463591e \\ \alpha_s \cong 0.1151937 \\ \dfrac{1}{\alpha_s} \cong 8.681032 \\ R_0 \cong 1.23929\times10^{-15}\ \text{m} \\ \hline \end{array}$$

3. UNDERSTANDING PROTON-NEUTRON STABILITY WITH THREE ATOMIC GRAVITATIONAL CONSTANTS

Let,

$$\left.\begin{array}{l} s \cong \left\{\left(\dfrac{e_s}{m_p}\right) \div \left(\dfrac{e}{m_e}\right)\right\} \cong 0.001605 \\ \cong \dfrac{G_s m_p m_e}{\hbar c} \cong \dfrac{\hbar c}{G_e m_e^2} \cong \dfrac{G_s^2}{G_e G_w} \end{array}\right\} \quad (10)$$

Nuclear beta stability line can be addressed with a relation of the form [relation 8 of Ref.3],

$$\begin{array}{l} A_s \cong 2Z + s\left(2Z\right)^2 \cong 2Z + \left(4s\right)Z^2 \\ \cong 2Z + kZ^2 \cong Z\left(2 + kZ\right) \end{array} \quad (11)$$

where $(4s) \cong k \cong 0.0064185$

By considering a factor like $\left[2 \pm \sqrt{k}\right]$, likely possible range of A_s can be addressed with,

$$\left.\begin{array}{l} \left(A_s\right)_{lower}^{upper} \cong Z\left[\left(2 \pm 0.08\right) + kZ\right] \\ \rightarrow \left\{\begin{array}{l} \left(A_s\right)_{lower} \cong Z\left(1.92 + kZ\right) \\ \left(A_s\right)_{mean} \cong Z\left(2.0 + kZ\right) \\ \left(A_s\right)_{upper} \cong Z\left(2.08 + kZ\right) \end{array}\right\} \end{array}\right] \quad (12)$$

Table 1. Likely possible range of A_s for Z=5 to 115

Proton number	$(A_s)_{lower}$	$(A_s)_{mean}$	$(A_s)_{upper}$
5	10	10	11
15	30	31	33
25	52	54	56
35	75	78	81
45	99	103	107
55	125	129	134
65	152	157	162
75	180	186	192
85	210	216	223
95	240	248	256
105	272	281	289
115	306	315	324

Interesting point to be noted is that, for Z=112, 113 and 114, estimated lower stable mass numbers are 296, 299 and 302 respectively. Corresponding neutron numbers are 184, 186 and 188. These neutron numbers are very close to the currently believed shell closure at N=184. It needs further study [53]. See Table 1.

4. UNIFIED ENERGY COEFFICIENTS OF SEMI EMPIRICAL MASS FORMULA (SEMF)

Let,

A characteristic nuclear binding energy coefficient be expressed as,

$$B_0 \cong \frac{e_s^2}{8\pi\varepsilon_0\left(G_s m_p/c^2\right)} \cong \left(\frac{1}{\alpha_s}\right)\left(\frac{e^2}{4\pi\varepsilon_0 R_0}\right) \cong 10.09 \text{ MeV} \quad (13)$$

With reference to a new factor of the form, $\ln\left(\frac{e^2}{4\pi\varepsilon_0 G_s m_p m_e}\right) \cong 1.515,$

(1) Volume or surface energy coefficient can be expressed as $a_v \cong a_s \cong 1.515 * 10.09 \cong 15.29$ MeV .
(2) Asymmetric energy coefficient can be expressed as, $a_a \cong 1.515a_v \cong 1.515a_s \cong 1.515*15.29 \cong 23.16$ MeV .
(3) Pairing energy coefficient can be expressed as, $a_p \cong B_0 \cong 10.09$ MeV .
(4) 10.09 MeV, 15.29 MeV and 23.16 MeV seem to follow a geometric series with a geometric ratio, 1.515.
(5) For $(Z \geq 10)$, by considering coulombic energy coefficient as $a_c \cong 0.695$ MeV , nuclear binding energy [1-6] can be estimated with,

$$B_A \cong \left\{\left[\left(A - A^{2/3} - 1\right)*15.29\right] - \left[\frac{Z^2}{A^{1/3}}*0.695\right] - \frac{\left(A-2Z\right)^2}{A}*23.16 \pm \left[\frac{10.09}{\sqrt{A}}\right]\right\} \text{MeV} \quad (14)$$

Data estimated with relation (14) can be compared with the standard relation [3],

$$B_A \cong \left\{\left(A*15.78\right) - \left(A^{2/3}*18.34\right) - \frac{Z\left(Z-1\right)}{A^{1/3}}*0.71 - \frac{\left(A-2Z\right)^2}{A}*23.21 \pm \frac{12.0}{\sqrt{A}}\right\} \text{MeV} \quad (15)$$

For Z=50, starting from A = (100 to 150), error in estimated binding energy seems to increase from -1.66 MeV to 1.63 MeV respectively.

4.1 Observations Pertaining to Term1 to Term2 of Relation (14):

(1) Ratio of (Term1-Term2)/10.09 MeV is a straight line and slope is practically constant for Z = 10 to 100.

(2) With further study, Term1 and Term2 can be unified into a single term [33].

5. UNDERSTANDING NUCLEAR BINDING ENERGY WITH SINGLE AND UNIFIED ENERGY COEFFICIENT

A. New Integrated Model

Based on the new integrated model proposed by N. Ghahramany et al. [10,11]

$$B(Z,N)=\left\{A-\left(\frac{\left(N^2-Z^2\right)+\delta\left(N-Z\right)}{3Z}+3\right)\right\}\frac{m_n c^2}{\gamma} \tag{16}$$

where, $\gamma =$ Adjusting coefficient $\approx$ (90 to 100).

if $N\neq Z,\ \delta\left(N-Z\right)=0$ and if $N=Z,\ \delta\left(N-Z\right)=1$.

Readers are encouraged to see references there in [10] for derivation part and other details pertaining to the estimation of the adjusting coefficient (90 to 100) [11]. Points to be noted are- close to the beta stability line, $\left[\frac{N^2-Z^2}{3Z}\right]$ takes care of the combined effects of coulombic and asymmetric effects and nuclear binding energy can be addressed with a single energy coefficient.

B. Unified Approach-1

Interesting points to be noted are:

1) $Z\cong 30$ seems to represent a characteristic reference number in understanding nuclear binding of light and heavy atomic nuclides.
2) With reference to electromagnetic interaction and based on proton number,
   a) For $Z\geq 30$, maximum strength of nuclear binding energy can be addressed with $\beta\cong\left(1/\alpha_s\right)\cong 8.68$.
   b) For $Z<30$, strength of nuclear binding energy can be addressed with,

$$\beta\cong\left(\frac{Z}{30}\right)^{\sqrt{k}}\left(\frac{1}{\alpha_s}\right)\cong\left(\frac{Z}{30}\right)^{0.08}\times 8.68. \tag{17}$$

3) For the time being it can be understood that, with reference to strong coupling constant, Z=30 onwards, 'strength' of nuclear interaction remains constant. It needs further study.
4) Close to stable mass numbers, mass number helps in increasing binding energy and squared neutron number aids in reducing the binding energy.
5) There exists a single and unified binding energy coefficient and it can be chosen to fall in between,

$$\left.\begin{array}{l} B_{effective}\cong\dfrac{e_s^2}{8\pi\varepsilon_0\left(G_s m_p/c^2\right)}-\left(\dfrac{e^2}{4\pi\varepsilon_0 R_0}\right)\cong 8.928\text{ MeV}\\ B_{effective}\cong\dfrac{e_s^2}{8\pi\varepsilon_0\left(G_s m_p/c^2\right)}-\dfrac{3}{5}\left(\dfrac{e^2}{4\pi\varepsilon_0 R_0}\right)\cong 9.395\text{ MeV}\end{array}\right\} \tag{18}$$

where $\left(\frac{e^2}{4\pi\varepsilon_0 R_0}\right)\cong 1.162\text{ MeV}$ and $\frac{3}{5}\left(\frac{e^2}{4\pi\varepsilon_0 R_0}\right)\cong 0.695\text{ MeV}$ can be considered as repulsive nuclear binding energy coefficients. To fit the data authors consider,

$$B_{effective}\cong\frac{8.928+9.395}{2}\cong 9.16 \tag{19}$$

Based on the above relations and close to the stable mass numbers of $\left(\mathrm{Z} \approx 2 \text{ to } 118\right)$, with a common energy coefficient of 9.16 MeV, authors would like to suggest the following two terms for fitting and understanding nuclear binding energy.

First term helps in increasing the binding energy and can be considered as,

$$T_1 \cong \eta \times A \times 9.16 \text{ MeV}$$
$$\text{where } \begin{cases} \eta \cong \left(\dfrac{Z}{30}\right)^{0.08} & \text{for } Z < 30 \\ \eta \cong 1 & \text{for } Z \geq 30 \end{cases} \tag{20}$$

Second term helps in decreasing the binding energy and can be considered as,

$$\left.\begin{aligned} T_2 &\cong \eta\left[\left(\left(\frac{k}{\ln(30)}\right)N^2\right)+\frac{1}{2}\right]\times 9.16 \text{ MeV} \\ &\cong \eta\left[\left(0.00189N^2\right)+\frac{1}{2}\right]\times 9.16 \text{ MeV} \end{aligned}\right\} \tag{21}$$

Considering light atomic nuclides, authors introduced the numerical factor $\frac{1}{2}$. It needs further study. Thus, close to stable mass numbers, binding energy can be fitted with,

$$\left.\begin{aligned} (B_A) &\cong T_1 - T_2 \\ &\cong \eta\left\{A-\left[\left(0.00189N^2\right)+\frac{1}{2}\right]\right\}9.16 \text{ MeV} \\ &\cong \left(\frac{Z}{30}\right)^{0.08}\left\{A-\left[\left(0.00189N^2\right)+\frac{1}{2}\right]\right\}9.16 \text{ MeV} \quad (\text{for } Z < 30) \\ &\cong \left\{A-\left[\left(0.00189N^2\right)+\frac{1}{2}\right]\right\}9.16 \text{ MeV} \quad (\text{for } Z \geq 30) \end{aligned}\right\} \tag{22}$$

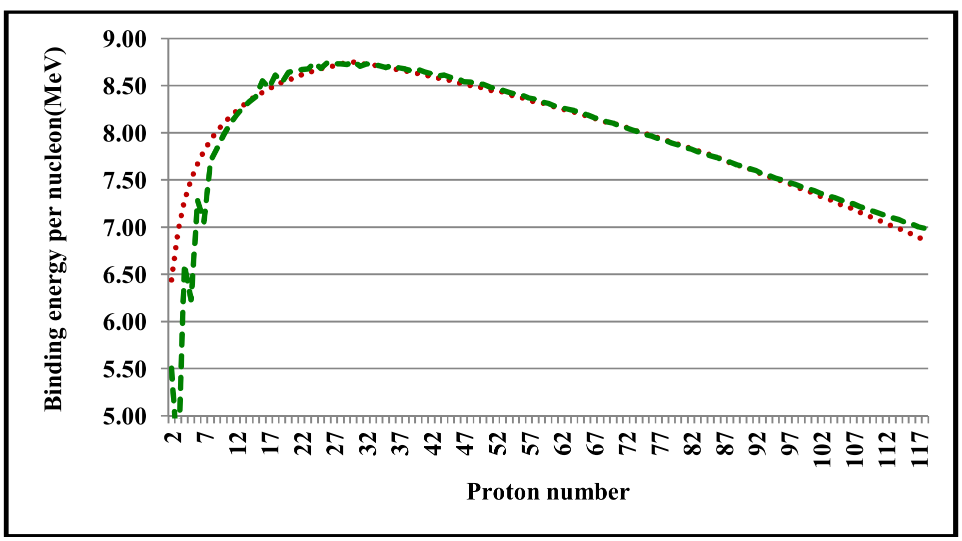

Fig. 1. Binding energy per nucleon close to stable mass numbers of Z = 2 to 118

Table 2. Estimated nuclear binding energy close to stable mass numbers of Z = 2 to 118

Proton number	Estimated mass number close to stable mass number	Neutron number	Estimated Binding energy (MeV)	SEMF binding energy	Error (MeV)
2	4	2	25.76	22.01	-3.75
3	6	3	41.77	26.88	-14.90
4	8	4	58.24	52.86	-5.37
5	10	5	75.02	62.29	-12.74
6	12	6	92.07	87.39	-4.67
7	14	7	109.32	98.81	-10.51
8	16	8	126.74	123.25	-3.49
9	19	10	152.33	148.85	-3.48
10	21	11	170.06	167.52	-2.55
11	23	12	187.91	186.14	-1.76
12	25	13	205.84	204.72	-1.13
13	27	14	223.86	223.22	-0.64
14	29	15	241.96	241.65	-0.31
15	31	16	260.12	259.98	-0.14
16	34	18	286.48	290.77	4.29
17	36	19	304.77	305.06	0.29
18	38	20	323.11	327.23	4.12
19	40	21	341.49	341.47	-0.01
20	43	23	368.02	371.57	3.55
21	45	24	386.47	389.59	3.12
22	47	25	404.96	407.47	2.51
23	49	26	423.47	425.20	1.72
24	52	28	450.08	454.57	4.50
25	54	29	468.63	468.89	0.25
26	56	30	487.21	489.58	2.37
27	59	32	513.81	515.20	1.40
28	61	33	532.40	532.52	0.11
29	63	34	551.02	549.67	-1.35
30	66	36	577.57	577.93	0.35
31	68	37	594.63	591.98	-2.65
32	71	39	619.48	619.81	0.32
33	73	40	636.44	636.62	0.19
34	75	41	653.36	653.27	-0.09
35	78	43	677.93	677.88	-0.05
36	80	44	694.75	697.05	2.30
37	83	46	719.11	721.32	2.20
38	85	47	735.83	737.59	1.76
39	88	49	759.99	761.58	1.59
40	90	50	776.59	780.20	3.60
41	93	52	800.55	803.88	3.33
42	95	53	817.05	819.75	2.70
43	98	55	840.80	843.16	2.37
44	100	56	857.20	861.24	4.05
45	103	58	880.74	884.37	3.63
46	106	60	904.14	909.61	5.47
47	108	61	920.36	922.70	2.34
48	111	63	943.56	947.65	4.09
49	113	64	959.68	962.85	3.17
50	116	66	982.66	987.48	4.81
51	119	68	1005.51	1009.66	4.15
52	121	69	1021.46	1024.59	3.13
53	123	70	1037.38	1039.35	1.97

Proton number	Estimated mass number close to stable mass number	Neutron number	Estimated Binding energy (MeV)	SEMF binding energy	Error (MeV)
54	127	73	1066.60	1070.45	3.85
55	129	74	1082.38	1085.10	2.72
56	132	76	1104.67	1108.72	4.05
57	135	78	1126.83	1130.06	3.23
58	138	80	1148.84	1153.27	4.43
59	140	81	1164.38	1165.55	1.17
60	143	83	1186.19	1188.52	2.33
61	146	85	1207.86	1209.31	1.45
62	149	87	1229.39	1231.90	2.51
63	151	88	1244.69	1245.86	1.18
64	154	90	1266.01	1268.20	2.19
65	157	92	1287.20	1288.44	1.25
66	160	94	1308.24	1310.44	2.19
67	163	96	1329.15	1330.38	1.22
68	166	98	1349.93	1352.04	2.12
69	169	100	1370.56	1371.69	1.13
70	171	101	1385.40	1385.09	-0.32
71	174	103	1405.83	1404.54	-1.29
72	177	105	1426.12	1425.66	-0.45
73	180	107	1446.27	1444.84	-1.43
74	183	109	1466.28	1465.66	-0.61
75	186	111	1486.15	1484.57	-1.58
76	189	113	1505.88	1505.10	-0.79
77	192	115	1525.48	1523.74	-1.74
78	195	117	1544.94	1543.98	-0.95
79	198	119	1564.25	1562.37	-1.88
80	201	121	1583.44	1582.34	-1.10
81	204	123	1602.48	1600.48	-2.00
82	207	125	1621.38	1620.17	-1.21
83	210	127	1640.15	1638.07	-2.08
84	213	129	1658.77	1657.49	-1.28
85	216	131	1677.26	1675.15	-2.11
86	219	133	1695.61	1694.32	-1.30
87	223	136	1718.30	1718.61	0.30
88	226	138	1736.31	1737.47	1.16
89	229	140	1754.17	1754.62	0.45
90	232	142	1771.90	1773.24	1.34
91	235	144	1789.49	1790.16	0.67
92	238	146	1806.94	1808.53	1.59
93	242	149	1828.28	1830.19	1.90
94	245	151	1845.39	1848.29	2.90
95	248	153	1862.36	1864.75	2.40
96	251	155	1879.18	1882.62	3.44
97	254	157	1895.88	1898.87	2.99
98	258	160	1916.07	1922.72	6.65
99	261	162	1932.42	1938.72	6.31
100	264	164	1948.62	1956.10	7.48
101	267	166	1964.69	1971.90	7.20
102	271	169	1983.96	1993.59	9.64
103	274	171	1999.68	2009.17	9.49
104	277	173	2015.26	2026.08	10.82
105	281	176	2033.80	2047.28	13.48
106	284	178	2049.04	2063.96	14.92
107	287	180	2064.14	2079.10	14.96

Proton number	Estimated mass number close to stable mass number	Neutron number	Estimated Binding energy (MeV)	SEMF binding energy	Error (MeV)
108	291	183	2081.95	2099.83	17.88
109	294	185	2096.71	2114.76	18.06
110	298	188	2114.00	2136.55	22.55
111	301	190	2128.41	2151.27	22.86
112	305	193	2145.18	2171.33	26.15
113	308	195	2159.24	2185.85	26.60
114	311	197	2173.17	2201.63	28.46
115	315	200	2189.21	2221.27	32.05
116	318	202	2202.79	2236.83	34.04
117	322	205	2218.32	2254.82	36.49
118	325	207	2231.56	2270.17	38.61

Table 3. Isotopic binding energy of Z=20

Proton number	Mass number	Neutron number	Estimated binding energy (MeV)	SEMF binding energy	Error (MeV)
20	40	20	343.58	339.70	-3.88
20	41	21	351.76	350.10	-1.65
20	42	22	359.91	363.19	3.28
20	43	23	368.02	371.57	3.55
20	44	24	376.10	382.69	6.59
20	45	25	384.15	389.32	5.18
20	46	26	392.16	398.73	6.57
20	47	27	400.14	403.85	3.70
20	48	28	408.09	411.76	3.67
20	49	29	416.00	415.54	-0.46
20	50	30	423.88	422.13	-1.75

Table 4. Isotopic binding energy of Z=28

Proton number	Mass number	Neutron number	Estimated binding energy (MeV)	SEMF binding energy	Error (MeV)
28	58	30	508.33	501.75	-6.58
28	59	31	516.39	511.65	-4.74
28	60	32	524.41	523.97	-0.44
28	61	33	532.40	532.52	0.11
28	62	34	540.36	543.50	3.13
28	63	35	548.28	550.82	2.53
28	64	36	556.17	560.58	4.41
28	65	37	564.03	566.79	2.76
28	66	38	571.85	575.45	3.60
28	67	39	579.63	580.65	1.01
28	68	40	587.38	588.30	0.91
28	69	41	595.10	592.57	-2.53
28	70	42	602.78	599.30	-3.48
28	71	43	610.43	602.74	-7.70
28	72	44	618.05	608.62	-9.43

Estimated binding energy can be compared with the standard relation (15). See Fig. 1. Dotted red curve plotted with relations (17) to (22) can be compared with the green curve plotted with the standard semi empirical mass formula (SEMF). For medium and heavy atomic nuclides, it is excellent. It seems that some correction is required for light and super heavy atoms. See Table 2 for the estimated data close to stable mass numbers.

Table 5. Isotopic binding energy of Z=40

Proton number	Mass number	Neutron number	Estimated binding energy (MeV)	SEMF binding energy	Error (MeV)
40	86	46	746.59	740.40	-6.19
40	87	47	754.15	749.73	-4.41
40	88	48	761.66	761.18	-0.48
40	89	49	769.15	769.63	0.48
40	90	50	776.59	780.20	3.60
40	91	51	784.01	787.83	3.82
40	92	52	791.39	797.57	6.19
40	93	53	798.73	804.43	5.70
40	94	54	806.04	813.41	7.37
40	95	55	813.32	819.55	6.23
40	96	56	820.56	827.80	7.24
40	97	57	827.76	833.27	5.50
40	98	58	834.94	840.84	5.91
40	99	59	842.07	845.67	3.60
40	100	60	849.18	852.61	3.44
40	101	61	856.24	856.85	0.61
40	102	62	863.28	863.18	-0.09
40	103	63	870.28	866.86	-3.41
40	104	64	877.24	872.63	-4.61
40	105	65	884.17	875.78	-8.39
40	106	66	891.06	881.02	-10.05

Table 6. Isotopic binding energy of Z=50

Proton number	Mass number	Neutron number	Estimated binding energy (MeV)	SEMF binding energy	Error (MeV)
50	110	60	940.78	931.76	-9.02
50	111	61	947.84	940.74	-7.11
50	112	62	954.88	951.65	-3.23
50	113	63	961.88	959.96	-1.92
50	114	64	968.84	970.20	1.36
50	115	65	975.77	977.88	2.11
50	116	66	982.66	987.48	4.81
50	117	67	989.52	994.55	5.03
50	118	68	996.35	1003.55	7.20
50	119	69	1003.14	1010.05	6.91
50	120	70	1009.90	1018.47	8.57
50	121	71	1016.62	1024.43	7.81
50	122	72	1023.31	1032.30	9.00
50	123	73	1029.96	1037.75	7.79
50	124	74	1036.58	1045.10	8.52
50	125	75	1043.16	1050.05	6.89
50	126	76	1049.71	1056.91	7.19
50	127	77	1056.23	1061.39	5.16
50	128	78	1062.71	1067.77	5.07
50	129	79	1069.15	1071.81	2.66
50	130	80	1075.56	1077.74	2.18
50	131	81	1081.94	1081.35	-0.59
50	132	82	1088.28	1086.85	-1.43
50	133	83	1094.59	1090.06	-4.53
50	134	84	1100.86	1095.15	-5.72
50	135	85	1107.10	1097.96	-9.14

Table 7. Isotopic binding energy of Z=66

Proton number	Mass number	Neutron number	Estimated binding energy (MeV)	SEMF binding energy	Error (MeV)
66	154	88	1272.17	1262.97	-9.20
66	155	89	1278.26	1270.46	-7.81
66	156	90	1284.33	1279.65	-4.68
66	157	91	1290.36	1286.71	-3.65
66	158	92	1296.36	1295.47	-0.89
66	159	93	1302.32	1302.10	-0.21
66	160	94	1308.24	1310.44	2.19
66	161	95	1314.14	1316.67	2.54
66	162	96	1319.99	1324.60	4.61
66	163	97	1325.82	1330.45	4.63
66	164	98	1331.61	1337.98	6.38
66	165	99	1337.36	1343.46	6.10
66	166	100	1343.08	1350.61	7.53
66	167	101	1348.76	1355.73	6.96
66	168	102	1354.41	1362.52	8.10
66	169	103	1360.03	1367.28	7.25
66	170	104	1365.61	1373.72	8.11
66	171	105	1371.16	1378.15	7.00
66	172	106	1376.67	1384.25	7.58
66	173	107	1382.15	1388.36	6.21
66	174	108	1387.59	1394.13	6.54
66	175	109	1393.00	1397.92	4.93
66	176	110	1398.37	1403.38	5.01
66	177	111	1403.71	1406.87	3.16
66	178	112	1409.01	1412.02	3.01
66	179	113	1414.28	1415.22	0.94
66	180	114	1419.52	1420.07	0.56
66	181	115	1424.72	1422.99	-1.72
66	182	116	1429.88	1427.56	-2.33
66	183	117	1435.02	1430.21	-4.81
66	184	118	1440.11	1434.49	-5.62
66	185	119	1445.17	1436.88	-8.30
66	186	120	1450.20	1440.90	-9.31

From the above Table 2 or Fig. 1, proposed relation (22) can be validated. With reference to unification paradigm, authors new approach seems to be more informative than the recent works of Ghahramany et al [10,11]. Advantage of relation (22) is that it constitutes only one energy coefficient and two simple terms. On applying the proposed relations (17) to (22) to $\left(A << A_s\right)$ and $\left(A >> A_s\right)$, authors noticed significant errors. See Tables 3 to 9 for the estimated isotopic binding energy of Z = 20, 28, 40, 50, 66, 82 and 100 respectively.

C. Unified approach-2

Based on the above data, believing in the workability of the number 0.00189 and to improve the accuracy in estimation of binding energy of isotopes, authors developed the following 5 term expression with single energy coefficient. Physics behind it can be understood in the following way.

Energy coefficient being 10.09 MeV, nuclear binding energy:

(1) Increases with increasing mass number. (Term-1)
(2) Decreases with increasing radius. (Term-2)
(3) Decreases with the ratio of proton number to neutron number. (Term-3)
(4) Decreases with $A\sqrt{ZN}$ where proportionality coefficient is $0.00189.$ (Term-4).
(5) Stable mass number plays a key role in estimating the isotopic binding energy of $Z.$ (Term-5)

Table 8. Isotopic binding energy of Z=82

Proton number	Mass number	Neutron number	Estimated binding energy (MeV)	SEMF binding energy	Error (MeV)
82	202	120	1596.76	1587.37	-9.39
82	203	121	1601.76	1593.56	-8.20
82	204	122	1606.71	1601.28	-5.44
82	205	123	1611.64	1607.16	-4.47
82	206	124	1616.53	1614.58	-1.95
82	207	125	1621.38	1620.17	-1.21
82	208	126	1626.20	1627.29	1.08
82	209	127	1630.99	1632.59	1.60
82	210	128	1635.74	1639.42	3.68
82	211	129	1640.45	1644.45	3.99
82	212	130	1645.14	1650.99	5.86
82	213	131	1649.78	1655.75	5.97
82	214	132	1654.40	1662.03	7.63
82	215	133	1658.97	1666.53	7.55
82	216	134	1663.52	1672.53	9.01
82	217	135	1668.03	1676.78	8.75
82	218	136	1672.50	1682.52	10.02
82	219	137	1676.94	1686.52	9.58
82	220	138	1681.35	1692.02	10.67
82	221	139	1685.72	1695.77	10.06
82	222	140	1690.05	1701.03	10.97
82	223	141	1694.35	1704.55	10.19
82	224	142	1698.62	1709.56	10.94
82	225	143	1702.85	1712.86	10.00
82	226	144	1707.05	1717.64	10.59
82	227	145	1711.21	1720.71	9.49
82	228	146	1715.34	1725.26	9.92
82	229	147	1719.44	1728.12	8.68
82	230	148	1723.50	1732.46	8.96
82	231	149	1727.52	1735.10	7.58
82	232	150	1731.51	1739.22	7.71
82	233	151	1735.47	1741.67	6.20
82	234	152	1739.39	1745.58	6.19
82	235	153	1743.28	1747.82	4.54
82	236	154	1747.13	1751.53	4.40
82	237	155	1750.94	1753.58	2.63
82	238	156	1754.73	1757.08	2.36
82	239	157	1758.48	1758.94	0.47
82	240	158	1762.19	1762.26	0.07
82	241	159	1765.87	1763.93	-1.94
82	242	160	1769.51	1767.06	-2.45
82	243	161	1773.12	1768.55	-4.57
82	244	162	1776.70	1771.49	-5.20
82	245	163	1780.24	1772.81	-7.43
82	246	164	1783.74	1775.57	-8.17
82	247	165	1787.22	1776.72	-10.50

Based on these points, for $\left(Z \approx 3 \text{ to } 118\right)$,

$$B_A \cong \left\{ A - A^{1/3} - \frac{Z}{N} - \frac{kA\sqrt{ZN}}{3.4} - \frac{(A_s - A)^2}{A_s} \right\} \times 10.09 \text{ MeV}$$
$$\cong \left\{ \left(1 - 0.00189\sqrt{ZN}\right) A - A^{1/3} - \frac{Z}{N} - \frac{(A_s - A)^2}{A_s} \right\} \times 10.09 \text{ MeV} \quad (23)$$

Close to the stable mass number,

$$B_{A_s} \cong \left\{ A_s - A_s^{1/3} - \frac{Z}{N_s} - \frac{kA_s\sqrt{ZN_s}}{3.4} \right\} \times 10.09 \text{ MeV}$$
$$\cong \left\{ \left(1 - 0.00189\sqrt{ZN_s}\right) A_s - A_s^{1/3} - \frac{Z}{N_s} \right\} \times 10.09 \text{ MeV} \quad (24)$$

Note points:

1) First three terms play a key role in estimating the binding energy of light atomic nuclides.
2) Term-1 and Term-4, both can be clubbed into a single term as, $A\left(1 - 0.00189\sqrt{ZN}\right)$ and can be called as “Screened mass number”. The coefficient $\frac{k}{ln(30)} \cong \frac{k}{3.4} \cong 0.00189$ can be called as ‘Mass number screening factor’.
3) Rather than the mass number, binding energy can be assumed to be proportional to the screened mass number.

Table 9. Isotopic binding energy of Z = 100

Proton number	Mass number	Neutron number	Estimated binding energy (MeV)	SEMF binding energy	Error (MeV)
100	256	156	1919.61	1909.69	-9.92
100	257	157	1923.36	1915.13	-8.22
100	258	158	1927.07	1921.96	-5.11
100	259	159	1930.75	1927.18	-3.57
100	260	160	1934.39	1933.78	-0.61
100	261	161	1938.00	1938.78	0.78
100	262	162	1941.58	1945.16	3.58
100	263	163	1945.12	1949.94	4.82
100	264	164	1948.62	1956.10	7.48
100	265	165	1952.10	1960.68	8.58

See Fig. 2. Dashed red curve plotted with relations (11) and (24) can be compared with the green curve plotted with the standard relation (15). For light, medium and heavy atomic nuclides, fit is reasonable.

See Figs. 3 to 11 for the estimated isotopic binding energy of Z = 20, 30, 40, 50, 60, 70, 80, 90, and 100 respectively. Dotted blue curve represents the estimated binding energy with relations (11) and (23). Green curve represents the binding energy estimated with standard relation (15).

Based on these Figs. 2 to 11, it is possible to say that,

1) Relations (23) and (24) can also be given some priority in understanding nuclear binding energy scheme.
2) For $(N < Z)$ and $(N \approx Z)$ estimated binding energy seems to be increasing compared to SEMF estimation.
3) For $(A >> A_s)$, estimated binding energy seems to be decreasing compared to SEMF estimation.

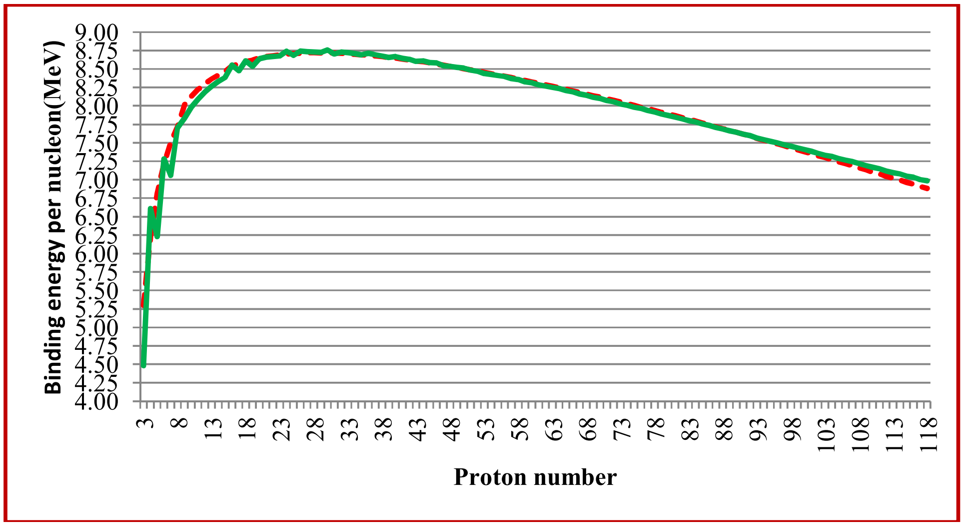

Fig. 2. Binding energy per nucleon close to stable mass numbers of Z = 3 to 118

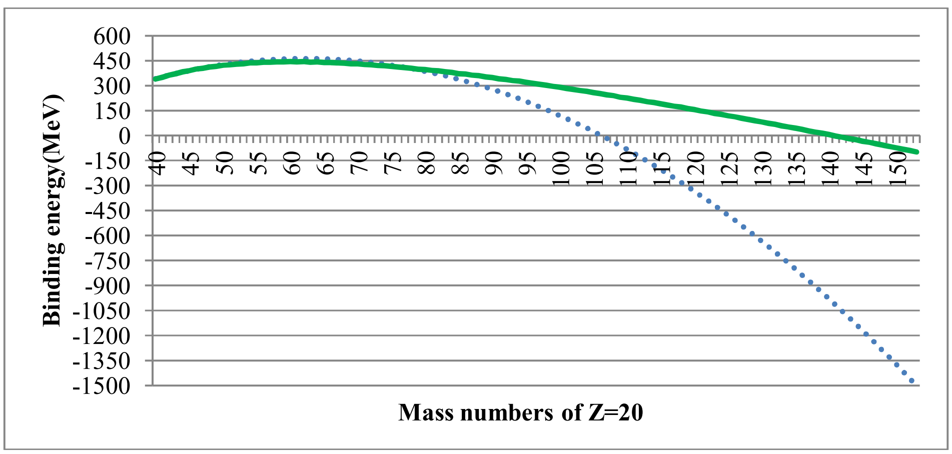

Fig. 3. Isotopic binding energy of Z=20

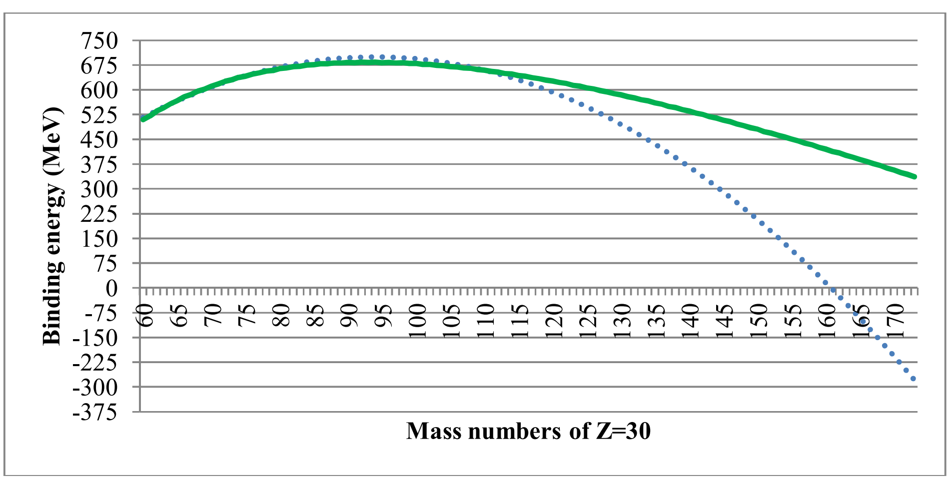

Fig. 4. Isotopic binding energy of Z=30

Fig. 5. Isotopic binding energy of Z=40

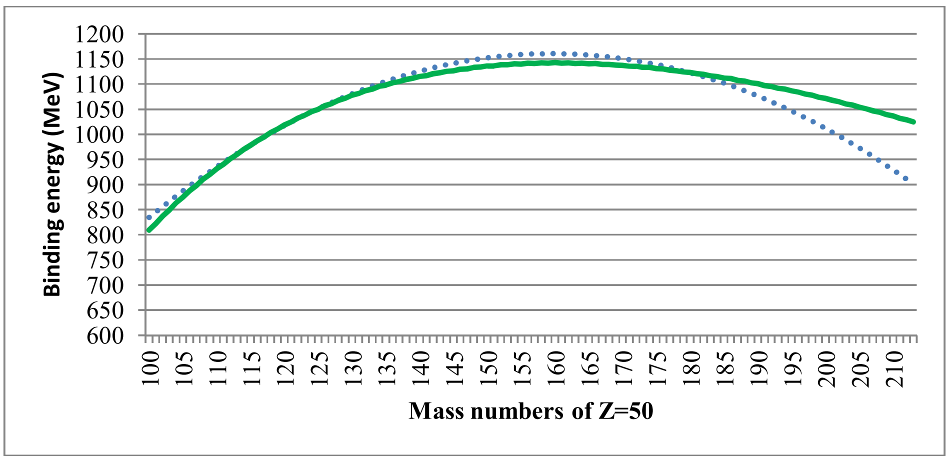

Fig. 6. Isotopic binding energy of Z=50

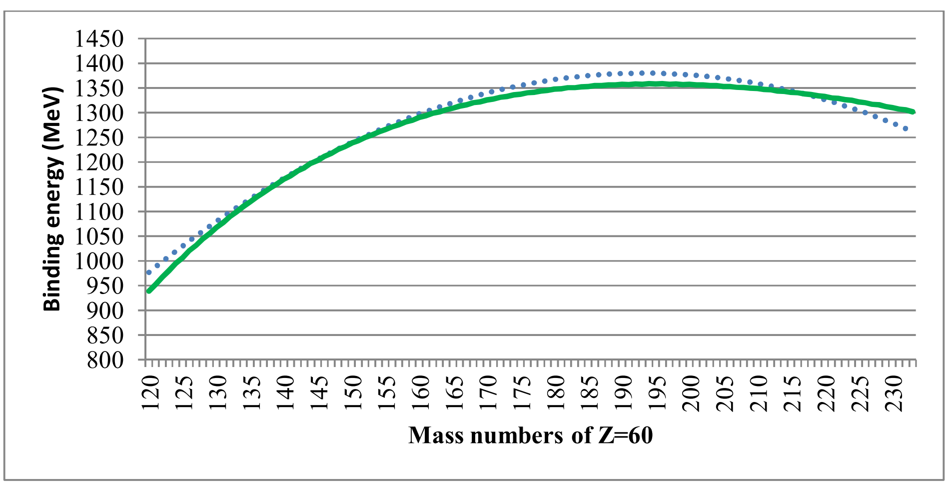

Fig. 7. Isotopic binding energy of Z=60

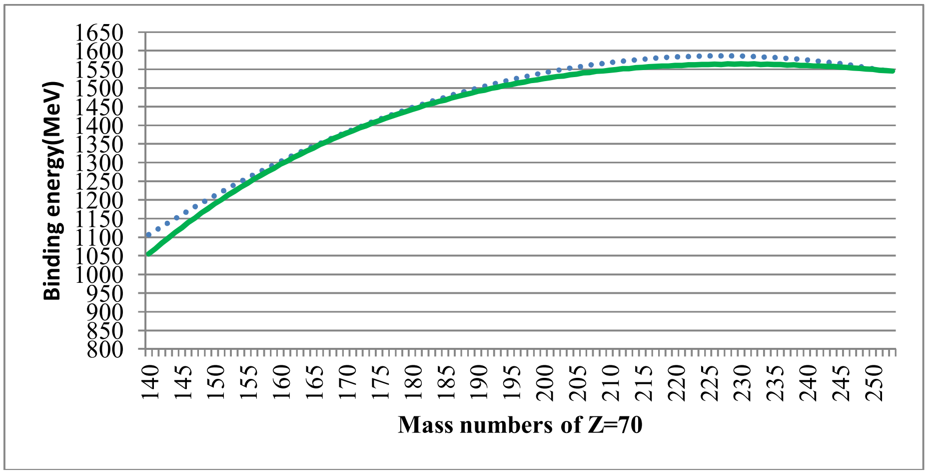

Fig. 8. Isotopic binding energy of Z=70

Fig. 9. Isotopic binding energy of Z=80

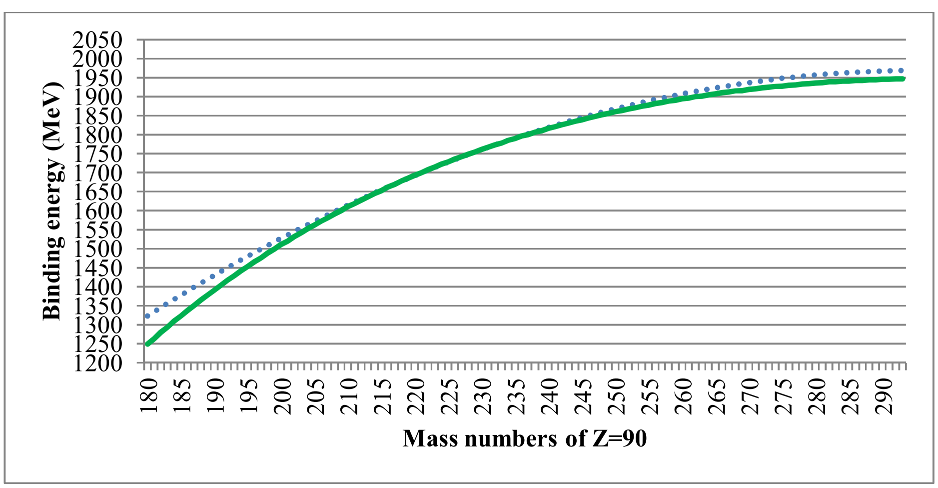

Fig. 10. Isotopic binding energy of Z=90

Fig. 11. Isotopic binding energy of Z=100

4) Fine tuning seems to be required in the terms $\left(\frac{Z}{N}\right)$ and $\left(\frac{(A_s-A)^2}{A_s}\right)$ of relation (23).

6. UNDERSTANDING NEUTRON LIFE TIME WITH ELECTROMAGNETIC AND WEAK GRAVITATIONAL CONSTANTS

One of the key objectives of any unified description is to simplify or eliminate the complicated issues of known physics. In this context, in a quantitative approach, authors noticed that, electromagnetic and weak gravitational constants play a crucial role in understanding and estimating neutron life time [22,54]. The following strange relation can be given some consideration.

$$t_n \cong \left(\frac{G_e}{G_w}\right)\left(\frac{G_e m_n^2}{\left(m_n - m_p\right)c^3}\right) \cong \left(\frac{G_e^2 m_n^2}{G_w\left(m_n - m_p\right)c^3}\right) \cong 874.94 \text{ sec} \tag{25}$$

Plausible point to be noted is that, relativistic mass of neutron seems to play a crucial role in understanding the increasing neutron life time. It can be understood with,

$$t_n \propto \frac{m_n^2}{\left[1-\left(v^2/c^2\right)\right]} \quad \text{and} \quad t_n \cong \frac{874.94 \text{ sec}}{\left[1-\left(v^2/c^2\right)\right]} \tag{26}$$

7. NUCLEAR CHARGE RADII

As per the current literature [55], nuclear charge radii can be expressed with the following formulae.

$$R_c \cong \left\{1+\left[0.015\left(\frac{N-(N/Z)}{Z}\right)\right]\right\} Z^{1/3} \times 1.245 \text{ fm} \tag{27}$$

$$R_c \cong \left\{1-0.349\left(\frac{N-Z}{N}\right)\right\} N^{1/3} \times 1.262 \text{ fm} \tag{28}$$

$$R_c \cong \left\{1-\left[0.182\left(\frac{N-Z}{A}\right)\right]+\frac{1.652}{A}\right\} A^{1/3} \times 0.966 \text{ fm} \tag{29}$$

Our earlier proposed relation [26] is,

$$R_{(Z,A)} \cong \left\{Z^{1/3} + \left(\sqrt{Z(A-Z)}\right)^{1/3}\right\}\left(\frac{G_s m_p}{c^2}\right) \tag{30}$$

Based on these relations and by considering the charge radii of stable atomic nuclides, R_0 and G_s can be fitted.

8. RESULTS AND DISCUSSION

Based on the data presented in Tables 1 to 9 and Figs. 1 to 11, authors would like to suggest that,

(1) From the proposed relations, authors recent and earlier works and from Ghahramany's integrated nuclear model [10,11], it is very to clear say that, nuclear binding energy can be understood with a single unified energy coefficient.
(2) Close to stable mass numbers, squared neutron number plays a major role in reducing major part of nuclear binding energy.
(3) The number, $4s \cong k \cong \frac{4G_s m_p m_e}{\hbar c} \cong \frac{4\hbar c}{G_e m_e^2} \cong \frac{4G_s^2}{G_e G_w} \cong 0.0064185$ seems to play a very interesting role in estimating neutron-proton stability. Hence it can be considered as a characteristic result oriented number in the context of understanding nuclear stability.
(4) The number, $\frac{k}{3.4} \cong 0.00189$ seems to play a very interesting role in estimating the major reduction part of nuclear binding energy. Hence it can also be considered as a characteristic result oriented number in the context of understanding nuclear binding energy.
(5) Authors are working on understanding the physics connected with $Z = 30.$ Application point of view, it is quite interesting to note that relation (23) of the proposed unified approach-2 is quite different from relation (22) of unified approach-1.
(6) Based on the relations (17) to (24) and by modifying the terms, $\left(\frac{Z}{N}\right)$ and $\left(\frac{(A_s - A)^2}{A_s}\right)$ binding energy for $(A << A_s)$ and $(A >> A_s)$, can be understood and semi empirical mass formula can be modified into a much more simple form.

9. CONCLUSION

1) Understanding nuclear binding energy with a single energy coefficient and two simple terms in terms of fundamental interactions is a very challenging task. In this context, authors tried their level best in presenting a very simple and effective semi empirical formula with one unique energy coefficient. It needs further investigation.
2) Current unification paradigm is failing in developing a 'practical unification procedure'. Even though our approach is speculative, role played by the four gravitational constants seems to be fairly natural. This kind of approach may help in producing a variety of such relations by using which in near future, an absolute set of relations can be developed. Proceeding further, estimated absolute theoretical value of G_N can be considered as a standard reference for future experiments.
3) By implementing four such gravitational constants in String theory models, it may be possible to explore the hidden unified physics. With further study, a practical model of materialistic quantum gravity can be developed and magnitude of the Newtonian gravitational constant can be estimated in a theoretical approach bound to Fermi scale.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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