Probe of the alpha particle conundrum in terms of quarks of quantum chromo dynamics

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Abstract:

The characteristics of α-particle is enigmatic in that its formation, configuration, role in nucleosyntheses, stability, compactness, having smallest radius among all poly-nucleon nuclides, highest value of core density, exhibition of different values of half-lives in decay process could not be unified through a suitable explanatory concept. The α- cluster model which is frequently used as an active non-mathematical tool for nucleosyntheses suffers from inconsistency in its applicability.

In the present communication all of the above mentioned peculiarities of α-particle have been interpreted in term of the quantum chromo dynamical (QCD) standard model of particle physics using d-quarks as the ultimate binding force. In addition, the formation and properties of nucleons of low mass number has been explained. The binding energy of the isotopes of low mass number nuclides is mainly contributed by the d-quarks involved in the formation of the nuclides. The reluctance of α-particle towards any type of combination goes against the idea of α- cluster model.

The mechanism of radioactive decay of α-particles and the possibility of occurrence of half-life periods of isotopes with all types of values from very high to extremely low have been considered. It is possible that both kinetic and mechanical forces are involved in the decay process.

It may be inferred that the nuclear architecture is built out of p – n pairs as bricks and the binding energy is derived mainly from d-quarks acting as cement.

Key words: α-particle, Structure and special properties, D-quarks, Binding Energy from d-quarks, Mechanism of α-decay, QCD

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Introduction:

Detected and identified by Rutherford [1] and later by Geiger and Marsden [2] at the early stages of recognition of radioactive emission, the α-particle with its mass of four and charge of two, is known to be the nucleus of Helium atom i.e., $^{4}He^{++}$. It is emitted from the radioactive substance with high kinetic energy but owing to its mass it could penetrate a distance of about 7cm in air when it collides with atmospheric nuclei to get two electrons to balance the positive charges. These electrons supply wings to the α-particle which escapes as gaseous Helium through the atmosphere so that its abundance is only 0.0005 % / volume. Despite this small terrestrial presence, the element is abundant in stellar atmosphere (particularly Sun, Greek name *Helios*, from which the name Helium was suggested and identified by the Sodium D_3 line) where it is produced by the fusion of H to form He and is the recognized source of energy of the Sun.

The mechanism of the formation of the α-particle at the time of nucleosyntheses from the combination of neutrons and protons is not conclusively proved. It may result from the combination of protons and neutrons to produce deuterium along with Paulion [3] which may later combine to form α-particle. Combination of two protons and two neutrons might also produce the same material although simultaneous 4 body collision is not a very encouraging proposition. Since two deuterons (^{2}D) do not usually produce ^{4}He, the only possibility is the combination of two Paulions.

Whatever may be the mechanism of formation of α-particle, the great stability and inertness of the nucleus presents a stumbling block in the syntheses of other nuclei. Thus two α-particles will not combine to form ^{8}Be (Be-bottleneck) or three α-particles will not form ^{12}C (for which Hoyle's mechanism is the only possibility) or for that matter, no mechanism will lead to the formation of nuclei with higher mass number.

To explain the nucleosynthses of elements of high mass number, a polyhedral architectural model based on simple symmetry rules has been proposed [4]. This shows the inclusion of virtual or real α-particles encaged in suitable polyhedron from which α-particles are emitted under suitable conditions in radioactive decay process.

The existing nuclear models namely the independent particle model (shell model) [5,6] the statistical (liquid drop model) [7,8] and conciliatory collective model [9] are all abstract mathematical models which mostly explain the properties of the nucleons and gives little hint to the nucleosynthesis process. The only model where attempts have been made to explain the formation of different nuclei in a systematic way is the much discussed α-cluster model [10] in which it is supposed that α-particles cluster together in some symmetrical fashion to produce different nuclei. The most notable objections to this model are:

i) This is applicable only to the nuclei with mass numbers which are multiples of four.

ii) α-particles are positively charged bodies and Coulombic repulsion will oppose the formation of such clusters.

iii) α-particle is so called “magic number” nuclei with two protons and two neutrons and will not accept or evict a nucleon showing its ‘physical’ inertness. Even Helium gas is chemically inert and is included in the list of inert gases.

Be that as it may, α-particles remain an enigma with some unexplained properties concerning its a) Radius b) Core density c) Structure and d) Bonding.

Radius of α-particle has been found to be abnormally low. Hofsdter [11] data shows the value as 1.67 fm in comparison to the radius of ^{2}D as 2.1 fm and ^{6}Li as 2.51 fm. This indicates a very compact structure for the α-particle.

The core densities of a few representative nucleons are shown in Fig. I. The value for α-particle is almost twice the value for each of all the other nucleons lying between Ca and Br which show an approximate value of 1.2 10^{19}C/cm^3. These two unexplained facts about α-particle remains a puzzling problem.

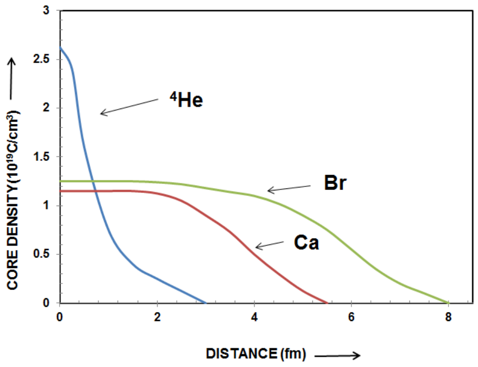
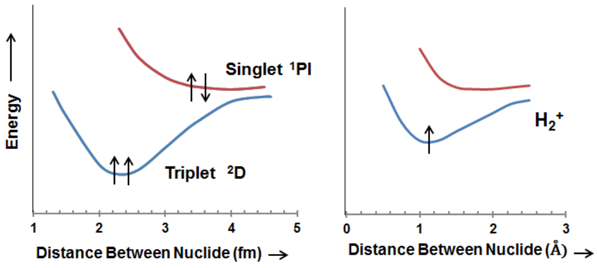


Fig. I: Core density values of nuclides

To understand the structure of the α-particle, it is first necessary to consider the interaction of a proton and / or neutron in terms of the distance separating them. The interactions are described in Table I.

Electronic biding and nuclear binding may be distinguished by considering the spin pairing of electrons in the former and the spin pairing of the nucleons in the latter case as shown in the formation of Hydrogen molecule ion and the formation of ^{2}D and the Paulion in Figure II.



Nuclear - Nuclear Interaction

Proton - Electron Interaction

Fig. II: Potential energy diagram for a system with two protons and one electron

Table I: Interaction of proton and neutron with distance separating them

Domain of Atomic Physics (involving extra nuclear electron)						Domain of Nuclear Physics (involving nucleons)			
Interacting Species	Eqv. to	Dist.	Elec. Spin pairing	Symbol	Remark	Dist.	Eqv. to	Nucl. Spin pairing	Remark
p + n	p + e + p	~ 1Å	+ ↑	H_2^+	Heitler-London treatment [12]	< 3fm	^2D	↑↑ (1) ↑↓ (0)	Bound, stable Unbound, unstable
n + n	p + 2e + p	~ 1Å	↑↓	H_2	As above	< 3fm	n – n	↑↓ (0)	Stable
p + p	p + p	–	–	–	Does not exist	–	p – p	↑↓ (0)	*****

*****No binding electron, only Coulombic Repulsion, nuclear spin pairing does not produce a stable species.

Formation of α-particle:

α-particle being a 4 nucleon system, its formation may be considered in any of the following three ways.

1) Condensation of 4 protons and two electrons. This is the process which is thought to occur at the time of creation of the universe. But this is unlikely in view of the fact that the condensation of 4 positively charged nucleons simultaneously is not a probable proposition.
2) Condensation of two protons (p – p) and two neutrons (n – n) respectively and subsequent conglomeration of these pairs to form α-particle. This is the accepted method of formation and is shown by a structure where the two protons are spin paired to form a boson and two neutrons are also spin paired (according to Pauli Exclusion Principle) so that the resultant combination is also a boson.
3) The other possibility is the condensation of two p – n pairs. It has been shown earlier [3] that the condensation of proton and neutron can occur in two ways: either the formation of ^{2}D i) with spin 1 or ii) the formation of a hypothetical isomer of hydrogen with spin 0 which is termed as Paulion [3]. As is already pointed out that two deuterons do not usually combine to form ^{4}He. The Paulion on the other hand shows an unbound state with about 74 KeV and two such species may combine to form ^{4}He with biding energy of approximately 25MeV. So it appears that Paulion condensation is the most probable mechanism of formation of ^{4}He. The Pl being a boson (spin 0), two such species will form ^{4}He which is also a boson.

Intra nuclear electron: β-emission mechanism:

According to de Broglie principle, electrons cannot exist inside a nucleus as the associated matter wave is too large to be accommodated in a nucleus of which the radius is about a few fm. This poses a problem as to the explanation of β^{-} decay (or β^{+}decay) which is a regular occurrence of most of the radioactive nuclei either natural or artificial. It has been suggested that the energy of π-meson which binds the nucleons together is partially converted to synthesize a β^{-} particle according to Einstein formula $E = mc^2$. This conversion of mass into energy and vice versa does not occur under ambient condition. An alternative mechanism is therefore needed to explain the mechanism of β^{-} decay.

The trouble perhaps originates from the fact that too much emphasis being given to the wave aspect of the electron. The dual (wave and particle) aspect of ultra-small (sub-nuclear) particle is a well-known phenomenon and an electron is no exception. Particle nature of electron is exhibited in the consistency of charge/mass ratio of electrons, the use of electron as projectiles in the bombardment of nuclei, detection of electrons in Wilson cloud chamber and everyday experience of dangling of electrons on the TV screen for our daily entertainment to name a few. It is, therefore, logical to conclude that electron can exhibit both particle and wave nature and it will perhaps not be a wild guess that the particle nature of electron is manifested mainly inside a nucleus and the wave nature is exhibited by those outside the domain of the nucleus.

It is possible that the electron as a particle exists in the nucleus in the form of d and u quarks with fractional charges of $-\frac{1}{3}$ and $+\frac{2}{3}$ respectively with mass of the order of 10^{-24} gm as is shown in the modern researches in particle physics. In the last 60 years, the study of sub-nuclear degrees of freedom has given rise to the standard model of Quantum Chromo Dynamics (QCD) in which nucleons are said to be consisting of quarks with partial charges along with leptons and boson [13-19].

The known elementary particles of the standard model are listed in Table II.

Table II: Elementary particle according Standard Model

	Description	Mass	Charge	Spin
Quarks (all fermions)	u (up)	2.2 MeV/c^2	⅔	½
	d (down)	4.7 MeV/c^2	-⅓	½
	c (churn)	1.28 GeV/c^2	⅔	½
	s (strange)	9.6 MeV/c^2	-⅓	½
	t (top)	173.1 GeV/c^2	⅔	½
	b (bottom)	4.18 GeV/c^2	-½	½
Leptons (all fermions)	e (electron)	0.511 MeV/c^2	-1	½
	ν_e (electron neutrino)	< 1 MeV/c^2	0	½
	μ (muon)	105.66 MeV/c^2	-1	½
	ν_u (ν neutrino)	< 1.7 MeV/c^2	0	½
	τ (tau)	1.7768 GeV/c^2	-1	½
	ν_τ (τ neutrino)	< 18.2 MeV/c^2	0	½
All bosons	g (gluon)	0	0	1
	ν (photon)	0	0	1
	Z (Z boson)	91.19 GeV/c^2	0	1
	W (W boson)	80.39 GeV/c^2	± 1	1
	H (Higgis boson)	124.97 GeV/c^2	0	0

The Standard Model of particle physics describes three basic forces. 1) the electromagnetic force 2) the strong force which holds the nucleons together and 3) the weak force which explains the radioactive decay in slowly releasing the energy by emitting particles. According to the model, weak forces are transmitted by particles called W and Z bosons and the third particle that i.e., Higgis boson supplies the mass along with W and Z bosons.

The configuration of the alpha particle:

This can be derived from the use of d-quarks with fractional charge of -⅓ of the electron. These quarks may be regarded as the valence material producing hybridization of nuclear forces which may be comparable with the hybridization of electronic orbitals e.g., sp, sp^2, sp^3 d^2sp^3 etc., giving rise to linear triangular, tetrahedral, octahedral geometries respectively in atomic physics.

Alpha particle is comprised of 4 protons and 2 electrons. These 4 protons can be symmetrically arranged in two ways, either square planar or tetrahedral. In the square planar arrangement, these 4 protons can be bonded by 4 interactions, whereas in the tetrahedral disposition these are bounded by 6 interactions as shown Figure III.

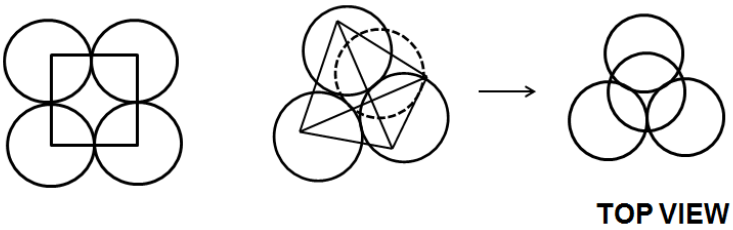


Fig. III: configuration of alpha particle

The two available electrons will be shared by 4 nucleons in square planar arrangement which means each proton is affected by ½ electron whereas in tetrahedral case each proton will be affected by 2/6 = ⅓ electron. Thus the alpha particle is produced as a compact tetrahedral unit which is held together by 6 d-quarks. This spherically symmetrical structure will have a very small radius (indeed the smallest possible radius value of all the known nuclear species).

The consideration of the formation of α- particle from the delocalization of 6 d-quarks leads to the value of its binding energy. Each d-quark has an energy of 4.7 MeV (vide Table II) and the 6 contributing quarks will give rise to 6 x 4.7 = 28.2 MeV as the binding energy of the alpha particle which is very close to the experimental value of 28.296 MeV. This concept strongly suggests the structure of α- particle as tetrahedral. The compact tetrahedral structure of the α- particle also explains its high core density.

It is a known fact that as the number of nucleons increases the radius of the nucleus increases. A glaring exception is in those of ^{2}D and ^{4}He. Although the α- particle contains double the number of nucleons compared to ^{2}D, the radius of ^{4}He is 1.67 fm while that of ^{2}D is 2.1 fm [11]. This results from the fact that ^{4}He has a compact structure arising from contribution of 6 d-quarks. The disposition of the nuclei of ^{2}D, ^{4}He and ^{6}Li is shown in Figure IV.

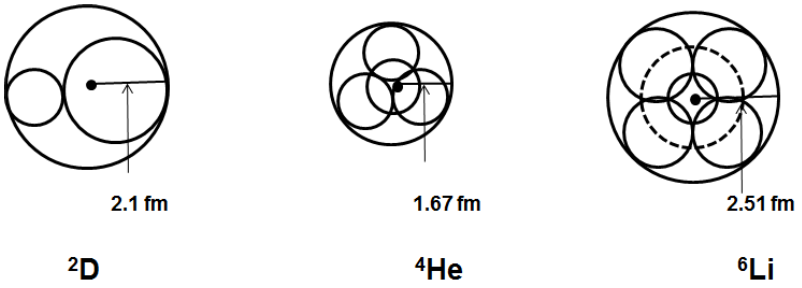


Fig. IV: Radius values of ^{2}D , ^{4}He and ^{6}Li

1) In ^{2}D, which contains 2 protons and 1 electron, just ⅓ of the electron charge (d-quark) is sufficient to hold the two nucleons together and as a result of only one interaction, the radius is found to be 2.1 fm.
2) In comparison, the α- particle (^{4}He) is acted upon by 6 d-quarks i.e., 2 available electrons as discussed earlier, as a result of which the compact structure is unique in that it shows the lowest of radius value of 1.67 fm among all poly nucleon entities.

3) In ^{6}Li there are six nucleons which are interacted by 3 electrons producing 9 d-quarks which are quite insufficient for stability of the octahedral disposition of the nucleon which requires 12 d-quarks. The radius value is 2.51 fm which is expected to be higher than those of ^{2}D and ^{4}He because of the presence of higher number of nucleons.

If the core densities (i.e., nucleon number/fm^3) of the above three species are compared, these are found to be in the ratio of $2/[4/3\ \pi\ (2.1)^3] : 4/[4/3\ \pi\ (1.67)^3] : 6/[4/3\ \pi\ (2.51)^3]$ for ^{2}D, ^{4}He and ^{6}Li respectively. These values come to be in the ratio of 0.22: 0.86: 0.38 which shows that the core density is highest for ^{4}He in comparison to its immediate neighbours. In fact the core density of alpha particle has maximum value among all known nuclei which is about twice those of the values of the rest (cf. Fig.I).

Exchange force and binding energy:

The strong short range force holds the nucleons (usually protons and neutrons) tightly in a sphere of radius <5 fm. According to Heisenberg, this force originates from the exchange of charge, spin or position of the nucleons. The charge was initially considered to be electronic but later in 1935 according to the finding of Yukawa [20], the charged particle was identified to be π-meson which resonates between nucleons to impart strong force of interaction remaining captive within the dimension of the nucleus.

The binding energy of the nuclei, on the other hand, originates from an exchange of mass of electrons being converted to energy in accordance with Einstein's law of $E = mc^2$ and as a result of this exchange, the nucleons lose their identity. If we consider the interaction of neutron and a proton, according to the standard model of QCD, the neutron can be considered as (udd) and the proton as (uud) where u- and d- are up and down quarks respectively. The exchange of d- and u- quarks simultaneously between these species interchanges their identity as shown in Fig V. Exchange of d-quarks mainly supply the binding energy.

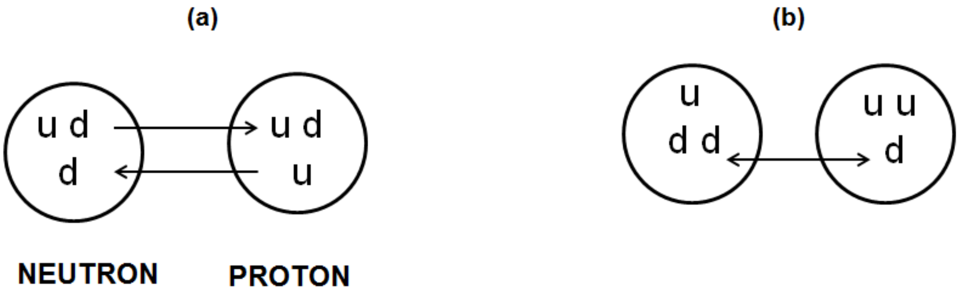
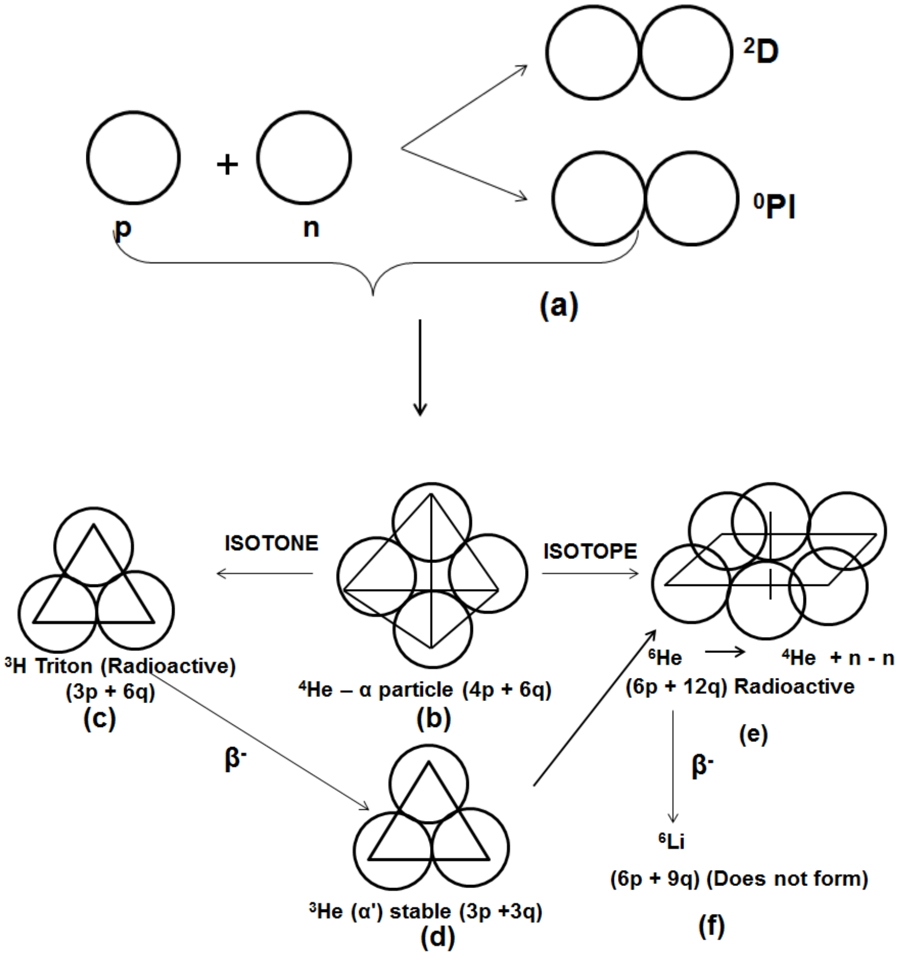
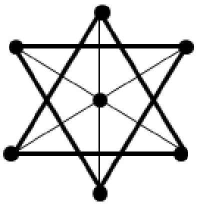


Fig. V: (a) Synergic Coulombic exchange of u- and d- quarks resulting in indistinguishability of proton and neutron and (b) d-quark exchange force

Structural inter-relation of nucleons of low mass number:

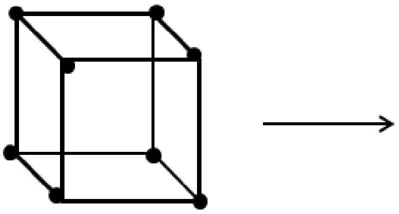
The structural inter-relation of a few low mass number nuclei is shown in Figure VI by the involvement of d-quarks to explain their stability and emission properties.





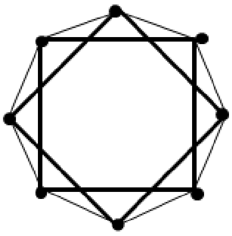
^{7}Li stable (7p + 12q)

(g)



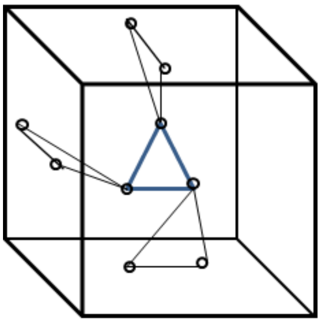
^{8}Be unstable (8p + 12q)

(h)



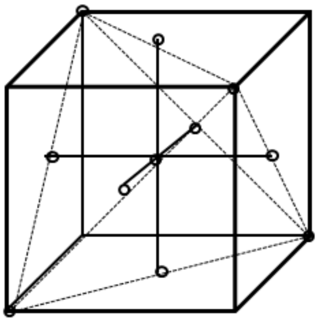
Skewed stable structure (insufficient quarks)

(i)



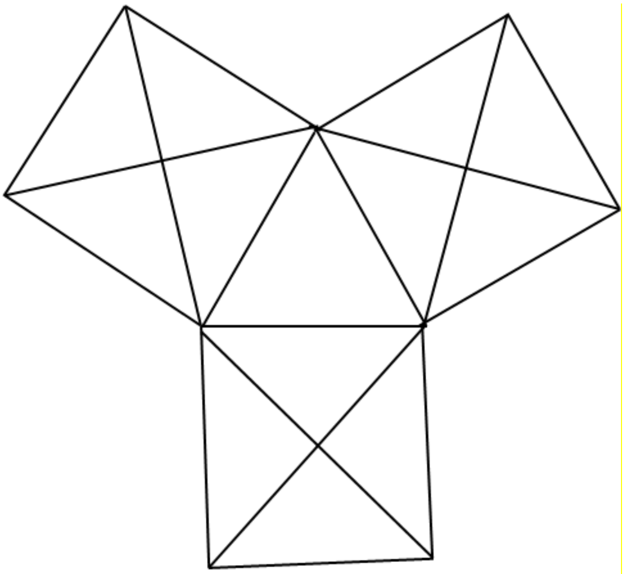
^{9}Be stable (9p + 15q)

(j)



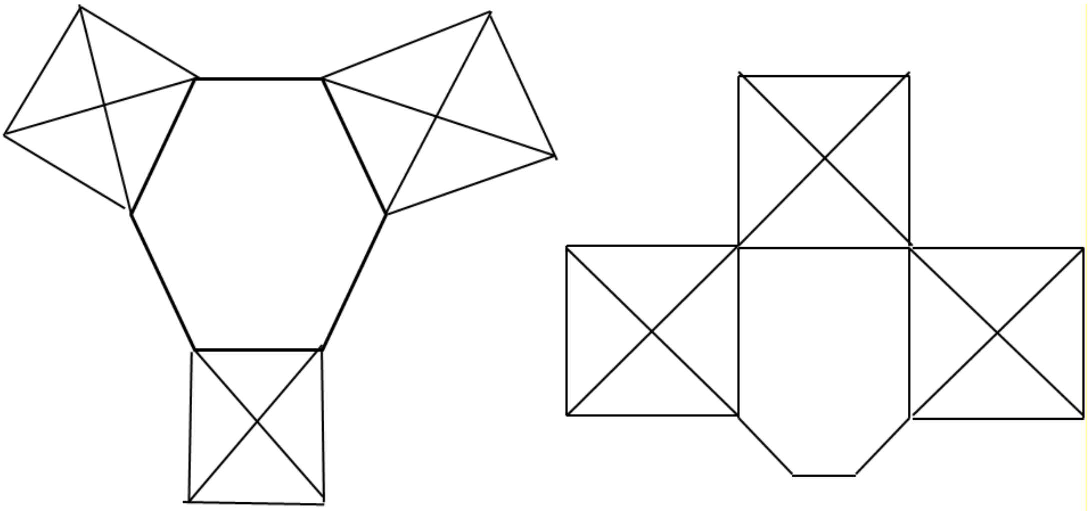
^{11}B stable (11p + 18q)

(k)



^{12}C stable (12p + 18q)

(l)

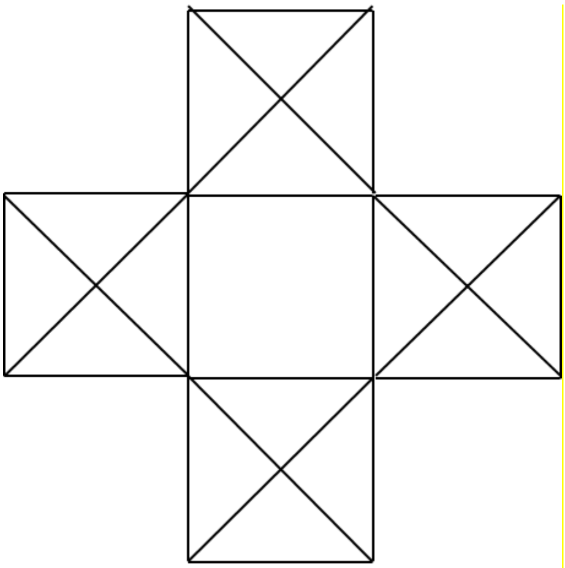


^{14}N stable

(m)

^{14}N stable (14p + 21q)

(n)



^{16}O stable (16p + 24q)

(o)

Fig VI. Configuration of nuclides in terms of quarks (a) to (o)

This shows the inter-relation of the structures but does not reflect the possibility of inter-conversion from one structure to another.

Each electron present in the isotopes gives rise to 3 d-quarks each with -⅓ charge of the electron. If these quarks can be arranged in a symmetrical three dimensional network and is able to accommodate the number of protons in the isotope then a stable species results e.g., ^{4}He, ^{9}Be, etc. If the number of quarks is greater or less than thrice the number of neutrons the species becomes unstable and radioactive (β^{-}) e.g., ^{3}H, ^{6}He etc. Even if the number of quarks is sufficient to produce a polyhedron with available protons, the stereo-chemical disposition guides the stability of the isotope e.g., ^{6}He and ^{8}Be.

It is seen that with the exception of proton, neutron and deuteron/Paulion, most of the known nuclides originate from condensation of Paulions and interestingly the geometrical (mathematical) centres of all such nuclides are void and represent perfect vacuum (contrary to Dirac's suggestion that vacuum does not exist and is actually filled with γ (β^{+} β^{-}).

Explanation of Figure VI

1) In the figure marked with (**a**), a proton and a neutron combine to form two products i) a deuteron with spin parallel i.e., a triplet state which is stable and ii) Paulion [3] with spin zero, singlet state which is unbound and unstable but perfectly allowed to form an α- particle (boson) by condensation.
2) The α- particle marked (**b**) in the figure consists of two protons and two neutrons which is equivalent to 4 protons and 2 electrons. As discussed earlier, the two electrons may be considered to give rise to 6 d-quarks which will form the interaction along the 6 sides of a tetrahedron and will form a stable structure for the alpha particle with 28.2 MeV of binding energy.
3) Marked with (**c**) in the figure is the structure of triton ^{3}H consisting of the two neutrons and a proton and is isotonic with the ^{4}He (α-particle). The two electrons are equivalent to six d-quarks of which only three are sufficient to produce a

triangular structure for ^{3}H. The extra three d-quarks may be emitted from this nucleon making it β^-active.

4) The structure marked (**d**) in the figure is isotopic with ^{4}He and is the result of a product formed by the β^- emission of triton. This isotope of α-particle ^{3}He (α′) contains two protons and an electron and three d-quarks are sufficient to produce a stable isotope of ^{4}He.

   Also isotopic with the α-particle is the ^{6}He marked as (**e**) in the figure which consists of 6 protons and 4 electrons. These 4 electrons yield 12 d-quarks which are sufficient to hold 6 protons in an octahedral disposition. But this isotope is short lived with t½ = 806.89 ± 0.11 ms [21] which breaks up to form stable ^{4}He and emit β^- particle. This emission produces ^{6}Li (**f**) theoretically which in turn contains only 9 d-quarks and is insufficient to form a stable species. The decomposition may emit energy in the form of γ radiation and thus ^{6}He is a species which yields α, β and γ rays simultaneously.

5) However, ^{7}Li contains an extra neutron and is stable (abundance 92.5%). This isotope consists of 7 protons and 4 electrons which gives rise to 12 d-quarks and is sufficient to hold 7 protons as is shown in the figure marked as (**g**).

6) ^{8}Be is the most discussed isotope which does not exist although it appears at the first sight that 8 protons can be held by 4 electrons (equivalent to 12 d-quarks) in a cubic arrangement (**h**). But this arrangement is unstable, because the two layers of square arrangement of protons will be unstable and a skewed arrangement as shown in (**i**) is expected to be stable. But this requires 16 d-quarks which are not available as a result of which ^{8}Be will not exist.

7) However, ^{9}Be exists and is stable (abundance 100 %). This contains 9 protons and 5 electrons producing 15 d-quarks. The arrangement (**j**) in the figure shows a stable

structure with 9 protons and 15 d-quarks of which three are of different dimensions as a requirement of stable configuration.

8) The next member ^{11}B (abundance 80.1 %) can be arranged in a cubic structure with 18 d-quarks coming from 6 electrons. This is shown in the figure marked with (**k**).
9) Marked with (**l**), (**m,**), and (**o**) are the isotopes of ^{12}C, ^{14}N and ^{16}O respectively in two dimensional representation. The structure of carbon with 12 p and 18 d-quarks and oxygen with 16 p and 24 d-quarks was discussed in a previous communication [4]. ^{14}N with 14 p and 21 d -quarks can be arranged in an alternative way as shown in the figure marked with (**n**). This less symmetric structure (**n**) is more favoured than (**m**) due to its having a quadrupole moment (2 x 10 mb). It is seen that the structure of these small mass number elements up to ^{16}O can be expressed in terms of the QCD method.

Binding energies of nuclides in terms of quarks:

It is interesting that the structural deductions of α-particle with a perfect tetrahedral arrangement gives rise to a binding energy value which is very close to the experimental one (28.2 MeV from d-quarks against 28.296 from experiment). This encouraging closeness of the value of binding energy is taken to be a cue for calculating the values of binding energy of nuclides up to ^{16}O.

In Table III, is shown the nuclides with binding energy values calculated from the number of quarks involved and also include the reported experimental values as given in [22]. The calculated values and the experimental values are plotted in Figure VII which shows very close similarity indicating that this method of calculation is not completely arbitrary.

Table III: Theoretical and Experimental Binding Energies of low mass number Nuclides

Nuclide	Number of d-quarks	Binding Energy Calculated (MeV)	Binding Energy Experimental (MeV)
^{4}He	6	28.2	28.3
^{7}Li	12	56.4	39.25
^{9}Be	12	56.4	58.16
^{11}B	18	84.6	76.2
^{12}C	18	84.6	92.2
^{14}N	21	98.7	104.66
^{16}O	24	112.8	122.6

However, the discrepancy in the binding energy vales indicates the involvement of some other forces which may come from the participation of π-mesons in the binding process according to the classical model.

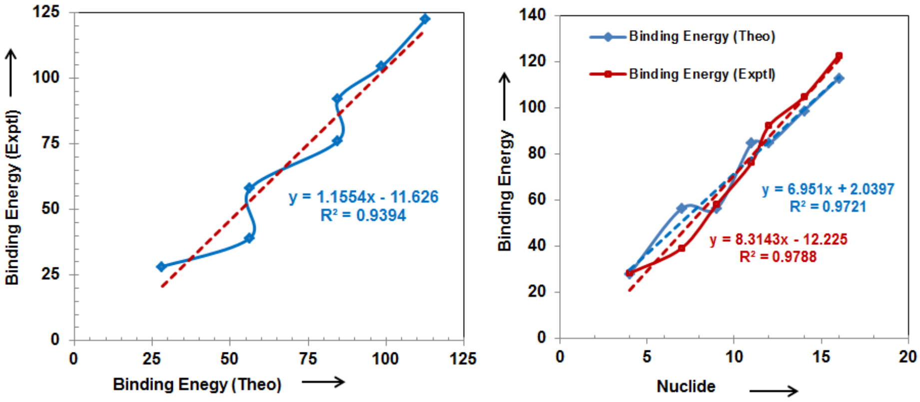


Fig VII: Calculated vs. Experimental Binding Energies

As shown in Figure V (a), according to the QCD model the proton and the neutron are interconverted by synergic exchange of q- and u- quarks. This exchange is guided by the Coulombic interaction between the u- (+ ⅔ e) and d- (-⅓ e) charges of the quarks. This attractive energy will depend on the inter-nucleonic distance and will be variable depending on the structure of the nuclide and will supply an additional binding energy.

The exchange of d-quarks as shown in Fig V (b) gives rise to the binding force of attraction and the Table III shows that this binding energy depends on the number of quarks and contributes mostly more than 80% of the binding energy.

It is thus seen that in both the extra-nuclear atomic domain and also in a proper nuclear domain the binding energy is mostly contributed by the exchange forces whereas Coulombic energy contributes only a small portion (~10%).

Thus the major forces in nature are of three types 1) nuclear force. 2) Coulombic force and 3) gravitational force. Of these forces nuclear and atomic domains are covered by the first two types of forces with different degrees of contribution and the third force (gravitation) guides the motion of heavy masses.

Possibility of alpha clustering as nuclear building block:

The facts that 1) radioactive nuclei spontaneously emit α- particles 2) the 'magic' stability of 2 protons and 2 neutrons and 3) the relatively high binding energy of 4n nuclei (with $A \leq 40$) than those of their neighbours, led to the belief that α- particles combine together to produce nuclei of higher mass number. In fact Brink et, al [10] suggested some possible geometric structure of simpler 4n nuclei and attempts were made to express the total binding energy as the sum of binding energy of contributing α- particles plus the inter α-particles binding energy of 2.5 MeV per bond. The model was also advocated by Hodgson

[23], Wildermath and Tang [24] and Wuosmaa et. al [25]. However, this model is not considered adequate when applied to nuclei with $A > 40$.

The structure and the stability of α- particle as discussed before does not contribute favourably to the idea of α- cluster model. The α- particles being doubly positive charged will be subjected to strong Coulmbic repulsion and with the absence of any strong nuclear attractive force, cluster formation seems improbable. Even when the mass number is small two α- particles do not form ^{8}Be (beryllium bottleneck) and three α- particles do not form ^{12}C. But since α- is emitted by higher mass number radioactive nuclei it is possible that in lower mass number nuclei p – n pairs (Paulion) form virtual α- particles and only in higher mass number nuclei real α- particles in addition to virtual α- particles are present. In terms of the presented polyhedral model [4] real α- particles may exist in the dodecahedron and icosahedron cages and inner polyhedra mostly contain virtual α- particles.

Radioactive α- emission:

1) Radioactive elements spontaneously emit α, β and γ rays --- α is a particle, β shows wave and particle properties while γ- rays are photons of high energy. We consider only α- particle emission.
2) Emission of α- particle is a statistical process where the activity depends on the number of α- particles present at an instant and the law is formulated as $N = N_0e^{-\lambda t}$ where N_0 is the initial number of radioactive nuclei, λ is a constant and t is time elapsed. $t_{½}$ is the time for $N = N_0/2$ and is known as half-life period.
3) The rule does not state anything about the origin of the α- particles present in the nuclide. Whether these exist as such at the time of emission or produced by a nuclear reaction in a kinetic process is not known.

4) The half-life periods of the nuclides vary from very small to very high values which mean that this cannot depend only on the initial numbers of α- particles. Although a trend has been recognized [26] in the values of half-lives of the decay products of ^{238}U (belonging to 4n+2 series) there is no general method for the calculation of $t_{½}$ of different radioactive nuclides.

5) The wide variations of the values of the half-life period of different nuclides cannot be justified by comparison with the life expectancy of a living being. This life expectation depends on the socio-economic condition, weather, breading and gene to mention some of the factors among others. In the case of the nuclei, the gene is the same for each (neutrons, protons and electrons or quarks, leptons and bosons), and the nuclides are not affected by any external condition like temperature, pressure, chemical composition or existence in solid, liquid or gaseous states.

6) The presence of free α- particles in sufficient number in the nucleus is doubtful in that the Coulombic repulsion will be high and with high mass number nuclei this will be considerable. It is quite possible that the α- particles remain in a virtual state and the real particles are produced in a nuclear reaction.

7) The emission of α- particles from the nuclei is explained by quantum mechanical tunnel effect [27 -29] in which although the energy of the α- particle may be less than the barrier height, a small fraction may attain the critical value and cross the barrier of the potential well. Preformation of the α- particle in the nucleus has been assumed, the probability of which varies from 0.1 -1.0, the maximum value attained in even Z - even N nuclei. The decay constant is described as the product of the preformation probability, the frequency indicating the number of times the particle arrives at the nuclear border and the probability of escape of the particle from the nuclides.

In terms of the presented polyhedral model [4] it may be supposed that the α- particles (virtual or real) are encaged in the polyhedron (dodeca- or icosahedron) and the dynamics of the vibration of the cage structure releases the α- particles periodically so as to produce different half-life periods for different nuclides which vary from very high value to a very low value. The preformation may be a kinetic process in which the virtual α- particles are converted to real α- particles by a nuclear reaction. The frequency factor may be the number of how many times the real α- particles attain the border potential and the probability factor is the chance of escape of the α-particle from the nucleus. This latter process may be guided by the mechanical vibration of the polyhedral lattice formed by Paulion condensation.

Conclusion:

The anomalies in the properties of α-particle can be satisfactorily addressed by invoking the concept of QCD. Thus the high core density, the very low radius, extreme stability and compactness of α- particles are shown to be resulting from interaction of six d-quarks. This also predicts the binding energy of the particle exactly. The concept can be utilized to describe the structure of some low mass number nuclei. The possibility of occurrence of α- particles as building block in the nucleosynthetic process has been discounted.

The mechanism of the decay of the nuclides by emitting a massive particle like α and the occurrence of half-life with all types of values from extremely small to astronomically high order remain a puzzling problem. The parameter on which this wide variation depends is really enigmatic. It appears that both kinetic and mechanical forces are involved in the process. Interpretation of properties of heavy nuclides in terms of quarks will be presented in a later communication.

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