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Analytical Study of Some Lightest Nuclei *H, He, Li* and *Be*

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Abstract

In the present study, the properties of the light elements, namely, *H, He, Li*, and *Be*, have been reviewed. Specifically, the nuclear decay of these nuclei has been reviewed. The mystery of the nuclear decay and potential is behind this work. The role of neutron has been investigated. The *N/Z* ratio has also been investigated in the study to relate the nuclear decay with the ratio. A new formula for nuclear potential has been suggested in the present study. This formula can describe the binding energy potential and the decayed particle energy depending on the *N/Z* ratio.

Keywords: Nuclear Decay, Nuclear Potential, Nuclear Structure, Radioactivity.

1. Introduction

There are many properties of the nucleus, but the big problem is philosophy of nuclear potential and radioactivity. Actually, no one knows the reality of those properties. Within this work, the radioactivity of the lightest nuclei has been taken into consideration. Radioactive decay (also known as nuclear decay) is the procedure through which unstable nuclei lose its energy by releasing particles or radiation, like alpha-particles, beta-particles and a gamma ray or electron in the internal conversion case. A material having such unstable nuclei is considered radioactive. Certain highly excited short-lived nuclear states can decay through neutron emission, or, more rarely, proton emission. Radioactive decays are stochastic processes. According to quantum theory, it is difficult to determine when a particular nucleus will decay [1-3]. However, for a collection of nuclei, the collection probable decay rate is described in terms of decay constants or more precisely half-lives. This can be considered as the basis of radiometric. The half-life of decay has no recognized upper limit. Radioactive atomic nuclei, which have zero spin, can have no specific orientation. Radioactive nuclear decay includes the production of a particle and or energy as one nucleus changes to a new nucleus. In most cases, the nucleus changes its identity to be a new one. There are many.

Different kinds of releases that happen. Alpha (α) decay leads to the emission of helium nucleus from the nucleus. This consists of two neutrons and two protons. Emission of α-particle produces a new element which has an atomic number two less than the original element and a weight which is four less. A usual alpha-decay action is the change of uranium-238 to thorium. The second one is beta **(*β*)** decay; this decay is a more complex process. Unlike the α-release, which simply ejects alpha particle, the *β*-emission includes the conversion of a neutron/proton in the atomic nucleus into a proton/neutron and electron/positron. The electron is then expelled from the nuclide. In this process, the number of protons increases by one, whereas the atomic weight stills the same. Such as is the case of α-emissions, *β*-releases are often accompanied with *γ*-radiation. Also electron capture, a different way for a nucleus to rise its neutron/proton ratio is by a phenomenon known as electron capture. In the process, an electron from close orbital is captured by the nuclides and joint with a proton to form a new neutron. For example, the silver-106 goes through electron capture to convert the palladium-106. And also, gamma (*γ*) radiation is just energy. It may be emitted by itself or more usually in conjunction with another radiation event. There is no conversion of number of protons or neutrons in a simple *γ*-emission. Regularly, isotope may create *γ*-radiation as a result of a conversion in stability. This kind of isotope may settle through a shifting of nuclide inside the nucleus. The configuration of the atom (is not) changed, but the nucleus could be measured further "comfortable" afterward the change. This shift raises the stability of the nucleus from the unstable isotope to more stability of the nucleus [3].

2. Results and Discussion

The nuclear decays of the elements with the lightest nuclei, namely, Hydrogen, Helium, Lithium, and Beryllium, have been considered. The properties of these nuclei are shown in **Table 1.**

Table 1. Data of Hydrogen, Helium, Lithium and Beryllium Isotopes.

Atomic number (Z)	Neutron Number (N)	N/Z	Element	Beta+ Decay	Proton emission	Electron capture	Beta- Decay	Neutron emission	Alpha Decay	$T_{1/2}$ [s]	Ref.
1	0	0.00	^{1}H	0	0	0	0	0	0		[4]
1	1	1.00	^{2}H	0	0	0	0	0	0		[5]
1	2	2.00	^{3}H	0	0	0	1	0	0	3.89E+08	[6]
1	3	3.00	^{4}H	0	0	0	0	1	0		[7]
1	4	4.00	^{5}H	0	0	0	0	1	0		[8]
1	5	5.00	^{6}H	0	0	0	0	1	0	2.85E-22	[9]
2	1	0.50	^{3}He	0	0	0	0	0	0		[6]
2	2	1.00	^{4}He	0	0	0	0	0	0		[7]
2	3	1.50	^{5}He	0	0	0	0	1	0	7.04E-22	[8]
2	4	2.00	^{6}He	0	0	0	1	0	0	8.07E-01	[9]
2	5	2.50	^{7}He	0	0	0	0	1	0	3.04E-21	[10]
2	6	3.00	^{8}He	0	0	0	1	0	0	1.19E-01	[11]
2	7	3.50	^{9}He	0	0	0	0	1	0		[11]
2	8	4.00	^{10}He	0	0	0	0	1	0	1.52E-21	[12]
3	1	0.33	^{4}Li	0	1	0	0	0	0		[7]

3	2	0.67	^{5}Li	0	1	0	0	0	0	3.71E-22	[8]
3	3	1.00	^{6}Li	0	0	0	0	0	0		[9]
3	4	1.33	^{7}Li	0	0	0	0	0	0		[10]
3	5	1.67	^{8}Li	0	0	0	1	0	0	8.40E-01	[11]
3	6	2.00	^{9}Li	0	0	0	1	0	0	1.78E-01	[11]
3	7	2.33	^{10}Li	0	0	0	0	1	0		[12]
3	8	2.67	^{11}Li	0	0	0	1	0	0	8.75E-03	[13]
4	1	0.25	^{5}Be	0	1	0	0	0	0		[8]
4	2	0.50	^{6}Be	0	2	0	0	0	1	4.96E-21	[8]
4	3	0.75	^{7}Be	0	0	1	0	0	0	4.60E+06	[8]
4	4	1.00	^{8}Be	0	0	0	0	0	1	8.19E-17	[9]
4	5	1.25	^{9}Be	0	0	0	0	0	0		[9]
4	6	1.50	^{10}Be	0	0	0	1	0	0	4.77E+13	[9]
4	7	1.75	^{11}Be	0	0	0	1	0	0	1.38E+01	[10]
4	8	2.00	^{12}Be	0	0	0	1	0	0	2.13E-02	[11]
4	9	2.25	^{13}Be	0	0	0	0	1	0	2.70E-21	[11]
4	10	2.50	^{14}Be	0	0	0	1	0	0	4.35E-03	[12]
4	11	2.75	^{15}Be	0	0	0	0	1	0	7.87E-22	[13]
4	12	3.00	^{16}Be	0	0	0	0	1	0	5.70E-22	[14]

Hydrogen nucleus ($_1H$) has three isotopes naturally occurring, sometimes indicated ^1H, ^2H, and ^3H. The first two of them are stable, whereas ^3H has a half-life of 12.3y. Also, there are heavier isotopes, which are all unnatural and have a half-life less than (10^{-21} second). Of these, ^{5}H is the most stable, and ^{7}H is the least. The $^3_1H_2(2)$ isotope has radioactivity by emitting β^- with a half-life (3.89E8 sec) and convert to $^3_2He_1(0.5)$ (stable). Regarding to Coulomb effect, the inverse must be the right. That means the $^3_1H_2(2)$ must be stable and the $^3_2He_1(0.5)$ unstable (the number between brackets is ratio of N/Z). The others H's isotopes (^{4}H, ^{5}H, ^{6}H) are emitting neutrons because they have overabundant neutrons comparing with Protons number.

While there are many known isotopes of helium ($_2$He) (criterion atomic weight around: 4.002602(2)); only the helium-3 (^{3}He) and the helium-4 (^{4}He) are stable. All radioisotopes have very short-lived; actually the longest-lived is ^{6}He with a half-life of 806.7ms. The least stable with a half-life of 7.6×10^{-22} s is ^{5}He, though it is likely that ^{2}He has shorter half-life. In the atmosphere of Earth, there is one ^{3}He for each million ^{4}He. However, helium is remarkable in that its isotopic richness varies greatly liable on its origin. In the interstellar medium, the amount of ^{3}He is about a hundred times higher. Rocks in the Earth's shell have isotope proportions varying by a factor of ten.The Helium's Isotopes, we notice that the $^5_2He_3(1.5)$ emits neutron and converts to $^4_2He_2(1)$ (stable). The $^6_2He_4(2)$ is Two-neutron Halo nucleus with weak binding energy. The $^6_2He_4(2)$ has Borromean system. However, it has β^- decay with a half-life (8.07E-1 sec) to be $^6_3Li_3(1)$ (stable). The $^6_2He_4(2)$ is even-even nucleus and unstable nucleus had converted to stable odd-odd $^6_3Li_3(1)$. This is contradicting with shell model, which consider the even-even property give s nucleus more stability. The

${}^{7}_{2}He_{5}(2.5)$ is emitting neutron to be ${}^{6}_{2}He_{4}(2)$. The ${}^{8}_{2}He_{6}(3)$ had β^{-} decay with a half-life (1.19E-1 sec) to be ${}^{8}_{3}Li_{5}(1.6)$, which had radioactivity with a half-life ($8.4*10^{-1}$sec) and converted to ${}^{8}_{4}Be_{4}(1)$, which had α-decay with half-life ($8.19*10^{-17}$sec) to be ${}^{4}_{2}He_{2}(1)$. Regarding to half-life, the decay increased the radioactivity of ${}^{8}_{4}Be_{4}(1)$ although it is even-even nucleus. The ${}^{9}_{2}He_{7}(3.5)$ and ${}^{10}_{2}He_{8}(4)$ isotopes are emitting neutrons. Naturally happening lithium nucleus ($_3$Li) has two stable isotopes, lithium-6 (^{6}Li) and lithium-7(^{7}Li), with the last being far riche : around 92.5 percent of the nuclei. Lithium-7 (^{7}Li) and lithium-6 (^{6}Li) are two of the primitive nuclei that were created in the Big Bang, with lithium-7 to be 10^{-9} of all primitive nuclides and the amount of (^{6}Li) around 10^{-13}. A small percentage of (^{6}Li) is also known to be formed by nuclear reactions in some certain stars. The lithium isotopes separate slightly during a diversity of geological processes, with mineral formation (chemical deposition and ion substitution). The Li isotopes, the ${}^{4}_{3}Li_{1}(0.3)$ is emitting proton to be ${}^{3}_{2}He_{1}(0.5)$ (stable) and the ${}^{5}_{3}Li_{2}(0.6)$ is also emitting proton with very short half-life 3.71×10^{-22} sec to be ${}^{4}_{2}He_{2}(1)$. No information about half-life of ${}^{4}_{3}Li_{1}(0.3)$, but the half-life of ${}^{5}_{3}Li_{2}(0.6)$ refers to something strange. The ${}^{8}_{3}Li_{5}(1.6)$ is unstable nucleus and decay to ${}^{8}_{4}Be_{4}(1)$ and also this has α-decay as explained above. Also the ${}^{9}_{3}Li_{6}(2)$ has β^{-} decay to be ${}^{9}_{4}Be_{5}(1.25)$ with a half-life ($1.7*10^{-1}$sec). The ${}^{10}_{3}Li_{7}(2.3)$ is emitting neutron. The ${}^{11}_{3}Li_{8}(2.6)$ is a two-neutron Halo nucleus, which has abnormal radius and weakly bound system. However, it has β^{-} decay with a half-life ($8.75*10^{-3}$sec) to be ${}^{11}_{4}Be_{7}(1.75)$, which also has β^{-} decay with a half-life (13.8sec) to be ${}^{11}_{5}B_{6}(1.2)$. Beryllium ($_4$Be) has twelve isotopes, but actually only one of them (Beryllium-9 ^{9}Be) is stable and a primitive nucleus. Beryllium is measured a monoisotopic element. Also, it is a mononuclidic nucleus, since its isotopes have short-lives that none are primitive and their abundance is too low (with atomic weight is 9.0122). Beryllium is sole the only monoisotopic nuclide, which includes even number of protons with odd number of neutrons. There are twenty-five monoisotopic nuclei, but all of them have odd proton numbers, and even neutron numbers. The Beryllium's isotopes, the ${}^{5}_{4}Be_{1}(0.25)$ is emitting proton to convert to ${}^{4}_{3}Li_{1}(0.3)$ unstable as discussed above. The ${}^{6}_{4}Be_{2}(0.5)$ has two types of decay by emitting two protons and α-decay with a very short half-life ($2.96*10^{-21}$sec), but ${}^{8}_{4}Be_{4}(1)$ has α-decay and be ${}^{4}_{2}He_{2}$. The ${}^{7}_{4}Be_{3}(0.75)$ decay by capturing electron from electronic orbits to be ${}^{7}_{3}Li_{4}(1.3)$ (stable) From the table (1), the ${}^{10}_{4}Be_{6}(1.5)$ has radioactivity and decay by emitting β^{-} in a half-life ($4.77*10^{13}$sec) to be ${}^{10}_{5}B_{5}(1)$ (stable).In spite of the half-life is not very short and the ratio of N/Z is 1.5 and inappropriate for light nuclei, this isotope is unstable. The ${}^{11}_{4}Be_{7}(1.75)$ isotope has β^{-} decay with half-life (13.8sec) as well as the ${}^{12}_{4}Be_{8}(2)$ isotope has β^{-} decay with half-life (0.0213sec) to be ${}^{12}_{5}B_{7}(1.4)$, which has also β^{-} decay with half-life (0.02sec).The half-life of ${}^{12}_{5}B_{7}(1.4)$ shorter than ${}^{12}_{4}Be_{8}(2)$. Although the ratio of N/Z is shorter, that means the half-life must be longer, not shorter regarding to the ratio. The ${}^{13}_{4}Be_{9}(2.25)$ isotope is emitting neutron. The ${}^{14}_{4}Be_{10}(2.5)$ is Two-neutron Halo nucleus, which decay with a half-life (4.35*10^{-3}sec) to be ${}^{14}_{5}B_{9}(1.8)$. The ${}^{14}_{5}B_{9}(1.8)$ isotope also decay with a half-life (0.012sec) to be ${}^{14}_{6}C_{8}(1.3)$, which has β^{-} decay With half-life (1.8*10^{11}sec). The ${}^{15}_{4}Be_{11}(2.75)$ and ${}^{16}_{4}Be_{12}(3)$ are emitting neutrons with half –life (7.87*10^{-22}sec) and (5.7*10^{-22}sec) respectively. In summary, the comparison between the ${}^{3}_{1}H_{2}(2)$ and ${}^{3}_{2}He_{1}(0.5)$ refers to the effect between neutrons that are larger than Coulomb's effect. ${}^{6}_{2}He_{4}(2)$ is unstable, although it is an even–even element, but ${}^{6}_{3}Li_{3}(1)$ is a stable odd–odd element. This finding absolutely contradicts that with the shell model. ${}^{8}_{4}Be_{4}(1)$ presents an abnormal behavior that shows decay increased the radioactivity. The half-life of ${}^{5}_{3}Li_{2}(0.6)$ refers to something strange. The half-life of ${}^{10}_{4}Be_{6}(1.5)$ is 1.51(4) ×106 years with a high N/Z ratio, and regarding to the light elements, this element refers to unusual behavior. The life of ${}^{12}_{4}Be_{8}(2)$ must be shorter than that of ${}^{12}_{5}B_{7}(1.4)$, but the results showed otherwise.

3. Conclusion and Suggestion

The behavior of nuclear decay shows strong neutron influence. This finding indicates that a neutron cannot be considered as a neutral particle, but has considerably affected as shown in neutron emission and β^{-} decay, especially the n-emission with extremely short half-lives. Neutrons play an important role against nuclear potential as a proton. Thus, we must rethink about the neutron structure. The N/Z ratio has considerable effects on the determination of the nuclear decays. According to the findings above, we suggest a new formula for nuclear potential, as follows.

$$V = a(\frac{N}{Z})(-V_o) \qquad (1)$$

Actually, there are several nuclear potential formulas, such as well ptential, Wood–Saxon potential, Yukawa potential and so on. All these formulas have focused on a radius. In Eq. (1), we introduced a new effect, which is the ratio of number of neutrons to protons. The *(a)* is parameter that has the value (-1, 1). Actually, the *(a)* parameter needs some fitting to make the results more accurate. However, Eq. (1) has been run to the) above elements and the results as shown in **Figure 1.** For Hydrogen' isotopes, **Figure 2.** For Helium' isotopes, **Figure 3.** For Lithium's isotopes and **Figure 4.** For Beryllium's isotopes. The ratio of N/Z depends on mass number as seen in **Figure 5.**

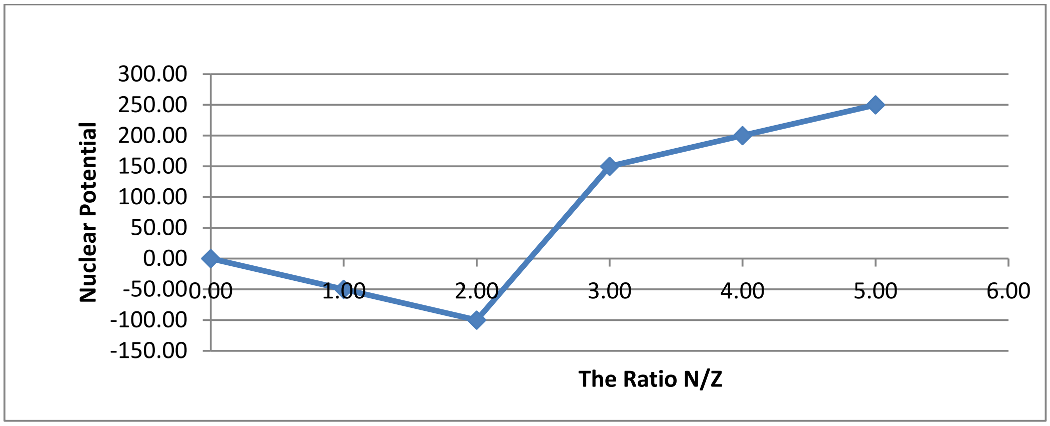

Figure 1. Nuclear Potental of Hydrogen' Isotopes.

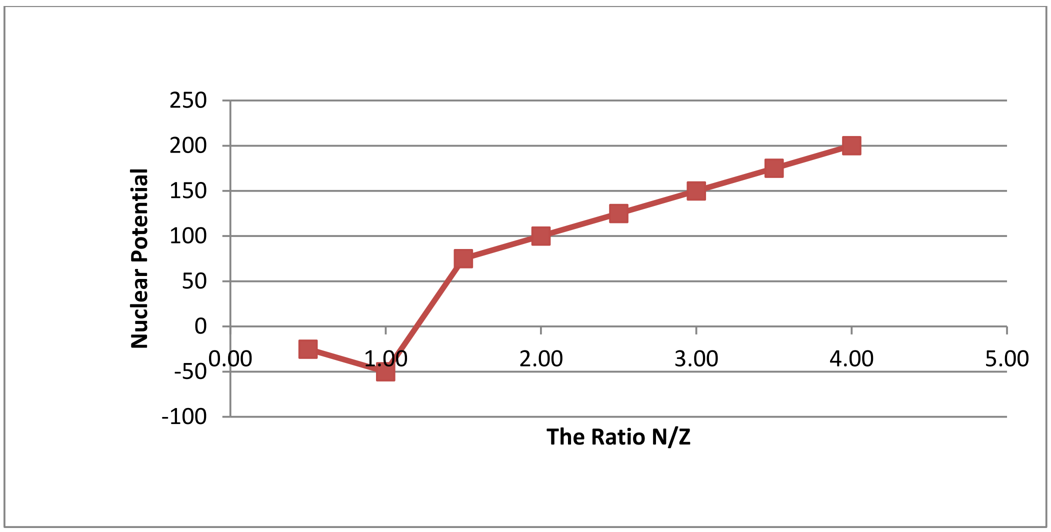

Figure 2. Nuclear Potential of Helium's Isotopes.

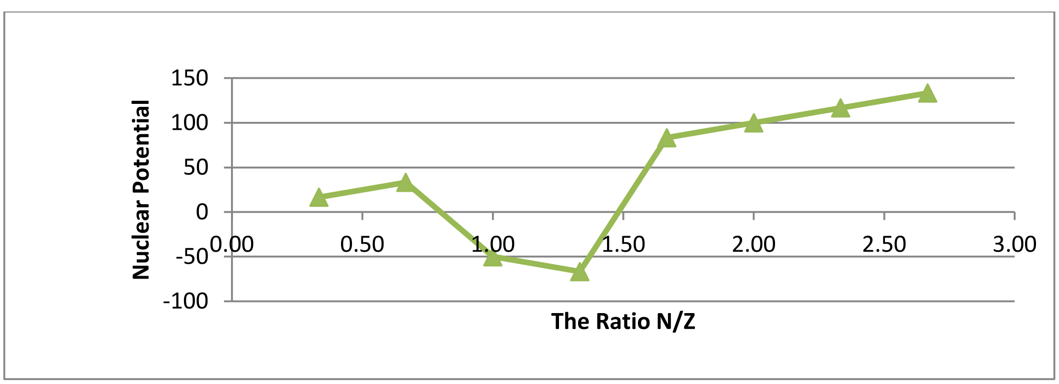

Figure 3. Nuclear Potential of Lithium's Isotopes.

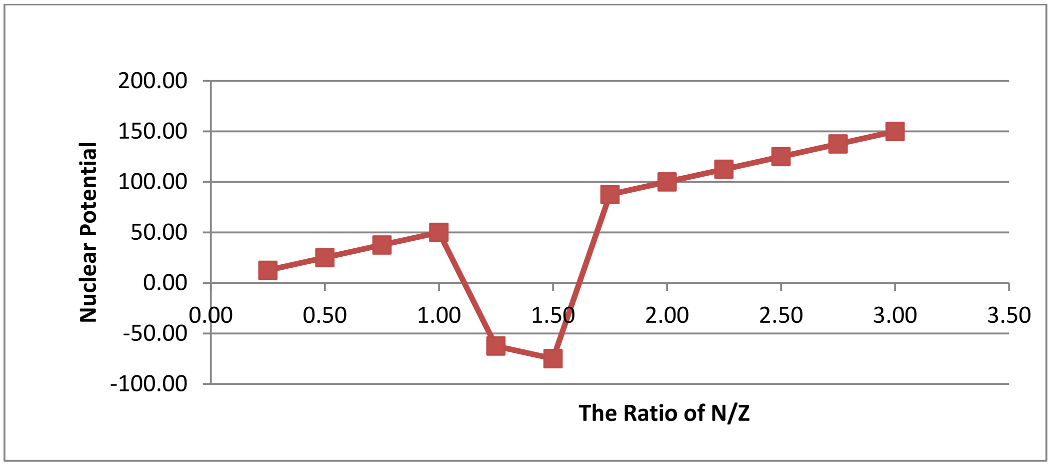

Figure 4. Nuclear Potential of Beryllium' Isotopes.

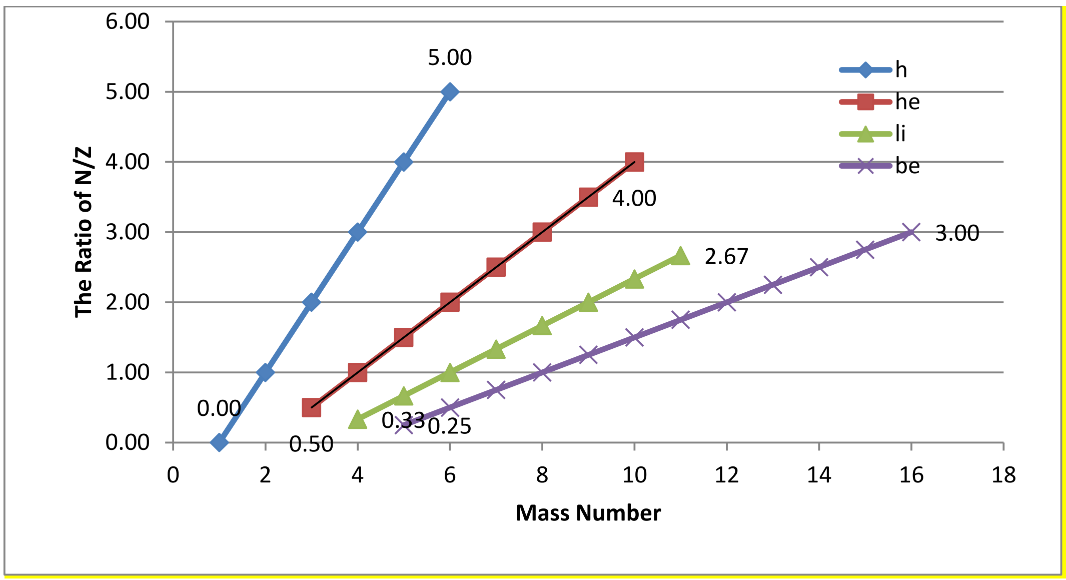

Figure 5. The change of N/Z ratio with Mass number.

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