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Estimation of alpha decay half lives for isotopes super heavy nuclei (even [Z]-even [N]), (even-odd), (odd-even) and (odd-odd) the range atomic number Z=104-118

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Abstract. Alpha decay is very important process in nuclear physics. According to the theory of quantum mechanics,the alpha particle before being to emitted, was preformed inside the mother nucleus and is assumed to move in a spherical region determined by the daughter nucleus. alpha-decay life time may provide a stringent test of the ability of nuclear structure theories to predict the nuclear density.According to a research that,this current this is it s result, first logarithm of alpha-decay half life for super heavy elements isotopes(104-118)compared by analytic formulae's andVSS based on experimental amounts of Q and half life accounted. There are several reasonable estimations for decay half life, once again alpha-decay half life with super heavy elements of Z=104-118 based on the formula of half experimental and half life of alpha decay including shell effects estimated by applying experimental Q amounts.As well as there is a good adaptation between experimental data and computations.

Keywords: Alpha-decay half-life; super heavy elements; VSS; shell effects

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1. INTRODUCTION

Superheavy nuclei probe the extremes of nuclear structure with respect to the number of nucleons that can form a bound system. Their existence and decay properties are one of the most fundamental problems in nuclear physics [1-2](.the investigation of these fields, either the oritically or experimentaly are of high interest among nucleus physics investigators which have a great developerment recently. There are some nuclides with atomic number 112,114,116,118 produced via reaction of heavy ions and bombarding of heavy goals ^{233,238}U,^{242}Pu,^{249}cf and ^{48}Ca. The carrying out of these processes sre time consuming acceterators and along of expenses[2]. The main modes of decay for superheavy elements are α dispatching and spontaneous split .To investigate α decay,different interpretative formulas which are introduced by different researchers,are studied .interpretative formulas such as viola-Seaborg- sobiczewski and a semi experimental formula including shell effects Impacts are suggested and used for studying α dispatching theory specially α decay half- live calculation formula.

2. PHYSICAL PROPERTIES OF NUCLEUS

Nucleus can be described according to some of the nucleus parameters 1-statistic properties of nucleus and 2- dynamic properties of nucleus) which are as follow:electric charge,radius, mass, binding energy,decay methods and half- lives(for radioactive nuclides),different types of

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reactions and the cross section of reactions, angular momentum transfers (or spin),parity, magnetic bipolar moment,electric quapolar moment and excitation state energy Some of these characteristics like mass, size,load and angular momentum, are time independent and some like radioactive decay and nucleus conversion are time dependent .

3. ALPHA DECAY

Alpha decay is infact the despatching of agroup of neoclons.this despatching is the result of colon repulsion. this event is of high importance for heavy elements.since the increasing rate of colon repulsion force (as a function of z^2) is more than nucleus dependence force which increasing as A increases. α decay is observed with atomic number of Z>83 for heavy elements and for those nucleus groups far from stable line is radiant nucleus with a high decay half live, especially natural radiant chain are decaying by α dispatching . the dispatching of each type at nucleon in a spontaneous radiant decay process is rarely occurred. For instance, deuteron is not observed in natural decay process. Proton dispatching for nucleus far from stable line β has increasing level of proton and it usually is as a two stage process which is observed after β^+ decay (delayed proton desatching - β) as atomic number increases,the split compete with alpha decay and is prevailed for some of radiant nucleus by Z>96 . Alpha decay is the dominate method of a lot of heavy nuclides by Z>105. in this process, nucleus parent (A,Z),dispatches an α element (which is the same with ^{4} He) and produces a nucleus daughter by mass number and charge number (A-4, Z-4) , then the column of alternative table of elements goes toward left side as 2 blocks. It should be noticed that the numbers of protons and neutrons must be stable individually in decay process. As, the heaviest element in nature is Bi, all the elements of A>210, Z>83 have tendency todecaying via α dispatching and ultra heavy elements Z>92 compete with nucleus split process want to be decaying by α dispatching . Among the elements of alternative table of elements, there are some nuclides like $^{144}_{60}\mathrm{Nd}$, $^{147}_{62}\mathrm{Sm}$, $^{152}_{64}\mathrm{Gd}$ $^{174}_{76}\mathrm{Hf}$, $^{190}_{78}\mathrm{Pt}$, which are capable of alpha emission with decay live of 10^{11} to 10^{15} weakly. There is some regular process in the α decay experiments as follow: 1. decay energy dependent on A (or Z or N) is usual, unless they are the magic numbers. This process is according to mass semi experimental formula

$$m(Z,A)=Zm(^1H)+Nm_n-\frac{B(Z,N)}{c^2} \qquad (1)$$

4. METHODOLOGY

The α decay half lives are calculated in the frame work of quantum mechanical tunneling of an alpha particle from a parent nucleus. Potential energy of alpha particle-daughter nucleus can be obtained from the total colon potential energy and centrifuge. The half lives of α disintegration processes are calculated using the WKB[1] approximation for barrier penetrability. The Q-values of α- decay are obtained from both the experimental data and theoretical predictions.

5. THE Q-VALUES OF ALPHA - DECAY

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[2] -G.wentzel,A.Kramrrs,Brillouin

To calculate alpha decay half live of decay experimental Q of reference is used [3]. When there is no experimental Q for alpha nuclide decay, theoretical Q was used. Q is calculated by following formulas.

$$\Delta N = \int_{t_1}^{t_2 = t_1 + \Delta t} A dt \tag{2}$$

$$Q=[m(a) + m(x) - m(b) - m(y)]c^2 \tag{3}$$

The theoretical Q-values have been obtained using the following relationship

$$Q_{th} = [m_i - (m_\alpha + m_f)]\, c^2 = \Delta m_i - (\Delta m_\alpha + \Delta m_f) \tag{4}$$

From the energetic point of view, spontaneous emission of α-particles is allowed if the released energy is a positive quantity. In this equation, m_i, m_f, m_α and Δm_i, Δm_f, Δm_α are the atomic masses and the atomic mass excesses of parent nucleus, the emitted α-particle and the residual daughter nucleus, respectively.

6. ATOMIC MASSES USED AS INPUT QUANTITIES

To calculate the theoretical amount of Q of alpha decays by the use of equation (2-2) mass excesses of references are used [3]

7. THE VIOLA-SEABORG-SOBICZEWSKI APPROACH

In 1911, Geiger and nuttall found out a relationship between α- decay energy Q and α- decay half-life T_α [5]:

$$Log_{10} T_\alpha = A + B Q_\alpha^{-1/2} \tag{5}$$

Where A and B are the parameters depending on the charge number of decaying nucleus. In 1966, viola and Seaborg generalized the law of Geiger and Nuttall and proposed the well known viola-Seaborg relationship:

$$\mathrm{Log}_{10} \mathrm{T}_\alpha = \mathrm{A} + \mathrm{B} \mathrm{Q}_\alpha^{-1/2} + (\mathrm{c}Z + \mathrm{d}) + \mathrm{h}_{\log} \tag{6}$$

Where Z is the proton number of the decaying nucleus, a,b,c,d are the parameters which may be obtained by fitting, values given by sobiczewski [5]

$$a= 1.66175, b=-8.5166, c=-0.20228, d=-33.9069 \tag{7}$$

In Eq.(6), the quantity $h_{\log}$ is the hindrance factor for odd-A or odd-odd nuclei estimated by Viola and Seaborg:

$$h_{\log} = \begin{cases} 0 & \text{for Z even- N even} \\ 0.772 & \text{for Z odd- N even} \\ 1.066 & \text{for Z even- N odd} \\ 1.114 & \text{for Z odd- N odd} \end{cases} \tag{8}$$

The uncertainties in the calculated half lives due to this semi-empirical approach are for smaller than the uncertainties due to errors in the calculated energy release. By substituting (5) and (6) in (4) the viola-Seaborg-sobiczewski formula for nucleus parent (even Z-even N), (even Z – odd N), (odd Z – even N) and (odd Z – odd N) are as follow, respectively.

$$Log_{10}\left[T_{\frac{1}{2}}(s)\right] = -33.9069 - 0.20228Z + \frac{1.66175Z - 8.5166}{\sqrt{Q_\alpha(MEV)}}$$

(9)

$$Log_{10}\left[T_{\frac{1}{2}}(s)\right] = -33.9069 - 0.20228Z + \frac{1.66175Z - 8.5166}{\sqrt{Q_\alpha(MEV)}} + 1.066$$

(10)

$$Log_{10}\left[T_{\frac{1}{2}}(s)\right] = -33.9069 - 0.20228Z + \frac{1.66175Z - 8.5166}{\sqrt{Q_\alpha(MEV)}} + 0.772$$

(11)

$$Log_{10}\left[T_{\frac{1}{2}}(s)\right] = -33.9069 - 0.20228Z + \frac{1.66175Z - 8.5166}{\sqrt{Q_\alpha(MEV)}} + 1.114$$

(12)

8. ANALYTICAL FORMULAE'S

The α decay half- lives have been determined assuming that the incoming point is the contact point and that the outgoing point corresponds to the equality of the coulomb energy with the experimental Q . The inertia parameter is simply the reduced mass.

Within this unified fission model the decay constant is simply the product of the assault frequency and penetrability. There is no pre formation factor.[7, 8]

Analytical formulae for the alpha decay half- lives have been proposed. G.Royer by the use of data analysis process of 373 alpha emission nucleus, following formula is obtained with a RMS deviation of 0.42. [9]

$$\log_{10}[T_{1/2}(s)] = -26.6 - 11.1A^{1/6}\sqrt{Z} + \frac{1.5837Z}{\sqrt{Q_\alpha}} \tag{13}$$

The Analytical formulae, α decay half- lives the same dependence on the mass and charge of the mother nucleus and experimental Q .for the subset of the 131 even-even nuclei, relation is obtained with a RMS deviation of only 0.285,

$$Log_{10}[T_{1/2}(s)] = -25.31 - 1.1629A^{1/6}\sqrt{Z} + \frac{1.5864Z}{\sqrt{Q_\alpha}} \tag{14}$$

For the subset of 106 even-odd nuclei the RMS deviation is 0.39 with the following formula:

$$\log_{10}[T_{1/2}(s)] = -26.65 - 1.0859A^{1/6}\sqrt{Z} + \frac{1.592Z}{\sqrt{Q_\alpha}} \tag{15}$$

The relation corresponds to the subset of 86 odd-even nuclei and a RMS deviation of 0.36, formula

$$\log_{10}[T_{1/2}(s)] = -25{,}68 - 1{,}1423A^{1/6}\sqrt{Z} + \frac{1{,}592Z}{\sqrt{Q_\alpha}} \tag{16}$$

Finally, for the subset of the 50 odd-odd nuclei the following formula leads to a RMS of 0.35, formula

$$\log_{10}[T_{1/2}(s)] = -29.48 - 1.113A^{1/6}\sqrt{Z} + \frac{1.6971Z}{\sqrt{Q_\alpha}} \tag{17}$$

The aforementioned formulas predicted the alpha decay half live of heavy and super heavy nucleuses well. Analytical formulae the alpha decay half-lives for sub barrier excitation energies E *, for the (even Z – even N), even- odd, odd-even and odd-odd nuclei.

$$Log_{10}[T_{1/2}(s)] = \left(-25.31 - 1.1629A^{1/6}\sqrt{Z} + \frac{1.5864Z}{\sqrt{Q_\alpha + E^*}}\right)\left(1 - 4.5182\times10^{-4}E^*\right) \tag{18}$$

$$Log_{10}[T_{1/2}(s)] = \left(-26.65 - 1.0859A^{1/6}\sqrt{Z} + \frac{1.5848Z}{\sqrt{Q_\alpha + E^*}}\right)\left(1 + 1.117\times10^{-2}E^* - 1.4903\times10^{-3}E^{*^2}\right) \tag{19}$$

$$Log_{10}[T_{1/2}(s)] = \left(-25.68 - 1.1423A^{1/6}\sqrt{Z} + \frac{1.592Z}{\sqrt{Q_\alpha + E^*}}\right)\left(1 + 8.9617\times10^{-3}E^* - 1.3446\times10^{-3}E^{*^2}\right) \tag{20}$$

$$Log_{10}[T_{1/2}(s)] = \left(-29.48 - 1.113A^{1/6}\sqrt{Z} + \frac{1.6971Z}{\sqrt{Q_\alpha + E^*}}\right)\left(1 - 8.8806\times10^{-3}E^*\right) \tag{21}$$

RMS deviation for sub barrier excitation energies E*, 0.28, 0.41, 0.27, and 0.5 for the (even Z-even N), even-odd, odd-even and odd-odd nuclei respectively. To assess the overall impact of the proton and neutron shells on the decay half lives and thus forms the nuclei stability are drawn figures 1 to 4. Logarithmic curve half-lives were calculated using the formula VSS in Figures 1 and 2 Logarithmic curve half-lives were calculated using the analytical formulas in Figures 3 and 4 for the emission of alpha studied are drawn. The relation of theoretical Qα values is used. Alpha emission traces the atomic number of pairs in Figures 1 and 3, and alpha emission traces the atomic number in Figures 2 and 4 are shown. The figure also generally observed that with increasing neutron number, the log-linear half-life values increased. For curves plotted with lower atomic numbers for curves with a peak at N= 162 and atomic number higher than one peak is observed at N=184. As discussed, the obvious discontinuities another reason is the core shell structure. In Figures 1 and 3, the distance between the curves for Z= 108 and Z=110 is quite impressive. In Figures 2 and 4, the same amount of difference to the peaks of the curves corresponds to Z=107 and Z=109 can be seen. The significant changes over the half-life of Z=108 to Z=110 and Z=107 to Z= 109 shell effects of high proton shell at Z=108 arises. It is shown that for a certain number of neutrons, with increasing atomic number of half-lives values of log declining influence of sharp peaks and decreases. This is due to Coulomb repulsion force increases with increasing atomic number.

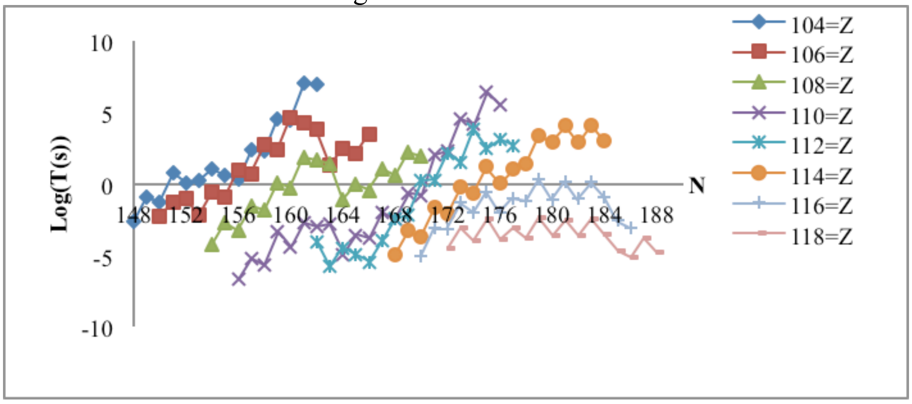

Figure 1. Logarithm of alpha decay half-lives calculated super heavy nuclei with proton number of even using the VSS formulae, according to the neutron number.

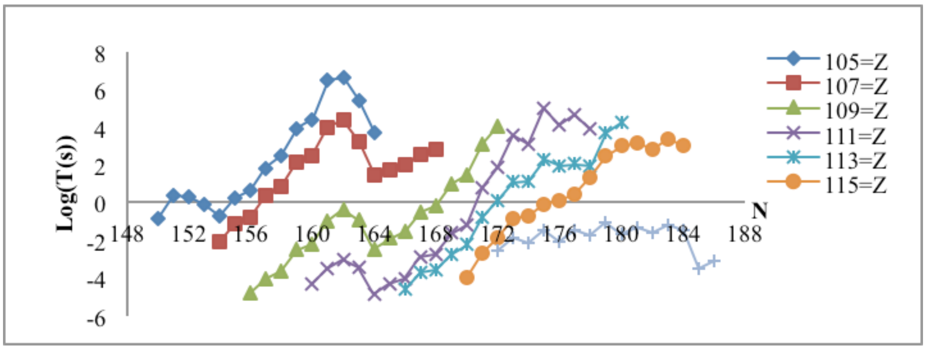

Figure 2. Logarithm of alpha decay half-lives calculated super heavy nuclei with proton number of odd using the VSS formulae, according to the neutron number.

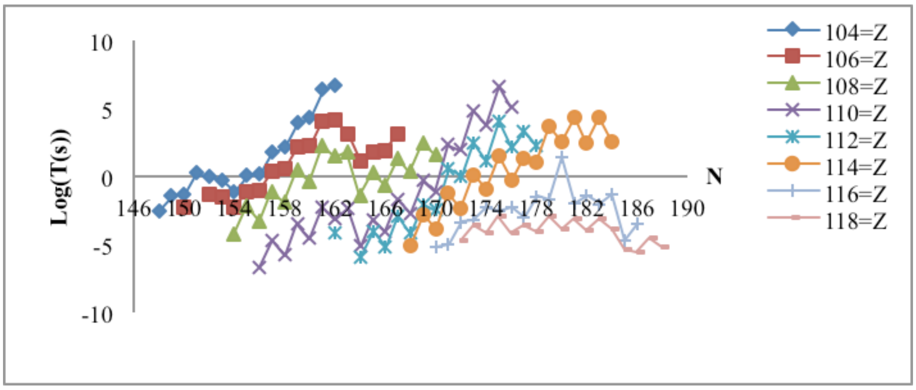

Figure 3. Logarithm of alpha decay half-lives calculated super heavy nuclei with proton number of even using the analytical formulae, according to the neutron number.

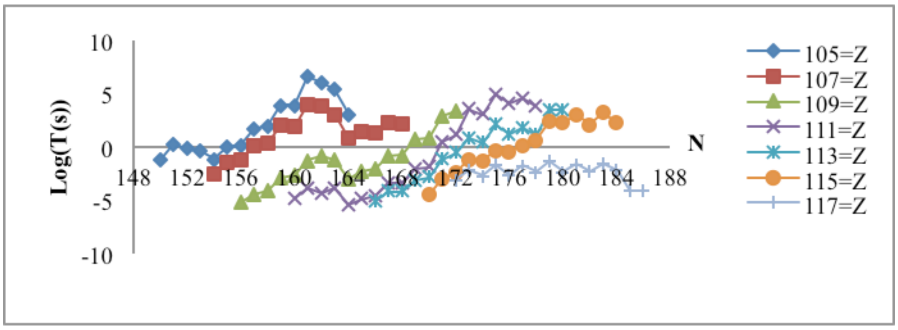

Figure 4. Logarithm of alpha decay half-lives calculated super heavy nuclei with proton number of odd using the analytical formulae, according to the neutron number.

Table1. Standard deviations $\log T(s)$

n	nuclei	σ_{VSS}	$\sigma_{formula}$	σ_{semFIS}
14	even- even nuclei	0.27	0.31	0.35
21	even- odd nuclei	0.98	0.56	0.53
6	odd- even nuclei	0.75	0.81	0.80
14	odd- odd nuclei	1.11	1.20	1.46

9. RESULTS

In general, the number of neutrons in the nuclei values of the half-lives increases. The reason for this is that the neutron absorber increases the forces of interaction between nucleons are without the Coulomb repulsion force value change. This process gave rise to a larger number of neutrons stopped and then we saw a sharp drop in the value of the half-lives nuclei But again, the half-lives does not begin to rise, the increasing trend for larger numbers of neutrons from 162 stopped after half-lives we saw a sharp drop in value because of the magic number N = 162,184 for deformed nuclei layer effects from it. The results of calculations for the 14 *even-even nuclei*, 6 *odd- even nuclei*, 21 *even- odd nuclei* and 14 *odd- odd nuclei*, including with atomic number between 104 and 118, are drawn in Figures 1, 2, 3, 4 respectively. For comparison, the experimental half-lives in the figures arrived. The results of calculations for the 6 *odd- even nuclei* individual with an atomic number between 104and 118 for the experimental Qα values were found in the references Figure 2 is given. This computation is done regardless of the orbital angular momentum, because the values of l corresponding nuclei in the references were not available. For comparison, the experimental half-lives in the diagram shown. In Figure 1, the standard deviation of the calculated values of the 14 *even- even nuclei*, σ_{rms} = 0.35-0.27. Figure 2 standard deviations of the calculated values of the *odd- even nuclei*, σ_{rms} = 0.8-0.75. Finally, in Figure 3 standard deviations of the calculated values of 21 *even- odd nuclei* σ_{rms} =0.98-0.53 and 14 *odd- odd nuclei*, σ_{rms} =1.1-1.46 (Figure 4).

This enormous difference between the experimental results and the results, particularly in the *odd-even nuclei* including *even-odd nuclei* and *odd-odd nuclei* shows.

However, this difference to a *odd- even nuclei* is acceptable. In fact, the differences arising from the orbital angular momentum l is ignoring.

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