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EFFECT OF MULTIPOLARITY-SIX DEFORMATION PARAMETER IN SUPER HEAVY NUCLEI

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ABSTRACT

The progress towards the exploration of Island of stability is the active research area in the Nuclear Physics field. Alpha Decay is an important tool to identify the super heavy nuclei and its properties. Analyzation of half life time values of Alpha Decay chain predicts information about long-lived super heavy elements. Many nuclear models have been so far estimated to determine the half life time values. More than ninety Trans-Actinide isotopes of fifteen super heavy elements have already been observed. Here in this work using Cubic plus Yukawa plus Exponential (CYE) model the alpha decay half life time values of super heavy nuclei in the Trans-Actinide region by incorporating higher order multi-polarity six deformation parameter is calculated and its stability is analyzed. The results obtained are compared with the theoretical and also with the available experimental values. The comparison of the calculated half lives follow the same trend as the reference values.

Keywords: Alpha decay,Deformation, Half Life, Super heavy nuclei,Trans-Actinides .

INTRODUCTION

The existence of the "Island of Stability"(IoS) in super heavy nuclei is predicted by a number of theoretical methods. Stability of super heavy elements depends on various factors such as nuclear shapes, deformations, energy, angular momentum etc. Also it is analyzed by the accurate measurement of half-life time values of alpha decay. In the present work half life time measurement is done based on Cubic plus Yukawa plus Exponential (CYE) model by two sphere approximation [1,2]. This model uses a Cubic potential in the pre-scission region connected by Coulomb plus Yukawa plus exponential potential in the post-scission region with zero point vibration energy. The calculation of alpha decay half-life without deformation [3] for the super heavy elements in the Trans-Actinide region is calculated initially and the model is enhanced further with the incorporation of higher multi-polarity hexacontratetrapole (β_6) deformation parameter.

METHODOLOGY

The properties of Trans-actinide elements are studied by a realistic model called as the Cubic plus Yukawa plus Exponential (CYE) model. It has a cubic potential for the overlapping region which is smoothly connected Yukawa plus exponential potential for the region after separation. Then the potential as a function of r for the post-scission region is given by

$$V(r) = \frac{Z_1 Z_2 e^2}{r} + V_n(r) - Q, \quad r \geq r_t \quad \text{--- (1)}$$

Where

$V_n(r)$ is the nuclear interaction energy and written in the form

$$V_n(r) = -D\left[F + \frac{r - r_t}{a}\right]\frac{r_t}{r}\exp\left[\frac{(r_t - r)}{a}\right]$$

$r_t = R_1 + R_2$ is the sum of their equivalent sharp surface radii. As long as the distance of their center of mass is greater than $r_t = R_1 + R_2$ (R_1 and R_2 are the radii of the daughter and the alpha particle) the only source of potential energy is the electrostatic repulsion and hence denotes the first term of equation.

The depth constant D is given by

$$D = 4a^3 g\,\frac{\left(\frac{R1}{a}\right) g\left(\frac{R_2}{a}\right)\exp(-r_{12}/a)Cs'}{r_0^2 r_{12}}$$

where g(x) = xcoshx – sinhx, and for the case of two separated nuclei,

$C_{S'} = [C_S(1)\, C_S(2)]^{1/2}$

The constant F is given by

$$F = 4 + \frac{r_{12}}{a} - \frac{f\left(\frac{R_1}{a}\right)}{\left(\frac{R_1}{a}\right)} - \frac{f\left(\frac{R_2}{a}\right)}{g\left(\frac{R_2}{a}\right)}$$

Where $F_{(x)} = x^2 \sin hx, R_i = r_0 A_i^{1/3}$

$$C_s(i) = a_s\,(1 - K_s I_i^2)\, and\, I_i = (N_i - Z_i / A_i,)(i = 1,2)$$

Half-life time of the system [4] is calculated using the formula

$T = \frac{1.433\ x\ 10^{-21}\ (1+exp\ K)}{E_v}$ --- (2)

Where k is a constant and given by

$$K = \frac{2}{\eta}\left\{\int_{r_a}^{r_t} [2B(r)V(r)]^{1/2}.dr + \frac{2}{\eta}\int_{r_t}^{r_b} [2B(r)V(r)]^{1/2}\right\}.dr$$

r_a and r_b being the two appropriate zeros of the integrand.

E_v is the zero point vibration energy. Super heavy nuclei (SHN) are axially symmetric [5]. Therefore, SHN are described by the deformation parameter expression for the radius vector describing the nucleus surface (in the intrinsic frame of reference) in terms of spherical harmonics and is written in the form,

$R(\theta, ¢) = R_0 + [1 + \sum_{l=1}^{\alpha} \sum_{m=-l}^{l} \beta_{lm} Y_l^m]$ …(3)

R_0 - is the nuclear radius for a spherical one also called as an equilibrium radius.

Y_l^m - are the spherical harmonics representing the surface disturbances

β_{lm} - deformed parameters

θ&¢ - polar angles with respect to arbitrary axis.

Since Y_l^m are the orthogonal, β_6 parameter corresponding to a specific shape is determined from the formula [6] as

$\beta_{lm} = \frac{\sqrt{4\pi}\ \int R(\theta,\emptyset)\ y_2^m (\theta,\emptyset)\ d\alpha}{\int R(\theta,\emptyset)\ y_0^0 (\theta,\emptyset)\ d\alpha}$ ---(4)

Where R is the radius vector.

The properties of a nucleus are very sensitive functions of its deformationparameters such as (Quadrupoleβ_2,hexadecapoleβ_4, hexacontatetrapole β_6,,Octupole-β_8). The analysis on nuclear deformation parameters has proved [7] that it is sufficient to consider the multi-polarities up to eight (i.e. up to β_8). The odd multi-polarities β_3, β5, β7 contribute only to light nuclei. Thus the deformation parameters β_2, β4, β6, β8 are sufficient enough for the study of properties in all super heavy nuclei [8].The contribution of higher order hexadecapole (β_4) deformation parameter in the calculation of half-life time values is predicted in the earlier work [9]. The predicted higher order hexacontatetrapole deformation parameter [10, 11] in super heavy nuclei is included in this work with its deformation parameter values taken from [13] and the half-life time values are calculated for the Trans-Actinide region in the range with atomic number Z= 104 to 121.

RESULTS AND DISCUSSION

The calculated half-life time values using CYE model with higher order multipolarity deformation parameter (β_6)are recorded in Table 1.

Table-1: Comparison of half-lives calculated using CYE model by incorporating higher order multi-polarity deformation parameter (β_6) with the theoretical and also with the available experimental values.

Nucleus	Q(MeV)	Log $_{10}T_{\frac{1}{2}}(s)$			
		CYE Model		Theory [12]	Expt. [14-24]
		WoD	With (β_6)		
$^{255}Rf_{104}$	8.95	0.76	0.55	1.038	0.204
$^{256}D_{105}$	9.19	0.37	0.20	0.699	0.230
$^{259}Sg_{106}$	9.815	-1.13	-1.19	-0.773	-0.319
$^{262}Bh_{107}$	10.576	-2.87	-3.05	-3.498	-2.097
$^{266}Ha_{108}$	10.381	-2.07	-2.02	-3.868	-2.638
$^{270}Mt_{109}$	10.227	-1.36	-1.26	-2.089	-2.301
$^{267}Da_{110}$	11.823	-4.89	-4.94	-4.405	-5.523
$^{272}Ro_{111}$	11.029	-2.77	-2.70	-2.265	-2.824
$^{277}Co_{112}$	11.666	-4.04	-3.90	-3.495	3.1155
$^{285}Ni_{113}$	9.927	-1.28	0.70	-0.619	0..643
$^{286}Fl_{114}$	10.373	-0.20	-0.01	-0.790	-0.886
$^{289}Ms_{115}$	10.504	-0.26	-0.32	-1.431	-1.319
$^{290}Li_{116}$	11.042	-1.36	-1.46	-3.254	-2.167
$^{293}Ts_{117}$	11.233	-1.56	-1.31	-1.331	-1.824
$^{294}Og_{118}$	11.862	-2.78	-2.00	-3.313	-2.149
$^{292}X_{119}$	13.17	-5.30	-4.89	-4.71[13]	-
$^{287}X_{120}$	13.98	-6.49	-6.00	-6.07[13]	-
$^{293}X_{121}$	14.14	-6.70	-6.27	-6.39[13]	-

The results are compared with the theoretical Formalism [12, 13] and also with the available experimental results [14-24]. Figure 1 shows the contour map of half-life time values without the inclusion of β_6 parameter. The large inner closed circles in the plot represent the region of in-stability in the Trans-Actinide nuclei.

This has been shown in Figure 2 which predicts the contour map of half-life time values with the inclusion of β_6 parameter. The closed circles in the plot represent the region of in-stability in the Trans-Actinide nuclei and the decrement in the area represents increase in the stability of the super heavy nuclei.

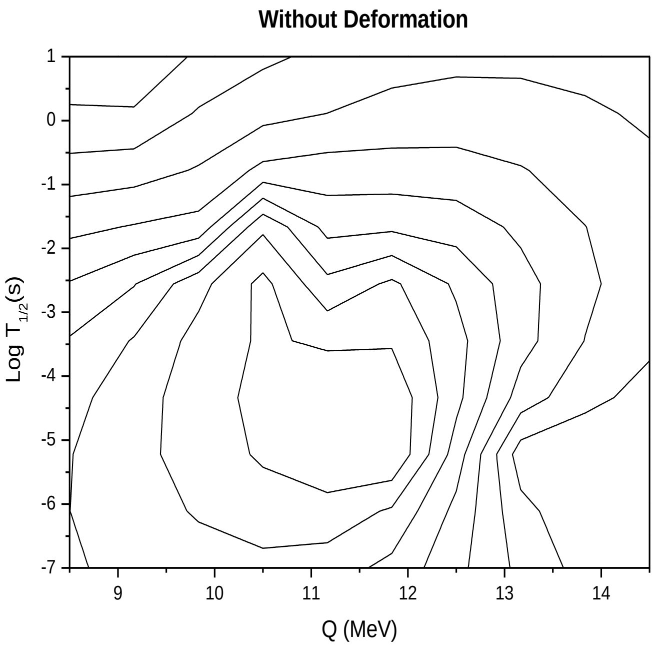

Figure1,showsthe contour map of half life time values without deformation. the inco

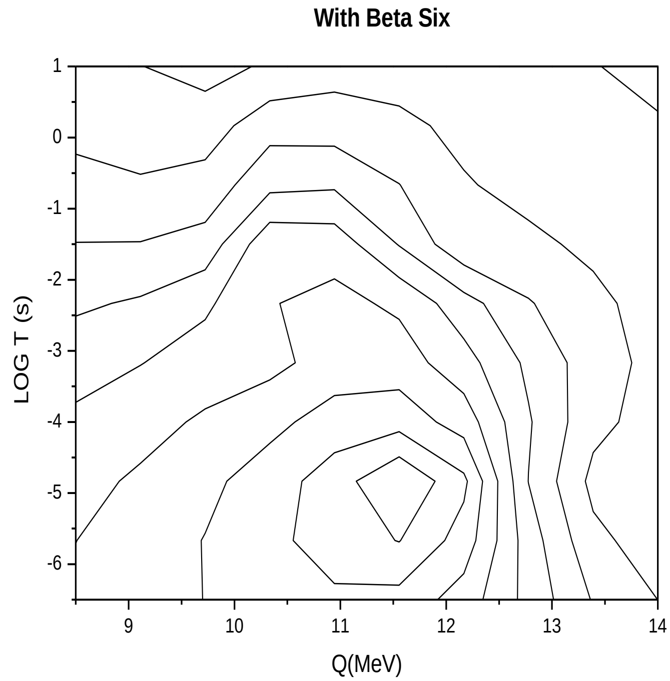

Figure 2, shows the contour map of half- life time values with incorporation of multi-polarity six deformation.

The inclusion of β_6 deformation parameter influences collective rotation of the nucleus leading to enlarged shell gap [25, 26] thereby increasing the binding energy to more than 1MeV and henceforth this increment correspondingly increases the half-life time values. Also comparison predicts that the calculated half life time values mostly increases with the inclusion of β_6 parameter [27] and reaches closer to the experimental value. Therefore, the contribution of higher order multi-polarity deformation-six parameter increases the stabilization of the nucleus. This had been proved for the nucleus ^{254}No[28]whose stability increases by increasing its binding energy to about 1.5MeV.

CONCLUSION

For a super heavy nuclei a decisive role after quadrupole deformation (β_2) which is the largest, dominant and positive in almost all the region of deformed nuclei is played by the starring hexadecapole deformation (β_4) parameter. The role of higher multi-polarity component (β_6) has been disregarded in the calculations for a long time in the study about the properties of super heavy nuclei. But even though these higher multi-polarity component (β_6) are smaller and since it changes through the region, the deformation – six (β_6) parameters becomes the main responsible parameter to increase the half-life time values. Therefore stabilization in the Trans-Actinide region due to the incorporation of higher order multi-polarity six deformation parameter will provide a new guide for future experiments to study about the properties of the heavy and super heavy nuclei.

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