REPERCUSSION OF ROTATIONAL ENERGY IN SUPER HEAVY NUCLEI

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Abstract:
Currently nuclear physics is travelling through an existing period of discovery of new super heavy elements (SHEs).Various numbers of interesting problems in the Nuclear Physics field are explored in the study of super heavy nuclei. The existence of an island of 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. and it is analyzed by the accurate measurement of half life time of alpha decay. Specially, study on the existence of competing decay mode, shell model calculations, ground state properties of nuclei, half-life times, spins and energies are the vigorously on-going research work. Description about the rotational property of the nuclei was first explained by A. Bohr. Rotation here prescribes the collective degree of freedom in nuclei. In the present work, first the half life time measurement with deformation is done based on Coulomb plus Yukawa plus Exponential (CYE) model which has the basis from unified fission model. 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 work is kindled more by finding the way to enhance the stability of super heavy nuclei. Therefore the model is enhanced further with the implementation of collective rotational energy for the precise measurement of half-life time values.

***Index Terms* – Coulomb plus Yukawa plus Exponential model, half-life, super heavy nuclei.**

I. INTRODUCTION

Theoretically the study of properties of super heavy nuclei guides us to discover new super heavy elements. Shape of the nucleus is an important property in the study of nuclear structure. The deformation as well as the rotational property alters the shape of the nucleus. Analyzing about this property helps in the accurate measurement of half-life time values which in turn provides special importance about the stability enhancement. Various models have been used to identify and investigate the properties of super heavy elements such as shell model calculations, ground state properties of nuclei, half-life times, spins and energies. Alpha decay is an important tool to identify and study the properties of super heavy elements (SHEs).The alpha decay half-life time calculation of the super heavy nuclei without deformation[1] have already been determined by using Cubic plus Yukawa plus Exponential (CYE) model in two sphere approximation[2,3]which has the basis from unified fission model is enhanced by incorporating deformation as well as rotational energy in Trans-Actinide region with atomic number ranging from Z = 104 to 121 and are analyzed here.

II. Theoretical Formalisms

In order to study the properties of Trans-Actinide elements a realistic model called as the Cubic plus Yukawa plus Exponential (CYE) model is used. It has a cubic potential for the overlapping region which is smoothly connected by 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

$$V(r) = V_c(r) + V_n(r) + V_d(r) - Q \qquad r \geq r_t \qquad \text{--- (1)}$$

Here, $V_c(r)$ is the coulomb potential between a spheroidal daughter and spherical emitted fragment,
$V_n(r)$ is the nuclear interaction energy due to finite range effects,
$V_d(r)$ is the change in the nuclear interaction energy due to deformation the nucleus.
Half-life time of the system is calculated using the formula

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

Here E_v is the zero point vibration energy.
The built in classical rotation influences the half –life and hence the rotational energy[4,5]is given by,

$$E_{rot} = \frac{l(l+1)\hbar^2}{2J} \qquad \text{--- (3)}$$

Where J is the rigid moment of inertia and *l* is the value of angular momentum.

III Alpha decay Half-life Time Calculation

The half-life time values of super heavy elements (SHE) in the Trans – Actinide region are calculated using CYE model in two sphere approximation with deformation effects[6] both in parent and daughter nucleus. The values for deformation parameters are taken from the reference[7].The results computed in column 3 of Table I are compared with the available theoretical[7,8] and experimental values[9-19].The model is further enhanced by incorporating rotational energy in the half-life time calculation. The deformation in the ground state makes the nuclei to rotate collectively[4] and therefore the hindrance effect of rotational energy has to be considered for half life time calculations. Therefore by incorporating the rotational energy in the transitional potential by taking into account the minimum value of angular momentum (*l*), the half-life time values are calculated. The results are compared with the theoretical[7,8] and also with the available experimental[9-19]values. They are tabulated in the column 4 of Table I. The contour plots for half-life time values by incorporating deformation and rotational energy are shown in Figures 1 and 2.

IV. Results and Discussion

The process of theoretical search against alpha decay leads to find stable super heavy nuclei. The deformation of the decaying parent and the daughter is very important because their hindrance may cause longevity and stability of super heavy nuclei. Since all heaviest elements found recently are believed to be well deformed, the deformation in the parent nucleus and the fragments are incorporated in the half-life time calculation of super heavy elements. Here the effect of ground state deformation are considered in the parent nucleus whereas the deformation effects have been included both in the coulomb energy and the surface energy due to Yukawa plus Exponential (Y+E) potential treating the daughter nucleus as spheroid and the emitted fragments as spherical. Thus alpha decay half-life time values are calculated for the deformed nucleus using CYE model. Also the decay properties of odd-odd super heavy nuclei have already been analyzed by this model[20.] The outcome brings out the fact the inclusion of deformation effects decreases the half-life time values. In most of the cases the calculated half-life time values approaches the experimental values due to the inclusion of deformation effects. The contour plot of half-life time values with deformation is recorded in Figure 1. The advantage of this model is further enhanced by its versatility in including the rotational energy while calculating the new transition potential. As only the deformed nuclei exhibits rotational spectra, here the half-life time values are calculated for the deformed nucleus by including rotational energy in the transition potential, with which the alpha particle is to penetrate the fission barrier. In deformed nuclei both the collective and non-collective components may present. So in this calculations both the collective and non-collective components are treated on the same footing and computed. Also the collective rotation is considered by small angular momentum values, the results reveal the fact that the obtained values remains saturated or alters very feebly with the increasing value of angular momentum[21]. Therefore the result of inclusion of rotational energy proves that the fission barriers of super heavy nuclei are consistently remains stable against rotation[22].The contour plot of half-life time values of deformed nuclei with the inclusion of rotational energy is recorded in Figure 2. Here the lines of the contour are similar to that of plot of contour lines with deformation inclusion and the incremental area denotes the feeble reduction in half-life time values. This analysis provides a strong basis to study about the rotational property of new super heavy elements.

Table I: Comparison of half-lives calculated using CYE model by incorporating Deformation as well as Rotational energy with the theoretical and also with the experimental results.

Nucleus	Q (MeV)	Log T(s)			
		With Deformation	With Rotational Energy (E_{rot})	Theory[8]	Experiment[9-19]
$^{255}Rf_{104}$	8.953	0.33	0.22	1.038	0.204
$^{256}Db_{105}$	9.197	-0.03	-0.12	0.699	0.230
$^{259}Sg_{106}$	9.815	-1.41	-1.53	-0.773	-0.319
$^{262}Bh_{107}$	10.576	-3.04	-3.042	-2.377	-2.097
$^{266}Ha_{108}$	10.381	-2.13	-2.129	-2.691	-2.638
$^{270}Mt_{109}$	10.227	-1.32	-1.297	-0.862	-2.301
$^{267}Da_{110}$	11.823	-4.87	-5.01	-4.405	-5.523
$^{272}Ro_{111}$	11.029	-2.73	-2.86	-2.265	-2.824
$^{277}Co_{112}$	11.666	-3.85	-3.97	-3.495	-3.155
$^{285}Ni_{113}$	9.927*(9.48-10.18)	-0.69	0.701	0.906	0.738
$^{286}Fl_{114}$	10.373	-0.01	-0.08	-0.790	-0.886
$^{289}Ms_{115}$	10.504*(10.2-10.54)	-0.31	-0.304	-0.058	-0.658
$^{290}Li_{116}$	11.042	-1.40	-1.434	-1.921	-2.167
$^{293}Ts_{117}$	11.233	-1.35	-1.40	-1.331	-1.824
$^{294}Og_{118}$	11.862	-2.48	-2.485	-3.313	-3.046
$^{292}X_{119}$	13.08	-4.86	-4.857	-4.540[7]	-
$^{287}X_{120}$	13.69	-6.03	-6.029	-4.717[7]	-
$^{293}X_{121}$	11.91	-1.71	-1.704	-2.585[7]	-

* denotes the exact Q (MeV) value chosen for calculation

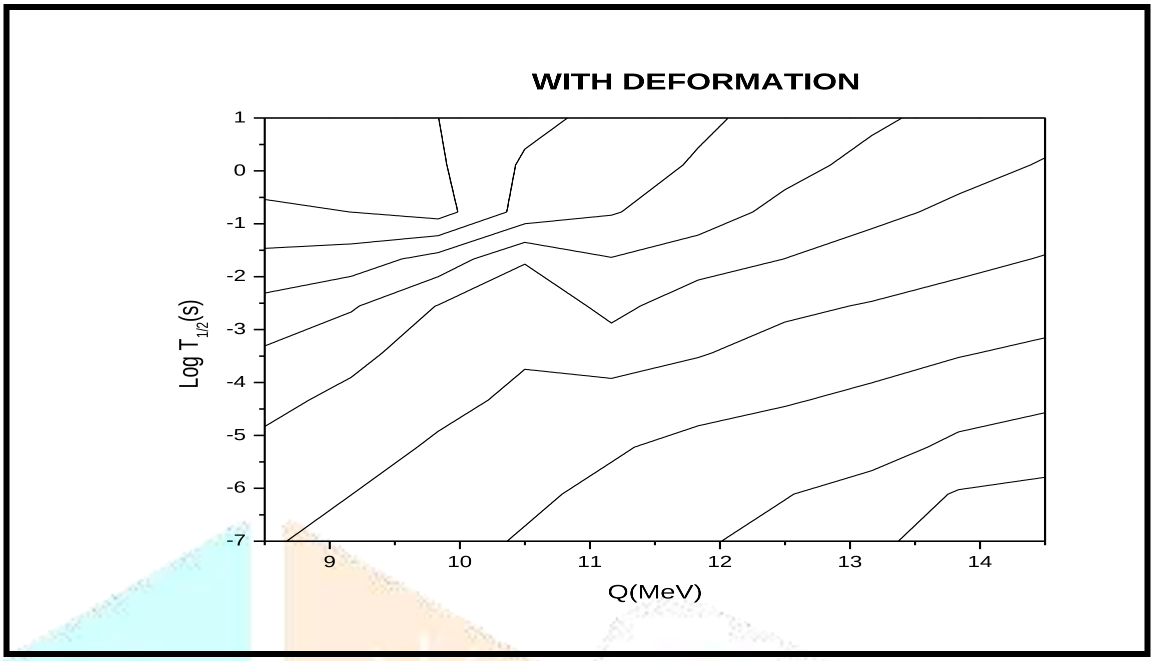

Figure 1, shows the contour plot of half-life time values incorporating deformation.

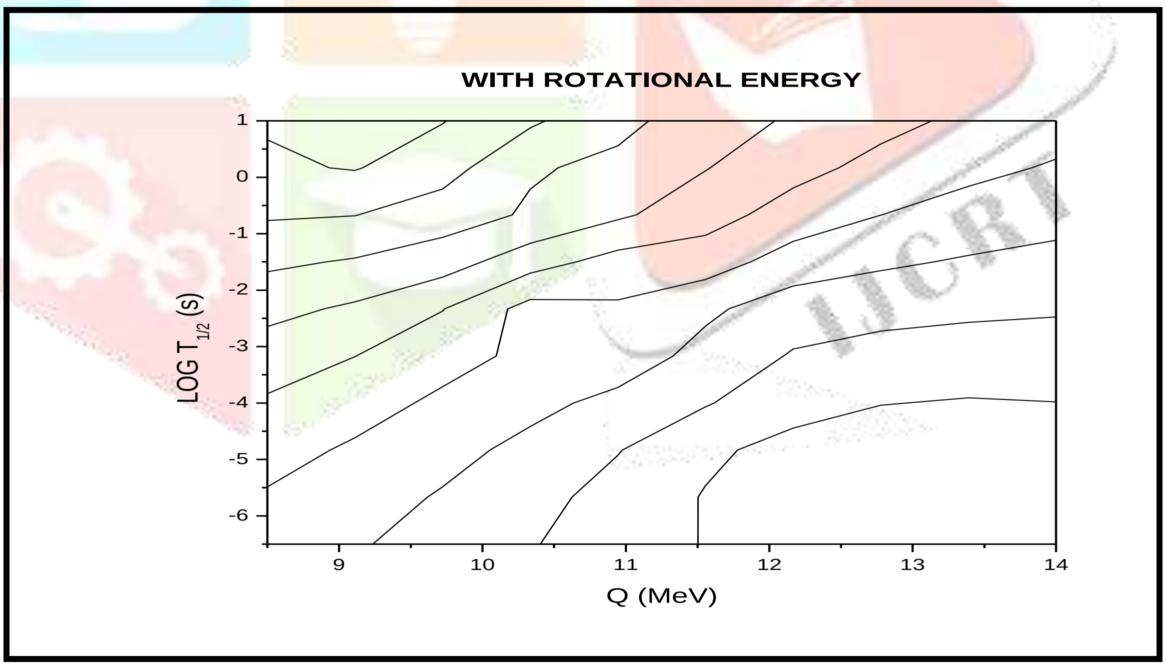

Figure 2, shows the contour plot of half-life time values with the incorporation of rotational energy.

V. Conclusion

The stability of super heavy elements depends on various factors and two of the factors are analyzed here. In the present work, using CYE model the ground state (static) fission barrier for the rotating super heavy nuclei have been determined by the including collective rotational energy. For most of the nuclei at lower value of angular momentum the half-life time values remains saturated. But for the increasing value of angular momentum the half- life time values decreases with the inclusion of rotational energy since because of large value of rigid moment of inertia lowers well the rotational energy and hence the transition potential, which makes the probability of alpha decay to increase. Thus more attention should be given regarding moment of inertia in future calculations which can provide most of the scarce information about the properties as well as the structure of the super heavy nuclei. Finally, concluding the fact that due to the inclusion of rotational energy in half-life time calculations of Trans-Actinide elements enables us to extract basic information about the super heavy elements which in turn will provide new guidance for future experiments.

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