An Investigation of The Effects of Rotational Energy In Super-Heavy Nuclei

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ABSTRACT
Currently, new extremely heavy elements are being discovered, which is a phase in nuclear physics (SHEs). The investigation of ultra heavy nuclei involves a wide range of intriguing Nuclear Physics issues. Several theoretical approaches anticipate the existence of an island of super heavy nuclei. The exact determination of the half-life of alpha decay is used to study the stability of super heavy elements, which depends on a variety of factors including nuclear shapes, deformations, energy, and angular momentum. Research is actively being conducted, in particular, on the existence of competing decay modes, shell model calculations, ground state features of nuclei, half-life periods, spins, and energies. A. Bohr provided the first description of the nuclei’s spinning characteristic. The aggregate degree of freedom in nuclei is here prescribed by rotation. First, the half-life time measurement with deformation is carried out in the current work using the Coulomb plus Yukawa plus Exponential (CYE) model, which is based on the unified fission model. The pre-scission region of this model employs a Cubic potential, which is coupled to the post-scission zone by Coulomb plus Yukawa plus an exponential potential with zero point vibration energy. Finding a method to improve the stability of extremely heavy nuclei fuels the work more. In order to quantify half-life times precisely, the model is further improved by the use of collective rotational energy.

Keywords: Coulomb plus Yukawa plus Exponential model, half-life, super heavy nuclei.

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. [1-5] The shape of the nucleus is altered by both rotational and deformational characteristics. Analysis of this feature aids in the precise estimation of half-life time values, which in turn has a significant impact on the improvement of stability. Models include computations of the shell model, the ground state characteristics of nuclei, half-lives, spins, and energies have all been used to find and study the properties of super heavy elements. [6-10] An essential technique for identifying and researching the characteristics of super heavy elements is alpha decay (SHEs). Cubic plus has already been used to calculate the ultra heavy nuclei's alpha decay half-life times without deformation1. [11-12] Incorporating distortion and energy of motion in the Trans-Actinide area with atomic numbers ranging from Z = 104 to 121 enhances the Yukawa plus Exponential (CYE) model, which has its
roots in the unified fission model, and is examined here.

2. Theoretical Formalisms

The Cubic plus Yukawa plus Exponential (CYE) paradigm is a realistic representation that is used to examine the properties of Trans-Actinide elements. [13] Yukawa's seamless connection to the overlapping zone gives it a cubic potential, while the region after dissociation has an exponential potential. The possibility for the post-scission area is thus provided by as a function of \( r \).

\[
V(r) = Vc(r) + Vn(r) + Vd(r) - Q r \geq r_t
\]

(1)

The nuclear strong interaction due to finite distance impacts is \( Vn(r) \), the nuclear interaction energy owing to distortion of the nucleus is \( Vd(r) \), and the Coulomb possibility between a spheroidal daughter and spherical emission fragment is \( Vc(r) \).

Utilizing the equation, the system's half-life time is determined.

\[
T = 1.433 \times 10^{-21} \left(1 + \exp K \right) \frac{E_v}{E_{rot}} (2)
\]

Here \( E_v \) is the zero point vibration energy.

The built in classical rotation influences the half-life and hence the rotational energy4,5 is given by,

\[
E_{rot} = \frac{(l + 1)\hbar^2}{2J}
\]

(3)

Where \( J \) is the rigid moment of inertia and \( l \) is the value of angular momentum.

3. Alpha decay Half-life Time Calculation

Using the CYE model in two sphere approximation with deformation effects6 in both the parent and daughter nucleus, the half-life times of super heavy elements (SHE) in the Trans - Actinide area are computed. The values for deformation parameters are taken from the reference7. The results computed in column 3 of Table I are compared with the available theoretical7,8 and experimental values9-19. The model is further enhanced by incorporating rotational energy in the half-life time calculation.[14] The deformation in the ground state makes the nuclei to rotate collectively4 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 theoretical7,8 and also with the available experimental9-19 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.

4. Results and Discussion

Theoretical research into alpha decay results in the discovery of 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\textsuperscript{20}. The conclusion highlights the fact that adding deformation effects reduces half-life time values. Due to the incorporation of deformation effects, the computed half-life time values frequently coincide with the experimental values. Figure 1 shows the contour plot of half-life time values with deformation. The flexibility of this model, which allows for the inclusion of rotational energy when computing the new transition potential, further increases its advantages. In this case, the half-life time values for the deformed nucleus are computed by incorporating rotational energy in the transition potential, with which the alpha particle is to break through the fission barrier, because only the deformed nuclei exhibit rotational spectra.

In deformed nuclei both the collective and non-collective components may present. So in this calculations both the collective and noncollective 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\textsuperscript{21}. Therefore the result of inclusion of rotational energy proves that the fission barriers of super heavy nuclei are consistently remains stable against rotation\textsuperscript{22}.

Figure 2 shows the contour plot of the half-life time estimates of deformed nuclei with rotational energy included. 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.

**Figure 1, shows the contour plot of half-life time values incorporating deformation**
Conclusion
Two of the factors that affect the stability of extremely heavy elements are examined here. The ground state (static) fission barrier for rotating super heavy nuclei has been calculated in the current work utilising the CYE model by taking into account collective rotational energy. The half-life time values stay saturated for the majority of nuclei at lower values of angular momentum. But as angular momentum increases, the incorporation of rotational results in a drop in half-life values.

REFERENCES


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