EFFECT OF MULTIPOLARITY DEFORMATION AND SPIN IN ODD-A NUCLEUS - $_{117}$Ts

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Introduction

Now a days, the study of superheavy nuclei (SHN) i.e, Z≥100 becomes the most interesting topics for both theorists and experimentalists. In the nuclear chart, these nuclei are located at the extremes of nuclear landscape. The key procedure for synthesizing SHN is the fusion of heavy nuclei just over the fission barrier [1]. The region of SHN is hopefully stretched up to Z=120 by the experimental techniques at Dubna Superheavy element factory. Still, the predicted center of Island of stability inferred by theoretical models [2] are not synthesized by experimental facilities. α-decay as an important probe for studying unstable nuclei, neutron-deficient nuclei and superheavy nuclei provides some important nuclear structure information, such as the properties of ground state, energy levels, nuclear shape coexistence, nuclear deformation and so on. In these experiments, α-decay is the dominant decay for Superheavy nuclei. Therefore, α-decay research is of great significance in the field of nuclear physics.

The aim of our work is to calculate the decay properties of odd-A Superheavy nuclei of Z=117 using our Cubic plus Yukawa plus Exponential model (CYEM) for spherical and spheroid nucleus with deformation effects (β_2, β_4 &β_6) and also centrifugal potential (l). Here our calculated half life time values are compared with the improved Royer's analytical values [3].

Theoretical Framework

The half-lives of the parent nuclei decaying via α emissions are calculated using the CYE model [4]. The parent and the daughter nuclei are considered to be spheroid, keeping the emitted cluster as spherical. If the daughter nucleus has a deformation, say quadrupole deformation only, and if the potentials are measured from the Q-value of the reaction, then the potential for the post-scission region as a function of the center of mass distance r of the fragment is given by

$$V(r) = V_c(r) + V_n(r) + \frac{l(l+1)\hbar^2}{2\mu r^2} - V_{df}(r) - Q; \quad r \geq r_t$$

For a prolate spheroidal daughter nucleus with longer axis along the fission direction, Pik-Pichak [5] obtained

$$V_c(r) = \frac{3}{2}\frac{Z_1 Z_2 e^2 \gamma}{r}\left[\frac{1-\gamma^2}{2}\ln\frac{\gamma+1}{\gamma-1} + \gamma\right]$$

and for an oblate spheroid daughter with shorter axis along the fission direction

$$V_c(r) = \frac{3}{2}\frac{Z_1 Z_2 e^2}{r}\left[\gamma\,(1+\gamma^2)\arctan\gamma^{-1} - \gamma^2\right]$$

For the overlapping region, we approximate the potential barrier by a third-order polynomial in r having the form [6]

$$V(r) = -E_v + [V(r_t) + E_v]\left\{s_1\left[\frac{r-r_i}{r_t-r_i}\right]^2 - s_2\left[\frac{r-r_i}{r_t-r_i}\right]^3\right\}; \quad r_i \leq r \leq r_t$$

And $r_t = a_2 + R_1$

If the nuclei have spheroid shape, the radius vector R (θ) making an angle θ with the axis of symmetry locating sharp surface of a deformed nuclei is given by ref [7]

$$R(\theta) = R_0\left[1 + \sum_{n=0}^{\infty}\sum_{m=-n}^{n}\beta_{nm}Y_{nm}(\theta)\right]$$

The equation for radius vector (R) becomes,

$$R = R_0\left\{1 - \beta_2\sqrt{\frac{5}{4\pi}}\left(\frac{3}{2}\cos^2\theta - \frac{1}{2}\right) + \beta_4\sqrt{\frac{9}{4\pi}}\left(\frac{1}{8}(35\cos^4\theta - 30\cos^2\theta + 3)\right) + \beta_6\sqrt{\frac{13}{4\pi}}\left(\frac{1}{16}(231\cos^6\theta - 315\cos^4\theta + 105\cos^2\theta - 5)\right)\right\}$$

The half life time of the system is calculated by using the relation,

$$T = \frac{1.433\times10^{-21}}{E_v}[1 + \exp(K)]$$

Here, K is the action integral and E_v is the zero-point vibration energy.

Results and Discussions

In the present work, we have calculated the α-decay half lives of odd-A nucleus with Z=117 using the CYE model without including deformation, with including quadrupole (β_2), hexadecapole (β_4) & higher order multipolarity hexacontatetrapole deformation(β_6) and spin(l). Our calculated half life time values are compared (Table 1) with the values of improved Royer's analytical values [3]. From the calculation, it is seen that our calculated values match well with the Royer's analytical values. Here, we predict the fact that the inclusion of multi-polarity β_6 deformation parameter increases the half life time value of the nucleus. The variation of the calculated logarithmic α-decay half life time values of odd-A nucleus of Ts (Z=117) with the neutron number N is shown in Fig.1. From this figure, it is found that when N > 184, the α-decay half-lives decrease sharply, and at N = 186, the α-decay half-lives reduce by more than 2 orders of magnitude. These phenomena reflect strong shell effects, signifying implying that the next neutron magic number after N = 126 is N = 184.

References

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Table 1. Comparison of calculated α-decay half lives of odd-A nucleus $_{117}$Ts without deformation (WOD) and with deformation & spin (WD&l) using CYE model with Royer's analytical values.

Parent nuclei	Q_α (MeV)	l_{min}	Log $T_{1/2}$ (s)		
			CYEM		Ref.[3]
			WOD	WD&l	
$^{279}_{117}$Ts	13.49	2	-6.31	-4.78	-6.20
$^{283}_{117}$Ts	13.00	2	-5.41	-4.22	-5.32
$^{287}_{117}$Ts	11.92	2	-3.12	-2.09	-3.09
$^{291}_{117}$Ts	11.46	2	-2.09	-1.09	-2.07
$^{295}_{117}$Ts	11.12	2	-1.29	0.46	-1.29
$^{299}_{117}$Ts	11.39	2	-2.05	-0.65	-2.04
$^{301}_{117}$Ts	11.54	2	-2.45	-1.14	-2.44
$^{307}_{117}$Ts	11.00	1	-1.18	-2.10	-1.40
$^{311}_{117}$Ts	8.84	2	5.49	7.89	5.27
$^{313}_{117}$Ts	8.31	0	7.50	9.59	6.91

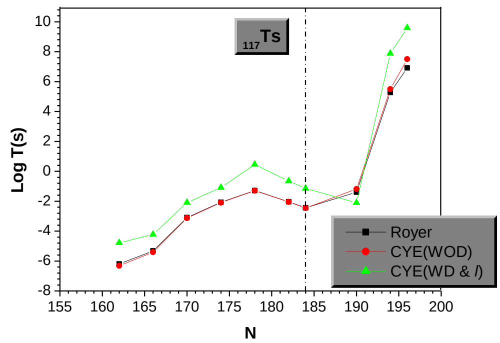

Figure 1. The variation of logarithmic half life time values of Ts nucleus with neutron number N

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