The role of higher multi-polarity beta six deformations and decay energy on exotic decay half-life of highly deformed heavy Nobelium (No) nucleus

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Introduction: A new kind of natural charged particle radio activity in which the emitted cluster is heavier than an alpha particle but lighter than a fission fragment was first predicted in 1980 by Sandulescu et al [1] but it was confirmed experimentally by Rose and Jones [2] from the University of Oxford. Study of such exotic decay systematic might improve our knowledge regarding nuclear clustering; inter nucleus potentials and the nature of asymmetric fission process in nuclei. In the present paper, we systematically investigated the influence of hexacontatetrapole (β_6) deformation in the parent nucleus along with the quadruple(β_2) , and hexadecaple (β_4) deformations on half-lives of highly deformed heavy $No^{254-262}$ isotopes using CYE model [3]. Half-life calculations are very sensitive to the Q-values so the effects of Q-value on the half-life calculation also studied.

Description of CYE model: Our model has Coulomb plus Yukawa plus exponential potential as interacting barrier for separated fragments and cubic potential for the overlapping region.

If the Q-value of the reaction is taken as the origin the potential for the post - scission region as the function of the centre of mass distance 'r' of the fragment is given by

$$V(r) = V_c(r) + V_n(r) - V_{df}(r) - Q$$

Here, V_c is the coulomb potential between a spheroid daughter and spherical emitted cluster, V_n is the nuclear interaction energy due to finite range effects of Krappe et al.,V_{df} is the change in nuclear interaction energy due to quadruple deformations in the daughter nuclei.

If Q is the energy released in the reaction, its value is given by

$$Q = \left[M_p(A_p, Z_p) - M_d(A_d, Z_d) - M_e(A_e, Z_e)\right] \times 931.501 \text{ MeV.}$$

The Q values are calculated using the mass table of Audi et al., and so we incorporate full shell effects in our model at the ground states.

For the overlapping region, we approximate the potential barrier by a third order polynomial having the form

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

Expressing the energies in MeV, lengths in fm and time in seconds for calculating the life time of the decay system we use the formula,

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

Results and discussions : In this work, we have computed the half-lives of cluster radioactivity from neutron rich No nuclei with atomic number in the range Z=254-262 using CYE model by incorporating hexacontatetrapole (β_6) parameter in the parent nucleus along with the quadruple(β_2) , and hexadecaple (β_4) deformations and presented in table1.The deformation parameter values are taken from Ref. [4] .From the calculations, we found that the half-lives decrease with the inclusion of two grid deformations (β_{2P}, β_{4P}) [5] and three grid deformations$(\beta_{2P}, \beta_{4P}, \beta_{6p})$**.**When only the hexacontatetrapole (β_{6p}) deformation taking into account, the half-live values are found to be increased. Now our calculated half-lives are in good agreement with the available data. Hence the hexacontatetrapole (β_6) deformation enhances the stability of the nuclei. In this work we have also calculated half-life values using the different available Q-values for the same decay mode and few are tabulated in table2. These calculations show that small variation in Q-value produces greater effect on half-life time. The half-life value is found to be increased with the decrease of Q-value and vice-versa.

Table1. The comparison of computed logarithmic half life of cluster decay for the case of without and with deformation with available data

Cluster decay	Q (MeV)	$LogT_{1/2}$ (s)					
		Calculated Values				Reference Values	
		Without deformation	With $(\beta_{2P}, \beta_{4P}, \beta_{2d})$	With $(\beta_{2P}, \beta_{4P}, \beta_{6p}, \beta_{2d})$	With (β_{6P}, β_{2d})	Ref.[6]	Ref.[7]
$No^{254} \to Pb^{206} + Ca^{48}$	152.73	20.54	17.51	18.26	21.12	23.57	20.4
$No^{255} \to Pb^{207} + Ca^{48}$	153.54	19.26	16.40	16.99	19.60	22.78	20.8
$No^{256} \to Pb^{208} + Ca^{48}$	153.78	18.75	15.94	16.53	19.12	22.51	18.9
$No^{257} \to Pb^{209} + Ca^{48}$	153.28	19.26	17.40	18.01	19.93	24.05	21.0
$No^{258} \to Pb^{208} + Ca^{50}$	152.77	19.80	17.45	17.91	20.19	24.01	20.2

$No^{259} \rightarrow Pb^{209} + Ca^{50}$	151.23	21.77	20.03	20.53	23.0	25.34	23.3
$No^{260} \rightarrow Pb^{212} + Ca^{48}$	147.38	26.80	24.26	24.89	27.32	28.01	-
$No^{261} \rightarrow Pb^{211} + Ca^{50}$	147.59	26.55	24.13	264.49	26.76	27.69	27.2
$No^{262} \rightarrow Pb^{212} + Ca^{50}$	146.60	27.79	25.51	25.94	28.07	28.73	26.8

Table2. Calculation of logarithmic half-life values with different Q-values using CYE model

Decay mode	Mass table	Q_c (MeV)	Cal. $LogT_{1/2}$(s)
$No^{254} \rightarrow Pb^{206} + Ca^{48}$	AME2012[9] KUTYO5[8] FRDM12[4]	152.73 144.27 151.34	20.54 32.09 22.42
$No^{255} \rightarrow Pb^{207} + Ca^{48}$	AME2012[9] KUTYO5[8] FRDM12[4]	150.48 144.46 151.80	23.42 31.66 21.62
$No^{256} \rightarrow Pb^{208} + Ca^{48}$	AME2012[9] KUTYO5[8] FRDM12[4]	153.02 144.70 151.90	19.80 31.17 21.31

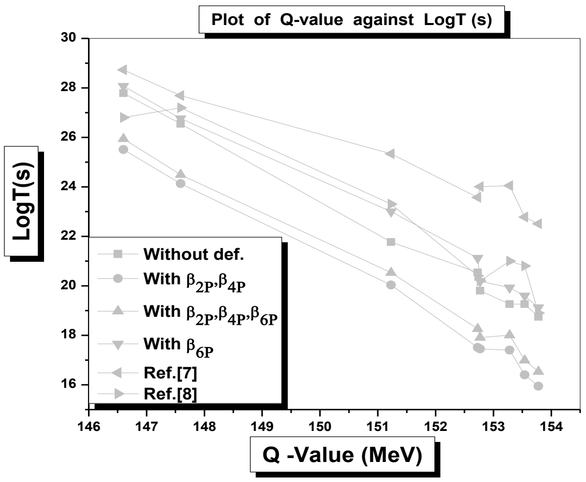

Figure1. Plot of the computed exotic decay half lives of $^{254-262}$No isotopes against Q-values.

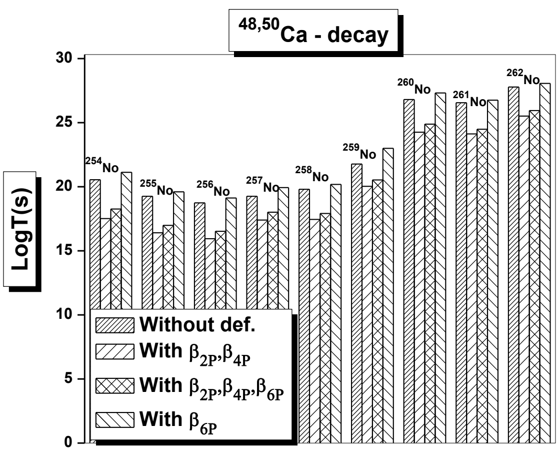

Figure2. The comparison of computed exotic decay half-lives of $^{254-262}$ No isotopes with and without deformation parameters.

Conclusion: Using cubic plus Yukawa plus exponential model, we have investigated the impact of higher multi-polarity parameter ($\boldsymbol{\beta_6}$) and decay energy on exotic decay half-life of heavy element $No^{254-262}$ along with the quadrupole, and hexadecapole deformations. Our study reveals that the multi-polarity beta six parameters enhance the stability of the parent nuclei and half-life calculations are very sensitive to the Q-values. Thus we conclude that deformation parameters and Q-values play a vital role in half-life time calculations.

References:

[1] A. Sandulescu, D.N.Poenaru and W.Greiner, SOV.J.Part Nucl 11,528. (1980).

[2] H.J.Rose and G.A.Jones, Nature (London) 307, 245 (1984).

[3] G.Shanmugam, G.M.CarmelVigilaBai and B.Kamalaharan, Phys.RevC51, 2616(1995).

[4] P.Möller ,et al., Nuclear ground-state masses and deformations: FRDM(2012).

[5] G.M.Carmel Vigila Bai,and R.Nithya Agnes, Pramana – J.Phys. 88:43 (2017).

[6]L.Zheng et al.,Nuclear Physics A(2013), http://dx.doi.org/10.1016/j.nuclphysa.2013.06.012

[7] D .N.Poenaru ,D.Schnabel, and W.Greiner, Atomic Data and Nuclear Data Tables 48, 231 - 327 (1991).

[8] H.Koura et al. KUTY Mass Formula, revised version 2005, Prog.Theor.Phys.113 (2005)305.

[9] G.Audi et al, Chinese Physics C, 36(12): 1669–1670(2012)