Probable alpha decay chains in $^{288\text{-}292}$117 super heavy nuclei

K. P. Santhosh,* B. Priyanka and M. S. Unnikrishnan
School of Pure and Applied Physics, Kannur University, Payyanur Campus, Payyanur - 670327, INDIA
** email: drkpsanthosh@gmail.com*

Introduction

The half-lives of different radioactive decay such as alpha decay, cluster decay and fission are the experimental signatures of the formation of super heavy nuclei (SHN) in fusion reaction. Hence the calculations of these half-lives are important in identifying the decay chains of SHN. SHN usually undergo sequential decay in to successive alpha decay chains and ends with spontaneous fission. Hence identifying and characterizing the alpha decay chains act as a decisive factor for the nuclide identification and their degree of stability in the synthesis of SHN.

The aim of this paper is to study the alpha decay and the spontaneous fission of the isotopes of the super heavy element Z=117 within the mass range of $288 \leq A \leq 292$ and thereby predict the alpha decay chains using the Coulomb and Proximity Potential Model for Deformed Nuclei (CPPMDN) [1] . The model is the improved version of Coulomb and Proximity Potential Model (CPPM) [2], proposed by Santhosh et al. These comparative studies ensure the validity of CPPMDN.

The Coulomb and proximity potential model for deformed nuclei

In CPPMDN, the potential energy barrier is taken as the sum of deformed Coulomb potential, deformed two-term proximity potential and centrifugal potential for the touching configuration and for the separated fragments. For the pre-scission region, simple power law interpolation was used. The inclusion of proximity potential reduces the height of the potential barrier, which closely agrees with the experimental result.

The interacting potential barrier for two spherical nuclei is given by

$$V = \frac{Z_1 Z_2 e^2}{r} + V_p(z) + \frac{\hbar^2 \ell(\ell+1)}{2\mu r^2}$$

Here Z_1 and Z_2 are the atomic numbers of the daughter and emitted cluster, 'z' is the distance between the near surfaces of the fragments, 'r' is the distance between fragment centers, ℓ represents the angular momentum, μ the reduced mass, V_P is the proximity potential given by Blocki *et al.*,

Using one dimensional WKB approximation, the barrier penetrability P is given as

$$P = \exp\left\{ -\frac{2}{\hbar} \int_a^b \sqrt{2\mu(V-Q)}\,dz \right\}$$

The turning points "a" and "b" are determined from the equation, V(a)=V(b)=Q.

The half life time is given by

$$T_{1/2} = \left(\frac{\ln 2}{\lambda}\right) = \left(\frac{\ln 2}{\upsilon P}\right)$$

where, $\nu = (\omega/2\pi) = (2E_v/h)$, represents the number of assaults on the barrier per second and λ the decay constant. E_v, is the empirical vibration energy.

Results and discussion

The Coulomb and Proximity Potential Model for Deformed Nuclei (CPPMDN) have been used to calculate the alpha decay half lives of the nuclei in the range $270 \leq A \leq 301$ with Z = 117. The energy released in the alpha transitions between the ground state energy levels of the parent nuclei and the ground state energy levels of the daughter nuclei is given as

$$Q_{gs\to gs} = \Delta M_p - (\Delta M_\alpha + \Delta M_d) + k(Z_p^\varepsilon - Z_d^\varepsilon)$$

where ΔM_p, ΔM_d, ΔM_α are the mass excess of the parent, daughter and alpha particle respectively. The Q value is calculated using the experimental mass excess values taken from Audi *et al.*, and for those nuclei where experimental mass excess were unavailable, it was taken from Koura-Tachibana-Uno-Yamada (KTUY) . The term kZ^ε describes the screening effect of atomic electrons.

The half life calculations are also done using the CPPM formalism and the Viola-Seborg semi-empirical relationship (VSS) for alpha half lives and is given as

$$\log_{10}(T_{1/2}) = (aZ+b)Q^{-1/2} + cZ + d + h_{\log}$$

Now, to identify the mode of decay of the isotopes under study, the spontaneous fission (SF) half lives is also calculated using the semi empirical relation given by Xu *et al.*, given as

$$T_{1/2} = \exp\left\{2\pi\left[C_0 + C_1A + C_2Z^2 + C_3Z^4 + C_4(N-Z)^2 - \left(0.13323\frac{Z^2}{A^{1/3}} - 11.64\right)\right]\right\}$$

As this equation was originally made to fit the even-even nuclei, and as we have considered only the odd mass (odd-even and odd-odd) nuclei in this work, instead of taking spontaneous fission half life T_{sf} directly, we have taken the average of fission half life T_{sf}^{av} of the corresponding neighboring even-even nuclei as the case may be. Here we would like to mention that, in the case of the nuclei ^{257}Db, T_{sf}^{exp}=0.0348s and T_{sf}^{av}=0.0264s, which shows the agreement between experimental and computed average spontaneous fission half lives. The spontaneous fission half lives are calculated because isotopes with small alpha decay half lives than spontaneous fission half lives survive fission and can be detected through alpha decay in the laboratory. Hence by comparing the alpha decay half lives with the spontaneous fission half lives we could identify the nuclei (both parent and decay products) that will survive fission.

As we were successful in reproducing the experimental results in the case of ^{293}117 and ^{294}117 [3], we had confidently extended our work in predicting the α decay half lives of 32 super heavy elements ranging from 270 ≤ A ≤ 301, focusing on the isotopes $^{288\text{-}292}$117 of the same element, with a view to find possible alpha decay chains which may open up a new line in experimental investigations. The work is presented in the figure 1. The experimental spontaneous fission half lives have also been given in these plots. Our study reveals that those isotopes of Z = 117 with A ≥ 299 and with A ≤ 271, do not survive fission and thus the alpha decay is restricted within the range 272 ≤ A ≤ 298.

Through our study, we have predicted 1α chain from $^{272,273,296\text{-}298}$117, 2α chains from ^{274,275,295}117, 3α chains from ^{276,277,292}117 and 5α chains from $^{288\text{-}291}$117. Our study predicts 5α chains consistently from $^{288\text{-}291}$117 and 3α chains consistently from ^{292}117. We hope that these findings will provide a new guide for future experiments.

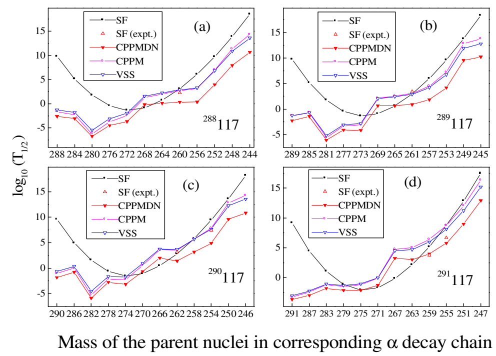

Fig.1. The comparison of the calculated alpha decay half lives with the spontaneous fission half lives for the isotopes $^{288\text{-}291}$117 and its decay products.

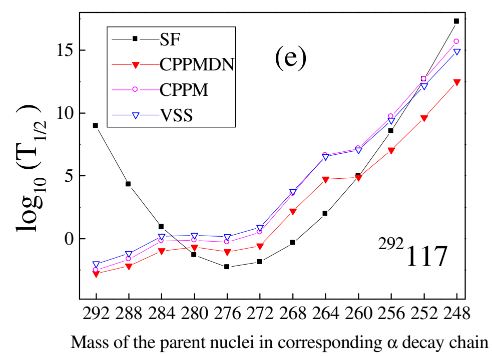

Fig.2. The comparison of the calculated alpha decay half lives with the spontaneous fission half lives for the isotopes ^{292}117 and its decay products.

References

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