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# Decay of heavy and superheavy nuclei

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**Abstract.** We present here, an overview and progress of the theoretical works on the isomeric state $\alpha$ decay, $\alpha$ decay fine structure of even–even, even–odd, odd–even and odd–odd nuclei, a study on the feasibility of observing $\alpha$ decay chains from the isotopes of the superheavy nuclei $Z = 115$ in the range $271 \leq A \leq 294$ and the isotopes of $Z = 117$ in the range $270 \leq A \leq 301$, within the Coulomb and proximity potential model for deformed nuclei (CPPMDN). The computed half-lives of the favoured and unfavoured $\alpha$ decay of nuclei in the range $67 \leq Z \leq 91$ from both the ground state and isomeric state, are in good agreement with the experimental data and the standard deviation of half-life is found to be 0.44. From the $\alpha$ fine structure studies done on various ranges of nuclei, it is evident that, for nearly all the transitions, the theoretical values show good match with the experimental values. This reveals that CPPMDN is successful in explaining the fine structure of even–even, even–odd, odd–even and odd–odd nuclei. Our studies on the $\alpha$ decay of the superheavy nuclei $^{271-294}115$ and $^{270-301}117$ predict $4\alpha$ chains consistently from $^{284,285,286}115$ nuclei and $5\alpha$ chains and $3\alpha$ chains consistently from $^{288-291}117$ and $^{292}117$, respectively. We thus hope that these studies on $^{284-286}115$ and $^{288-292}117$ will be a guide to future experiments.

**Keywords.** Alpha decay; fine structure; spontaneous fission.

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## 1. Introduction

A scientific knowledge on nuclear stability in the superheavy mass region is a long-standing question. Hence, considerable attention has been given by the experimentalists to the investigation of the existence of superheavy nuclei (SHN) beyond the valley of stability. The half-lives of different radioactive decays such as $\alpha$ decay, cluster decay and spontaneous fission are experimental signatures of the formation of SHN in fusion reaction. Hence, the calculations of these half-lives are important in identifying the decay chains of SHN. Usually, $\alpha$ decay takes place between ground states having the same angular momentum and parity. But the advances in technology have made it experimentally possible to identify the nuclei in exited states having relatively large life span (isomeric states). So, the theoretical studies on the favoured and unfavoured $\alpha$ decay of such excited states are relevant.

In this paper, we have presented a systematic study on the isomeric state $\alpha$ decay, $\alpha$ decay fine structure of even–even, even–odd, odd–even and odd–odd nuclei, a study on the feasibility of observing $\alpha$ decay chains from the isotopes of the SHN with $Z = 115$ in the range $271 \leq A \leq 294$ and the isotopes of $Z = 117$ in the range $270 \leq A \leq 301$, using the recently proposed Coulomb and proximity potential model for deformed nuclei (CPPMDN) [1], which is the modified version of Coulomb and proximity potential model (CPPM) [2], incorporating $\beta_2$ and $\beta_4$ deformation values of the parent and daughter nuclei.

## 2. Coulomb and proximity potential model for deformed nuclei (CPPMDN)

In Coulomb and proximity potential model for deformed nuclei (CPPMDN), the potential energy barrier is taken as the sum of the deformed Coulomb potential, deformed two-term proximity potential and centrifugal potential for the touching configuration and for the separated fragments. For the pre-scission (overlap) region, simple power-law interpolation is used. The interacting potential barrier for two spherical nuclei is given by

$$V = \frac{Z_1 Z_2 e^2}{r} + V_{\rm p}(z) + \frac{\hbar^2 \ell(\ell+1)}{2\mu r^2}, \quad \text{for } z > 0. \tag{1}$$

Here, $Z_1$ and $Z_2$ are the atomic numbers of the daughter and the emitted cluster, $z$ is the distance between the near surfaces of the fragments, $r$ is the distance between fragment centres, $\ell$ represents the angular momentum, $\mu$ is the reduced mass, $V_{\rm p}$ is the proximity potential given by Blocki *et al* [3], as

$$V_{\rm p}(z) = 4\pi\gamma b \left[\frac{C_1 C_2}{(C_1 + C_2)}\right] \Phi\left(\frac{z}{b}\right). \tag{2}$$

With the nuclear surface tension coefficient,

$$\gamma = 0.9517\left[1 - 1.7826(N-Z)^2/A^2\right] \text{MeV/fm}^2, \tag{3}$$

where $N$, $Z$ and $A$ represent neutron, proton and mass number of the parent, $\Phi$ represents the universal proximity potential [4] given as

$$\Phi(\varepsilon) = -4.41 e^{-\varepsilon/0.7176}, \quad \text{for } \varepsilon > 1.9475 \tag{4}$$

$$\Phi(\varepsilon) = -1.7817 + 0.9270\,\varepsilon + 0.0169\,\varepsilon^2 - 0.05148\,\varepsilon^3, \quad \text{for } 0 \leq \varepsilon \leq 1.9475 \tag{5}$$

with $\varepsilon = z/b$, where the width (diffuseness) of the nuclear surface $b \approx 1$ and Süsmann central radii $C_i$ of fragments related to sharp radii $R_i$ is

$$C_i = R_i - \left(\frac{b^2}{R_i}\right). \tag{6}$$

For $R_i$ we use semiempirical formula in terms of mass number $A_i$ as [3]

$$R_i = 1.28 A_i^{1/3} - 0.76 + 0.8 A_i^{-1/3}. \tag{7}$$

The potential for the internal part (overlap region) of the barrier is given as

$$V = a_0\,(L - L_0)^n \quad \text{for } z < 0, \tag{8}$$

where $L = z + 2C_1 + 2C_2$ and $L_0 = 2C$, the diameter of the parent nuclei. The constants $a_0$ and $n$ are determined by the smooth matching of the two potentials at the touching point.

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

$$P = \exp\left\{-\frac{2}{\hbar}\int_a^b \sqrt{2\mu(V - Q)}\mathrm{d}z\right\}. \tag{9}$$

Here, the mass parameter is replaced by $\mu = mA_1A_2/A$, where $m$ is the nucleon mass and $A_1, A_2$ are the mass numbers of the daughter and emitted cluster, respectively. The turning points $a$ and $b$ are determined from the equation, $V(a) = V(b) = Q$. The half-lifetime is given by

$$T_{1/2} = \left(\frac{\ln 2}{\lambda}\right) = \left(\frac{\ln 2}{\upsilon P}\right), \tag{10}$$

where

$$\upsilon = \left(\frac{\omega}{2\pi}\right) = \left(\frac{2E_{\mathrm{v}}}{h}\right)$$

represent the number of assaults on the barrier per second and λ is the decay constant. $E_{\mathrm{v}}$, the empirical vibration energy is given as [5]

$$E_{\mathrm{v}} = Q\left\{0.056 + 0.039\exp\left[\frac{(4 - A_2)}{2.5}\right]\right\}, \quad \text{for } A_2 \geq 4. \tag{11}$$

The Coulomb interaction between the two deformed and oriented nuclei, taken from ref. [6] with higher multipole deformation [7,8] included is given as

$$V_{\mathrm{C}} = \frac{Z_1Z_2e^2}{r} + 3Z_1Z_2e^2 \sum_{\lambda,i=1,2} \frac{1}{2\lambda+1}\frac{R_{0i}^{\lambda}}{r^{\lambda+1}} Y_{\lambda}^{(0)}(\alpha_i)\left[\beta_{\lambda i} + \frac{4}{7}\beta_{\lambda i}^2 Y_{\lambda}^{(0)}(\alpha_i)\delta_{\lambda,2}\right] \tag{12}$$

with

$$R_i(\alpha_i) = R_{0i}\left[1 + \sum_{\lambda}\beta_{\lambda i}Y_{\lambda}^{0}(\alpha_i)\right], \tag{13}$$

where

$$R_{0i} = 1.28A_i^{1/3} - 0.76 + 0.8A_i^{-1/3}.$$

Here, $\alpha_i$ is the angle between the radius vector and symmetry axis of the $i^{\mathrm{th}}$ nuclei. The two-term proximity potential for interaction between a deformed and spherical nucleus was given by Baltz *et al* [9], as

$$V_{P2}(R,\theta) = 2\pi\left[\frac{R_1(\alpha)R_{\mathrm{C}}}{R_1(\alpha) + R_{\mathrm{C}} + S}\right]^{1/2}\left[\frac{R_2(\alpha)R_{\mathrm{C}}}{R_2(\alpha) + R_{\mathrm{C}} + S}\right]^{1/2} \times \left[\left[\varepsilon_0(S) + \frac{R_1(\alpha)+R_{\mathrm{C}}}{2R_1(\alpha)R_{\mathrm{C}}}\varepsilon_1(S)\right]\left[\varepsilon_0(S) + \frac{R_2(\alpha)+R_{\mathrm{C}}}{2R_2(\alpha)R_{\mathrm{C}}}\varepsilon_1(S)\right]\right]^{1/2}. \tag{14}$$

Here, $R_1(\alpha)$ and $R_2(\alpha)$ are the principal radii of curvature of the daughter nuclei at the point where polar angle is $\alpha$, $S$ is the distance between the surfaces along the straight line connecting the fragments, $R_C$ is the radius of the spherical cluster and $\varepsilon_0(S)$ and $\varepsilon_1(S)$ are the one-dimensional slab-on-slab function.

## 3. Results and discussions

Within CPPMDN, we have performed a detailed study on the ground state and isomeric state $\alpha$ decay half-lives of nuclei in the range $67 \leq Z \leq 91$ [10] and $\alpha$ decay fine structure studies of the nuclei in the range $78 \leq Z \leq 102$ (even–even) [1], $84 \leq Z \leq 102$ (even–odd) [11], $83 \leq Z \leq 101$ (odd–even) [12] and $83 \leq Z \leq 101$ (odd–odd) [13]. We have also studied the $\alpha$ decay chains of the SHN $^{271-294}115$ [14] and $^{270-301}117$ [15] with the hope that these findings will provide a new guide for future experiments. The details of the studies are given in the following sections.

### 3.1 *$\alpha$ decay of even–even nuclei in the region $78 \leq Z \leq 102$ to the ground state and excited states of the daughter nuclei*

The CPPMDN is applied to the $\alpha$ decay of even–even nuclei [1] in the range $78 \leq Z \leq 102$ from ground state of the parent nucleus to the ground state and excited states of the daughter nucleus taking quadrapole $\beta_2$ and hexadecapole $\beta_4$ deformations of parent and daughter treating $\alpha$ particle as a spherical one. The $Q$ value for the $\alpha$ decay between the ground states of the parent and daughter nuclei is evaluated using the experimental mass tables of Audi *et al* [16], and is given as

$$Q_{\text{g.s.}\to\text{g.s.}} = \Delta M_{\text{p}} - (\Delta M_\alpha + \Delta M_{\text{d}}) + k(Z_{\text{p}}^{\varepsilon} - Z_{\text{d}}^{\varepsilon}), \tag{15}$$

where $\Delta M_{\text{p}}$, $\Delta M_{\text{d}}$, $\Delta M_\alpha$ are the mass excesses of the parent, daughter and $\alpha$ particle, respectively. The $Q$ value for the $\alpha$ transition between the ground level of the parent nucleus and the various levels of the daughter nucleus with excitation energy $E_i^*$ is

$$Q = Q_{\text{g.s.}\to\text{g.s.}} - E_i^*. \tag{16}$$

The $\alpha$-particle emission from a nucleus obeys the spin-parity selection rule:

$$|I_j - I_i| \leq \ell \leq |I_j + I_i| \quad \text{and} \quad \frac{\pi_i}{\pi_j} = (-1)^\ell, \tag{17}$$

where $I_j$, $\pi_j$ and $I_i$, $\pi_i$ are the spin and parity of the parent and daughter nuclei, respectively.

The branching ratios of $\alpha$ decay to each state of the rotational band of the daughter nucleus is evaluated with the help of the decay width which is defined as

$$\Gamma(Q_i, \ell) = \hbar v \frac{1}{2} \int_0^\pi P(Q_i, \theta, \ell) \sin(\theta) \mathrm{d}\theta, \tag{18}$$

where $v$ is the assault frequency and $P(Q_i, \theta, \ell)$ is the penetrability of $\alpha$ particle in the direction $\theta$ from symmetry axis, for axially symmetric deformed nuclei. The branching ratio of the $\alpha$ decay from the ground state of the parent nucleus to the level $i$ of the daughter nucleus is determined as

$$B_i = \frac{\Gamma(Q_i, \ell_i)}{\sum_n \Gamma(Q_n, \ell_n)} \times 100\%, \tag{19}$$

where the sum $n$ is going over all states, which can be populated during the $\alpha$ transition from the ground state of the parent nucleus. It is seen that the branching ratio is the highest for transitions to the $0^+$states followed by the $2^+$ states. The $\alpha$ transitions to the remaining states are strongly hindered. It was also found that, the experimental and calculated branching ratios for the transition from ground state to ground state and transition from the ground state to the $\ell = 2$ first excited state match well but the branching ratios to the other states (rotational as well as states of other natures) slightly differ from the experimental values.

The hindrance factor (HF) for the transitions to the different states is given by

$$\mathrm{HF} = \frac{\lambda_{\mathrm{cal.}}}{\lambda_{\mathrm{exp.}}} = \frac{T_{1/2}^{\mathrm{exp.}}}{T_{1/2}^{\mathrm{cal.}}}. \tag{20}$$

The lowest value of the HF is obtained for the $0^+ \rightarrow 0^+$ transitions. As we move to the higher excited states the HF increases. The HF increases while branching ratio decreases as we go from the ground state–ground state transitions to the ground state–excited state transitions.

In order to check the validity of our formalism, we have also evaluated the standard deviation of the half-lives as well as of the branching ratios. The standard deviation is estimated using the following expression:

$$\sigma = \left\{ \frac{1}{(n-1)} \sum_{i=1}^{n} \left[ \log\left( \frac{T_i^{\mathrm{cal.}}}{T^{\mathrm{exp.}}} \right) \right]^2 \right\}^{1/2}. \tag{21}$$

The computed standard deviation of the half-lives for all transitions is 0.88, while the same calculated using data from Denisov *et al* [17] is 1.48. The estimated standard deviation for the branching ratios is 1.09. It is found that the standard deviation for the ground state–ground state transition is only 0.05 and it increases, as we move to the higher excited states which is due to the effect of nuclear structure.

### 3.2 *$\alpha$ decay of nuclei in the range $67 \leq Z \leq 91$ from the ground state and isomeric state*

Using CPPMDN, the $\alpha$ decay half-lives for favoured and unfavoured transitions of nuclei [10] in the mid-$Z$ and heavy region, $67 \leq Z \leq 91$ have been calculated. In this study, we mainly concentrate on four types of $\alpha$ decay transitions: (i) ground states–ground states (g.s.→g.s.), (ii) ground states–isomeric states (g.s.→i.s.), (iii) isomeric states–ground states (i.s.→g.s.) and (iv) isomeric states–isomeric states (i.s.→i.s.).

The energy released in $\alpha$ transitions between the energy level of the parent nucleus with excitation energy $E_{\mathrm{jp}}$ and the level of the daughter nucleus with excitation energy $E_{\mathrm{id}}$ is

$$Q_{j\rightarrow i} = Q_{\mathrm{g.s.}\rightarrow\mathrm{g.s.}} + E_{j\mathrm{p}} - E_{i\mathrm{d}}. \tag{22}$$

It is seen that the calculated $\alpha$ decay half-lives agree very well with the experimental data and the standard deviation of half-life is found to be 0.44. This proves the validity of our formalism and so we have extended our study to predict [10] half-lives of a few $\alpha$ decay transitions from ground state and isomeric state, which will be useful for future experiments.

We have studied the plot connecting $\log_{10}T_{1/2}$ against $Q^{-1/2}$. From this plot it is clear that, for all favoured transitions, the decay between both the ground states and isomeric states follow Geiger–Nuttal law. The isomeric state $\alpha$ decay shows a behaviour similar to that of the ground state and the nuclear structure of the isomeric state imitates that of the ground state.

### 3.3 *Systematic study on the α decay fine structure of even–odd nuclei in the range $84 \le Z \le 102$*

The $\alpha$ decay half-lives of even–odd nuclei [11] in the range $84 \le Z \le 102$ have been evaluated using CPPMDN. The comparison of the computed total half-life with experimental values of various parent nuclei shows that they are in good agreement with each other. Those transitions in which the calculated half-life values show a deviation of 3 to 4 orders from experimental ones; the calculated HF values are found to be very high (hindered) and it is clear that experimental intensities (branching ratio) for these transitions are very low. Thus, transitions having high intensity (branching ratio) are less hindered and vice versa.

On examining the calculated branching ratios, unlike in the case of even–even nuclei [1], for most decay, branching ratios to the excited states are larger than the value to the ground state of daughter nuclei. This is due to the similarity of structure between ground state of the parent and the corresponding excited state of the daughter. The computed standard deviation of logarithmic half-life for all transitions is 1.25 and that for logarithmic branching ratio is 1.10.

### 3.4 *Fine structure in the α decay of odd–even nuclei*

In this study, the $\alpha$ decay partial half-life and branching ratio for each transition of odd–even nuclei [12] in the range $83 \le Z \le 101$ are evaluated using CPPMDN. Most of the calculated half-lives irrespective of ground state to ground state or ground state to excited state, are in good agreement with the experimental ones. Transitions showing large deviations between calculated and experimental values correspond to less intense transitions and they have much longer half-lives compared to other probable transitions. We have evaluated the branching ratio of the calculated and experimental half-lives and a comparison shows that in most of the transitions, the calculated branching ratios are close to the experimental values.

Ground state to ground state transitions have more intensity and can be very effectively reproduced using our formulation. But in some elements, a few favoured transitions show a much deeper affinity to certain excited levels of daughter nuclei. This may be due to microscopic properties of nuclear structure, and hence structure hindrance may govern the prominent role of decay process. We have also evaluated the HF using eq. (20). It was found that the transitions having low intensity correspond to high HF, or we can say such transitions are highly hindered.

A systematic study on the ground state→ground state decay of the parent nuclei and its decay products was done and this provided us a general trend that as the deformation values decreases, the calculated half-lives (and also HF) decrease or vice versa. But, in the case of some parents the trend seen is just the opposite. This reverse trend is due to the presence of the neutron shell closure of the daughters $^{207}$Tl ($N = 126$), $^{247}$Bk ($N \approx 152$) and $^{249}$Bk ($N = 152$), respectively in the corresponding decay chain. This reveals the fact that, in general, as the deformation values decrease, the decay is less hindered. A similar behaviour can be seen for the ground state to excited state decays as that of ground state to ground state decays. Thus, it is clear that our model is able to predict conclusively the transitions to the excited states also. It should also be noted that, the high HF values are due to the presence of the proton and neutron magicity of the daughters.

A study on the angular momentum values for the nuclei $^{221}$Fr and its decay product $^{217}$At revealed that as the angular momentum increases, the centrifugal barrier plays a prominent role and the decay becomes angular momentum hindered. Thus, it is also found that our formalism is successful to predict angular momentum-hindered transitions. These facts reveal the interplay of angular hindrance and nuclear structure hindrance. The computed standard deviation of half-life of all transitions is found to be 1.08 and the branching ratio is 1.21.

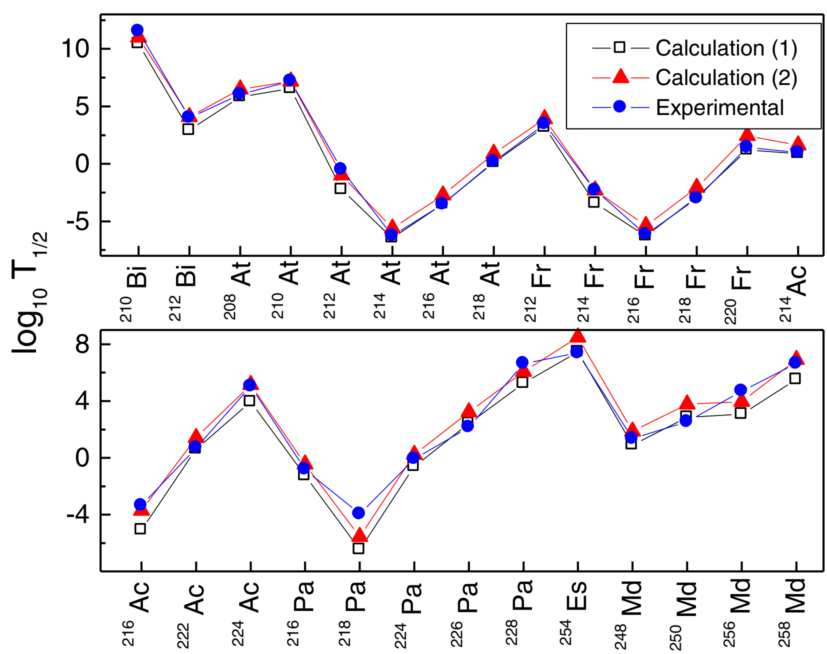


**Figure 1.** The comparison of calculated total half-life values of various nuclei with the corresponding experimental values.

### 3.5 *Systematic studies on α decay fine structure of odd–odd nuclei in the region $83 \leq Z \leq 101$*

Using CPPMDN, we have evaluated $\alpha$ decay half-lives of odd–odd nuclei [13] in the region $83 \leq Z \leq 101$ from ground state of parent nuclei to ground and excited states of the corresponding daughter nucleus. The calculated partial half-lives using the CPPMDN are explicitly denoted as $T_{1/2}^{\text{cal.(1)}}$. A comparison of the calculated partial half-lives with the corresponding experimental values shows a good agreement between the two. The few transitions, which show a deviation of order three with respect to the experimental value, either belong from the transition between undefined angular momentum states or it may be very feeble intense transitions having large uncertainty in experimental value.

To get a better match, we have parametrized the assault frequency using the prescription given by Denisov *et al* [18] as

$$\log_{10} \upsilon = a_0 + a_1\left((-1)^{\ell} - 1\right) + a_2 I + a_3\beta_2 + a_4\beta_4 + a_5\ell\,(\ell+1)A^{-1/6}, \quad (23)$$

where $I$ is the proton–neutron symmetry, $A$, $N$ and $Z$ are, respectively the number of nucleons, neutrons and protons in the daughter nucleus, $\beta_2$ and $\beta_4$ are the quadruple and hexadecapole deformation values of the nuclei which interact with $\alpha$ particle. The constants in eq. (23) are taken from [13]. Using this modified assault frequency, we have recalculated the partial half-life values for all the transitions which are denoted as $T_{1/2}^{\text{cal(2)}}$. Figure 1 represents the comparison of total $T_{1/2}$ for all nuclei, evaluated using both the procedures, with the experimental half-life values. The computed standard deviation of logarithm of half-life is found to be 1.44 for calculation using former assault frequency and that with modified assault frequency is 0.93.

The $\alpha$ half-life studies done above on various ranges of nuclei reveal that CPPMDN is successful in explaining $\alpha$ decay from ground state and isomeric state; and $\alpha$ fine structure of even–even, even–odd, odd–even and odd–odd nuclei.

### 3.6 *α decay chains in $^{271-294}$115 SHN*

The $\alpha$ decay half-lives of $^{271-294}$115 SHN [14], including the recently synthesized $^{287}$115 and $^{288}$115 have been calculated using CPPMDN. The half-life calculations are also done using the Viola–Seborg [19] semiempirical relationship (VSS) for $\alpha$ half-lives and is given as

$$\log_{10}(T_{1/2}) = (aZ + b)Q^{-1/2} + cZ + d + h_{\log}. \quad (24)$$

Now, to identify the mode of decay of the isotopes under study, the spontaneous fission (SF) half-lives is also calculated using the semiempirical relation given by Xu *et al* [20], as

$$T_{1/2} = \exp\left\{2\pi\left[C_0 + C_1 A + C_2 Z^2 + C_3 Z^4 + C_4 (N-Z)^2 - \left(0.13323\frac{Z^2}{A^{1/3}} - 11.64\right)\right]\right\}. \quad (25)$$

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

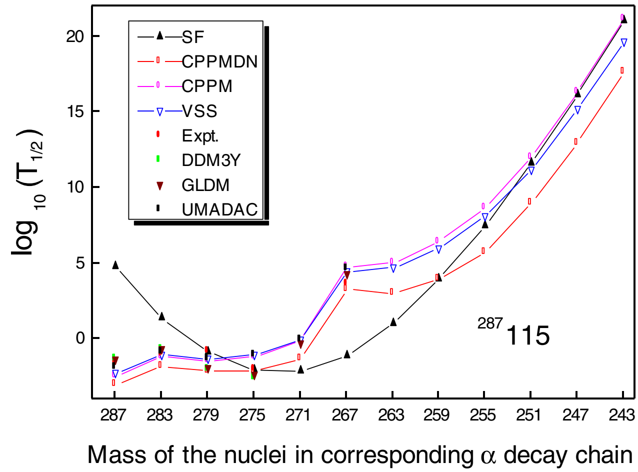


**Figure 2.** The comparison of the calculated $\alpha$ decay half-lives with the SF half-lives for the isotope $^{287}115$ and its decay products.

taking SF half-life $T_{\mathrm{sf}}$ directly, we have taken the average of fission half-life $T_{\mathrm{sf}}^{\mathrm{av}}$ of the corresponding neighbouring even–even nuclei as the case may be.

The SF half-lives are calculated because isotopes with $\alpha$ decay half-lives smaller than SF half-lives survive fission and can be detected through $\alpha$ decay in the laboratory. Now, by comparing the $\alpha$ decay half-lives with the SF half-lives we could identify the nuclei (both parent and decay products) that will survive fission. Thus, we predict 4$\alpha$ chains to be seen for $^{287}115$ and 3$\alpha$ chains for $^{288}115$. These predictions are given in figures 2 and 3. As one may notice, our prediction agrees well with the experimental observations. It is also noted that the $\alpha$ half-lives calculated using our formalisms matches well with

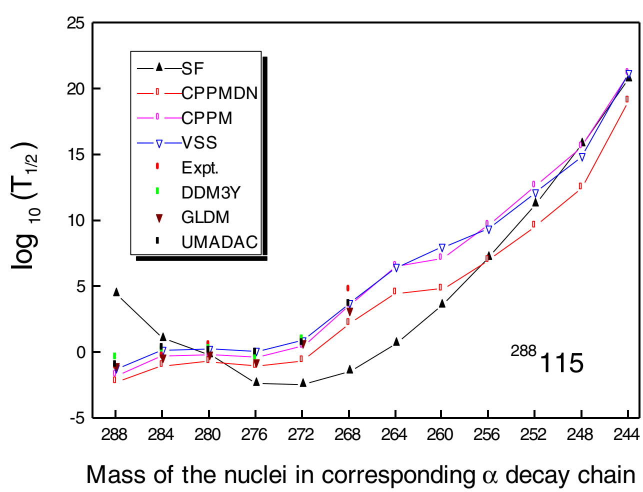


**Figure 3.** The comparison of the calculated $\alpha$ decay half-lives with the SF half-lives for the isotope $^{288}115$ and its decay products.

the experimental values and also with the VSS, GLDM and UMADAC with a few order differences in some cases.

As we could successfully reproduce the experimental results in the case of $^{287}115$ and $^{288}115$, we have confidently extended our work in predicting the $\alpha$ decay half-lives of 22 superheavy elements ranging from $271 \leq A \leq 294$ of the same element, with a view to find possible $\alpha$ decay chains which may open up a new line in experimental investigations.

Our study predicts two $\alpha$ chains from $^{273,274,289}115$, three $\alpha$ chains from $^{275}115$ and four $\alpha$ chains consistently from $^{284,285,286}115$ nuclei. We, thus hope that the study on $^{284}115$, $^{285}115$ and $^{286}115$ will be a guide to future experiments.

### 3.7 *Feasibility of observing $\alpha$ decay chains from $^{270-301}117$ SHN*

CPPMDN has been used to calculate the $\alpha$ decay half-lives of the nuclei in the range $270 \leq A \leq 301$with $Z = 117$ [15]. The half-life calculations are also done using the CPPM formalism and the VSS relationship.

Now, to identify the mode of decay of the isotopes under study, the SF half-life is also calculated using the semiempirical relation given by Xu *et al* [20], in eq. (25). Instead of taking SF half-life $T_{\mathrm{sf}}$ directly, we have taken the average of fission half-life $T_{\mathrm{sf}}^{\mathrm{av}}$ of the corresponding neighbouring even–even nuclei as the case may be.

We have predicted $3\alpha$ chains for $^{293}117$ and $6\alpha$ chains for $^{294}117$ by comparing $\alpha$ half-lives and SF half-lives and it can be seen that our predictions go hand-in-hand with the experimental observations. As we were successful in reproducing the experimental results in the case of $^{293}117$ and $^{294}117$ [21], we have confidently extended our work in predicting the $\alpha$ decay half-lives of 32 superheavy elements ranging from $270 \leq A \leq 301$, focussing on the isotopes $^{288-292}117$ of the same element, with a view to find possible $\alpha$ decay chains which may open up a new line in experimental investigations. Our study reveals that these isotopes of $Z = 117$ with $A \geq 299$ and $A \leq 271$, do not survive fission and thus, the $\alpha$ decay is restricted within the range $272 \leq A \leq 298$.

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

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