Alpha-Decay Chain of Superheavy Nucleus $^{291}117$

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After first prediction of possible existence of superheavy island in 1960, synthesizing new superheavy elements has become a blistering topic in nuclear physics. In 2010, synthesis of new element 117 (the isotopes $^{293}117$ and $^{294}117$) and their α-decay chains have been reported [1]. Theoretically, Z = 117 isotopes have been analyzed by Bhuyan *et al.* [2] and by Santhosh *et al.* [3]. Recently in 2016, element with Z = 117 is named as Tennessine with the symbol Ts by IUPAC. Existence of such superheavy nuclei is controlled mainly by the alpha decay and spontaneous fission. The superheavy nuclei which have small alpha decay half-life compared to spontaneous fission half-life can be detected in the laboratory through alpha decay. Encouraged by the study in the direction to discover element Z = 117 [4, 5], we have studied alpha decay chain of $^{291}117$ and calculated alpha decay half-lives and spontaneous half-lives of decay chain of $^{291}117$. This kind of theoretical study may provide a very helpful insight to conduct experiments to realize the presence of nuclei with Z = 117. For this study, α-decay half-lives are calculated by Royer's formula [6]:

$$log_{10}T_\alpha(sec) = a + bA^{1/6}\sqrt{Z} + \frac{cZ}{\sqrt{Q_\alpha}} \quad (1)$$

Here, A and Z represent the mass and the charge number of the parent nuclei and Q_α represents the energy released during the reaction which is calculated using binding energies of parent and daughter nuclei. These binding energies are calculated from RMF+BCS approach using TMA parameter which has been proved already as a successful tool for the study of exotic nuclei throughout the periodic chart [7, 8]. The constants used here are: a = -25.68, b= -1.1423, c = 1.5920 for Z = odd and N= even (as is the case here).

The spontaneous fission half-life T_{SF} is calculated using the semiempirical formula proposed by Xu *et al.* taken from Ref. [9].

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

The constants are C_0 = -195.09227, C_1 = 3.10156, C_2 = -0.04386, C_3 = 1.4030 x 10^{-6}, and C_4 = -0.03199. We use this formula for $^{290}116$ and $^{292}118$ and then take average to calculate spontaneous fission half life for $^{291}117$. The same pattern we follow for other odd-even nuclei in the chain.

To establish our results of RMF for these odd superheavy nuclei for odd-even chain, we first compare our results with experimentally known decay chain of $^{293}117$ [1] in Table I, where we have shown α-decay half lives (T_α) as obtained with RMF using Royer's formula [6] of equation (1) and spontaneous fission half-lives (T_{SF}) as obtained using formula given by Xu *et al.* [9] mentioned in equation (2). On the basis of ratio T_{SF}/T_α we predict decay of the specified nuclei either through α-decay if the ratio is large or decay through spontaneous emission if the ratio is small. These predictions are mentioned in Table I which exactly match with the experimental decay pattern [1]. Therefore, the applicability of RMF in describing odd-even decay chain strongly validates from Table I.

For further investigation of other possible decay chains in Z = 117, we calculate α-decay half lives and spontaneous fission half-lives

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TABLE I: Results of α-decay half lives as obtained with RMF calculations for chain of $^{293}117$ using Royer's formula [6] are given with experimental data [1] along with spontaneous fission half-lives obtained by using formula of Xu *et al.* [9].

Z	N	A	T_α (RMF)	T_α (Expt.)	T_{SF}	T_{SF}/T_α	Decay Mode (RMF)	Decay Mode (Expt.)
117	176	293	73ms	21ms	1.5E+08s	2.1E+09	α	α
115	174	289	4.75s	0.32s	3.2E+03s	6.7E+02	α	α
113	172	285	0.17s	7.9s	1.2s	7.0E+00	α	α
111	170	281	0.025s	-	6.4E-03s	2.5E-01	SF	SF

TABLE II: Same as Table I but for $^{291}117$

Z	N	A	T_α (RMF)	T_{SF}	T_{SF}/T_α	Decay Mode (RMF)	Decay Mode (Expt.)
117	174	291	0.2605s	2.6E+09s	1.0E+10	α	-
115	172	287	0.0035s	5.9E+04s	1.7E+07	α	α
113	170	283	0.0028s	2.3E+01s	8.4E+03	α	α
111	168	279	0.0109s	1.4E-01s	1.2E+01	α	α

from equations (1) and (2). We find that $^{291}117$ shows long α-decay chain for which α-decay half lives and spontaneous fission half-lives are tabulated in Table II. From ratio T_{SF}/T_α mentioned in Table II, it is clear that $^{291}117$ is more likely to decay through α-emission similar to $^{293}117$ [1]. The decay chain of $^{291}117$ is also compared with available data of experiments [10] which also fortify our prediction. Our results of Q_α and Log T_α are also found in reasonable agreement with FRDM data [11] as shown in Fig. 1.

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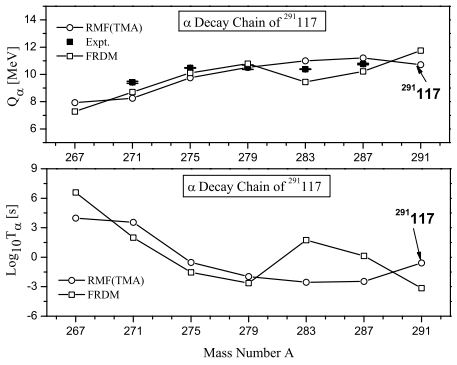

FIG. 1: Q-values and α-decay half lives for decay chain of $^{291}117$ are compared with available experimental data [4, 5] and FRDM resutls [11].

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