α-Decay Chain of Superheavy Nuclei ^{287}Lv

U K Singh[1,2],* A Jain[1,2], S K Jain[1], and G Saxena[3]
[1]*Department of Physics, School of Basic Sciences, Manipal University Jaipur, Jaipur-303007, India*
[2]*Department of Physics, St. Wilfred P.G. College, Jaipur-302020, India and*
[3]*Department of Physics (H&S), Govt. Women Engineering College, Ajmer - 305002, India*

Introduction

The study of superheavy nuclei and their decay characteristics is a rapidly evolving area in nuclear physics. With advancements in experimental methods, superheavy nuclei have been successfully synthesized. The superheavy nuclei ^{290}Lv and ^{291}Lv were synthesized using the hot fusion reaction of ^{245}Cm with ^{48}Ca, resulting in the production of ^{293}Lv nuclei [1]. Another set of superheavy nuclei, ^{292}Lv and ^{293}Lv, was produced via the hot fusion reaction of ^{248}Cm with ^{48}Ca, forming ^{296}Lv [2]. In addition, because of its short half-life and α-decay features, ^{287}Lv is important for understanding nuclear stability and decay processes in superheavy nuclei. Previous studies successfully explained the predictions and applicability of theoretical models for heavy and superheavy nuclei. A review of the available literature indicates that only a limited number of isotopes of $Z = 116$ have been synthesized. Our work aims to explore additional isotopes of the superheavy element $Z = 116$. Specifically, the goal of the present study is to identify potential isotopes of $Z = 116$ and $N = 171$ by analyzing the competition between the α-decay modes and spontaneous fission (SF).

Formalism

In this study, α-decay half-lives are calculated by using the recently Modify Manjunatha Formula (MMF-2020) [3]. It is written as :

$$log_{10}T_\alpha(s) = a\left(\frac{Z_d^{0.4}}{\sqrt{Q_\alpha}}\right)^2 + b\left(\frac{Z_d^{0.4}}{\sqrt{Q_\alpha}}\right) + c + dI + eI^2 \quad (1)$$

where I = $\frac{N-Z}{A}$ and Q_α is the value of energy that is released during the decay process and it is calculated by binding energy, which is taken from RMF theory with NL3* parametre [4]. The value of constants a, b, c, d and e are given in table I.

TABLE I: coefficient of formula MMF2020 .

Nuclei	*a*	*b*	*c*	*d*	*e*
$e-e$	-5.57326	48.18490	-80.35736	5.12241	27.43124
$e-o$	5.91103	-5.40389	-16.24855	-23.34471	135.61109
$o-e$	2.20340	12.14202	-40.09277	21.60729	-13.56287
$o-o$	-7.50692	49.99578	-70.73322	-48.97284	215.35032

and the half life of SF calculated by using the modified Bao formula (MBF) [5]

$$log_{10}T_{1/2}^{SF}(s) = c_1 + c_2\left(\frac{Z^2}{(1-KI^2)\,A}\right) + c_3\left(\frac{Z^2}{(1-KI^2)\,A}\right)^2 + c_4E_{s+p} \quad (2)$$

In this case $k = 2.6$ with other coefficients being $c_2 = -37.0510$, $c_3 = 0.3740$, $c_4 = 3.1105$. The values of c_1 for varies for different sets of nuclei : $c_1\,(e-e) = 893.2644$, $c_1\,(e-o) = 895.4154$, $c_1\,(o-e) = 896.8447$ and $c_1\,(o-o) = 897.0194$

Results and discussion

In this study, we have systematically estimated the half-lives of both α-decay and SF for various superheavy nuclei using Equations

*Electronic address: umesks@gmail.in

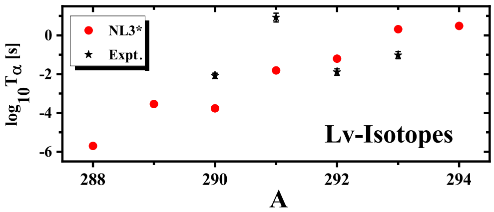

FIG. 1: α-decay half life of $^{290-293}$Lv isotopes are compared with available experimental data [6].

(1) and (2), respectively. These equations were applied to a series of isotopes to provide a comparative analysis of the two primary decay modes α-decay and SF. By plotting the logarithmic values of the half-lives, $\log_{10} T_{1/2}$, as a function of the mass numbers of the parent nuclei in Figure. 1, we are able to visually examine trends and patterns that emerge between different isotopes. The α-decay half-lives for $^{290-293}$Lv show a strong correlation between our theoretical predictions and experimental results [6], highlighting the accuracy of our model in predicting decay characteristics. The close agreement between our theoretical estimations and the available experimental data significantly enhances confidence in the model's predictive capability. This agreement between computed half-lives and actual observations provides a solid foundation for extending these predictions to other superheavy nuclei. On the basis of this, we have found that the α-decay chain of ^{287}Lv, which is shown in Table II, here we got a long decay chain that illustrates its sequential transformation through alpha particle emissions. Each step in the chain leads to a lighter isotope, providing key information on the decay properties of superheavy nuclei. Confirming this predicted decay chain through experimental [7] would significantly validate our theoretical models of nuclear stability.

TABLE II: Comparison of logarithmic half-life and α-decay mode (DM) of ^{287}Lv decay chain.

Nucleuss	$log_{10}T_\alpha$ *Expt.*	$log_{10}T_\alpha$ *RMF*	$log_{10}T_{SF}$	*DM RMF*	*DM Expt.*
^{287} Lv	-	-3.73	5.83	α	-
^{283} Fl	-	-9.44	2.18	α	-
^{279} Cn	-2.30	-1.35	-0.79	α	-
^{275} Ds	-2.00	-1.56	6.03	α	-
^{271} Hs	-2.00	-1.89	9.33	α	-
^{267} Sg	2.03	4.50	9.64	α	SF/α
^{265} Rf	2.82	5.50	6.57	α	α

Furthermore, the successful validation of these models would contribute to a more comprehensive understanding of decay processes in superheavy elements. Such findings are critical for guiding future research aimed at the synthesis and characterization of α-decay chain of ^{287}Lv, pushing the boundaries of nuclear physics and deepening our knowledge of the limits of the periodic table. Continued experimental efforts, in conjunction with refined theoretical models, will likely shed further light on the complex interactions governing the stability and decay of superheavy nuclei, paving the way for future discoveries in this rapidly advancing field.

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