Prediction of decay modes of $Z = 119$ superheavy nuclei within the mass range 286≤A≤310

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Introduction

The past few decades have witnessed a lot of strides in the production and spectroscopic studies of superheavy elements (SHEs) owing to the remarkable feats achieved in state-of-art facilities like radioactive heavy ion beams (RIBs) and accelerator technologies. Two fusion evaporation techniques employed for the synthesis of superheavy nuclei (SHN) are cold and hot fusion reactions. Till now the elements upto Z=118 [1] have been syhthesized in the laboratories using the above two techniques. Alpha decay and spontaneous fission (SF) are the main modes of decay in superheavy mass region. Although the two phenomena share the same underlying physics i.e., both are explained on the basis of quantum mechanical theory, the two widely differ in principle. The process of α decay is described by the alpha cluster penetrating the coulomb barrier after its formation in parent nucleus. However, the phenomenon of SF is highly intricate as there are large uncertainties involved in masses, charges of the two fragments and energy released during the process. There is a wealth of literature available regarding the theoretical attempts being made to study the properties of α decay as well as spontaneous fission in the superheavy region. In present work, we analyze the competition among possible decay modes of the superheavy nuclei.

Formalism

Within the versatile framework of axially deformed relativistic mean-field theory using NL3* effective force binding energies are computed which in turn are used to compute Q_α values which is an basic input for estimating the α decay half lives for the isotopic chain $284 \leq A \leq 310$ of $Z = 119$ superheavy nuclei. For calculation of α decay half lives, we employed the semi-empirical formulae by Viola-Seaborg relation(VSS) [2], generalized liquid drop model(GLDM) proposed by Dasgupta, Schubert and Reyes [3], Royer [5], Brown [4] and Ni et al. [6]. The estimation of SF half-life is carried out using the phenomenological formula proposed by Ren and Xu [7].

Results and Conclusion

A comparative study of alpha decay and spontaneous fission is made for the isotopic chain of $Z = 119$ in the mass number range 284 to 310 using the semi-empirical relations mentioned in the last section. Figure 1 and Table 1 depicts the comparison of the calculated alpha decay and spontaneous fission half-lives against mass number of considered chain of nuclear isotopes. From the calculations, it is obvious that the alpha decay is the principal decay mode upto $A = 296$ and the α decay predicted by the phenomenological formulae are in good agreement with each other and also show a reasonable agreement with the predictions of finite range droplet model(FRDM). Further, in the mass range $297 \leq A \leq 310$, SF is the main decay channel due to the heavy mass number of the isotopes. It is also evident from Figure 1 that beyond the mass number $A > 296$ the spontaneous fission half-life becomes smaller than alpha decay half-life and therefore, SF becomes as a dominant mode of decay for $A > 296$ nuclides. The present calculation suggests that there is a possibility to synthesize the Z=119 SHN by observing the alpha decay.

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TABLE I: Decay energies(in MeV) for prolate shape and half-lives of α and spontaneous fission for $Z = 119$ isotopic chain and prediction of mode of decays is given.

Nuclei	Q_α^{RMF}	Q_α^{FRDM}	$\log(T^\alpha_{1/2})$						$\log(T^{SF}_{1/2})$	Mode of
			VSS	Royer	GLDM	Brown	Ni et. al.	FRDM	Ren-Xu	decay
$^{284}119$	14.00	13.02	-6.29	-6.86	-6.64	-6.98	-7.29	-4.42	-6.33	α
$^{285}119$	13.89	13.79	-6.43	-6.67	-6.81	-6.79	-7.66	-6.25	-1.77	α
$^{286}119$	13.83	13.74	-5.97	-6.57	-6.33	-6.69	-7.00	-5.81	1.95	α
$^{287}119$	13.79	13.45	-6.26	-6.53	-6.67	-6.63	-7.51	-5.60	4.84	α
$^{288}119$	13.99	13.38	-6.27	-6.90	-6.69	-6.95	-7.26	-5.14	6.90	α
$^{289}119$	14.12	13.35	-6.84	-7.15	-7.30	-7.15	-8.01	-5.79	8.15	α
$^{290}119$	14.22	13.36	-6.68	-7.35	-7.16	-7.31	-7.61	-5.09	8.59	α
$^{291}119$	14.38	13.20	-7.30	-7.64	-7.80	-7.56	-8.40	-5.13	8.24	α
$^{292}119$	10.45	13.17	1.68	0.94	1.72	0.03	-0.46	-4.71	7.10	α
$^{293}119$	15.32	12.88	-8.86	-9.22	-9.39	-8.92	-9.73	-4.47	5.17	α
$^{294}119$	15.13	12.80	-8.22	-8.95	-8.87	-8.66	-8.93	-3.97	2.47	α
$^{295}119$	16.18	12.88	-10.16	-10.56	-10.73	-10.06	-10.85	-4.49	-0.99	α
$^{296}119$	16.02	13.08	-9.58	-10.34	-10.36	-9.86	-10.10	-4.54	-5.21	α
$^{297}119$	16.03	12.74	-9.95	-10.38	-10.56	-9.88	-10.67	-4.19	-10.19	SF
$^{298}119$	11.48	12.50	-1.01	-1.84	-1.25	-2.33	-2.76	-3.34	-15.90	SF
$^{299}119$	11.37	12.80	-1.09	-1.60	-1.72	-2.10	-3.09	-4.32	-22.35	SF
$^{300}119$	9.96	13.15	3.11	2.22	3.11	1.28	0.76	-4.67	-29.53	SF
$^{301}119$	11.04	13.27	-0.25	-0.80	-0.92	-1.3	-2.37	-5.25	-37.43	SF
$^{302}119$	11.09	13.38	-0.04	-0.95	-0.29	-1.48	-1.93	-5.13	-46.04	SF
$^{303}119$	11.24	13.38	-0.76	-1.34	-1.47	-1.82	-2.81	-5.46	-55.36	SF
$^{304}119$	11.65	14.14	-1.42	-2.36	-1.79	-2.70	-3.11	-6.55	-65.37	SF
$^{305}119$	11.95	13.84	-2.47	-3.07	-3.21	-3.31	-4.27	-6.33	-76.08	SF
$^{306}119$	6.44	13.97	17.69	16.65	18.57	14.09	13.25	-6.23	-87.48	SF
$^{307}119$	5.88	13.81	20.81	20.07	20.06	17.12	15.65	-6.29	-99.55	SF
$^{308}119$	5.31	13.43	25.26	24.14	26.61	20.73	19.72	-5.23	-112.30	SF
$^{309}119$	9.03	13.31	5.76	5.05	4.95	3.91	2.77	-3.35	-125.71	SF
$^{310}119$	8.88	12.76	6.63	5.57	6.70	4.38	3.78	-3.88	-139.79	SF

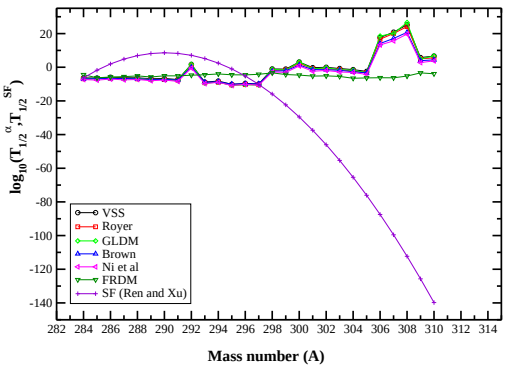

FIG. 1: Alpha decay and SF half-lives are plotted against the mass number for the isotopic chain of $Z = 119$ in the mass range 284 to 310.

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