Role of shapes and deformations in the identification of superheavy nuclei $^{293}_{117}$X and $^{294}_{117}$X

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Introduction

The quest for superheavy nuclei has got a dramatic rejuvenation in recent times due to the emergence of hot fusion reactions over and above the cold fusion reactions. While the cold fusion reactions involving a doubly magic spherical ^{208}Pb target and a deformed projectile like ^{70}Zn were used by GSI to produce heavy elements with Z=110 - 112, the hot fusion evaporation reactions with a deformed trans-uranium target like ^{244}Pu and a doubly magic spherical projectile ^{48}Ca is used in the synthesis of superheavy nuclei Z=114, 115, 116, 117 and 118 at Dubna. In the production of Z=112 nuclei at GSI the fusion cross-section was extremely small (1 picobar) which led to the conclusion that reaching still heavier elements will be very difficult. At this time, the emergence of hot fusion reactions using ^{48}Ca projectiles at Dubna has dramatically changed the situation and nuclei with Z=114, 115, 116, 117 and 118 were synthesized and detected by their decaying alpha chains with terminating spontaneous fission events. While Z=115 isotopes gave long alpha decay chains, Z=114, 116 and 118 were found to yield short alpha decay chains as expected. The lifetimes of superheavy nuclei with Z=110 - 112 were milliseconds and microseconds. The superheavy nuclei with Z=114 - 118 lived for upto 30 seconds. This pronounced enlargement of lifetimes for these nuclei has given a great encouragement in reaching the spherical superheavy element.

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One of the important steps in detecting the formation of superheavy nuclei is to analyze accurately the lifetimes of alpha decay chains. In the experiments at Dubna, this was done by comparing the measured alpha lifetimes with the empirical Viola-Seaborg relation, which connect the lifetimes and Q-values with some constants which are determined by fitting with well-known cases. We feel that this could be done by evaluating alpha decay lifetimes by rigorous theories and this may throw more light on the physics of the superheavy nuclei. With this intention, we use here [1] a unified fission model developed by Shanmugam and Kamalaharan (SK) which was first used for cluster radioactivity and then extended to alpha decay studies. This SK model uses a cubic potential in the pre-scission region connected by Coulomb plus Yukawa plus exponential potential in the post-scission region. Apart from using such a realistic potential this model has many more virtues. They are the inclusion of the zero point vibration energy, usage of correct barrier heights including centrifugal contribution and no adjustable parameters. The advantage of this model is further enhanced by its versatility in incorporating the deformation of the decaying parent and the daughter and also their shapes which turn out to be very important now because of the hindrance they can cause aiding to longevity and stability of superheavy nuclei. One other advantage of this model is that it can naturally be applied to the study of the terminating spontaneous fission events.

Aim of this work

The aim of this work is to apply our model for calculating the lifetimes of the recently detected [2] alpha decay chains of $^{293}_{117}$X and

TABLE I: Lifetimes of alpha decays from odd-Z superheavy nuclei $^{294}_{117}$X and $^{293}_{117}$X

A_p	Z_p	A_d	Z_d	Q (MeV)	β_{2p}	β_{4p}	β_{2d}	$T_{calculated}$	T_{expt}
294	117	290	115	10.81	-0.087	-0.02	-0.079	208 ms	112 ms
290	115	286	113	9.95	-0.079	0.002	0.072	12.6 s	0.023 s
286	113	282	111	9.63	0.072	-0.03	0.099	12.92 s	28.3 s
282	111	278	109	9	0.099	-0.02	0.136	146.2 s	0.74 s
278	109	274	107	9.55	0.136	-0.041	0.192	0.928 s	11.0 s
274	107	270	105	8.8	0.192	-0.076	0.212	12.22 s	1.3 min
293	117	289	115	11.03	-0.087	-0.012	0.053	83 ms	21 ms
289	115	285	113	10.31	0.053	-0.015	0.072	1.338 s	0.32 s
285	113	281	111	9.74	0.072	-0.022	0.099	0.9742 s	9.423 s

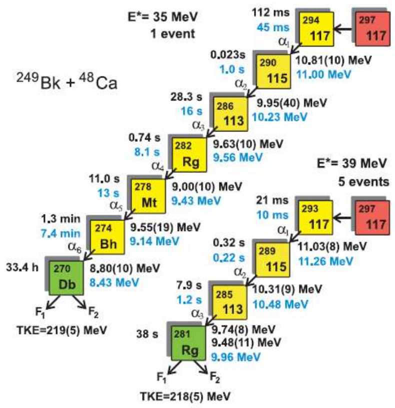

FIG. 1: Recently detected alpha decay chains of $^{294}_{117}$X and $^{293}_{117}$X [2]

$^{294}_{117}$X. The Q values are those of Oganessian et. al while shape, deformations and spins are taken from Atomic and Nuclear Data Tables of Moller et. al. It is found (Refer Table I) that apart from neutron excess, the hindrance due to oblate to prolate shape changes with deformation $\beta_2 < 0.1$ do enhance the nuclear lifetimes of $^{293}_{117}$X and $^{294}_{117}$X.

References

[1] G. Shanmugam, S. Sudhakar and S. Niranjani, Phys. Rev. C **72**, 034310(2005).

[2] Oganessian et. al Phys. Rev. Lett. **104**, 142502 (2010)