Dominant decay modes of SHN $Z = 118 - 130$

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Introduction

The study on superheavy nuclei (Z>104) has remained an important area of research in modern nuclear physics. In last four decades, theoretical studies have suggested proton shell closure and neutron shell closure beyond Z=82 and N=126 in the superheavy region is at Z=114 and N=184, and it is expected that isotopes around this doubly magic nuclei will form an island of stability [1]. The superheavy elements with Z=107-112 have been successfully synthesized at GSI, Darmstadt. Isotopes of these elements along with Z=113-116 and 118 have been synthesized at JINR-FLNR, Dubna and Z=110-113 have been produced at RIKEN, Japan [2]. The SHN synthesized in laboratory decay mainly via alpha emission and spontaneous fission, but can also undergo proton decay for a range of mass numbers and there exists a possibility of heavy cluster decay from SHN. The proton emission, the alpha decay, and the cluster decay can be explained using quantum tunneling phenomena. The decay studies are important, as it brings out the degree of stability of nuclei with different proton and neutron numbers, and gives information about possible decay modes and nuclear structure. There is abundance of literature on the lifetime and stability of SHN upto Z=130 [3]. In this work, we study the dominant decay mode of Z=118-130 isotopes using recently developed Cubic Plus Proximity model [4].

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Theoretical Framework

In decay process the parent nuclei get split into daughter and fragment nuclei. The post-scission region potential is $V_{ext}(r) = V_n(r) + V_c(r) + V_l(r)$. The nuclear interaction between daughter and fragment proximity potential is described as [5],

$$V_n(r) = 4\pi\gamma b \frac{C_1 C_2}{C_1 + C_2}\phi(s).$$

We have considered pre-scission potential as a cubic potential [6]. The tunneling probability is obtained using improved transfer matrix method [7]. In the barrier region the wavefunction in barrier region is considered as plane wave and at the boundaries WKB wavefunction is most suited. The tunneling probability and half-life calculations are as described in Ref.[4]. For the present study, we have used the WS-4 binding energy data as it provides good description of nuclear masses in heavy and superheavy region [8].

Result and Discussion

The peaks obtained in alpha decay half-life plot of Z=118 (fig. 1) suggest that some isotopes are relatively more stable than neighbouring ones, which leads to neutron magic/semi-magic numbers at N=178, 184, 196, 200, 220 & 228 which coincides well with Ismail et al [9]. In fig. 2 the competition between various decay modes of Z=118 such as proton decay, alpha decay and spontaneous fission half-lives are plotted for the isotopes, and the dashed lines indicate the current experimental detection limits $10^{-6}s \leq T_{1/2} \leq 10^{30}s$.

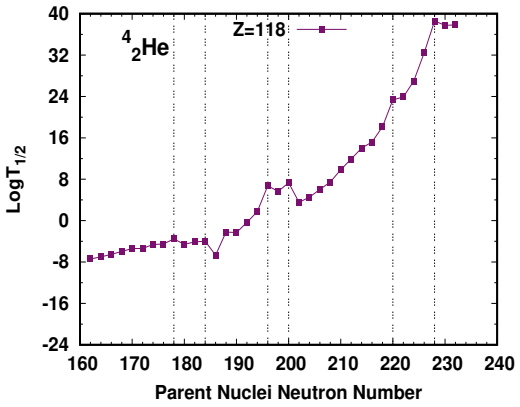

FIG. 1: The alpha decay half life of $Z = 118$ isotopes

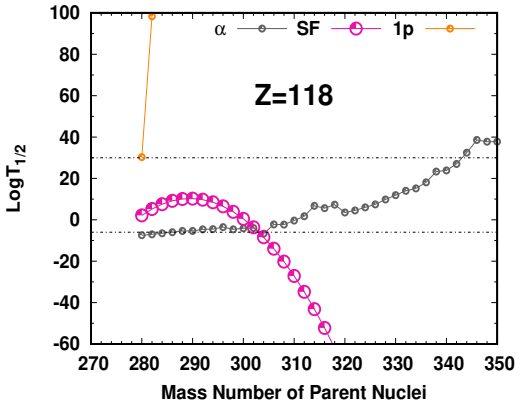

FIG. 2: Competition between decay modes of $Z = 118$

Investigation of competition between various decay modes brings out the dominant decay mode associated with an isotope; for a given Z with increasing A the dominant mode of decay is seen to shift from proton decay to alpha decay and finally spontaneous fission. It is well noticed from fig. 2 that emission of proton from Z=118 is not a possible decay mode. The converging point at A=304 in fig. 2 determines that A $<$ 304 is α - decay possible nuclei and A$>$ 304 will follow SF. The dominant decay modes for Z=118-130 is presented in table 1. These results brings out the possible decay modes associated with isotopes of SHN $Z = 118 - 130$, and may help experimentalist in identifying the isotopes to be synthesized in laboratories in the future.

TABLE I: Prediction of dominant decay modes for Z=118-130 isotopes

Parent Z	Region of dominating decay modes 1p	α	SF
118	-	$280 \leq A \leq 302$	$304 \leq A \leq 350$
120	-	$284 \leq A \leq 308$	$310 \leq A \leq 350$
122	-	$290 \leq A \leq 314$	$316 \leq A \leq 350$
124	-	$296 \leq A \leq 320$	$322 \leq A \leq 350$
126	-	$302 \leq A \leq 328$	$330 \leq A \leq 350$
128	-	$308 \leq A \leq 334$	$336 \leq A \leq 350$
130	-	$316 \leq A \leq 342$	$344 \leq A \leq 350$

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