Study of heavy particle emission from Z=120 isotopes

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Introduction

The cluster/heavy particle radioactivity (HPR) is the ground state phenomenon lying between alpha decay and spontaneous fission. Usually, shorter half-lives and large branching ratios are obtained for heavy cluster emission as compared to alpha decay for superheavy nuclei using cluster-like models [1]. The peculiar decay mode was first investigated for trans-lead region and Poenaru *et.al.* [2] has extended the same for Z≥110 nuclei leading to the emission of $Z_{cluster}$≥28 using Analytical Super Asymmetric Fission Model (AFSAF). According to this, the emission of heavy clusters is always governed through lead (Pb) isotopes, emitted as the complementary fragments. The same observations were made through the Preformed Cluster Model (PCM) in past to understand the dynamics of Z=113, 115 and 117 nuclear systems [3]. Prox-77 and Prox-00 potentials were tested for odd-Z nuclei by including the spherical and deformed fragmentation approaches. In present analysis, the heavy cluster emission from $^{299-302}$120 isotopes [4] is investigated by including Prox-00 and Mod Prox-00 potentials for β_{2i}-deformed approach.

The Model

The Preformed Cluster Model (PCM) [3, 7] based on fragmentation theory is worked out in terms of mass/charge asymmetry, relative separation $\bar{R}$, neck parameter, deformation and orientation parameters. Using these parameters the heavy cluster decay half-lives are calculated by including cluster and daughter preformation probabilities (P_0), barrier impinging frequency (f_0), and barrier penetrability (P), and given as:

$$\lambda^{PCM} = \nu_0 P P_0\ ,\ T_{\frac{1}{2}} = \frac{\ell n2}{\lambda} \qquad (1)$$

Here P_0 and P refer respectively to the mass asymmetry (η) and radial distance (R) of the fragments, and ν_0 is called assault frequency.

The Preformation probability (P_0) is calculated by solving the Schrödinger equation in η-motion and is given as:

$$P_0 = \mid \psi(\eta(A_i)) \mid^2 \sqrt{B_{\eta\eta}} \frac{2}{A} \qquad (2)$$

On the other hand, the penetration probability is calculated through the WKB approximation:

$$P = P_a W_i P_b \qquad (3)$$

$$P_a = exp\Big[-\frac{2}{\hbar}\int_{R_a}^{R_i}\big\{2\mu[V(R)-V(R_i)]\big\}^{\frac{1}{2}}dR\Big] \qquad (4)$$

$$P_b = exp\Big[-\frac{2}{\hbar}\int_{R_i}^{R_b}\big\{2\mu[V(R)-Q]\big\}^{\frac{1}{2}}dR\Big] \qquad (5)$$

where R_a is the first turning point of the barrier with V_{Rb}=Q value.

The details of proximity potentials Prox-00 and Mod Prox-00 are discussed in [5] and [6] references respectively.

Calculations and discussion

The decay half-lives of heavy clusters emitted from $^{299-302}$120 nuclear systems are calculated through Preformed Cluster Model (PCM) [3, 7] by including Prox-00 and Mod Prox-00 potentials. Following the trend of proximity potentials in [7], we started the calculations with Prox-77 approach having different radius parameter and universal function as compared to Prox-00 and Mod Prox-00 potentials. The half-lives could not be attained

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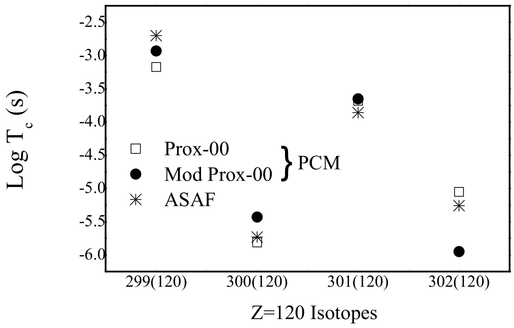

FIG. 1: The decay half-lives calculated by including Prox-00 and Mod Prox-00 potentials and compared with the estimates of ASAF measurements [4].

within the Prox-77 potential which otherwise finds nice agreement for actinide nuclei [7]. Further, to address the ASAF data [4] the decay half-lives are calculated through Prox-00 and Mod Prox-00 potentials. Nice comparison between PCM fitted and ASAF calculations is obtained as depicted from the Fig.1 with these potentials.

In order to look for the mass distribution of fragments, the preformation probability is plotted in Fig.2 for Z=120 nuclear systems. The figure signifies that emission of Sr-clusters is prominent which is mainly governed through complementary Pb-isotopes; hence, considered as the probable candidate for heavy particle radioactivity (HPR). It is relevant to mention that the preformation distribution is presented for $^{299,302}120$ nuclei in Fig.2. Same structure is accounted for $^{300,301}120$ nuclear systems. Further, the maxima around the fission fragments can also be visualized for Z=120 isotopes due to higher deformations of I and Hg. Interestingly, the spontaneous fission peaks have comparable magnitude as compared to heavy cluster emission. Hence, for Z=120 the investigation of spontaneous fission is equally important as that of heavy particle emission. The preformation probability is plotted for Prox-00 potential. Similar results are obtained for Mod prox-00 potential but not shown here to avoid repetition.

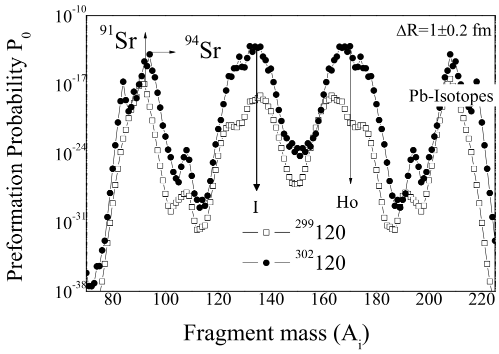

FIG. 2: Variation of Preformation Probability with fragment mass for the decay of $^{299-302}120$ nuclear systems.

Conclusively, the half-lives of clusters for Z=120 can be addressed through Prox-00 or Mod Prox-00 potentials. The distribution of fragments signifies the emission of heavy clusters is due to Pb peaks. The spontaneous fission is also dominating for $^{299-302}120$ isotopes due to highly deformed fission fragments.

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