Decay landscape of ^{237}Np nucleus explored through collective clusterization approach

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Introduction

Certain nuclei can undergo spontaneous radioactive decay through several distinct mechanisms, including α-particle emission, cluster radioactivity, and spontaneous fission. The choice of a outgoing decay mode fundamentally depends on the binding energies of the decaying fragments, potential energy barrier and the magicity effect. Although α decay is the dominant form of radioactivity in actinides, experiments have confirmed that these nuclei can also emit heavier clusters, such as ^{10}Be ^{14}C ^{24}Ne and ^{30}Mg. In a recent work [1] one of us and collobrators have carried out a study of α decay of various isotopes of trans Sn nuclei with in the framework of the preformed cluster model, where role of various proximity interactions was explored.

Here, in present work, we have performed a comparative analysis of the spontaneous decay with in the formalism of preformed cluster model (PCM) by incorporating the interaction potential Prox 77 and Prox NGO for various decay channelssuch as α-decay, cluster emission, heavy particle radioactivity (HPR) and spontaneous fission (SF) etc. In this study, we have explored comparitive analysis of different decay modes operating in the exit channel of radioactive nucleus ^{237}Np.

Methodology

The preformed cluster-decay Model (PCM) [1, 2] is used to define decay constant and half lives

$$\lambda_{PCM} = f_0 P P_0\,,\ T_{\frac{1}{2}} = \frac{\ell n2}{\lambda} \qquad (1)$$

In Eq. (1), P_0 is the preformation probability, f_0 is the assault frequency and P is the barrier penaterability calculated with in WKB approximation. The structure information of the decaying fragments contained in P_0 is estimated by solving the Schrdinger equation in η coordinate by using fragmentation potential

$$V_R(\eta) = -\sum_{i=1}^{2} B_i(A_i, Z_i) + V_c + V_p \qquad (2)$$

where V_C and V_P are respectively, the Coulomb and nuclear proximity potential.

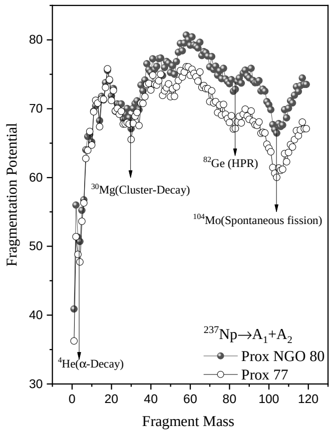

FIG. 1: The variation of fragmentation potential as a function of fragment mass A_2 for the decay of ^{237}Np using two different proximity potential.

Results and Discussion

We have plotted the fragmentation potential as a function of the fragment mass number, illustrated in Figure 1. The figure shows well-defined minima at certain mass regions corresponding to energetically favored decay channels. The lowest minima is associated with αdecay, reflecting the strong preformation of the α particle and the stabilizing effect of shell closure of the daughter nuclei. Additionally, the valleys appear for cluster and heavy particle emissions, such as ^{30}Mg and ^{82}Ge, where the residual daughter lies close to magic neutron or proton numbers, most notably N = 126 and Z = 82, thereby gaining additional

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TABLE I: .The calculated half-lives are also compared with the experimental one.

Parent Nucleus	Decay Mode	ΔR		$Log_{10}T_{1/2}$(s)		
		Prox 77	Prox NGO 80	Prox 77	Prox NGO 80	Expt.(s)
^{237}Np	$(\alpha)^4$He+^{223}Pa	0.6	0.0	13.84	14.32	13.81
^{237}Np	(CR)^{30}Mg+^{207}Tl	0.6	0.0	26.45	29.28	$\geq$ 26.93
^{237}Np	(HPR)^{82}Ge+^{155}Pm	0.6	0.0	24.03	29.61	-
^{237}Np	(SF)^{104}Mo+^{133}Sb	-0.6	-0.9	24.28	25.71	25.49

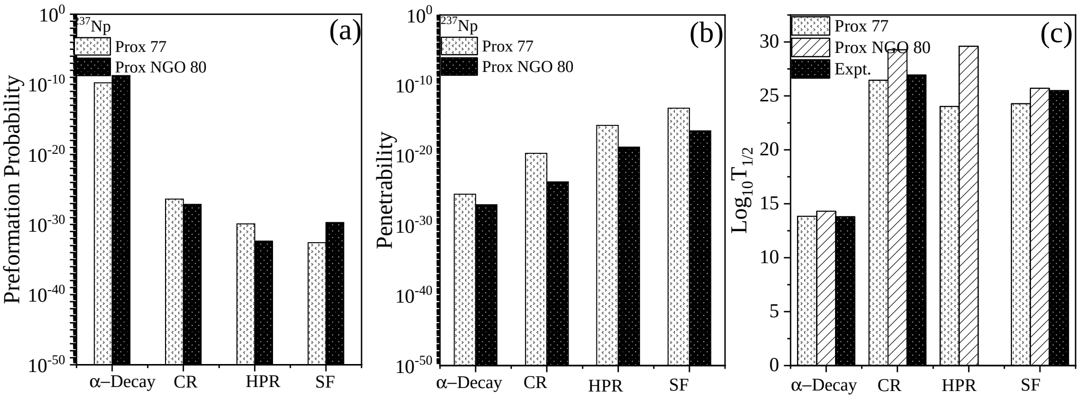

FIG. 2: (a) Preformation probability , Penatrability and half lives of α decay, cluster radioactivity,HPR and Spontaneous fission.

stability due to shell closure effects. The spontaneous fission region also shows minima linked to fragment combinations involving the magic numbers N = 82. Although the overall profile of the fragmentation potential remains nearly same for both choices of proximity potentials, the NGO based interaction exhibits relatively higher magnitude which affect the barrier characteristics and decay probabilities accordingly. Important point to note here is that four decay modes i.e α decay, cluster decay, HPR and SF are equally pronounced for both choices of proximity interaction. In Table 1, the calculated $T_{1/2}$ for all the decay mechanisms agree well with the experimental data. For Prox77, neck length parameter (ΔR=0.6 fm) is used to adress the experimental half-lives. However, with ProxNGO80, reasonable agreement with experimental data is obtained at touching configuration. On the other hand for SF, overlapping surface in the neck length parameterΔR (=-0.6 to -0.9 fm) seems optimum for prox 77 and NGO 80 respectively.

The decay dynamics of ^{237}Np nucleus show that the αparticle is always preformed with largest preformation probability, though its corresponding barrier penetrability (P) is significantly small. It is relevant to note that the half-life is not governed by a single factor, but depends on the combined effect of both the preformation probability and the barrier penetrability. The preformation factor for CR, HPR and SF lower than that of α channel suggesting that α decay is major contributor in exit channel followed by SF and CR/HPR. . In conclusion the Prox NGO 80 gives decent accord of $T_{1/2}$ values at the touching configuration. Hence, NGO 80 seems to be a reliable proximity potential for addressal of a αdecay, cluster radioactivity, heavy particle radioactivity, and spontaneous fission. It will be of further intrest to extend this multichannel decay analysis to other trans lead nuclei.

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References

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