# Nuclear Studies of Various Proton Halo Nuclei via Cluster Radioactivity

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## Introduction

Among the four regions of the nuclear landscape, the unexplored regions have particular interest among scientists. So the study of those nuclei located in these regions provides new surprises in the field of nuclear physics. Over the past decade, remarkable progress has been made in the study and understanding of such nuclei.

Our perspective is limited to the various proton halo (p-halo) nuclei that can exist and their decay from super-heavy elements through cluster radioactivity.

## Coulomb and Proximity Potential Model

If $Z_1$ and $Z_2$ are the atomic numbers of daughter and emitted cluster, the interacting potential barrier for a parent nucleus exhibiting exotic decay is given by

$$V = Z_1 Z_2 e^2/r + V_p(z) + \frac{\hbar^2 l(l+1)}{2\mu r^2} \quad \text{for } Z > 0 \qquad (1)$$

where 'r' is the distance between fragment centers, $l$ the angular momentum, $\mu$ the reduced mass and Vp is the proximity potential
The barrier penetrably P is given as:

$$\mathrm{P} = \exp\{-\frac{2}{\hbar}\int_a^b \sqrt{2\mu(V-Q)}dz\} \qquad (2)$$

The turning points 'a' and 'b' are given by $V(a) = V(b) = Q$, where Q is the energy released.

$$\mathrm{Q} = \Delta M(A,Z) - \left(\Delta M(A_1,Z_1) + \Delta M(A_2,Z_2)\right) + \left[k_1\left(Z^{\varepsilon_1} - Z_1^{\varepsilon_1}\right) - k_2\left(Z_2^{\varepsilon_2}\right)\right]$$

The halflife time is given by

$$T_{1/2} = \ln 2/\nu P. \qquad (3)$$

Where, ν = 2Ev/h, represent the number of assaults on the barrier per second and $E_v$, the empirical zero point vibration energy.

## Results and Discussions

The structure of various proton-rich exotic nuclei and p-halo nuclei; and their decay probabilities from the super-heavy parent isotopes are studied [1,2]. Structures are identified from the separation energy findings, RMS radii, and driving potential calculations. The computed potential energy surfaces are used to analyze the molecular structures in these selected nuclei because minima in the driving potential arise on account of the closed shell effects of either one or both the reaction partners, daughter or cluster.

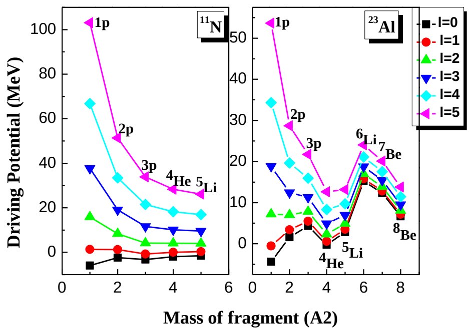


**Fig. 1** Variation of driving potential

We have also studied the probability of emission of exotic fragments and p-halo nuclei from various isotopes in the super-heavy region Z=103-128 by estimating the decay lifetime and identified the probable emissions of these nuclei in this region. The shell closures of daughter nuclei are analyzed from the computed lifetime.

We have also analyzed the effect of inclusion of nuclear proximity potential along with Coulomb potential through GN plots in the proton halo decay studies in various mass regions of super-heavy elements Z=115-128 [3,4]. The validity of GN law in the case of proton halo decay is also explained here.

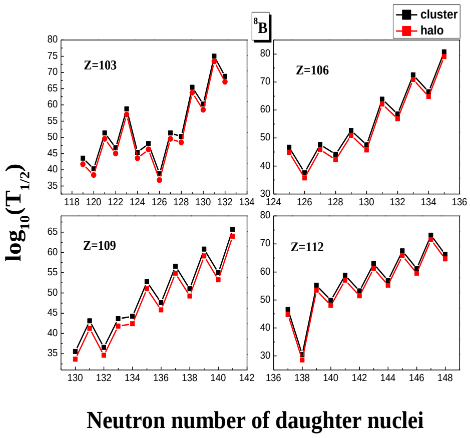


**Fig. 2** Variation of half-life

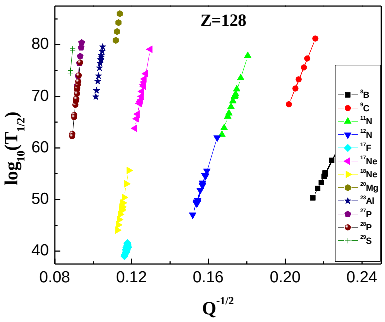


**Fig. 3** GN Plot of various p-halo nuclei

Based on the same model, we have further evaluated the decay probabilities of various exotic nuclei from even-even super-heavy parents by considering them as spherical as well as deformed nuclei [5]. The effect of ground state deformation of the parent, daughter, and cluster nuclei on half-lives and barrier penetrability were studied. The shell structure effects on the decay lifetime are also analyzed.

Finally we have explained the preformation probability of cluster and p-halo nuclei within the heavy parents using our newly proposed formula developed in connection with Q value, mass and charge asymmetry, and the cluster mass. The predicted cluster and p-halo preformation probabilities are in good agreement with the results obtained from other formulas and models.

Studies of halo nuclei are attracting the interest of physicists worldwide, and this will definitely be a topic of discussion in the years to come.

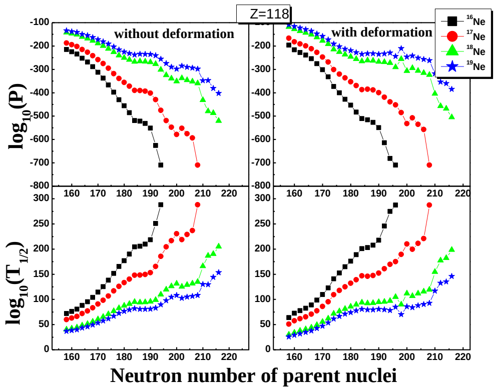


**Fig. 4** Comparison of half-life with and without deformation

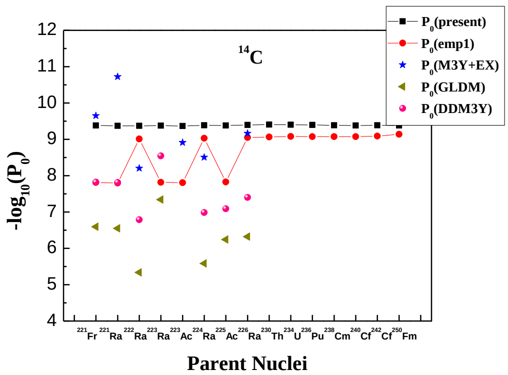


**Fig. 5** Comparison of preformation probability

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## References


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