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Nuclei Near and Far From β-Stability Line

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Abstract: Proton to neutron ratio around β-stability line presents an open challenge to the nuclear physicists. The prominent milestone in this regard is the discovery of the super heavy elements, nuclear halos in the lightest neutron-rich nuclei, experimental mapping of the nuclear shell structure near and far from stability. In this present paper, the behavior of the p- and n- halo nuclei near the β-stability line are discussed considering the variation of radius with respect to the mass number and N~Z for different nuclei. Our aim is to study the nuclear properties through neutron and proton skin. The isospin symmetry breaking is for heavy halo nuclei of strong interest.

Keywords: Neutron and proton drip line nuclei; β stability line; n- and p- skin

1. INTRODUCTION

Nuclei having very different N/Z ratio compared to stable nuclei with the same A, large radial cut-off, high momentum distribution are generally known as drip-line nuclei. The magic nuclei having N = Z appear near the β-stability line for which *v(r) ~ r* curve is symmetric. For proton drip-line nuclei, *v(r) ~ r* is deeper for n- than p-halo in the medium heavy nuclei.

By choosing Wood-Saxon potential it is observed that nuclei with $l = 2$ higher orbital angular momentum lying deep are more stable compared to the $l = 0$ state. It appears for the nuclei having mass range A~ 20 – 40. Considering the Schrodinger's equation in radial form for a finite well potential in the mass range A~ 200 – 220 nuclei having shell structure level $^2s_{1/2}$ $^1d_{3/2}$ $^1d_{5/2}$ are seen to be strongly bound and nuclei having shell structure $^1d_{3/2}$ $^2s_{1/2}$ $^1d_{5/2}$ are stable sd – shell nuclei in the mass range A~20 – 40.

The nuclei such as $^{40}_{12}Mg_{28}$, $^{42}_{13}A_{l29}$, $^{44}_{14}Si_{30}$ and their isotopes are the recently found neutron drip line nuclei. Since N > Z they occur near the β^- - stability zone. More the columbic force between the 1n, 2n…. and the core these unstable nuclei can come closer to the β^- - stability line and become more stable.

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The proton drip line nuclei which are against the proton emission are approximately known up to Pb region. Proton drip line nuclei lie much closer to the β - stability line than the neutron drip line due to the higher columbic barrier.

The Schrodinger equation for radial wave function is written as

$$\left\{\frac{d^2}{dr^2}-\frac{l(l+1)}{r^2}+\frac{2m}{\hbar^2}\left(\varepsilon_{nlj}-V(r)-V_{ls}(r)\right)\right\}R_{nlj}(r)=0 \quad (1)$$

Centrifugal potential:

$$\frac{\hbar^2 l(l+1)}{2mr^2}$$

Wood-Saxon potential:

$$\frac{-\nu_0}{1+\exp\left(\frac{r-R}{a}\right)}$$

The barrier height of the potentials [Centrifugal+ Wood-Saxon] $\alpha \frac{\ell(\ell+1)}{r^2}$

$$r \sim r_{\circ}A^{1/3}$$

Eq. (1) will be solved for neutrons with the boundary conditions.

At r = 0, $\mathrm{R}_\ell(\mathrm{r})=0$

For large value of r, V(r) = 0

For $\varepsilon_\ell<0$, $\mathrm{R}_\ell(\mathrm{r})\ \alpha\ \ \alpha \mathrm{r}k_\ell(\alpha\mathrm{r})$ where $\alpha^2=-\frac{2m\varepsilon_\ell}{\hbar^2}$

For $\varepsilon_\ell>0$, $\mathrm{R}_\ell(\mathrm{r})\ \alpha\ \ \cos(\delta_\ell)\mathrm{krj}_\ell(\mathrm{kr})-\sin(\delta_\ell)\,\mathrm{krn}_\ell(\mathrm{kr})$

where $\mathrm{k}^2=\frac{2m\varepsilon_\ell}{\hbar^2}$, δ_ℓ= Phase shift

For a given potential and energy Eigen values there are several solutions of the Eigen phases. The number of Eigen phases for a given potential and a given energy values is equal to that of the different Eigen states with different (*l, j*) values.

The values of the phase shifts determine the relative amplitudes of different (*l, j*) components.

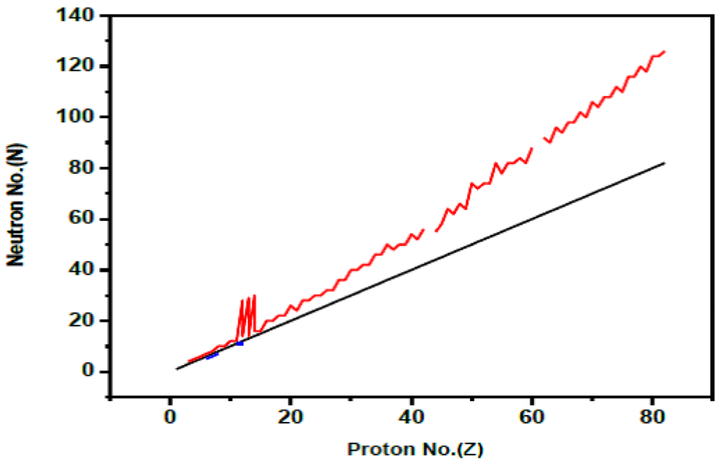

Figure 1: Neutron vs Proton no. for the nuclei in the mass region up to 220.

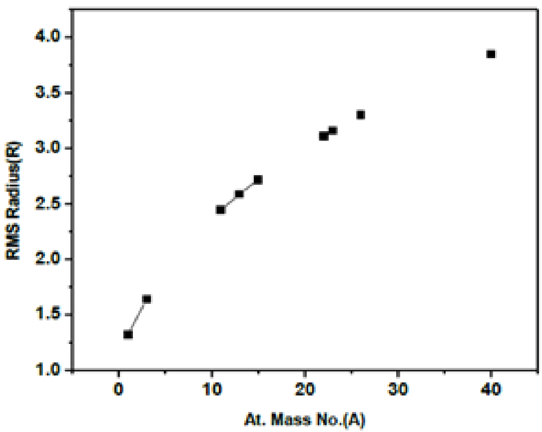

Figure 2: RMS radii vs atomic mass no. for nuclei near the β^+ stability line.

CONCLUSION

The RMS value for different nuclei gradually increases with respect to the atomic mass no. both for the nuclei near the β^+ and β^- - stability line in the mass region 0 – 220 as shown in the figure 2 (A~0 – 40) and figure 3 (A~0 – 220). The N~Z graph for the different nuclei near and far from the β-stability line are shown in figure 1 (red line- β^- - stability nuclei, blue line- β^+ stability nuclei and black line- β stability nuclei)

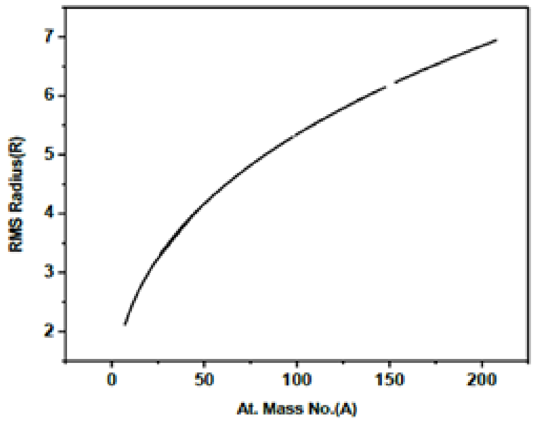

Figure 3: RMS radii vs atomic mass no. for nuclei near the β^- Stability line.

By designing a specific model to study the internal structure of these halo nuclei near and far from the stability line has wide applications in various fields.

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