Nuclear Structure of Even Even Nd Isotopes

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Introduction

Experimentally and theoretically most actively explored area of periodic table is the region of light rare earth nuclei because of their applications in different fields including astrophysics and nuclear medicine. Among them we choose Neodymium (Nd) in the mass number range $124 \leq A \leq 188$ because some isotopes of Nd e.g ^{142}Nd is useful in the production of Thulium ($_{69}Tm$) and Ytterbium ($_{70}Yb$). Apart from that Nd isotopes with neutron number around $N \sim 90$ are identified as an example of shape transition between spherical and axially deformed nuclei.[1]

Theoretical Formulation

We start our calculation from the Lagrangian density [2, 3]. Using classical variational principle we get the field equations for nucleons and mesons. The static solutions of these equations gives us the ground state properties such as the binding energy. The solutions are carried out by a self consistent iteration method with initial deformation value β_0. We calculate quadrupole deformation parameter β_2 from the formula $Q = Q_n + Q_p = \sqrt{\frac{16\pi}{5}}(\frac{3}{4\pi}AR^2\beta_2)$ The separation energy is calculated using B.E values in the formula given below

$$S_{2n} = B.E(N, Z) - B.E(N-2, Z) \qquad (1)$$

Using S_{2n} values in the equation given below, we calculate dS_{2n}

$$dS_{2n} = \frac{S_{2n}(N+2, Z) - S_{2n}(N, Z)}{2} \qquad (2)$$

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Results and Discussion

To explore the dependence of stability of a nucleus on its shape, size and shell structure, we obtain B.E./A, deformation parameter (β_2), charge radius (r_{ch}), two neutron separation energy (S_{2n}), and differential change of two neutron separation energy (dS_{2n}). In our previous work, using RMF model we have successfully investigated ground state properties of some heavy and super heavy nuclei [4–7]. So, We choose RMF Model with PK1 [8] force parameter since it bears success in explaining ground state properties over a wide range of isotopes.

Fig.1 shows the variation of B.E./A in comparison to the available experimental values [9] as a function of Nd's neutron number showing an extremely excellent agreement with experimentally accessible [9] data possessing a maximum error of 0.042 MeV. which corresponds to 0.50%.We get a prominent peak at N=82 quiet obvious because N=82 corresponds to the neutron magic number. Except that we also get peaks at N=74 and 126.

The variation of r_{ch} is compared with experimentally accessible values [10] in Fig. 2 Where we saw a qualitative agreement between our calculated values and experimental values. Both the graphs show a large slope from N=82 to N=92. Except that we get small peaks at N=102 and N=112.

Quadrupole deformation parameter (β_2) is an important parameter in investigating shape and size of a nucleus. We see shape transition from prolate (N=76) to oblate (N=78) with zero deformation at N=80, 82 and 84. A sharp increase in β_2 from N = 84 to N = 92 can be seen in Fig.3 and the increase can be related to the increase in r_{ch}. The variation is small from N=92 to N=112. Also we get nearly zero

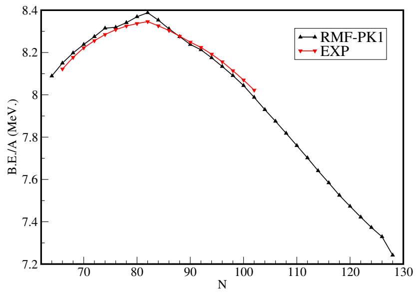

FIG. 1: Variation of B.E/A as a function of neutron number of Nd.

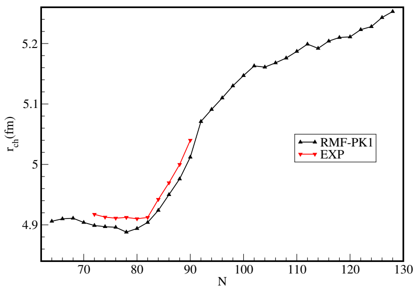

FIG. 2: Variation of r_{ch} as a function of neutron number of Nd.

deformation at N=126.

The comparison of our calculated results with experimentally obtained results [9] and with FRDM (Finite Range Droplet Model)results [11] of (dS_{2n}) and S_{2n} shows qualitative similarity with sharp drops at N= 82 and 126 in S_{2n} and deeps in dS_{2n} which can be observed in Fig.4. Except these two shell closures, our calculation gives us a new shell/sub-shell closure at N=74 which we can

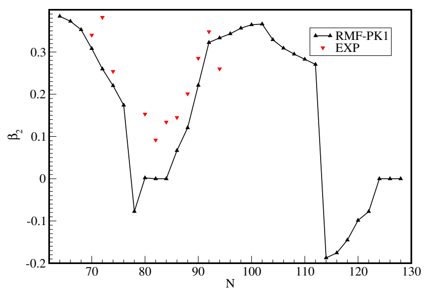

FIG. 3: Variation of β_2 as a function of neutron number of Nd.

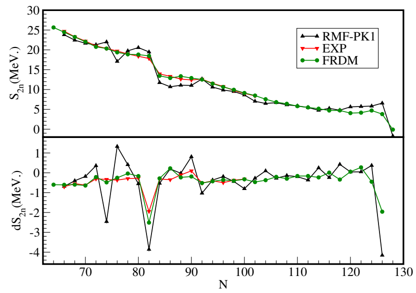

FIG. 4: Variation of separation energy as a function of neutron number of Nd.

observe as a sharp drop in S_{2n} in $S_{2n} \sim N$ and a deep in dS_{2n} in $dS_{2n} \sim N$. As $S_{2n} \sim N$ curve is OES free so it gives better results regarding the shell closures and drip lines. From our calculation we are getting the two neutron drip line at N= 128.

Conclusion

Except N= 82 and 126, we get some sign of stability at N= 74 from B.E/A and separation energies. So, we thought there may be a shell or sub-shell closure of neutron at N=74.

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