The strength of nuclear shell effect at $N = 82$ in the transitional nuclei

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Introduction

From last few decades, it is possible to study the exotic nuclei by using the radioactive isotope beams (RIB) facilities, which reveals the new concept entitled as *aforementioned* magic number. In other word, the confirmation of magic number near $\beta-$stability line are not mandatory universal [1]. Further, the structural properties of nuclei far away from the $\beta-$stability line are also active areas of research in both theories and experiments [2]. In particular, the neutron-rich transitional nuclei such as Zr−, Mo−, Ru− and Pd− with mass numbers A =100−130 are of special interest for various reasons. For example, they lie far away from the $\beta-$stable region of *Nuclear Landscape*, result in a well established deformation, but close enough in the magnitude of microscopic excitations to compete with the collectivity of double shell closure nuclei [3]. Moreover, these nuclei are also holding an active participation in the nucleosynthesis of heavy nuclei in astrophysical r-process [4].

In addition to these, the nuclear structure of these nuclei is characterized by a strong competition between various shapes, which gives rise to the shape instabilities that lead to coexistence nuclear shape transitions in the isotopic chains. Hence, one can say the nuclear shape are not only vary with the nucleon number but also with the excitation energy and spin. In this present work, the quantities of interest are the nuclear potential energy surface, nuclear shape, nuclear binding energy (BE),

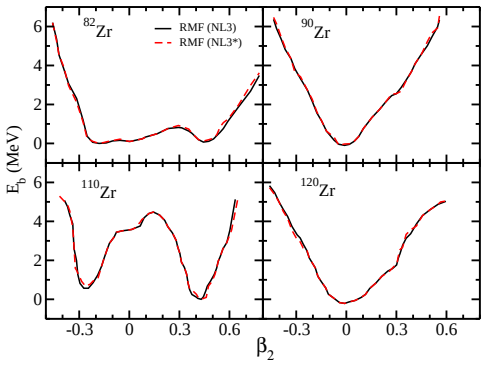

FIG. 1: The potential energy surface of ^{82,90,110,120}Zr as a function of quadrupole deformation parameter β_2.

two neutron separation energies (S_{2n}), the differential variation of neutron separation energy ΔS_{2n}, the root-mean-square charge distribution $r_{\rm ch}$ and the single particle energy level for the *even-even* mass transition nuclei. Base on these decisive observables, we have focused on the evolution on the structural properties of transition nuclei.

Calculations and Discussions

In the present work, we have used axially deformed relativistic mean field model (RMFM) with the successful NL3 [5] and the recently proposed NL3* [6] force parameters, which are excellent in the description of ground and excited states along with many collective aspect for spherical and deformed nuclei. In RMFM, the mean-field equations are solved self consistently by taking different inputs of the initial deformation called β_0 [5]. Here, the desired number of major shells for Fermions and bosons are $N_F = 18$ and $N_B = 20$ for the considered mass region. However, the number of mesh points for Gauss-Hermite

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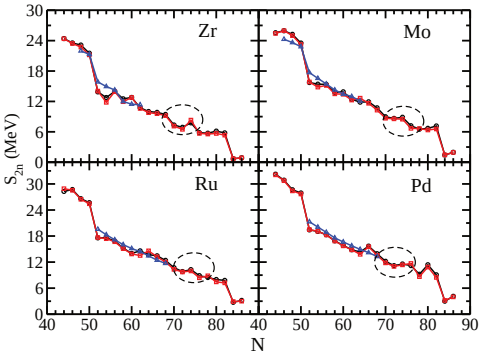

FIG. 2: The S_{2n} energy as a function of neutron number for $^{82-126}$Zr, $^{84-128}$Mo, $^{86-130}$Ru and $^{88-132}$Pd nuclei are compared with the experimental data [7].

and Gauss-Lagurre integration are 20 and 24, respectively. In case of a quantum mechanical system, the path followed by the different solutions at various deformation define a potential barrier or potential energy surface, which can be used for the determination of the ground state of a nucleus. First of all, we have calculated the potential energy surface as a function of deformation parameter β_2, for the proton rich nucleus ^{82}Zr, the double magic nucleus ^{90}Zr and the neutron rich nucleus ^{110,120}Zr are shown in Fig. 2, as a representative case. We notice from the figure that there are more than one minima appear at different β_2. The maximum magnitude of binding energy for the corresponding minima shows that the ground state solution appear at a certain value of β_2 and other are the intrinsic excited state.

The present calculations mainly explain the nuclear structure as well as the sub-structure properties, based on the basic ingredients such as binding energy, quadrupole moment, nucleonic density $\rho(r_\perp, z)$, and *rms* charge radii etc. Using the obtained ground state *BE* from the RMFM, we have estimated the two neutron separation energy for Zr, Mo, Ru and Pd isotopes along experimental data [7], shown in the Fig. 2. From the figure, it is clear that in an isotopic chain, the S_{2n} energy shows the well-known regularities for a given atomic number. Further, a sharp discontinuities (kinks) appears at neutron magic numbers at $N = 50$ and 82. In energy terminology, one can write, the energy necessary to remove two neutrons from a nucleus (Z, $N_{\rm magic}$+2) is much smaller than that to (Z, $N_{\rm magic}$), which breaks the regular trend. We have also calculated the ΔS_{2n}, the charge radii and the single-particle energies along the isotopic chains of these transitional nuclei [8]. From these above mentioned observables, we also observed a large shell gap at $N = 82$ near drip-line region, almost same in magnitude at N= 50, which is a well known feature of magicity in mean-field calculation.

Summary and Conclusions

The conjecture has been made from the binding energy, neutron separation energies, differential variation of separation energy, the root-mean-square charge radii and the single particle energy levels of transitional nuclei. We have shown that Zr, Mo and Ru isotopes undergo a transition from oblate to prolate shapes at $N \sim 64$ and 74. But, in case of Pd follows a smooth pattern through out the isotopic chain [8]. We have also shown the dependence of nuclear charge radii on deformation also play an crucial role on their structural transition. Further, we have also observed a large shell gap at $N = 82$ near drip-line region, which might be an example of *aforementioned* magic number in the isotopic chain.

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