Shape co-existence in tungsten isotopes

Nithu Ashok[1],* Jhilam Sadhukhan[2], and Antony Joseph[1]
[1] *Department of Physics, University of Calicut, Kerala - 673635, India*
[2] *Variable Energy Cyclotron Centre, 1/AF, Bidhan Nagar, Kolkata - 700064, India and*
[2] *Homi Bhabha National Institute, Anushakti, Mumbai - 400094, India*

Introduction

Shape of a nucleus is one of the fundamental property which give an insight into the nucleonic distribution. Shape co-existence is a characteristic feature found in deformed nuclei. It is a phenomenon in which spherical configuration competes with the deformed one and more than one stable state exists at different deformations [1]. This mainly depends on the single particle level density near fermi surface, which is inversely proportional to effective mass. We have made an attempt to analyse the phenomena of shape co-existence within the nuclear energy density functional framework. In particular, many studies have shown that nuclei belonging to the transitional region exhibit properties like transition of shape between prolate, oblate and spherical configurations. Here, we have selected tungsten(W) isotopes as a representative of this region. Different studies have shown that W exhibit shape transition along the isotopic chain.

Theory

For the present study, we solve the constraint Hartree Fock Bogoliubov(HFB) equations[2] to extract the potential energy curve (PEC) in a self-consistent manner. The axially symmetric computer code HFBTHO [3] is used for this purpose. We consider the axial quadrupole moment Q_{20} as the deformation degree of freedom with a linear constraint in the total Routhian defined as:$E^{'} = E - \lambda(<\hat{Q}_{20}> - Q_{20})$, [4] where λ is the Lagrangian multiplier. In the particle-hole channel, Skyrme energy density functionals with different parameterizations: SkM*, SLy6, SkP and UNEDF0 are used. In the particle-particle channel, density dependent mixed pairing interaction is utilized.

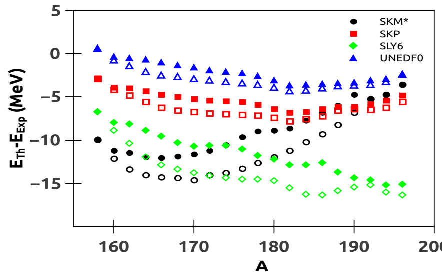

FIG. 1: Binding energies of ground(solid) and isomeric states(open) w.r.t experimental values.

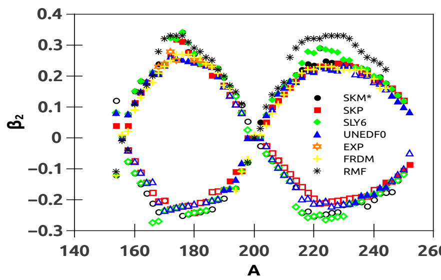

FIG. 2: Deformation parameter of ground and isomeric states.

Results and Discussion

We have systematically studied the ground states and the shape isomers of W isotopes ranging from 2p to 2n drip line. From the PEC (not shown here), we have observed that these isotopes exhibit prolate as well as oblate

*Electronic address: `nithu.ashok@gmail.com`

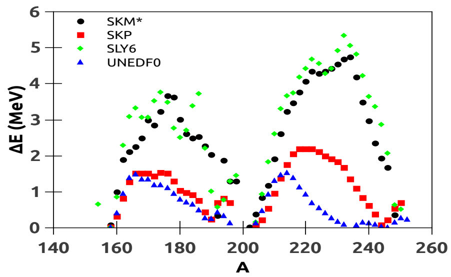

FIG. 3: Shape coexistence of W isotopes.

configurations. In Fig.(1), we have plotted the relative energies corresponding to different Skyrme parametrizations with respect to the experimental binding energies [5]. The deviation from experimental values is very small for UNEDF0, and then comes SKP, both having effective mass 1. In Fig.(2), deformation parameter for ground (solid) as well as the isomeric (open) states are plotted and compared with available experimental values. Also, and the FRDM and RMF values are shown. We can find a transition of shape from prolate to oblate and vice versa. Most of the W isotopes in ground state have prolate shape. Moreover, isotopes having magic numbers have spherical configuration. All the Skyrme forces predicts similar trend of shape for all the isotopes with a few exceptions.

Different shapes (prolate, oblate or spherical) can co-exist in a nucleus if the energy difference between the ground and isomeric state is very small. With the aid of constrained calculations, we have obtained the energies corresponding to ground and excited states. Quantitatively, shape co-existence is defined as the energy difference between the ground and shape-isomer states. i.e, $\Delta E = E_{gs} - E_{iso}$. ΔE requires to be less than 2 MeV for a shape oscillation. The calculated value of ΔE as a function of mass number (A) is given in Fig. (3).

In the isotopic chain under investigation, we have found that in the case of UNEDF0 and SKP parametrizations, almost all the isotopes show shape co-existence. In the case of SkM* and SLy6, with less effective mass, this property is found to exist only for isotopes near to magic numbers. This can also be accounted for by the effect of surface symmetry coefficient (a_{surf}) of Skyrme interactions. The values of a_{surf} corresponding to SkM*, SLy6, SkP and UNEDF0 are 17.6, 17.7, 18.2 and 18.7, respectively [6]. Forces with large value of surface symmetry coefficient posses high surface tension and lead to less deformability and vice versa. A small change in this value causes a large variation in the energy difference between ground and excited states. So it may be concluded that SkP and UNEDF0 with large values of a_{surf}, have very small energy differences and show the phenomena of shape co-existence, while the other two parametrizations, have large energy difference between ground and the shape isomers.

Acknowledgements: One of the authors(Nithu Ashok) gratefully acknowledges UGC for the financial support under JRF scheme.

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