Microscopic Study of Pairing Energies and Separation Energies in Rhenium Isotopes within HFB Formalism

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Introduction

The most important part in the recent progress of nuclear structure studies and enrichment of our understanding of nuclear physics is mainly related to the availability of energetic radioactive ion beam (RIB) facilities and sensitive detection technologies. To get a clearer picture of the nuclear structure, we have to observe, a variety of structural phenomena and nuclear shapes in detail [1]. The ground state binding energy, revealing deep insight into the nuclear structure has applications in energy generation, medicine, and nuclear astrophysics. Here in this work, we have made an attempt to analyse the ground state properties of odd-even and odd-odd nuclides of Rhenium (Z=75) isotopes. These studies aim to address the properties like neutron pairing energy ($E_{pair}(n)$), binding energy (BE) and two-neutron separation energy (S_{2n}) in detail.

Theoretical Framework

In the present study, the ground-state properties of Re nuclei ranging from N=83 to N=136 have been reproduced by using the HFBTHO computer code (v2.00d) [2] with Universal Nuclear Energy Density Functional (UNEDF0) Skyrme parameterizations, which utilizes the axial transformed harmonic oscillator (THO) single-particle basis to expand quasi-particle wave functions. It iteratively diagonalizes the Hartree–Fock–Bogoliubov (HFB) Hamiltonian based on the generalized Skyrme-force until a self-consistent solution is obtained. Here we have employed the zero-range Skyrme interaction in the mean-field part and density dependent delta interaction (DDDI) in the pairing part. The HFB equation in matrix form is given by,

$$\begin{pmatrix} (h-\lambda) & \Delta \\ -\Delta^* & -(h-\lambda)^* \end{pmatrix} \begin{pmatrix} U_n \\ V_n \end{pmatrix} = E_n \begin{pmatrix} U_n \\ V_n \end{pmatrix} \tag{1}$$

where E_n is the quasiparticle energy and λ is the chemical potential.

Due to breaking of the time reversal symmetry, the theoretical calculations are difficult for odd mass nuclei. In the case of odd isotopes, computations are made by using the blocking of quasi-particle states called Equal Filling Approximation (EFA) to take care of the time reversal symmetry in the mean-field model.

In this work, we present our theoretical results of ground state properties like $E_{pair}(n)$, BE and S_{2n} of Rhenium isotopes. The two-neutron separation energy is given by,

$$S_{2n}(N,Z) = BE(N,Z) - BE(N\text{-}2,Z) \tag{2}$$

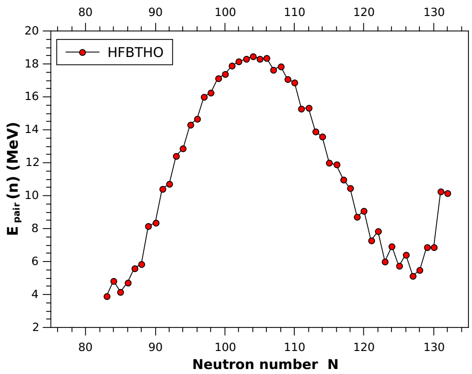

FIG. 1: Variation of neutron pairing energy with neutron number of Rhenium isotopes

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Results and Discussion

In the present study, first we have analysed the variation of neutron pairing energy with neutron number N of Re isotopes. From Figure 1, we observed that $E_{pair}(n)$ first increases with increase in N, reaches a maximum and then decreases. The decrease of the neutron pairing energy around N=126 may be due to the larger shell gap at this magic number. The computed values are in good agreement with the recently available experimental data [3] and the results from Relativistic Continum Hartee-Bogoliubov (RCHB) theories [4].

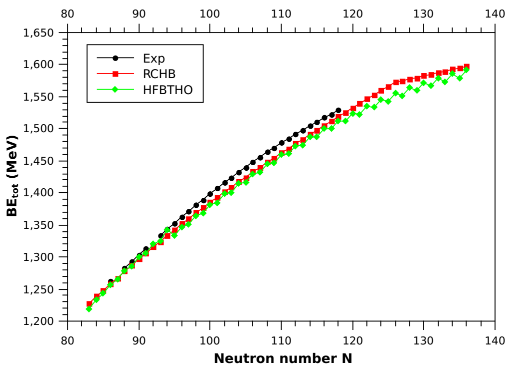

FIG. 2: Variation of total binding energy with neutron number of Rhenium isotopes

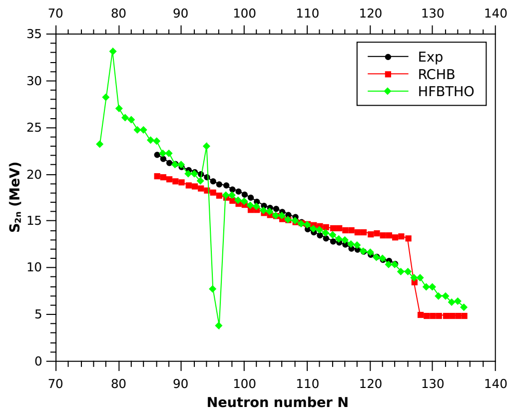

FIG. 3: Variation of two-neutron separation energy with neutron number of Rhenium isotopes

In Figure 2, we have analysed the results of total binding energy for a series of Re isotopes. Here we observe that the BE increases with increase in N. The sharp increase of BE values changes around N=126, indicating the neutron magicity. It can be seen clearly that, the theoretical estimates from HFB model are nicely matching with the experimental data and the values of RCHB theories.

The calculated results of 2-n separation energies of Re isotopes are shown in Figure 3. Our theoretical estimates are in resonable agreement with the experimental data and RCHB data. From the figure, it is evident that for Re isotopes, the S_{2n} values decrease gradually with increase in neutron number except at N=95 and N=126. There is a fall in S_{2n} value near these neutron numbers. This change in separation energy shows the signature of shell closure near N =126 for Re.

In summary, by using HFB approach we have estimated the ground state properties like $E_{pair}(n)$, BE and S_{2n} over a series of isotopes of Re nuclei. From the above figures, we can easily notice the odd-even staggering in all the three properties of Re isotopes considered here. Here we can see that, the nucleon pairing energy and 2-n separation energy play significant roles in deciding the closed shell nuclei in an isotopic chain. Also, the theoretically computed results from HFB model are reasonably reproducing the latest experimental observations and the resuls available from RCHB model.

Acknowledgments

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