Microscopic study of Binding Energies in Odd-Mass Exotic Isotopes within RHB and HFB Formalism

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Introduction

The physics of exotic nuclei is one of the most interesting and developing subjects in nuclear physics. The technical advancements in the available experimental facilities have made possible the study of the wide range of the nculides of the periodic table. The properties of exotic nuclei on the edge of existence play a fundamental role in our understanding of various nuclear properties and interactions. Exotic nuclei are characterized, in most cases by unbalanced ratio between the proton number (Z) and neutron number (N). Till now, we do not know much about most of the nuclei which exists and specially Odd-Mass nuclei as it is tedious task to study these nuclei due to breaking of the time reversal symmetry. We have made an attempt to investigate the ground state binding energies of the chain of Odd-Mass isotopes in Silicon and Sulphur. Ground state binding energy, and thus the mass of nucleus, is one of the characteristic properties, reflecting deep information of the nuclear structure which has applications in medicine, energy generation, and nuclear astrophysics. We present our theoretical results of ground state binding energies(B.E.) of Odd-A (A is mass number) nuclides of $^{23-43}$Si and $^{27-47}$S isotopes.

Method

The presented work has been done by using the models based on Hartree-Fock-Bogoliubov and Relativistic Hartee Bogoliubov (RHB) Theories. A brief discussion of these models is given below.

A. HFB Theory

This theory is a combination of Hartree-Fock (HF) and BCS theory. Details of the theory can be extracted from ref. [1, 2] based on the zero range Skyrme effective interactions [3] used in the mean field part.

B. RHB Theory

The total Lagrangian density of mesons exchange approximation (DD-ME2 parameterization) involving the isoscalar scalar σ meson, the isoscalar vector ω meson, and the isovector vector ρ meson can be written as [4],

$$\begin{aligned}\mathcal{L} = \sum_i \overline{\psi_i}(i\gamma_\mu\partial^\mu - m)\psi_i + \frac{1}{2}\partial_\mu\sigma\partial^\mu\sigma \\ -\frac{1}{2}m_\sigma^2\sigma^2 - \frac{1}{2}\Omega_{\mu\nu}\Omega^{\mu\nu} + \frac{1}{2}m_\omega^2\omega_\mu\omega^\mu \\ -\frac{1}{4}\vec{R}_{\mu\nu}\vec{R}^{\mu\nu} + \frac{1}{2}m_\rho^2\vec{\rho}_\mu.\vec{\rho}^\mu - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} \\ -g_\sigma\overline{\psi}\psi\sigma - g_\omega\overline{\psi}\gamma^\mu\psi\omega_\mu \\ -g_\rho\overline{\psi}\vec{\tau}\gamma^\mu\psi.\vec{\rho}_\mu - e\overline{\psi}\gamma^\mu\psi A_\mu \quad (1)\end{aligned}$$

Where, first term represents the Lagrangian of free nucleons with bare mass m and, $\overline{\psi}$ defines its Dirac spinors.

Result and Discussion

We present our results for Binding Energies for the Odd-Mass isotopic chains of Si and S nuclides. HFB Calculations are carried out for different skyrme parameterizations by using the HFB code [5] with harmonic oscillator basis and SLY5 parameterization [6]. RHB calculations are computed with DIRHB code [7] and DD-ME2 parameterization [4]. Binding

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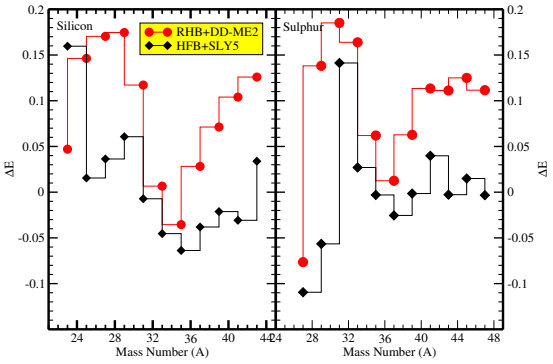

FIG. 1: (color online) ΔE in units of MeV, plotted as a function of mass number A for the exotic Odd-Mass nuclides of Si and S.

Energy is the underlying property of the nuclides which provides the deep insights about the nuclear structure. It is the energy required to disassemble a whole system into separate parts. In general, binding energy represents the mechanical work that must be done against the forces which hold an object together. Figure 1 represents the variation of the quantity ΔE against the mass number A of particular nuclides of Si and S. The quantity ΔE is defined as the difference between the Experimental Binding Energy [8] per nucleon and the Theoretical Binding Energy per nucleon.

$$\Delta E = \left(\frac{BE}{A}\right)_{Exp} - \left(\frac{BE}{A}\right)_{The} \qquad (2)$$

Our theoretical results are matching reasonably with the experimental results available [8]. These results also show that the quantity ΔE depends the type of effective interaction used. Negative values of the quantity ΔE defined in equation (2) shows that the theoretical estimates just exceeds the experimental data extracted from ref. [8]. The results obtained with the Relativistic-Hartree-Bogoliubov theory are shown in Figure 1 and it has been analysed that the absolute value quantity ΔE varies from 0.01 to 0.17 for Si isotopes and 0.01 to 0.19 for S isotopes. Absolute value of ΔE varies from 0.01 to 0.16 for Si isotopes and 0.003 to 0.19 for S isotopes, when the results are calculated with Hartree-Fock-Bogoliubov theory based on skyrme parameterization SLY5.

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