An Investigation of Binding Energy for Even-Even Exotic Isotopes within Skyrme-Hartree-Fock-Bogoliubov Formalism

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Introduction

The properties of exotic nuclei on the edge of existence play a fundamental role in our understanding of various nuclear properties and interactions. The physics of exotic nuclei is one of the fastest developing subjects in nuclear physics. The exotic nuclei have shorter life times and are characterized, in most cases by unbalanced ratio between the proton number(Z) and neutron number(N). The ground state binding energy, and thus the mass of nucleus, is one of the characteristic properties, revealing deep insight into the nuclear structure which has applications in medicine, energy generation, nuclear waste transmutation and nuclear astrophysics [3]. We present our theoretical results of ground state binding energies(B.E.) of even-even nuclides of $^{22-44}$Si, $^{26-48}$S, $^{30-52}$Ar and $^{36-58}$Ca isotopes. The theoretically computed results with UNEDF0 parameterization of functional are reasonably reproducing the latest experimental observations [4].

Method

We employed self-consistent mean field models analogous to Kohn-Sham density functional theory to construct the Skyrme Energy Density Functionals [1, 2] from Hartree-Fock-Bogoliubov Hamiltonian based on single-particle wave functions of the transformed harmonic oscillator with zero-range pairing interactions. For the proton states, we have added to the central potential, the direct Coulomb field

$$V_d^C(\mathbf{r}) = e^2 \int d^3\mathbf{r}' \frac{\rho_p(\mathbf{r}')}{|\mathbf{r}-\mathbf{r}'|} \qquad (1)$$

as well as the exchange Coulomb field, which in the present implementation is treated within the Slater approximation given below in equation:

$$V_{ex}^C(\mathbf{r}) = -e^2 \left(\frac{3}{\pi}\right)^{1/3} {\rho_p}^{1/3}(\mathbf{r}) \qquad (2)$$

Result and Discussion

Binding energy is the energy required to disassemble a whole system into separate parts. A bound system typically has a lower potential energy than the sum of its constituent parts and this is what keeps the system together. Often this means that energy is released upon the creation of a bound state. This definition corresponds to a positive binding energy. In general, binding energy represents the mechanical work that must be done against the forces which hold an object together. In the FIG.1, we have presented the results of fractional relative error (ΔE_f) in binding energy per nucleon for the even-even exotic isotopes of Silicon (green4 left triangles), Sulphur (blue right triangles), Argon (maroon circles) and Calcium (red squares). Fractional Relative error is computed by the relation $\Delta E_f = [(BE/A)_{exp} - (BE/A)_{theo}]/(BE/A)_{exp}$. A represents the total number of nucleons. Theoretical data is in good agreement with the experimental data [4] as we can see clearly in FIG. 1. For Silicon isotopes, The fractional relative error ranges from 0.01 (for ^{18}Si) to 0.08 (for ^{34}Si). For Sulphur isotopes, it ranges from 0.012 (for ^{32}S) to 0.05 (for ^{26}S). For Sulphur isotopes, ΔE_f

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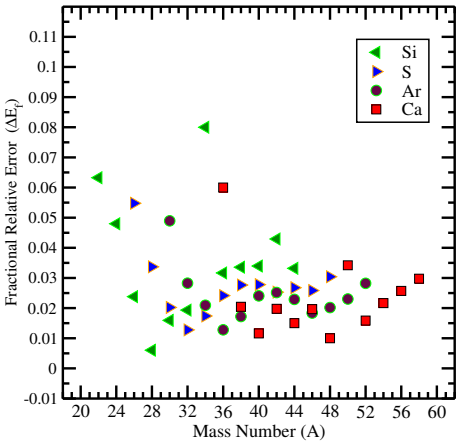

FIG. 1: (color online) Relative error variation in Binding energy per nucleon as a function of mass number (A) for the even-even exotic isotopes of Silicon, Sulphur, Argon and Calcium. The theoretical estimates are computed from Axially deformed solution of the Skyrme-Hartree-Fock-Bogoliubov equations using the transformed harmonic oscillator basis model (HFBTHO) based on Energy Density Functional (EDF) parameterization UNE0. The experimental data is taken from [4].

ranges from 0.013 (for ^{36}Ar) to 0.05 (for ^{30}Ar). Finally, for the Calcium isotopes, ΔE_f ranges from 0.01 (for ^{48}Ca) to 0.06 (for ^{36}Ca). The total range of the fractional relative error for all the exotic even-even isotopes of Si, S, Ar and calcium lies between 0.01 to 0.064 except for ^{34}Si, where it is 0.08. All and all, the theoretical data is in good agreement with the experimental data [4].

Upon analyzing FIG. 1, it can be easily deduced that the proton rich nuclides have more relative error in binding energy per nucleon than that of neutron rich nuclides. This is because of the fact that, in proton rich nuclides, the proton number is more than that of the neutron number and excess of proton number attributes to the coulomb charge distribution.

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