Nuclear Structure of Even-Even $^{128-208}Sm_{62}$ Isotopes

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Introduction

A key aspect in the field of nuclear physics and medicine is Samarium (Sm) as ^{144}Sm is utilized in nuclear reactor control rods and the isotope ^{153}Sm is used to cure many forms of cancer. There have so far been 34 ($^{129-162}Sm$) isotopes found, of which 7 are stable, 17 are neutron deficient, and 10 are neutron rich. Our primary objective is to examine the structure of Sm isotopes and look for shell or sub-shell closures in the range of $^{128208}Sm_{62}$ isotopic chains other than N=82 and N=126 using relativistic mean field (RMF) theory.

Theoretical Formulation

We start our calculation from the Lagrangian density [1–6] where the nucleons are Dirac spinors and mesons are bosons.

$$L = \overline{\psi_i}(i\gamma_\mu\partial_\mu - M)\psi_i + \frac{1}{2}\partial^\mu\sigma\partial_\mu\sigma - \frac{1}{2}m_\sigma^2\sigma^2 - \frac{1}{3}g_2\sigma^3 - \frac{1}{4}g_3\sigma^4 - g_s\overline{\psi_i}\psi_i\sigma - \frac{1}{4}\Omega^{\mu\nu}\Omega_{\mu\nu} + \frac{1}{2}m_\omega^2V^\mu V_\mu + \frac{1}{4}c_3(V_\mu V^\mu)^2 - g_\omega\overline{\psi_i}\gamma^\mu\psi_i V_\mu - \frac{1}{4}\overrightarrow{B}^{\mu\nu}\overrightarrow{B}_{\mu\nu} + \frac{1}{2}m_\rho^2\overrightarrow{R}^\mu.\overrightarrow{R}_\mu - g_\rho\overline{\psi_i}\gamma^\mu\overrightarrow{\tau}\psi_i\overrightarrow{R}^\mu - \frac{1}{4}F^{\mu\nu}F_{\mu\nu} - e\overline{\psi_i}\gamma^\mu\frac{(1-\tau_{3i})}{2}\psi_i A_\mu \quad (1)$$

The symbols have their usual meaning. Using classical variational principle we get the field equations i.e Dirac euation for nucleons and K.G equation for mesons. The static solutions of these equations gives us the ground state properties such as the binding energy. The solutions are carried out by a self consistent iteration method with initial deformation value β_0. We calculate quadrupole deformation parameter β_2 from the formula $Q = Q_n + Q_p = \sqrt{\frac{16\pi}{5}}(\frac{3}{4\pi}AR^2\beta_2)$ The separation energy is calculated using B.E values in the formula given below

$$S_{2n} = B.E(N,Z) - B.E(N-2,Z) \quad (2)$$

Using S_{2n} values in the equation given below, we calculate dS_{2n}

$$dS_{2n} = \frac{S_{2n}(N+2,Z) - S_{2n}(N,Z)}{2} \quad (3)$$

Results and Discussion

We obtain B.E./A, deformation parameter (β_2), two neutron separation energy (S_{2n}), and differential change of two neutron separation energy (dS_{2n}), in order to get some understanding of the structure of Samarium and to look for shell or sub-shell closure. In our previous work, using RMF model we have succesfully investigated ground state properties of some heavy and super heavy nuclei [3–6]. We choose the force parameters PK1 [7] and NLSH [8] since RMF theory is a successful parameter-dependent model.

The variation of B.E./A as a function of Sm's neutron number is shown in Fig. 1. Our calculated findings exhibit an extremely excellent agreement with experimentally accessible [9] data with FRDM [10] values as well as with that of the RCHB [11] model. In this case, all four of the models exhibit distinct kinks at N=82 and N=126. 82 and 126 are known neutron magic numbers, therefore it is to be anticipated. But when we examine the quadrupole deformation parameter (β_2), we obtain spherical shapes with no deformation at N=82,84, and 126 for both of the parameters we selected. However, the majority of isotopes are prolate

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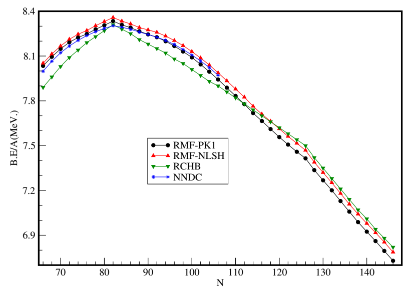

FIG. 1: Variation of B.E/A as a function of neutron number of Sm.

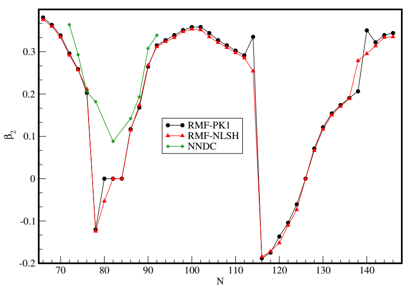

FIG. 2: Variation of β_2 as a function of neutron number of Sm.

in shape, despite the fact that prolate and oblate deformations are both frequent. Fig. 2. makes all of these things easy to observe.

The stability of an element in an isotopic series is shown by a larger nucleon separation gap, which denotes a shell or sub-shell closure. Fig. 3 depicts the variation in the rate of change of the two neutron separation energy (dS_{2n}) and S_{2n} as a function of the Sm isotopes.

We get fairly little kinks at N=86 and 92, with the sole exception of N=82 and 126. The results are extremely well reproduced as deep by the $dS_{2n} \sim N$ plot, providing validation of the findings. Furthermore, deeps at N=112 and 132 are achieved shown in the figure. As a result, we can speculate that neutrons at N=86, 92, 112, and 132 may have their sub-shells closed.

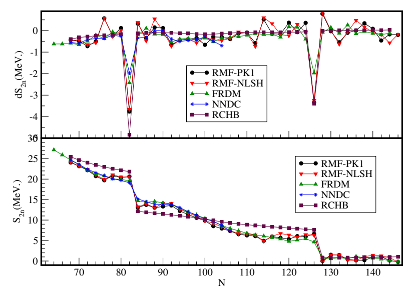

FIG. 3: Variation of separation energy as a function of neutron number of Sm.

Conclusion

According to B.E./A, the most stable isotopes in the isotopic sequence are $^{144}Sm_{62}$ and $^{188}Sm_{62}$. At N=82,84, and 126 for both of our parameters, we obtain spherical shapes with zero deformation. The majority of isotopes have a prolate form in their ground state. The S_{2n} and dS_{2n} investigation indicates that, besides major neutron shell closures at N=82 and 126, sub shell closures may occur at N=86, 92, 112, and 132.

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