Shell closure at N~154 of Es element

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Introduction

To get a deeper and clearer picture about the ground state structural properties of a nucleus we have to study about separation energies along with binding energies and nuclear radii [1]. Pairing of two neutrons at times results in two different locations of one neutron separation energies (S_{1n}) and two neutron separation energies (S_{2n}). So, it is important for us to study both S_{1n} and S_{2n}. We have also calculated the differential variation of S_{2n} (dS_{2n}) with respect to parent neutron number. In this paper we choose such an element which is of highest atomic no. of being observed in macroscopic quantity in its pure form i.e Es_{99} with mass no in the range 240≤A≤269. We have investigated the above said properties of Es isotopes with NL3*[2] and NLSH [3] force parameters using in axially deformed relativistic mean field model (RMF).

Formalism

The separation energies are calculated by using binding energies calculated with NL3*[2] and NLSH [3] force parameters in RMF formalism [4,5] in the formulas[6,4] given below

S_{1n} = B.E(N,Z) – B.E(N-1,Z)

S_{2n} = B.E(N,Z) – B.E(N-2,Z)

And

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

And the starting point of our Q-value calculation is the relativistic Lagrangian density for many body system [4,5]

$$\begin{aligned} L = {} & \bar{\psi_i}(i\gamma^\mu\delta_\mu - M)\psi_i + \frac{1}{2}\delta^\mu\sigma\delta_{mu}\sigma - \frac{1}{2}m_\sigma^2\sigma^2 \quad (1) \\ & -\frac{1}{3}g_2\sigma^3 - \frac{1}{4}g_3\sigma^4 - g_s\bar{\psi_i}\psi_i\sigma - \frac{1}{4}\Omega^{\mu\nu}\Omega_{\mu\nu} \\ & +\frac{1}{2}m_\omega^2 V^\mu V_\mu + \frac{1}{4}c_3(V_\mu V^\mu)^2 - g_\omega\bar{\psi_i}\gamma^\mu\psi_i V_\mu \\ & -\frac{1}{4}\vec{B}^{\mu\nu}.\vec{B}_{\mu\nu} + \frac{1}{2}m_\rho^2\vec{R}^\mu.\vec{R_\mu} - g_\rho\bar{\psi_i}\gamma^\mu\vec{\tau}\psi_i.\vec{R^\mu} \\ & -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} - e\bar{\psi_i}\gamma^\mu\frac{(1-\tau_{3i})}{2}\psi_i A_\mu \end{aligned}$$

Result and Discussion

The variation of S_{1n} and S_{2n} with neutron number of parent nuclei (N) is shown in figure-1 and figure-2 respectively.

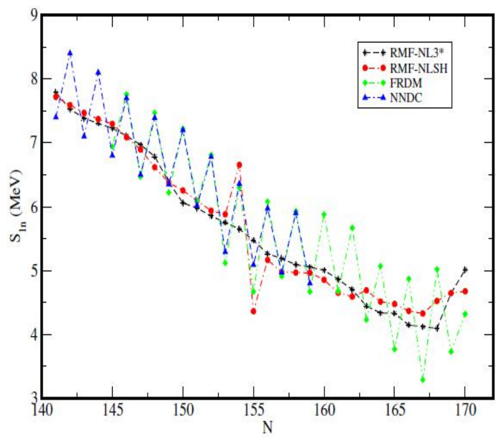

FIG-1: Plot of one neutron separation energy of Es as a function of neutron number (N)

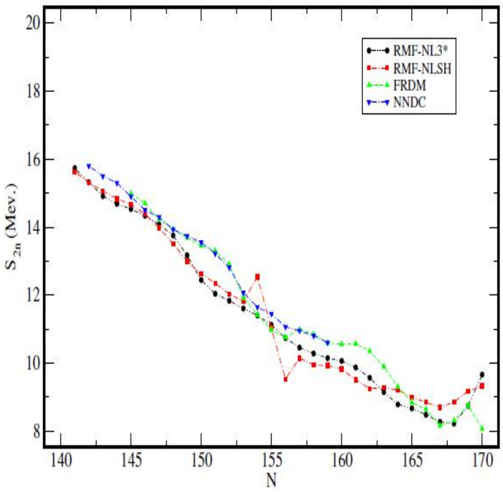

FIG-2: Plot of two neutron separation energy of Es as a function of neutron number (N)

The obtained results are compared with experimentally available data and also with finite range droplet model (FRDM) [6]. In FIG-1 we see similar oscillatory structures with peaks at even N for FRDM and experimental curves. The NL3* and NLSH curves are gradually decreasing monotonous curves except at N=154 for NL-SH curve. FIG-2 also shows a clear peak at N=154 for the RMF-NLSH curve. The peaks at N=154 both in S_{1n} and S_{2n} indicate a greater stability of the nuclei against neutron emission.

The two neutron separation energies and their evolution with neutron number are a very good beginning point for investigating various nuclear structure models. The variation of dS_{2n} (N,Z) with neutron number N shows nonlinear structure which can be observed from FIG-3. In Fig-3 the RMF-NLSH curve shows a deep at N=154 which is thought as due to shell closure of neutron confirming the results of S_{1n} and S_{2n} graph. We mentioned here as a major shell closure at N =154. In addition to this, dS_{2n} clearly shows non-linear behavior at N = 159. It conveys a possible phase/shape transition [7] and its dependence on proton number is reflected in the behaviour of S_{2n}.

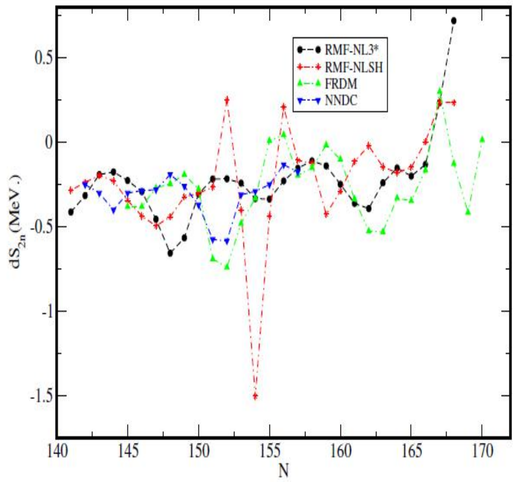

FIG-3: Plot of differential variation of two neutron separation energy of Es as a function of neutron number (N).

Conclusion

The calculated neutron separation energies S_{1n} and S_{2n} using binding energies obtained with NL3* and NLSH force parameters in RMF describe the shell closure of neutron at N=154 and stability against neutron decay of Es isotope providing a good contribution towards the study of structural properties of Es isotopes.

References

[1] DAE Symp. on Nucl. Phys. 64 (2019)
[2] G.A Lalazisis, J. Köning, and P. Ring, Phys. Rev. C 55, 540 (1997)
[3] M.M. Sharma, M.A. Nagarajan, and P. Ring; Phys. Lett. B312 (1993) 377
[4] Rashmirekha Swain B.B. Sahu, S.k. patra, Chin. Phys. C 42, 084102 (1-9)(2018).
[5] R R Swain et. all, International Journal of Modern Physics E ,Vol. 28, No. 6 1950041 (2019).
[6] P. Mller, J.R. Nix, and K. -L. Kratz, At. Data and Nucl. Data Tables, 66: 1318 (1997)
[7] F. Iachello, and N. V. Zamfifir, Phys Rev. Lett., 92: 212501 (2004)