Structural properties of Super-heavy Nuclei with $Z = 126$

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Introduction

The competition between the Coulomb repulsive force and the nuclear attractive force leads to the formation of super-heavy nuclei (SHN) which becomes the hot area for nuclear science, now a days due to possible island of stability beyond ^{208}Pb is a matter of discussion from last five decades [1–3]. Earlier, it was predicted that the next proton magic number beyond $Z = 82$ would be 126 considering the equality of the proton and neutron magic numbers for known closed shell nuclei. However, several microscopic calculations suggests a shift of this number to 114. One of the cause of the shifting is the Coulomb effect on the spherical single particle levels. Again the nuclei with zero shell effects would not be stable and decay immediately, as predicted by macroscopic liquid drop models for $Z > 100$ nuclides. Recently, however, the spectroscopic studies of the nuclei beyond $Z = 100$ have become possible [4], and the heaviest nucleus studied so far in this series of experiments [5] is ^{254}No (Z=102, N=152) and the synthesis of heaviest element in laboratory is $Z = 118$ in the hot fusion reaction process at JINR Dubna [6] . So the possibility of the existence of these super-heavy elements is mainly due to the attractive shell corrections against the destructive Coulomb repulsion. Thus, the progress in experimental techniques has drawn our attention and opened up the field once again for further theoretical investigations in structure physics of nuclei in the super-heavy mass region. In the present work, our aim is to look for a suitable combination of proton and neutron in such a way that the resultant combination will be the next magic nucleus after ^{208}Pb. This work is not a new, but a revisit of the systematic investigation of nuclear structure and reconfirmed the double closed nucleus as $Z = 126$ with $N = 209$.

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Theoretical formalism

The relativistic mean-field Lagrangian density for many body system is taken as [7]

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

All the quantities have their usual well known meanings. From the above Lagrangian we obtain the field equations for the nucleons and mesons. These equations are solved by expanding the upper and lower components of the Dirac spinors and the boson fields in an axially deformed harmonic oscillator basis, with an initial deformation β_0. We use the well known NL3 parameter set [8]. This set reproduces the properties of not only the stable nuclei but also well predicts for those far from the β-stability valley.

Results and discussion

In this present work we study the structural properties of $Z = 126$ super-heavy element within the range $306 \leq A \leq 339$ by employing the relativistic mean-field theory (RMF). Since binding energies are the most important quantities of nuclei which directly

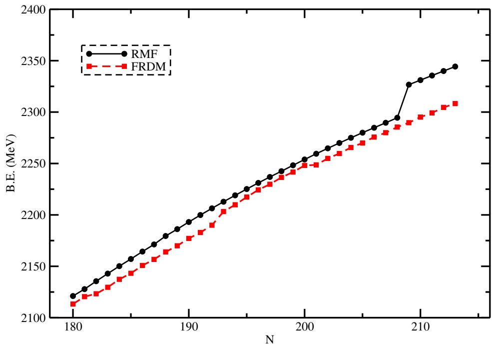

FIG. 1: The plot between the neutron number and the binding energies of RMF (black line with circle) and FRDM (red line with square)

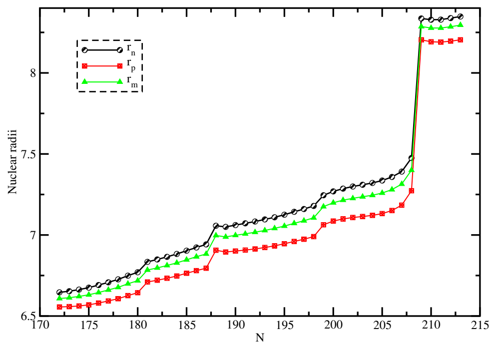

FIG. 2: The plot between the neutron number and the nuclear radii in RMF formalism r_n(black line with circle), r_p(red line with square), r_m(green line with triangle)

related to the stability of nuclei we have shown in Figure.1 for all the isotopes. From the figure, it is clearly observed that, the BE obtained in both the RMF [7] models and FRDM [9] are showing similar nature. The nuclear radii for proton (r_p), neutron (r_n) and matter (r_m), in RMF formalism is shown in figure.2. The figure shows that, the radii show smoothly increasing in nature till $A = 334$ and after that it attains a sharp jump at $A = 335$ (Z=126,N=209). All the rms radius are showing the same monotonic nature. There is no other data or calculations available for comparison.

Conclusion

Concluding, we have studied the ground state properties like binding energy, nuclear radii and other observables of super-heavy nuclei Z = 126 by using RMF formalism with NL3 force parameters. From the obtained binding energy, we also calculate the neutron separation energy (S_n) and two-neutron separation energy (S_{2n}) which will be presented at the conference. From the neutron separation energy we also found the magicity characteristics at $N = 209$. From the binding energy analysis, we found that the most stable isotope in the series is ^{335}126, i.e. at $N = 209$.

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