Evolution of N = 32,34 shell closure in relativistic mean field theory

Bharat Kumar[1,2],* S. K. Biswal[1,2], and S. K. Patra[1,2]
[1] *Institute of Physics, Bhubaneswar-751 005, India. and*
[2] *Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai 400085, India*

Introduction

The evolution of the shell structure far away from the stability is one of the main research endeavors. The numbers 2, 8, 20, 28,..., which represent the number of protons or neutrons of closed-shell spherical nuclei, have been interpreted with considerable success by the single-particle shell model . Nowadays, these numbers are well reproduced by microscopic calculation like Hartree-Fock (HF) or Hartree-Fock-Bogoliubov (HFB) mean-field approaches, in which the nucleon-nucleon interaction is either taken as a parameterized effective force or modeled with meson exchange in a relativistic formalism. Magic numbers being associated with a shell closure, i.e. with a large energy gap between occupied and unoccupied single-particle levels, pairing correlations usually are weak or absent in the ground state (GS) of magic nuclei.

In present calculations, we evaluated N = 32,34 the shell clouser of the nuclei K, Ca and Sc, within the framework of relativistic mean field(RMF)[1] approach using NL3 parameter set. A definite set of coupled equations are obtained from the Lagrangian which are solved self-consistently in an axially deformed harmonic oscillator basis with $N_F = N_B = 12$, Fermionic and Bosonic oscillator quanta, respectively. New magic numbers and new islands of stability lies in the range defined by two-neutron separation energy and differential two-neutron separation energies are presented.

*Electronic address: bharat@iopb.res.in

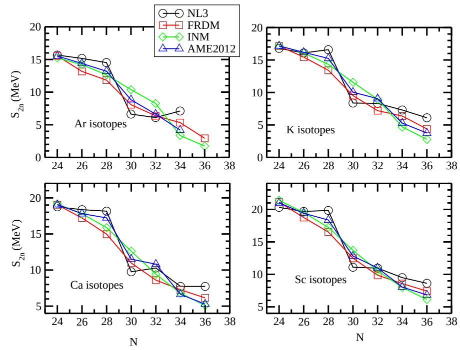

FIG. 1: The S_{2n} energy as a function of neutron number for Ar,K, Ca and Sc isotopes are compared with the experimental data[2] and theoretical results wherever available[3].

Results and Discussion

Two-neutron separation energy $S_{2n}(Z, N)$ and differential variation of the two-neutron separation $dS_{2n}(Z, N)$, can be estimated from the ground-state nuclear binding energies.

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

The calculated S_{2n} energy from RMF as a function of neutron number for Ar, K, Ca and Sc isotopes are compared with latest experimental data [2]. From the Fig. 1, it is clear that in an isotopic chain, the S_{2n} energy shows the well-known route for a given atomic number, i.e, the S_{2n} decrease smoothly as the number of neutron increases in an isotopic chain. Sharp kinks appear at neutron magic numbers at N=28 and 32. These kinks are more clear,

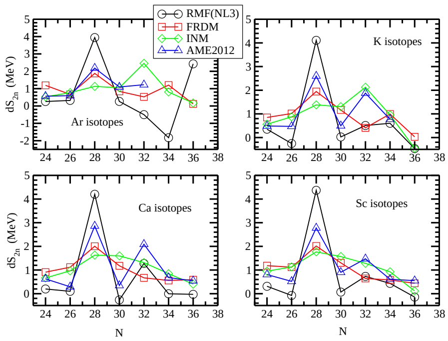

FIG. 2: The differential variation of the separation energy dS_{2n} as a function of neutron number for Ar, K, Ca and Sc isotopes with the experimental data[2] and theoretical calculations wherever available[3].

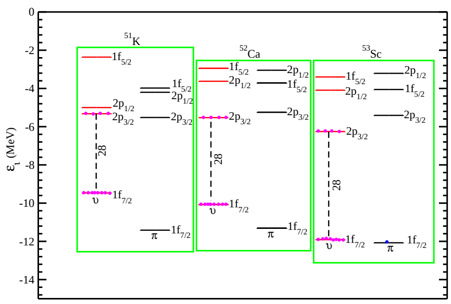

FIG. 3: The single-particle energy levels for ^{51}K, ^{52}Ca, and ^{53}Sc from RMF model with NL3 force parameter.

when we calculate the $dS_{2n}(Z,N)$ for NL3 force parameter which is displaced in Fig.2. In general, the large, sharp and deep fall in the dS_{2n} over a isotopic chain shows the signature of neutron shell closure. As a further confirmatory test, the single-particle energy levels for neutrons in isotopic chain are examined. The obtained single-particle levels ϵ_i for ^{51}K,^{52}Ca and ^{53}Sc isotopes near Fermi levels are shown in Fig.3. We get shell closure at N=28, and 32 for ^{52}Ca and ^{53}Sc. However, we do not see considerable gap at N=32 for ^{51}K, instead we noticed a reasonable shell gap at N=34 for this nucleus. We get ϵ_i=2-3 MeV for 2p$_{3/2}$-2p$_{1/2}$ in case of ^{52}Ca. For ^{53}Sc, the odd proton(π) is located in the 1f$_{7/2}$ state, as evidenced by the ground-state spins and parities of odd-A Sc isotopes. The ^{53}Sc isotope is also support the N= 32 shell gap between the orbital 2p$_{3/2}$ and 2p$_{1/2}$ within the range of nearly 2 - 3 MeV.

Summary and Conclusion

We have used self-consistent relativistic mean-field theory with the most popular NL3 force parameter to study the evolution of the N=32,34 shell closure in ^{51}K, ^{52}Ca and ^{53}Sc isotopes. We calculated the binding energy, two neutron separation energy, differential variation of separation energy and the single-particle energy levels of the above nuclei. The microscopic calculation of ^{51}K isotope shows that 2p$_{1/2}$ and 1f$_{5/2}$ neutron orbitals gives the N=34 magic number. But N=34 can not be predicted in the case of ^{52}Ca and ^{53}Sc isotopes. These isotopes support the N=32 magic number with neutron orbitals 2p$_{3/2}$ and 2p$_{1/2}$.

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