The structure and stability of superheavy nuclei

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After the discovery of artificial transmutation of elements by Sir Ernest Rutherford in 1919 [1], the search for new elements is an important issue in nuclear science. The existence of 14 more transuranium elements beyond the last heaviest naturally occurring ^{238}U, which make a separate block in Mendeleev′s periodic table was a revolution in the Nuclear Chemistry. This enhancement in the periodic table raises few questions in our mind:

- Whether there is a limited number of elements that can co-exist either in nature or can be produced from artificial synthesis by using modern technique ?
- What is the next double shell closure nucleus beyond ^{208}Pb ?

To answer these questions, first we have to understand the agent which play the important role in the nucleus against Coulomb repulsion. The obvious reply is the shell energy, which stabilises the nucleus against Coulomb disintegration [2]. In this work, our aim is to look for the next double shell closed nucleus beyond ^{208}Pb which may be a possible candidate for the experimentalists to look for. For this, we have used two well-defined but distinct approaches (i) non-relativistic Skryme-Hartree-Fock (SHF) with FITZ, SIII, SkMP and SLy4 interactions [3, 4] (ii) Relativistic Mean Field (RMF) formalism [5] with NL3, G1, G2 and NL-Z2 parameter sets. These models have been successfully applied in the description of nuclear structure phenomena both in $\beta-$stable and $\beta-$unstable regions of the periodic chart. The constant strength

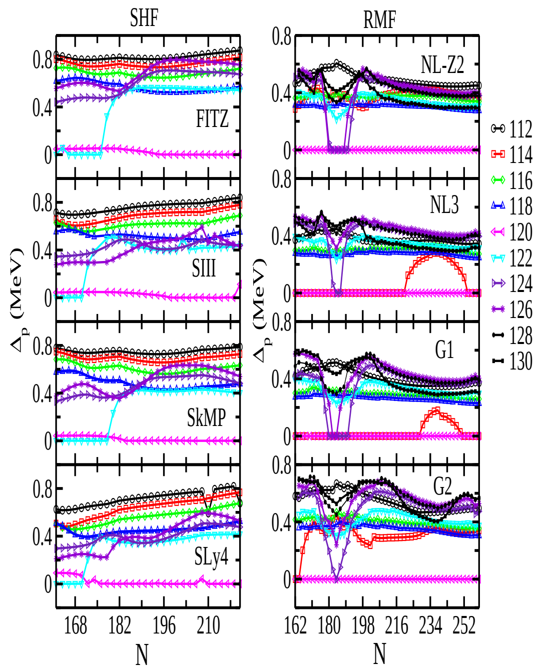

FIG. 1: The proton average pairing gap Δ_p for Z=112-126 with N=162-220 and Z=112-130 with N=162-260.

scheme is adopted to take care of pairing correlation [6].

A wide range of nuclei starting from the proton-rich to the neutron-rich region have scanned in the superheavy valley (Z=112 to Z=130). It is well understood and settled that the properties of a magic number for a nuclear system has the following characteristics:

- The average pairing gap for proton Δ_p and neutron Δ_n at the magic number is minimum.
- The binding energy per particle is maximum compared to the neighboring one,

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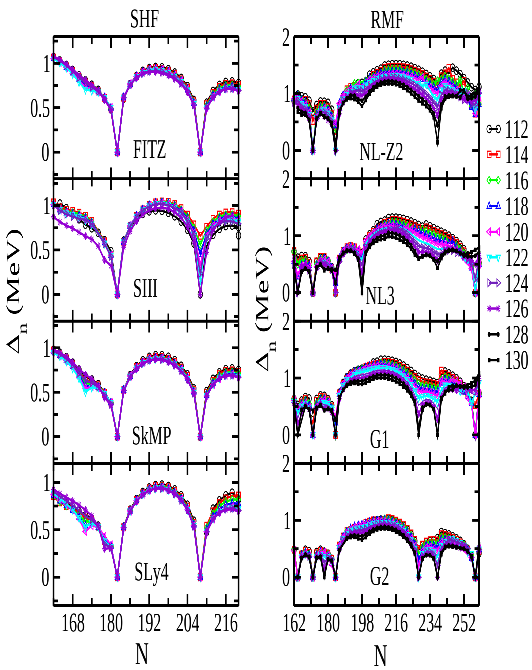

FIG. 2: Same as FIG.1 but for neutron average pairing gap Δ_n.

i.e.there must be a sudden decrease (jump) in two neutron (or two proton) separation energy S_{2n} just after the magic number in an isotopic chain.

- At the magic number, the shell correction energy E_{shell} is maximum negative. In other words, a pronounced energy gap in the single-particle levels $\epsilon_{n,p}$ appears at the magic number.

We focus on the shell closure properties in the superheavy valley based on the above defined three important observables. To identifying these, we have calculated the pairing gap Δ_p and Δ_n, two-neutron separation energy S_{2n}, shell correction energy E_{shell} and single-particle energy $\epsilon_{n,p}$ for the whole Z =112−130 regioncovering the proton-rich to neutron-rich isotopes. To our knowledge, this is one of the first such extensive and rigorous calculation in both SHF and RMF models using a large number of parameter sets. For a representative case, the Δ_p and Δ_n for RMF and SHF are displayed in Fig 1. and 2. From the figures, the Δ_p vanishes at Z=120 with Δ_n almost zero for N=182,208 and N=172,184,258 for SHF and RMF respectively. Moreover, we have similar results for S_{2n}, E_{pair}, E_{shell} and $\epsilon_{n,p}$. Although the results depend slightly on the forces used, the general set of magic numbers beyond ^{208}Pb are Z=120 and N=172, 182/184, 208 and 258. The highly discussed proton magic number Z = 114 in the past (last four decades) is found to be feebly magic in nature.

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