Search for next neutron shell closure in superheavy region

S. Santhosh Kumar[1,*] and R. Rengaiyan[2]
[1]*Dept. of Physics, Avvaiyar Govt. College for Women, Karaikal – 609 602, U.T. of Puducherry, INDIA*
[2]*Dept. of Physics, Arignar Anna Govt. Arts College, Karaikal – 609 605, U.T. of Puducherry, INDIA*
**email: santhosh.physics@gmail.com*

Introduction

The stability of the heaviest and superheavy elements have been a long-standing fundamental question in nuclear science. Theoretically, the mere existence of the heaviest elements with Z>104 is entirely due to the quantal shell effects. If the heaviest nuclei were governed by the classical liquid drop model, they would fission immediately from their ground states due to the large electric charge. However in the mid 1960s, with the invention of the shell-correction method, it was realized that atomic numbers could exist due to the strong shell stabilization [1-3]. Most of the heaviest elements found recently are believed to be well deformed. Since in the region of superheavy elements the single particle level density is relatively large, small shifts in position of single particle gaps and be crucial for determining the shell stability of the nucleus.

Spherical Shell closure

Most macroscopic-microscopic approaches predict Z = 144 to be magic, self consistent calculations suggest that the centre of proton shell stability should be moved upto higher proton numbers Z = 120, 124 or 126 [4]. According to ref. [4] the spherical magic neutron number in the superheavy region is N = 184; all the N = 184 isotones have been predicted to have spherical shape. Also it was reported that forces with small effective masses(ie., small level density) are much more likely to show significant shell effects at lower neutron numbers around N=172. The original island of superheavy elements is predicted to be around Z=114 and N=184 [5] mainly due to the fact that $^{184}114$ is predicted to be doubly magic nucleus with spherical shape, where shell effect is the strongest. At the line of connecting the nucleus with maximum binding energy per nucleon in each isotopic chain, nuclei with fixed proton number have maximum binding energy per nucleon, therefore they would be stable against neutron emission, which can play an important role to synthesize superheavy nuclei.

Methodology

In this method the level density is obtained from the relation $\rho(E^*) = (kTN_o\ln 2)^{-1}\exp[s(E^*)]$ where the entropy $S(E) = -\Sigma[(1-n_i)\ln(1-n_i)+n_i\ln n_i]$. n_i are the single particle occupation probability. The neutron separation energy is obtained from the relation $S_N=TN/\{\Sigma[(1-n_i^N)n_i^N]\}$. The total excitation energy is obtained from $E_x=U(M,T)=U_{eff}(T)+E_{rot}(M)$ and the cranked Nilsson method is used to obtain the single particle energies.

Results and Discussion

Superhavy nuclei formed either through hot fusion reaction or cold fusion reaction may be in excited states and hence their decay will be greately influenced by thermal and collective excitation. The stability of the nucleus mainly depends on its decay mode, such as α-decay, particle decay, etc. In the context of neutron emission the experimentally discovered nuclei in the superheavy region shows a different trend that the shell closure may exist at neutron number N=178, which is more pronounced than N=184. It is to be noted here that the nuclei considered are from Z=104-118. Here we have calculated the neutron separation energy(S_N) and thus the level density of around ninety isotopes in the said region. The calculated neutron separation energies for even-even and odd-odd nuclei are shown in figs.1 and 2. The figures reveal that the S_N is more at N=178 than at 184 and 172, which is different from many literatures by α-decay study. As Z increases the peak maximum falls at N=178 for Z≥112. Ofcourse, we found all the isotones of Z = 114 is spherical at its ground state neutron emission probability is very less in the isotone with N = 178. This analysis, therefore, indicates the existence of shell closure at N=178, which depends on the combination of both proton and neutron numbers rather than on either one alone. This result shows a conceptual behavior in close with the findings of Gambhir et al. [6] and Lalazissis et al. [7]. The nuclear level density for these nuclei are also calculated and a higher fluctuation is find for Z=112 at N = 178 and closure neutron numbers, which indicates the least stability of isotope $^{290}112$. Compared to proton separation energy S_N is always more and it shows the possibility of neutron emission or α-particle emission when sufficient energy is gained by the nucleus.

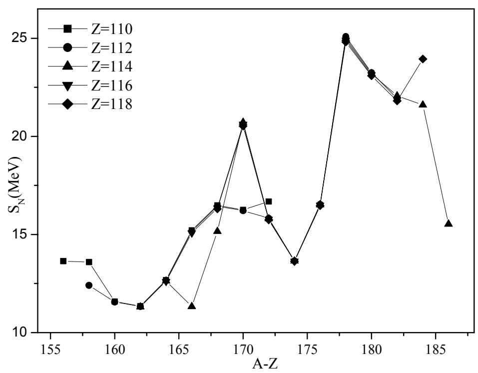

Fig.1 S_N Vs neutron number for even-even nuclei

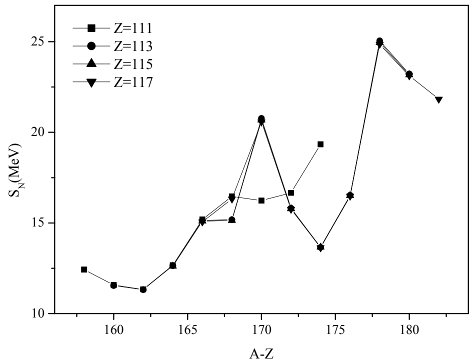

Fig.2 Neutron separation energy Vs neutron number for odd-odd nuclei

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References

[1] W.D.Myers and W.J.Swiatecki, Nucl. Phys., **81**, (1966) 1.
[2] A.Sobiczewski et al., phys. Let. **22**, (1966) 500.
[3] U.Mosel and W. Greiner, Z. Phys. **222**, (1969) 261.
[4] S.Cwiok et al., Nucl. Phys. **A611**, (1996) 211.
[5] C.samanta and S.Adhikari, Phys. Rev. **C65**, (2002) 037301.
[6] Y.K.Gambhir et al., ann. Phys., **320**, (2005) 429.
[7] G.A.Lalazissis et al., Nucl. Phys. **A608**, (1996) 202.