STUDY OF N = 16 SHELL CLOSURE WITHIN RMF+BCS APPROACH

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One of the most important problems in nuclear physics today is to understand how shell structure changes with neutron-to-proton ratio throughout the nuclear chart. It has been established now that shell structure influences the locations of the neutron and proton drip lines and the stability of matter. Few examples of changes in shell structure are the appearance of new magic numbers N = 16 in the ^{24}O [1, 2] and the emergence of an N = 32 sub-shell closure in ^{52}Ca [3]. In this paper we have investigated N = 16 shell closure with the use of Relativistic Mean Field plus BCS approach [4, 5]. Our RMF calculations have been carried out using the model Lagrangian density with nonlinear terms both for the σ and ω mesons as described in detail in Ref. [4].
We have calculated two neutron shell gap for C and O isotopes using RMF+BCS approach using TMA force paramenter [5]. The abrupt increase in shell gap for shell closure is found for N = 8 which is a conventional shell closure. Moreover, another rise in two neutron shell gap is found while moving from N = 14 to N = 16 for both C and O isotopes. This gives rise to new spherical shell closure at N = 16 for ^{22}C and ^{24}O. For higher Z isotopes like Ne, Mg etc. this shell gap at N = 16 is not so pronounced. It is also gratifying to note that our result from RMF+BCS using TMA parameters [5] are in good agreement with the experimental data [6]. To get into more insight, we have also studied neutron single particle energy for N = 16 isotones as a function of Z ranging from 6 to 20. This shell closure at N = 16 is due to gap between $2s_{1/2}$ and $1d_{3/2}$ state which is found more than 3 MeV for Z = 6 and 8. For Z = 6, $1d_{5/2}$ and $2s_{1/2}$ are found nearly at same energy, and for higher Z the $2s_{1/2}$ state moves towards $1d_{3/2}$ state resulting a diminished energy gap for N = 16. Even for Z = 20, $2s_{1/2}$ state almost overlaps with $1d_{3/2}$ state. Therefore, towards proton rich side i.e. at Z = 20 for Ca isotopes these two states $2s_{1/2}$ and $1d_{3/2}$ get separated from $1d_{5/2}$ state in this fashion that they develop a new shell gap at N = 14. Hence, moving towards neutron rich to proton rich side this reorganization of sd shell results N = 16 shell closure to N = 14 shell closure. Therefore from our calculations ^{34}Ca is found to be another doubly magic nucleus in Ca isotopic chain.
Since now shell closure at N = 16 in ^{24}O is experimentally established [1, 2] and from this paper we predict that the same shell closure N = 16 should also occur in ^{22}C. To clarify the above statement we have also calculated pairing energy contribution for C isotopes with the use of TMA [5], NLSH [7] and NL3 [8] and observed that pairing energy vanishes at N = 6, 8 and 16 giving rise to two new shell closure at N = 6 and N = 16 giving further support to N = 16 shell closure in C isotope as found in ^{24}O. It is also important to note that our results from three different parameters i.e. TMA, NLSH and NL3 are similar and provide support to the doubly magic character of ^{22}C.

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