Particle-hole Symmetry the Characteristic of Spherical-configuration Rule Out Theoretical Prediction of Shell Quenching in N=82

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Introduction

The evidence of magic number has been observed from the appearance of discontinuities in the systematic study, for examples, in binding energies, separation energies, first excited states in even-even nuclei, and electromagnetic transition rates.

We have seen in this decades, some magic numbers disappeared and new shell gaps appear in certain regions (far from stability line) of the nuclear chart. These observations triggered numerous theoretical investigations. Therefore, that need more work to figure out clear picture. The enhancement in the energy of 2^+ state in even-even nuclei might be contributed by other interaction apart from the closed shell configuration.

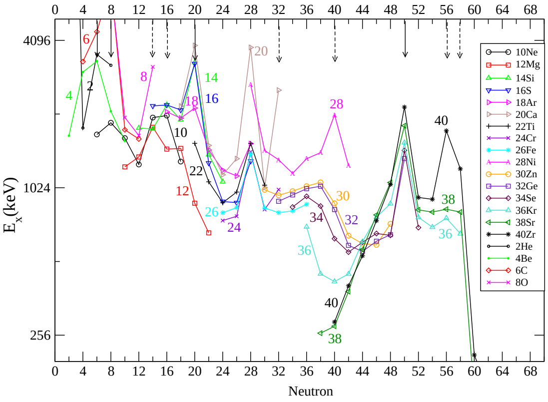

FIG. 1: Experimentally known energies of the first excited 2^+ states in the even-even nuclei.

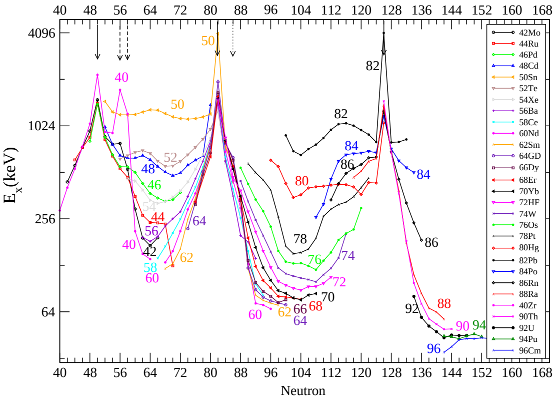

FIG. 2: Experimentally known energies of the first excited 2^+ states in the even-even nuclei.

The main purpose of the present manuscript is to review the magic number with respect to their feature of spherical structure along the isotonic and isotopic chains and new magic numbers will also be commented on. Attempts to disprove the prediction [1-3] of shell quenching in N=82 shell has been made on the basis of particle-hole symmetry.

Experimental observations

The energy of first excited 2^+ state in even-even nuclei (isotopic chains) is shown in Fig. 1, 2. The energy variation maxima 'peaks' appear at neutron number (2, 6, 8, 20, 28, 50, 82, 126), as well as for proton number in isotonic chain for all most nuclei around the stability line. The small and sudden change in energy appears for certain nucleon number (14, 16, 32, 40, 56, 58, 64, 86) in few nuclei.

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Discussion

An Essential Condition for Spherical Configuration of Magic Number Known as Particle-hole Symmetry

Only those magic numbers must be called closed shell configuration (spherical configurations) if only their close by valence particles/holes exhibit particle-hole symmetry. In the reference of spherical magic number, the energies of 2^+ states decrease as the number of nucleon in next open shell increases up to mid shell filled, and also the energies of 2^+ states decrease as the number of nucleon in same shell decreases upto mid shell opened. This could be because the deformation increases as the number of valence particles/holes increases. The enhanced in the energy of 2^+ state at certain number in some cases could not be closed shell configurations. That could be some other interactions due to certain number of protons and neutrons.

Spherical Configuration Expected for New Magic Number 14 and 16

In order to generate an excited 2^+ state in a doubly magic nucleus at least one nucleon has to be excited across the shell gap, since all single-particle levels are fully occupied and coupled to a total spin J = 0, such that a simple recoupling of angular momenta to J = 2 is not possible. Such excitation leads to a high excitation energy of several MeV for the 2^+ state. In even-even nuclei with one closed and one open shell, the energy of 2^+ state is less then the doubly closed shell nuclei, the reason is due to break a pair of nucleons in the open shell, about 1-1.2 MeV. The energy of 2^+ state in doubly magic nuclei, except for 2, 6, 8, is observed about 4 MeV. It has been proved from shell model that the energy gap for spherical potential between two shells is almost same. The energy of 2^+ state in doubly magic nuclei with 14, 16 is also observed about 4 MeV. On the other hand, close by nucleons number corresponding to 14, 16 show little bit particle-hole symmetry. Therefore, 14, 16 might be spherical magic number.

Objection to the Theoretical Prediction of Shell Quenching in ^{128}Pd

Phenomena like the quenching [1] of the known shell gaps studied, theoretically. It predicted theoretically [1–3] that quenching of shell (82) would be appeared in $^{128}_{46}\mathrm{Pd}_{82}$, $^{130}_{48}\mathrm{Cd}_{82}$. The shell gaps appear for (N = 82) in $^{134}_{52}\mathrm{Te}_{82}$, $^{136}_{54}\mathrm{Xe}_{82}$. Therefore, the particle-hole symmetry (from proton shell with 50) does not support shell quenching in $^{128}_{46}\mathrm{Pd}_{82}$, $^{130}_{48}\mathrm{Cd}_{82}$. Recently experimental results of ^{130}Cd [4] provides no evidence for N=82 shell quenching in this nucleus. Therefore, there will be no shell quenching expect in $^{128}_{46}\mathrm{Pd}_{82}$ from the particle-hole symmetry. However, the energy of 2^+ state in $^{128}_{46}\mathrm{Pd}_{82}$ is needed to disprove the theoretical prediction of shell quenching in $^{128}\mathrm{Pd}_{82}$.

References

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