THE EFFECT OF THE PAIRING INTERACTION ON THE ISOSPIN FORBIDDEN $0^+ \rightarrow 0^+$ BETA DECAYS

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INTRODUCTION

The studies of super allowed nuclear beta decays play an important role in determining the value of weak coupling constant G_V because there is a simple relation between the measured ft values for such decays and the weak coupling constant when isospin is a conserved quantum number. These studies also provide data for a stringent test of the electro-weak interaction properties [1-3]. It is possible to determine the Cabibbo-Kobayashi-Maskawa (CKM) mixing amplitude between u and d quarks [1] if the vector coupling constant of nuclear β decay is combined with that of muon β decay. Thus, for the calculation of the weak coupling constant with a great accuracy, it is needed to measure experimentally the ft values for such decays very precise and to determine the isospin impurities, in the nuclear states caused by the electromagnetic interaction or by possible other interaction components violating charge independence. However, the greatest contributions to the uncertainty in G_V come not from the experimental ft values, but from the theoretical correction terms [4]. The test of the calculations done for the theoretical correction terms can be provided by the measured decay matrix elements for the isospin forbidden Fermi β decays to non-analog 0^+ states in the daughter nuclei [5-7].

In the present study, based on Pyatov-Salamov method [8], the Log(ft) values for the isospin forbidden $0^+ \to 0^+$ Fermi β decay in some nuclei have been calculated and the dependence of the Log(ft) values on the isovector (η) and pairing correlation (C) parameters of the average field potential. The details of Pyatov-Salamov method and the formalism used in numerical calculations have been given in Ref. [8,9].

RESULTS AND DISCUSSION

In the calculations, the Woods-Saxon potential with the Chepurnov parameterization [10] was used. The basis used in our calculation contains all neutron-proton transitions which change the radial quantum number n by $\Delta n=0$, 1, 2, 3. The single quasi particle Fermi sum-rule is fulfilled with the approximately ~0.1% accuracy.

In our study, we have calculated the energies for the Isobar Analog Resonance (IAR) state and Anti Analog Resonance in ^{60}Mn, $^{64-66}$Ga and ^{78}Rb isotopes, and the Log(ft) values for the isospin forbidden $0^+ \to 0^+$ Fermi β decays in these nuclei. It has been shown in Ref. [11] that there is a strong dependence of the β decay matrix elements from the anti-analog states of the $^{64-66}$Ga isotopes to the ground states of the $^{64-66}$Zn isotopes on the Coulomb radius. The dependence of our results on the Coulomb radius has been removed because the Coulomb potential has been treated self-consistently in our calculations.

Figure 1 shows the dependence of the average Coulomb energy shift (ΔE_C) for the single quasi particle and the energies of the analog (ω_{IAR}) and anti-analog (ω_{ANT}) states in ^{66}Ga on the strength of the isovector potential, η with (a) and without (b) pair interaction among nucleons. As expected, the energy of the analog-state (ω_{IAR}) weakly depends on the isovector correlations in our self-consistent approach in both cases. This is because such energy is physically determined by the Coulomb potential (with respect to the parent nucleus). On the other hand, the energy splitting of the analog and anti analog states is directly proportional to the strength of the isovector potentials when there is no pairing interaction among nucleons. In the $\eta \to 0$ limit, these two states are close to each other and become strongly mixed in isospin by the Coulomb potential.

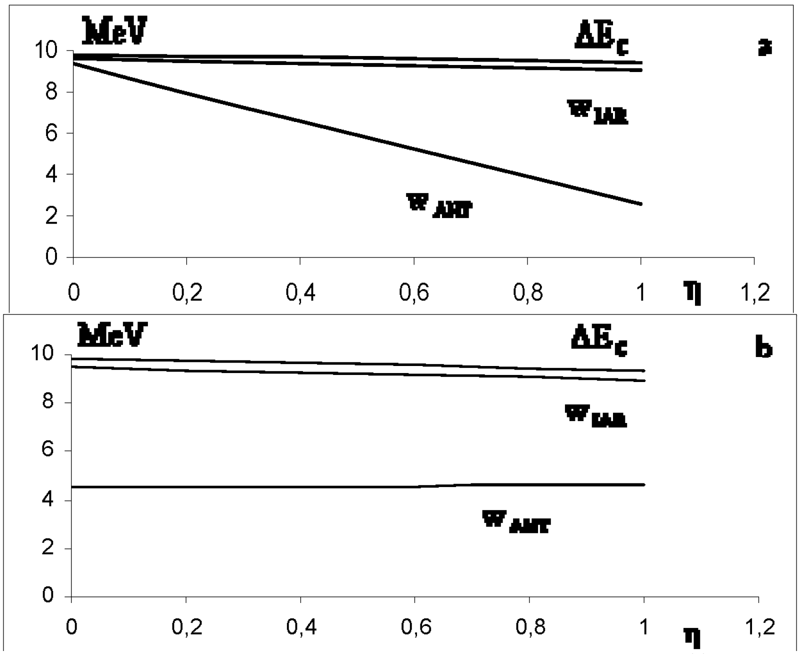

Fig 1. The η dependence of the quantities ΔE_C,, w_{IAR}, and w_{ANT} in ^{66}Ga,(a) without and (b) with pairing ($C_n=C_p=12/A^{1/2}$) interaction among nucleons.

If the pairing interactions among nucleons are considered, the IAR state energy decreases at an amount of approximately ~ 100 KeV although there is no considerable change in the value of ΔE_C, and the dependence of the energy of the anti analog state on the isovector parameter disappears. (See Fig. 1b). The value for the energy of the anti analog state almost remains constant at ω_{ANT}=5.6 MeV. This value is very close to mass difference in ^{66}Ga and ^{66}Zn isotopes (4.669 MeV).

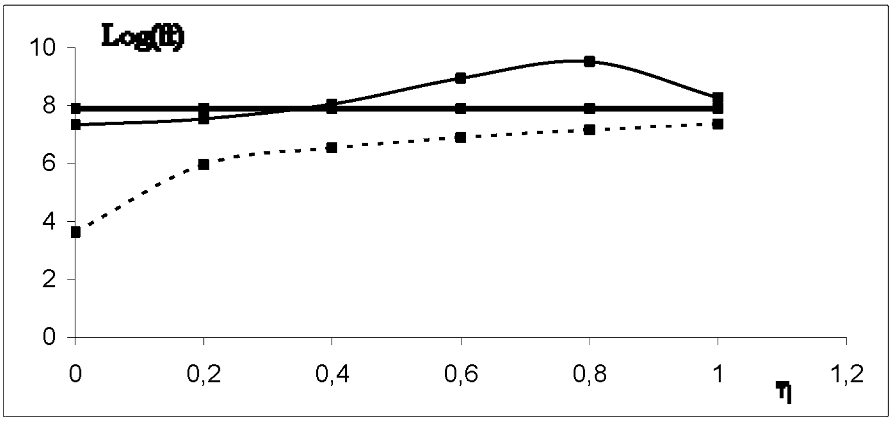

Fig.2. The η dependence of the Log(ft) value for the isospin forbidden $^{66}Ga \rightarrow ^{66}Zn$ decay. Full (dashed) curve-and solid line with a boldface correspond to the cases of with (without) pairing interaction among nucleons ($C_n=C_p=12/A^{1/2}$) and the experimental values [12], respectively.

Figure 2 show the dependence of the Log(ft) values for the isospin forbidden Fermi decay between the ground states of ^{66}Ga and ^{66}Zn on the strength of the isovector potential. As seen from figure, the probability of having the isospin forbidden β decay decreases with the increase of the η value in case of having no pairing interactions (namely, the Log(ft) values increase). The following interpretation for the reason of such a tendency of the Log(ft) values occurring in case of no pairing interaction can be given: The degree of the isospin symmetry violation is maximum at $\eta=0$ and, accordingly, the Log(ft) values become very small (~3.8). However, the competition between the Coulomb and isovector potential increases and the degree of the isospin symmetry violation decrease as the influence of the isovector forces increases. Therefore, the isospin forbidden β decay probability shows a tendency of decreasing. In case of having pairing interactions among nucleons, the number of the interactions which compete with the Coulomb potential causing to the isospin symmetry violation increases. Namely, pairing interaction, isovector interaction and the Coulomb interaction will compete with each other. Thus, it can be seen from Fig. 2 that in this case (with pairing interaction), the isospin forbidden β decay probability decreases and the Log(ft) values fluctuate in the range of 7.3-9.5 as the η value increases. The calculated Log(ft) value at $\eta=0.63$ (standard value of the isovector parameter) is larger than the corresponding experimental value by one unit. The dependence of the Log(ft) values for the isospin forbidden β decay on the parameter of the pairing correlation among nucleons has been depicted in Fig. 3. In this numerical calculation, the standard value of the isovector parameter ($\eta=0.63$) has been used.

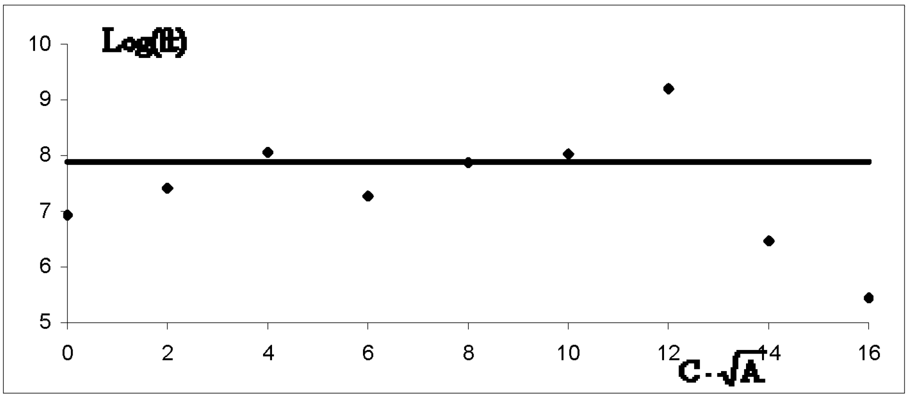

Fig. 3. Dependence of the Logft values for the isospin forbidden ^{66}Ga→^{66}Zn decay on the pairing correlation (C·A$^{1/2}$) among nucleons. Points show the calculated Log(ft) values and the solid line with a boldface correspond to the experimental value[12].

As seen from Fig. 3, this dependence shows fluctuation characteristics and the calculated Log(ft) values for $C_n=C_p=C=8/A^{1/2}-10/A^{1/2}$ are closer to the experimental values.

In Fig. 4, the dependence of the Log(ft) values for the isospin forbidden ^{78}Rb→^{78}Kr decay on the pairing correlation parameter has been given. This dependence has also a tendency of fluctuating as it was in Fig. 3.

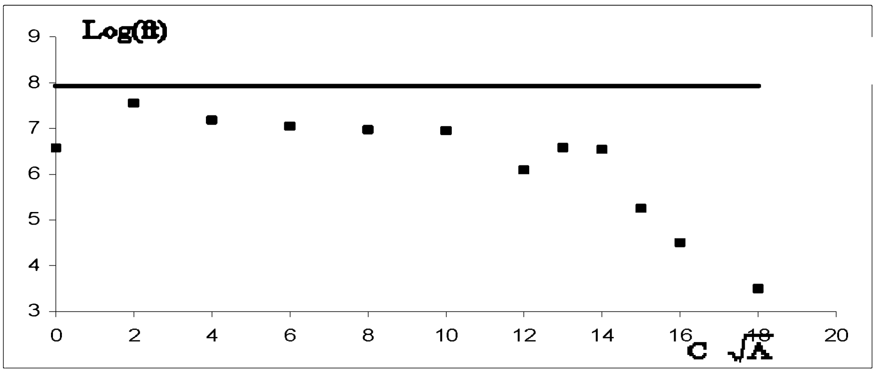

Fig. 4. Dependence of the Log(ft) values for the isospin forbidden ^{78}Rb→^{78}Kr decay on the pairing correlation (C·A$^{1/2}$) among nucleons. Points show the calculated Log(ft) values and the solid line with a boldface correspond to the experimental value[12].

Let us note that all the calculated Log(ft) values for the ^{78}Rb→^{78}Kr decay are smaller than the corresponding experimental values.

The calculated Log(ft) values for isospin forbidden $0^+ \to 0^+$ beta decay in some nuclei has been compared with the corresponding experimental values in the following table. The first three columns of this table show nuclei which make isospin forbidden beta decay, the calculated Log(ft) values for $C_n=C_p=0$ and $C_n=C_p\neq0$, respectively. The last column gives the corresponding experimental values. The calculated Log(ft) value for the $^{28}_{12}Mg \to ^{28}_{13}Al$ decay is close to the experimental value when no pairing interaction among nucleons is considered. The Log(ft) value for this decay in case of pairing interaction has not been shown in table because it is not an isospin forbidden β decay. Moreover, it can be said that for some decays in table, there is a disagreement between the calculated and experimental Log(ft) values with the inclusion of the pairing interaction among nucleons. The reason for this disagreement can be attributed to the fact that these isotopes are deformed.

Table. The comparison of the calculated Log(ft) values for some isospin forbidden β decays with the experimental values [12]

	$C_n=C_p=0$	$C_n=C_p\neq$	Exp. [12]
${}^{28}_{12}Mg\rightarrow{}^{28}_{13}Al$	8,001	-	7,96
${}^{60}_{25}\mathrm{Mn}\rightarrow{}^{60}_{26}\mathrm{Fe}$	6.79	6.80 $(12/A^{1/2})$	6.70
${}^{64}_{31}\mathrm{Ga}\rightarrow{}^{64}_{30}\mathrm{Zn}$	6.62	6.32 $(12/A^{1/2})$	6.57
${}^{66}_{31}\mathrm{Ga}\rightarrow{}^{66}_{30}\mathrm{Zn}$	6.93	7.87 $(8/A^{1/2})$	7.89
${}^{78}_{37}\mathrm{Rb}\rightarrow{}^{78}_{36}\mathrm{Kr}$	5.21	6.95 $(10/A^{1/2})$	7.93

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