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DESCRIPTION OF THE GAMOW-TELLER β^{+}-DECAYS AND (n,p) TRANSITIONS IN SPHERICAL NUCLEI

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In recent years Marian Gmitro paid much attention to the theory of double beta($\beta\beta$)-decay [1]. In that paper he presented the results of calculations of half–lifes of the two–neutrino $\beta\beta(2\nu)$–decay in the random phase approximation (RPA) with a direct calculation of commutators of weak hadron currents. It should be noted that a simple formula for calculating nuclear matrix elements of the $\beta\beta(2\nu)$–decay was also obtained in ref.[2]. Progress in describing the $\beta\beta(2\nu)$–decay [3] was achieved by a more exact calculation of nuclear matrix elements of the Gamow–Teller (GT) operators in the RPA with particle–hole and particle–particle residual forces [4, 5, 6, 7]. In this paper we will give the results of calculations of decays in the regions $A \sim 100$ and $A \sim 142$ and of the strength function of GT transitions and will discuss the renormalization in nuclei of the constant of an axial–vector weak interaction.

In the RPA with the inclusion of particle-hole and particle-particle residual interactions there were calculated matrix elements of the σt^+ operators corresponding to GT $0^+_{g.s.} \to 1^+_i$ decays in doubly even spherical [4, 5, 6] and deformed [7] nuclei. The states in a daughter nucleus are considered to be one–phonon obtained as a result of the action of the creation operator of a charge–exchange phonon on the phonon vacuum corresponding to the ground state of a doubly even parent nucleus. In this case, ft–value for the β–decay $0^+_{g.s.} \to 1^+_i$ is

$$ft_i = (\frac{g_V}{g_A})^2 \cdot \frac{6163.4}{B(GT, 0^+_{g.s.} \to 1^+_i)} ,$$

where $B(GT, 0^+_{g.s.} \to 1^+_i)$ is the strength of the transition, $0^+_{g.s.} \to 1^+_i$, $g_V(g_A)$ is the vector (axial-vector) constant of a weak interaction. In recent years, new experimental data emerged [8, 9, 10, 11] on β^+–decays of neutron–deficit spherical nuclei in the regions $A \sim 100$ and $A \sim 142$. In the calculations we used the single–particle energies and wave functions of the Saxon–Woods potential for the zones $A = 99$ and $A = 141$ [4] and took into account the monopole pairing and effective separable $(\vec{\sigma}, \vec{\sigma})$ residual forces. As in refs.[4, 5, 6], the effective constant of a particle–hole interaction was equal to $\kappa_1^{01} = 23.0/A$; the constant of a particle–particle interaction, to $G_1^{01} = -7.5/A$, i.e. a particle–hole interaction was chosen repulsive; and a particle–particle interaction, attractive.

Table 1 gives the experimental and calculated values for the $\log(ft)_\Sigma$–values for the

Table 1: Gamow–Teller β^+– decays in spherical nuclei

Transitions	$\log(ft)_\Sigma$		
	experimental values	calculated with $\lvert g_A/g_V\rvert = 1.0$, $\kappa_1^{01} = 23.0/A$	
		$G_1^{01} = 0.0$	$G_1^{01} = -7.5/A$
$^{94}Ru \to ^{94}Tc$	3.56(8)	3.1	3.6
$^{96}Pd \to ^{96}Rh$	3.2(1)	2.9	3.4
$^{98}Pd \to ^{98}Rh$	3.51(6)	3.1	3.7
$^{100}Cd \to ^{100}Ag$	3.20(8)	3.0	3.3
$^{102}Cd \to ^{102}Ag$	3.41(1)	3.0	3.4
$^{104}Cd \to ^{104}Ag$	3.9(1)	3.0	3.5
$^{104}Sn \to ^{104}In$	3.2(2)	2.8	3.1
$^{106}Sn \to ^{106}In$	3.20(5)	2.9	3.2
$^{108}Sn \to ^{108}In$	3.45(2)	3.0	3.3
$^{142}Dy \to ^{142}Tb$	4.1(2)	3.2	3.9
$^{144}Dy \to ^{144}Tb$	4.3(2)	3.3	3.9
$^{146}Dy \to ^{146}Tb$	3.8(2)	3.3	3.9
$^{148}Dy \to ^{148}Tb$	3.95(1)	3.3	4.0
$^{150}Dy \to ^{150}Tb$	4.1(1)	3.4	4.0

Table 2: Full Gamow–Teller strength S_+ for (n,p) transitions

Reactions	S_+	
	experimental values	calculated with $\kappa_1^{01} = 23.0/A$, $G_1^{01} = -7.5/A$
$^{54}Fe(n,p)^{54}Mn$	3.8(4)	4.2
$^{90}Zr(n,p)^{90}Y$	1.0(3)	1.2
$^{120}Sn(n,p)^{120}In$		0.8

GT β^+-decay of neutron–deficit spherical atomic nuclei. Here

$$(ft)_\Sigma^{-1} = \sum_i (ft)_i^{-1} ,$$

and the summation is made over the states populated in the β^+-decay. As the calculations show, the low-lying states of doubly odd neutron–deficit nuclei are separated by the gap of 3—4 MeV from higher–lying states. Therefore, the results of calculations of the strength manifesting itself in the β^+–decay of these nuclei are independent of the position of low–lying states and are more reliable than the calculated characteristics of β–decays of nuclei lying near the valey of the β stability. Particle-particle residual interactions enhance correlations in the ground state which lead to the decrease in the total GT σt^+ strength and shift part of the strength from the low-lying to the high-lying part of the spectrum. In the calculations, the main rôle is played by the matrix elements of the spin-isospin operators between the single particle wave functions. This is confirmed by the fact that the use of more complex residual interactions with the same, as we have, number of constants fixed from the experimental data, provides results similar to ours [6].

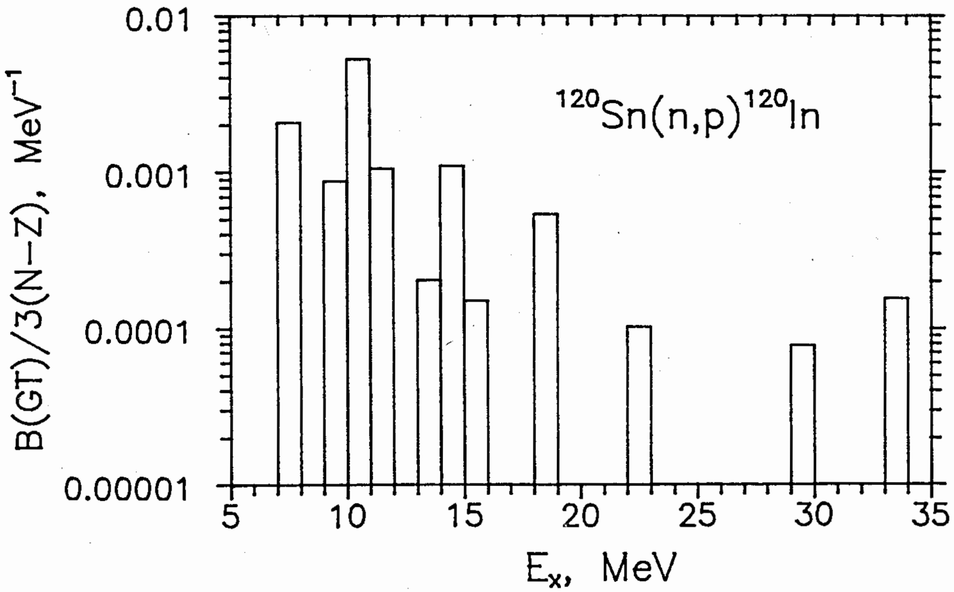
Let us consider decays of even Dy isotopes; ^{148}Dy is a nucleus with a closed subshell $\nu d_{3/2}$ and has 82 neutrons. The β^+–decay of the $^{142,144,146}Dy$ isotopes is due to transitions between partially closed subshells $\pi 2d_{5/2} - \nu 2d_{3/2}$ and $\pi 1h_{11/2} - \nu 1h_{11/2}$. Superfluid correlations and a residual interaction cause mixing of these transitions with a small part of $\pi 1h_{11/2} - \nu 1h_{9/2}$ transitions. The latter become dominating in the β^+–decays of $^{148,150}Dy$.

It is seen from the ***table 1*** that under the renormalisation $\lvert g_A/g_V\rvert = 1.0$ and $G_1^{01} = -7.5/A$ a rather good description is obtained of the $\log(ft)_\Sigma$–quantities for decays of neutron–deficit spherical nuclei with $A = 94 \sim 150$. It has been shown in ref.[5] that in some cases one can use the values $\lvert g_A/g_V\rvert = 1.26$ and $G_1^{01} = -7.9/A$ describing the $\log(ft)_\Sigma$–quantities. However, in this case, there appear strong correlations in the ground state and the use of the RPA becomes doubtful.

It has been shown in ref.[5] that particle-particle interactions strongly influence the total GT strength of (n,p) transitions

$$S_+ = \sum_i B^+(GT, 0^+_{g.s.} \to 1^+_i) ,$$

where the summation is made over all solutions of the RPA equations. Experimental data [12, 13] and the results of calculations of the total strength S_+ are shown in *table 2*. The calculated value of $S_+ = 1.2$ for the reaction $^{90}Zr(n,p)^{90}Y$ well agrees with the experimental value $S_+ = 1.0 \pm 0.3$ obtained later. The distribution of the transition strength over excitation energies in the reaction $^{120}Sn(n,p)^{120}In$ is shown in the figure. The latter shows that the GT strength of (n,p) transitions is mostly concentrated in the interval of excitation energies 7—15 MeV. The energy is reckoned from the ground state of the ^{120}Sn nucleus. Note also that the strength functions of GT transitions have been calculated also in refs.[14, 15].



The Gamow-Teller strengtht distribution. The excitation energy is reckoned from the ground state of the ^{120}Sn nucleus.

The renormalisation in atomic nuclei of the axial-vector constant of the weak interaction is obtained from the comparison of the calculated probabilities of GT β–decays of nuclei with experimental data. In such a way, the value of $|g_A/g_V| = 0.7$—1.0 was obtained in refs [16, 17]. Based on our calculations of GT decays of neutron–deficit spherical nuclei, given in *table 2*, one can assert that in complex nuclei the following condition should hold

$$|\frac{g_A}{g_V}| \geq 1.0 \, .$$

For exact determination of the renormalisation g_A quantity in nuclei one should study GT decay of ^{100}Sn, a nucleus with both closed shells, in which particle–particle residual forces do not influence the rate of β–decay. Further experimenal study of β–decays of other neutron–deficit spherical and deformed nuclei is needed.

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Описание гамов-теллеровских β^+-распадов и (n,p)-переходов в сферических ядрах

Представлены результаты вычислений суммарных $\log ft_{\Sigma}$-величин для распадов нейтронодефицитных ядер и силовых функций (n,p)-переходов. Показано, что в сферических ядрах для констант слабого взаимодействия выполняется условие $|g_A/g_V| \geq 1,0$.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

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Kuz'min V.A., Soloviev V.G. E4-91-169

Description of the Gamow-Teller β^+-Decays and (n,p) Transitions in Spherical Nuclei

The results of calculation of the total $\log(ft)_{\Sigma}$-quantities for decays of neutron-deficit nuclei and strength functions of (n,p) transitions are presented. It is shown that in spherical nuclei the $|g_A/g_V| \geq 1.0$ conditions hold for the constants of a weak interaction.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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