объединенный
институт
ядерных
исследований
дубна

E4-88-79

V.A.Kuzmin, V.G.Soloviev

GAMOW-TELLER β^+ DECAYS AND STRENGTH FUNCTIONS OF (n,p) TRANSITIONS IN SPHERICAL NUCLEI

Submitted to "Nuclear Physics A"

1988

1. Introduction

In describing vibrational states of atomic nuclei the key role is attributed to particle-hole interactions [1]. They form low- and high-lying (giant resonances) collective vibrational states. Besides particle-hole interactions some authors take into account particle-particle interactions. The interacting boson model [2] taking account of particle-particle interactions proved to be advantageous in describing some characteristics of collective low-lying states thus reviving interest in the study of the role of particle-particle interactions. A consistent treatment in the Random Phase Approximation (RPA) including both particle-hole (p-h) and particle-particle (p-p) interactions allowed the authors of ref.[3] to resolve the discrepancy between the experimental and calculated two-neutrino double β decay rates.

The study of the β^+ decay of nuclei far from stability provides experimental information on the charge-exchange strength distribution. Thus, the β^+ decays from the ground $0^+_{g.s.}$ states of doubly even nuclei to the excited 1^+ states of doubly odd nuclei provide data on the distribution of the Gamow-Teller (GT) strength. Experiments of this sort have been performed in refs.[4-8] for some spherical nuclei with A=146-152. Due to a large energy of the β^+ decay of neutron-deficit short-lived isotopes, it is believed that almost the whole GT $\sigma t_{(+)}$ strength S_+ is observed. This allowed the authors of refs.[5,9] to make a conclusion on a strong renormalisation in nuclei of the weak axial-vector constant g_A.

As is known, progress has been achieved in the experimental study of the giant GT resonance in (p,n) reactinns, i.e. of the $\sigma t_{(-)}$ branch. For the total strength of the GT transitions there is the model independent sum rule

$$S_- - S_+ = 3(N-Z). \tag{1}$$

It connects the total GT strength S_- related to the 0°(p,n) cross section and partially to the β^- decay with S_+ related to the 0°(n,p) cross section and β^+ decay. It was concluded from the (p,n) reactions that about (40-50)% of the sum-rule GT strength is missing under the assumption $S_+=0$. Since the GT strength is missing, as has been pointed out in ref.[10], it is interesting to measure the 0°(n,p) cross sections. The experiments [11] for the reaction ^{54}Fe(n,p)^{54}Mn allowed one to extract information on S_+.

The foregoing shows that the β^+ decay and strength functions of (n,p) transitions are worthy of further theoretical investigation, for instance, within the quasiparticle-phonon nuclear model (QPNM)[12-14]. The advantage of the QPNM has been demonstrated in [15] in describing the fragmentation of the GT resonance. Of some interest is the effect of the p-p interaction on the probabilities of the GT β^+ decay and on the strength functions of (n,p) transitions. The QPNM can be generalised to the p-h and p-p interactions in describing charge-exchange states.

The present paper is devoted to the description in the QPNM of the GT β^+ decays and strength functions of (n,p) transitions in spherical nuclei in the RPA including both the p-h and p-p interactions.

2. The RPA Equations for the GT States Including Particle-Hole and Particle-Particle Interactions

The QPNM Hamiltonian [14,15] is added by the term describing the GT p-p interaction

$$H_{CS}^{PP} = -2\,G_1^{01} \sum_{\mu} P_{1\mu}^+ P_{1\mu}\,,$$

$$P_{1\mu}^+ = \sum_{j_p m_p\, j_n m_n} (-1)^{j_p - m_p} \langle j_n m_n | \sigma_\mu^+ t_{(+)} | j_p m_p \rangle\, a_{j_n m_n}^+ a_{j_p m_p}^+\,, \tag{2}$$

$$f(j_p, j_n) \equiv \langle j_p \| \sigma t_{(-)} \| j_n \rangle .$$

where $a_{j_p m_p}^+$ and $a_{j_n m_n}^+$ are the proton and neutron creation operators and $j_p m_p$ and $j_n m_n$ are the quantum numbers of single-particle proton and neutron states. The $\sigma\tau$ interactions are taken into account whereas $[Y_2,\sigma]_1\tau$ are not; the role of the latter is insignificant.

Now we perform the canonical Bogolubov transformation

$$a_{jm} = u_j\, \alpha_{jm} + (-1)^{j-m} v_j\, \alpha_{j,-m}^+$$

and introduce the GT phonon creation operator

$$\Omega_{1\mu i}^+ = \sum_{j_p j_n} \left[\psi_{j_p j_n}^i A^+(j_p j_n; 1\mu) + (-1)^{\mu} \varphi_{j_p j_n}^i A(j_p j_n; 1-\mu) \right], \tag{3}$$

where

$$A(j_p j_n; \lambda\mu) = \sum_{m_p, m_n} \langle j_p m_p j_n m_n | \lambda\mu \rangle\, \alpha_{j_n m_n}\, \alpha_{j_p m_p}.$$

The corresponding part of the p-p interaction (2) is expressed through the operators $\Omega_{1\mu i}$ and $\Omega^+_{1\mu i}$ and added to the p-h interaction (see refs.[14,15]). Then, the RPA Hamiltonian is

$$H_{csv} = \sum_{j_p m_p} \varepsilon_{j_p} d^+_{j_p m_p} d_{j_p m_p} + \sum_{j_n m_n} \varepsilon_{j_n} d^+_{j_n m_n} d_{j_n m_n} - \tag{4}$$

$$-\frac{1}{3}\sum_{i,\mu}\left\{\varkappa_1^{01}\left[(D^i_+)^2+(D^i_-)^2\right]+G_1^{01}\left[(D^i_g)^2+(D^i_w)^2\right]\right\}\Omega^+_{1\mu i}\Omega_{1\mu i},$$

where

$$D^i_+ = \sum_{j_p j_n} f(j_p j_n) u^{(+)}_{j_p j_n} g^i_{j_p j_n}, \quad D^i_- = \sum_{j_p j_n} f(j_p j_n) u^{(-)}_{j_p j_n} w^i_{j_p j_n},$$

$$D^i_g = \sum_{j_p j_n} f(j_p j_n) v^{(-)}_{j_p j_n} g^i_{j_p j_n}, \quad D^i_w = \sum_{j_p j_n} f(j_p j_n) v^{(+)}_{j_p j_n} w^i_{j_p j_n},$$

$$u^{(\pm)}_{j_p j_n} = u_{j_p} v_{j_n} \pm v_{j_p} u_{j_n}, \quad v^{(\pm)}_{j_p j_n} = u_{j_p} u_{j_n} \pm v_{j_p} v_{j_n}$$

$$g^i_{j_p j_n} = \psi^i_{j_p j_n} + \varphi^i_{j_p j_n}, \quad w^i_{j_p j_n} = \psi^i_{j_p j_n} - \varphi^i_{j_p j_n},$$

and ε_j are single-quasiparticle energies.

Let us find an average value of H_{csv} over the one-phonon state

$$\Omega^+_{1\mu i}\Psi_0, \tag{5}$$

where Ψ_0 is the ground state wave function of a doubly even nucleus. To find the RPA equations, we use the variational principle

$$\delta\left\{\langle\Psi_0^*\Omega_{1\mu i}H_{csv}\Omega^+_{1\mu i}\Psi_0\rangle - \langle\Psi_0^* H_{csv}\Psi_0\rangle - \omega_i\left[\sum_{j_p j_n} g^i_{j_p j_n} w^i_{j_p j_n} - 1\right]\right\} = 0, \tag{6}$$

and get

$$\varepsilon_{j_p j_n} g^i_{j_p j_n} - \omega_i w^i_{j_p j_n} - \frac{2}{3}\left(\varkappa_1^{01} D^i_+ u^{(+)}_{j_p j_n} + G_1^{01} D^i_g v^{(-)}_{j_p j_n}\right) f(j_p j_n) = 0,$$

$$-\omega_i g^i_{j_p j_n} + \varepsilon_{j_p j_n} w^i_{j_p j_n} - \frac{2}{3}\left(\varkappa_1^{01} D^i_- u^{(-)}_{j_p j_n} + G_1^{01} D^i_w v^{(+)}_{j_p j_n}\right) f(j_p j_n) = 0, \tag{7}$$

where $\varepsilon_{j_p j_n} = \varepsilon_{j_p} + \varepsilon_{j_n}$. As a result of simple transformations the secular equation for the energies ω_i of one-phonon states is

$$\begin{vmatrix} \varkappa_1^{01}X^i_+ - 1 & \varkappa_1^{01}X^i_{+-} & G_1^{01}X^i_{1+-} & G_1^{01}X^i_{1+} \\ \varkappa_1^{01}X^i_{+-} & \varkappa_1^{01}X^i_- - 1 & G_1^{01}X^i_{1-} & G_1^{01}X^i_{1-+} \\ \varkappa_1^{01}X^i_{1-+} & \varkappa_1^{01}X^i_{1-} & G_1^{01}X^i_g - 1 & G_1^{01}X^i_{gw} \\ \varkappa_1^{01}X^i_{1+} & \varkappa_1^{01}X^i_{1-+} & G_1^{01}X^i_{gw} & G_1^{01}X^i_w - 1 \end{vmatrix} = 0, \tag{8}$$

where

$$X^i_\pm = \frac{2}{3}\sum_{j_p j_n} \frac{\left(f(j_p j_n) u^{(\pm)}_{j_p j_n}\right)^2 \varepsilon_{j_p j_n}}{\varepsilon^2_{j_p j_n} - \omega_i^2},$$

$$X^{i}_{+-} = \frac{2}{3}\sum_{j_p j_n} \frac{[f(j_p j_n)]^2 u^{(+)}_{j_p j_n} u^{(-)}_{j_p j_n} \omega_i}{\varepsilon^2_{j_p j_n} - \omega_i^2} ,$$

$$X^{i}_{1\pm} = \frac{2}{3}\sum_{j_p j_n} \frac{[f(j_p j_n)]^2 u^{(\pm)}_{j_p j_n} v^{(\pm)}_{j_p j_n} \omega_i}{\varepsilon^2_{j_p j_n} - \omega_i^2} ,$$

$$X^{i}_{1\pm\mp} = \frac{2}{3}\sum_{j_p j_n} \frac{[f(j_p j_n)]^2 u^{(\pm)}_{j_p j_n} v^{(\mp)}_{j_p j_n} \varepsilon_{j_p j_n}}{\varepsilon^2_{j_p j_n} - \omega_i^2} ,$$

$$X^{i}_{\substack{g\\w}} = \frac{2}{3}\sum_{j_p j_n} \frac{[f(j_p j_n) v^{(\mp)}_{j_p j_n}]^2 \varepsilon_{j_p j_n}}{\varepsilon^2_{j_p j_n} - \omega_i^2} ,$$

$$X^{i}_{gw} = \frac{2}{3}\sum_{j_p j_n} \frac{[f(j_p j_n)]^2 v^{(+)}_{j_p j_n} v^{(-)}_{j_p j_n} \omega_i}{\varepsilon^2_{j_p j_n} - \omega_i^2} .$$

For the energies found from eq. (8) we calculate the functions $g^{i}_{j_p j_n}$ and $w^{i}_{j_p j_n}$ using eqs. (7) and the normalisation condition of the wave function (5). At $G^{01}_1 = 0$ eq.(8) turns into equations obtained in ref.[15]. The wave functions of one-phonon states (5) are a superposition of excitations in the nuclei with $N-1$, $Z+1$ and $N+1$, $Z-1$. For each solution i one can separate a dominating branch. Moreover, for each RPA solution average numbers of neutrons and protons over one-phonon states are calculated in order to determine what branch a given state corresponds to.

3. Effect of Particle-Particle Interactions on the β^+ Decay

Considerable part of the GT strength appears in the β^+ decay of the ground state of a doubly even nucleus into the excited 1^+ states of a doubly odd nucleus in case of a large energy of the β^+ decay. The matrix element of the β^+ decay from the ground state of a doubly even nucleus into the one-phonon $1^+ i$ state with the wave function (5) is

$$\langle \Psi_0^* \Omega_{1\mu i} H^1_\beta \Psi_0 \rangle = \frac{1}{\sqrt{3}} \sum_{j_p j_n} f(j_p j_n) (v_{j_p} u_{j_n} \psi^{i}_{j_p j_n} + u_{j_p} v_{j_n} \varphi^{i}_{j_p j_n}) . \qquad (9)$$

The matrix element of the GT β^- decay between the ground and one-phonon $1^+ i$ states has the form

$$\langle \Psi_0^* \Omega_{1\mu i} H^1_\beta \Psi_0 \rangle = \frac{1}{\sqrt{3}} \sum_{j_p j_n} f(j_p j_n) (u_{j_p} v_{j_n} \psi^{i}_{j_p j_n} + v_{j_p} u_{j_n} \varphi^{i}_{j_p j_n}) . \qquad (10)$$

The comparison of the matrix elements shows that due to the neutron excess the terms connected with the direct amplitude $\psi^{i}_{j_p j_n}$ for the β^+ decay are less than the corresponding terms for the β^- decay. The effect of the p-p interactions is the change of the energy ω_i and amplitudes $\psi^{i}_{j_p j_n}$ and $\varphi^{i}_{j_p j_n}$.

The strength of the GT transitions to the $1^+ i$ state is defined for the (p,n) and β^- decay and (n,p) and β^+ decay by

$$B^{(-)}(1^+_i) = \left| \sum_{j_p j_n} f(j_p j_n)(u_{j_p} v_{j_n} \psi^{i}_{j_p j_n} + v_{j_p} u_{j_n} \varphi^{i}_{j_p j_n}) \right|^2 , \qquad (11)$$

Table 1. GT β^+ transitions $0^+_{g.s.} \to 1^+$.

β^+ transition	$\log f\tilde{t}$				Part of total strength	
	exp.	calculation			$\lvert g_A/g_V\rvert=1$	$\lvert g_A/g_V\rvert=1.25$
		$\varkappa_1^{01}=0$, $G_1^{01}=0$	$\varkappa_1^{01}A=-23$, $G_1^{01}=0$	$\varkappa_1^{01}A=-23$, $G_1^{01}A=7.5$	$G_1^{01}A=7.5$	$G_1^{01}A=7.9$
$^{152}Yb \to {}^{152}Tm$	3.4	2.8	3.0	3.4	0.60	0.50
$^{152}Er \to {}^{152}Ho$	3.9	2.9	3.2	3.5	0.80	0.77
$^{150}Er \to {}^{150}Ho$	3.6	2.9	3.1	3.5	0.55	0.50
$^{150}Dy \to {}^{150}Tb$	4.1	3.0	3.3	3.6	0.80	0.80
$^{148}Dy \to {}^{148}Tb$	3.9	3.0	3.3	3.8	0.50	0.43
$^{146}Dy \to {}^{146}Tb$	3.8	3.0	3.3	4.1	0.30	0.20
$^{126}Ba \to {}^{126}Cs$	4.4	3.4	4.0	4.4*)	0.20*)	
$^{120}Xe \to {}^{120}I$	4.4	3.3	4.0	4.5*)	0.14*)	
$^{96}Pd \to {}^{96}Rh$	3.3	2.7	3.1	3.4	0.35	0.32

*) Calculations with $G_1^{01} = \frac{6.0}{A}$ MeV.

Consider now the GT transitions in the β^+ decay of $^{146,148}Dy$. In comparison with the independent quasiparticle model, the p-h interaction decreases twice the integral strength of the β^+ transitions. The inclusion of the p-p interaction provides an additional suppression by 3-5 times. The low-lying states used in the calculations of $\log f\tilde{t}$ are separated from the high-lying ones by a gap of 4-5 MeV. With increasing constant from G_1^{01}=7.5/A MeV up to G_1^{01}=7.7/A MeV for ^{148}Dy, the gap diminishes by 0.5 MeV. For the β^+ decay of ^{146}Dy at G_1^{01}= 7.3/A MeV we have $\log f\tilde{t}$=3.9 MeV and 50% of the total strength is exhausted in the β^+ decay; the calculations at $\lvert g_A/g_V\rvert$ = 1.25 were performed with G_1^{01}=7.7/A MeV. In this case, the RPA is inapplicable at $G_1^{01} \geq$ 7.9/A MeV.

For the β^+ decay of $^{96}Pd \to {}^{96}Rh$ at $\varkappa_1^{01}$=-23/A MeV and G_1^{01}=0 $\log f\tilde{t}$=3.0 and the high-lying levels are separated by a gap of 3 MeV. At G_1^{01}=7.1/A MeV we have $\log f\tilde{t}$=3.3 equal to that measured in ref.[16]. With increasing G_1^{01} the integral strength, appearing in the β^+ decay, decreases gradually thus increasing $\log f\tilde{t}$.

Now let us show the decrease of the β^+ transition rates with increasing G_1^{01} taking as an example the β^+ decay of the ground state of ^{146}Dy into the 1^+ state of ^{146}Tb described by the wave function $\Omega^+_{1\mu i}\Psi_0$ with the dominating component $p1h_{11/2}\, n1h_{9/2}$. We shall write out the components of the wave function $\Omega^+_{1\mu i_0}\Psi_0$ which have the largest $\psi^{i_0}_{j_p j_n}$, $\varphi^{i_0}_{j_p j_n}$ and the largest β^+ transition amplitudes

$$b^{(+)}(i_0, j_p j_n) = f(j_p j_n)(v_{j_p} u_{j_n} \psi^{i_0}_{j_p j_n} + u_{j_p} v_{j_n} \varphi^{i_0}_{j_p j_n}). \qquad (16)$$

At $\varkappa_1^{01}$=-23/A MeV and G_1^{01}=0 the state i_0 has the energy ω_{i_0}=8.042 MeV and the total transition strength, defined by eq.(12), equal to $B^{(+)}(1^+, i_0)$=3.431 which is smaller than $\lvert b^{(+)}(i_0, p1h_{11/2}\, n1h_{9/2})\rvert^2$=6.47. The configuration $\{p1h_{11/2}\, n1h_{9/2}\}$ gives a 99.8% contribution to the normalisation of the wave function $\Omega^+_{1\mu i_0}\Psi_0$. However, the transition strength decreases 1.9 times in comparison with 6.47.

At $\varkappa_1^{01}$=-23/A MeV and G_1^{01}=6/A MeV the total transition strength to the state i_0 decreases 1.5 times in comparison with G_1^{01}=0. The contribution of the configuration $\{p1h_{11/2}\, n1h_{9/2}\}$

to the normalisation of the wave function is 97.4% and $|b^{(+)}(i_0; p1h_{11/2}\, n1h_{9/2})|^2=6.3$. Other configurations give a very small contribution to the normalisation of the wave function. However, their amplitudes (16) increased in comparison with $G_1^{01}=0$; they mainly have an opposite sign to the amplitude $b^{(+)}(i_0; p1h_{11/2}\, n1h_{9/2})$. As a result the transition strength to the state is 2.7 times as small as $|b^{(+)}(i_0; p1h_{11/2}\, n1h_{9/2})|^2$. This situation is typical of most of the transitions given in Table 1.

A further increase in G_1^{01} decreases $B^{(+)}(1^+, i_0)$ by increasing the role of the amplitudes differing from $b^{(+)}(i_0; p1h_{11/2}\, n1h_{9/2})$ and of the ground state correlation. This results in the decrease of the total strength S_+. Still increasing G_1^{01} leads to the fragmentation of the configuration $\{p1h_{11/2}\, n1h_{9/2}\}$ over several levels. In the case of ^{146}Tb it appeares at $G_1^{01}=7.5/A$ MeV and in other nuclei at $G_1^{01}=8/A$ MeV. At $G_1^{01}=7.5/A$ MeV in ^{146}Tb 75% of the strength of this configuration is distributed over two states, the first is given in Table 2 and the second has the energy $\omega_{i_1}=6.098$ MeV and $B^{(+)}(1^+, i_1)=0.476$. The $B^{(+)}(1^+, i_0)$ value decreased considerably for the state shown in Table 2 and the $B^{(+)}(1^+, i)$ value somewhat increased for other states i. The total strength S_+ became 2.6 times as small as $G_1^{01}=0$ and 4.5 times as small as $\varkappa_1^{01}=G_1^{01}=0$. For ^{146}Tb the RPA with the p-h and p-p interactions is still valid for $G_1^{01}=7.5/A$ MeV. For most of the nuclei, an increase in G_1^{01} resulting in a 2-3 times increase of $\widetilde{ft}$ value is still possible without violating the RPA, i.e. at $G_1^{01}>(8-12)/A$ MeV the RPA is not applicable.

The effect of the p-h and p-p interactions on the GT β^+/EC transitions with small energies to the low-lying states has

Table 2. Structure of the one-phonon 1^+ i_0 state of ^{146}Tb with the dominating two-quasiparticle component $p1h_{11/2}\, n1h_{9/2}$ which is calculated at $\varkappa_1^{01}=-23A$ MeV and $G_1^{01}=0$, 6.0/A and 7.5/A MeV

Two-quasiparticle components		$G_1^{01}=0$, $\omega_{i_0}=8.042$ MeV, $B^{(+)}(1^+,i_0)=3.431$			$G_1^{01}\cdot A=6.0$, $\omega_{i_0}=7.127$ MeV, $B^{(+)}(1^+,i_0)=2.321$			$G_1^{01}\cdot A=7.5$, $\omega_{i_0}=5.824$ MeV, $B^{(+)}(1^+,i_0)=0.361$		
j_p	j_n	$\psi^{i_0}_{j_pj_n}$	$\varphi^{i_0}_{j_pj_n}$	$b^{(+)}(i_0;j_pj_n)$	$\psi^{i_0}_{j_pj_n}$	$\varphi^{i_0}_{j_pj_n}$	$b^{(+)}(i_0;j_pj_n)$	$\psi^{i_0}_{j_pj_n}$	$\varphi^{i_0}_{j_pj_n}$	$b^{(+)}(i_0;j_pj_n)$
$2d_{5/2}$	$2d_{3/2}$	0.043	−0.026	0.012	0.010	−0.080	−0.097	−0.038	−0.137	−0.224
$1h_{11/2}$	$1h_{11/2}$	0.032	−0.054	−0.142	−0.011	−0.094	−0.287	0,006	−0,122	−0.359
$2d_{3/2}$	$2d_{3/2}$	−0.012	0.023	0.029	0.014	0.032	−0,046	0,005	0.037	−0.050
$3s_{1/2}$	$3s_{1/2}$	0.018	−0.037	−0.076	−0.015	−0.052	−0.117	0,017	−0.057	−0.119
$2d_{5/2}$	$2d_{5/2}$	0.025	−0.020	−0.020	0,002	−0.063	−0.085	−0,024	−0.095	−0,136
$1g_{7/2}$	$1g_{7/2}$	−0.023	0.014	−0.008	−0.001	0.052	−0,049	0.091	0.081	−0.101
$2d_{3/2}$	$2d_{5/2}$	−0.025	0.041	−0.114	−0.012	−0.054	−0.153	−0.689	0.052	−0.066
$1h_{11/2}$	$1h_{9/2}$	0.999	−0.005	2.543	0.987	−0.016	2.509	0.680	−0.058	1.717
$1h_{9/2}$	$1h_{11/2}$	0.055	0.048	−0.213	−0,059	0.048	−0.200	0,044	0.034	−0.154
$1g_{7/2}$	$1g_{9/2}$	0.028	0.017	−0.032	−0.005	0.062	−0,098	−0,014	0,092	−0.144
$1g_{9/2}$	$1g_{7/2}$	−0.044	−0.005	−0.023	0.002	−0,056	−0.023	0.056	−0,097	−0.015
$1i_{13/2}$	$1i_{13/2}$	−0.010	−0,002	−0.004	0.099	−0,006	0,031	0.144	0.018	0.044
$2f_{5/2}$	$2f_{7/2}$	0.007	0,003	−0.002	−0.088	0,006	0.019	−0.126	0.016	0,025

been studied in ref.[19]. The constant G_1^{01} was chosen from the energies of low-lying states so that the β^+/EC transition was not considerably weakened. The smallest $\tilde{ft}$ -values were used to compare the results of calculations[19] with experimental data. If for the available experimental data one uses $\tilde{ft}$ values, the difference from the calculation reduces.

We have calculated the β^+ decays of ^{126}Ba and ^{120}Xe which have rather large decay energies; $\log \tilde{ft}$ values are shown in Table 1. The $\log \tilde{ft}$ values calculated at $\varkappa_1^{01}= G_1^{01}= 0$ and $\varkappa_1^{01}=-23/A$ MeV, $G_1^{01}=0$ are in agreement with the calculation [19] and the $\log \tilde{ft}$ values calculated with $\varkappa_1^{01}=-23/A$ MeV, $G_1^{01}=6/A$ MeV are in agreement with the experimental data. It is to be noted that our calculations for a small β^+ decay energy are rough. The quasiparticle-phonon interactions can change the amplitudes (16) for the low-lying states out of which only a part appears in the β^+ decay with small energy.

The RPA with both the p-h and p-p interactions enables one to describe $\log \tilde{ft}$ for the β^+ transitions in even spherical nuclei. Fast β^+ transitions are observed in odd-A nuclei [4,9,20]; the most thoroughly studied is the β^+ decay of ^{147m}Dy for which $\log \tilde{ft}=3.67$. The question now arises of whether the β^+ transitions in odd-A nuclei can be described correctly.

Since we have to extract the most important degrees of freedom, we write down the wave function, for instance, of an odd Z nucleus as

$$\Psi_{\nu_p}(J_p,M_p) = C_{J_p\nu_p}\Big\{ \alpha^+_{J_pM_p} + \sum_{i,j_n} D^{1i}_{j_n}(J_p,\nu_p) \sum_{m_n,\mu} \langle j_nm_n 1\mu | J_pM_p\rangle \alpha^+_{j_nm} \Omega^+_{1\mu i} \Big\}\Psi_0 \qquad (17)$$

where Ψ_0 is the ground state wave function of a doubly even nucleus with $Z-1$. One can easily derive, as in refs.[1,14], the system of equations for the energies and coefficients $C_{J_p\nu_p}$ and $D^{1i}_{j_n}(J_p,\nu_p)$ of the wave function (17). Since we do not solve equations of this sort, we do not give them but make some estimations.

Our estimations are illustrated by the GT β^+ decay of ^{147m}Dy into the levels of ^{147}Tb. Following ref.[20], we consider the level $\frac{11}{2}^-$ of ^{147}Dy to be close to the neutron one-quasiparticle state $n1h_{11/2}$ and write its wave function as

$$\Psi_{\nu_n}(\tfrac{11}{2}^-,M_n) = C_{11/2,\nu_n}\, \alpha^+_{1h_{11/2},M_n}\, \Psi_0 , \qquad (18)$$

where Ψ_0 is the ground state wave function of ^{146}Dy. Assume that the β^+ decay proceeds to the components $n1h_{11/2}\otimes\Omega^+_{1\mu i}\Psi_0'$, and therefore, the wave function ^{147}Tb becomes

$$\Psi_{\nu_p}(J_pM_p) = C_{J_p\nu_p}\sum_i D^{1i}_{n1h_{11/2}} \sum_{m_n} \langle \tfrac{11}{2} m_n 1\mu | J_pM_p\rangle \alpha^+_{1h_{11/2},m_n}\Omega^+_{1\mu i}\Psi_0' \qquad (19)$$

Ψ_0' is the ground state wave function of ^{146}Gd. The matrix element of the β^+ decay of ^{147m}Dy from the one-quasiparticle state $n1h_{11/2}$ with the wave function (18) into the states $n1h_{11/2}\otimes\Omega^+_{1\mu i}\Psi_0'$ of ^{147}Tb described by the wave function (19) is

$$\langle \Psi^*_{\nu_p}(J_pM_p) H^1_\beta \Psi_{\nu_n}(\tfrac{11}{2}^-,M_n)\rangle = C_{J_p\nu_p} C_{11/2,\nu_n} \sum_{i,\mu,M_n} \langle \tfrac{11}{2} M_n 1\mu | J_pM_p\rangle \cdot D^{1i}_{n1h_{11/2}} \sum_{j_p,j_n} \frac{f(j_p,j_n)}{\sqrt{3}} \left(v_{j_p} u_{j_n} \psi^i_{j_pj_n} + u_{j_p} v_{j_n} \varphi^i_{j_pj_n} \right). \qquad (20)$$

Here the sum over j_pj_n coincides with the matrix element (9) describing the β^+ decay of ^{146}Dy into the 1^+ states of ^{146}Tb. Assuming that the β^+ decay proceeds from the one-quasiparticle state $\nu 1h_{11/2}$ of ^{147}Dy to the $\nu 1h_{11/2} \otimes \Omega^{+}_{1\mu i} \Psi_0'$ state of ^{147}Tb, we get $\log \widetilde{ft}$ equal to $\log \widetilde{ft}$ for the β^+ decay of ^{146}Dy to the 1^+ state of ^{146}Tb, i.e. $\log \widetilde{ft}$=3.9. Due to $C_{11/2,\nu_n} < 1$ and $C_{j_p,\nu_p} D^{1i}_{nh_{11/2}} < 1$ we get $\log \widetilde{ft} > 3.9$ for the β^+ decay of ^{147m}Dy on ^{147}Tb. Estimates of this type are tabulated in Table 3.

The analysis shows that fast β^+ decays of odd-A spherical nuclei are in agreement with the calculations within the RPA with both the p-h and p-p interactions.

Table 3. GT β^+ transitions in odd-A nuclei

β^+ transition	$\log \widetilde{ft}$ exp.	$\log \widetilde{ft}$ calc.
^{149}Ho $\rightarrow$ ^{149}Dy	4.2	> 3.8
^{147}Dy $\rightarrow$ ^{147}Tb	3.9	> 4.1
^{147}Tb $\rightarrow$ ^{147}Gd	4.2	> 4.1

We now turn our attention to β^- decays for comparison. A small part of the total GT strength is observed in β^- decays. As an example, we consider β^- transitions from the ground state of ^{80}Zn to the 1^+ levels in ^{80}Ga with an excitation energy of 0.7-2.7 MeV. According to ref.[21] the energy of the β^- transition is 7.1 MeV and the integrated $\log \widetilde{ft}$ is 4.0. The states 1^+ of ^{80}Ga are described as one-phonon states; and the matrix elements of the GT β^- transitions, by formula (10). The low-lying 1^+ states in ^{80}Ga are not separated from the high-lying ones by the gap, and therefore, the results of calculations depend on the energy interval ΔE which contains the levels populated in the β^- decay. The decays observed experimentally[21] populate the 1^+ levels in ^{80}Ga

lying in the interval ΔE=2 MeV. The quasiparticle-phonon interactions can shift a part of the GT strength from one energy interval to another.

According to our calculations of the β^- decays of ^{80}Zn, at $\varkappa_1^{01} = G_1^{01} = 0$ 50% of the total strength S_- is concentrated on the low-lying states in the interval ΔE= 3 MeV with $\log \widetilde{ft}$=2.4. For $\varkappa_1^{01}$=-23/A MeV, G_1^{01}=0 the total GT strength S_- decreases by 0.34%; in the low-lying region 0.5% of the total GT strength lies at ΔE= 2 MeV with $\log \widetilde{ft}$=4.3 and 2.2% of the total strength lies at ΔE=3 MeV with $\log \widetilde{ft}$=3.5. For $\varkappa_1^{01}$=-23/A MeV and G_1^{01}=7.5/A MeV the total GT strength decreases by 1% and $\log \widetilde{ft}$ for the β^- transitions to the low-lying regions changes slightly. This calculation indicates that the p-p interactions slightly affect the β^- transitions.

We have calculated the matrix elements of the two-neutrino double β decay of ^{128,130}Te with the constants $\varkappa_1^{11}$ and G_1^{01} which were used to calculate $\log \widetilde{ft}$ for the β^+ transitions shown in Table 1. The calculated matrix elements and the lifetimes are in agreement with the results of ref.[3] and with the experiment. The necessity of taking into account the p-p interaction to suppress the strength of the two-neutrino double β decay has been confirmed in ref.[22]. The separable interaction in our calculations, δ-function in ref.[3] and effective forces calculated from the Bonn potential in ref.[22] did not influence the results of calculations. The difference in the constants of the p-h and p-p interactions in our calculation is due to numerical factors. It is to be mentioned that in ref.[23] the suppression of the double β decay is caused by ground state correlations due to quadrupole vibrations.

4. On Renormalisation of the Weak Axial-Vector Constant g_A in Nuclei

A large part of the total GT strength of S_+ manifests itself in the β^+ decay of neutron-deficit nuclei. Therefore, it is assumed that from the $\log \tilde{ft}$ values of the GT β^+ decays one can find the ratio of the constants $|g_A/g_V|$ of the axial--vector and vector weak interactions, thus determining the renormalisation in nuclei of the constant g_A. Experiments [4-9,20] on β^+ decays of neutron-deficit nuclei revealed fast GT transitions with $\log \tilde{ft} < 4$. The comparison of the RPA calculations with p-h interactinns with the experimental data indicated a large renormalisation of the constant g_A. It was obtained in refs.[4-6,9] that $|g_A/g_V|$ =0.6 - 0.8 which changed while passing from one nucleus to another. The investigation of the β^+ decay of ^{147m}Dy in ref.[20] gave $|g_A/g_V|$ =0.7±0.1. The comparison of the experimental data with more accurate calculations including the renormalisation of the vertex and the configuration mixing in the particle-particle channel allowed the authors of ref.[24] to get $|g_A/g_V|$ =0.7 - 1.0. A comprehehsive comparison in ref.[25] of the experimentally observed GT β^- decays with the shell model calculations showed that in the middle of the sd-shell $|g_A/g_V|$ =0.95.

Our calculations of $\log \tilde{ft}$, tabulated in Table 1, have been performed for two cases $|g_A/g_V|$=1 and 1.25. To get the same $\log \tilde{ft}$ in the calculations with $|g_A/g_V|$=1.25, the constant is increased from G_1^{01}=7.5/A MeV to 7.9/A MeV, apart from the decay of ^{146}Dy for which G_1^{01}=7.7/A MeV. It follows from the calculations with $|g_A/g_V| = 1$ that from 30% up to 80% of the total GT strength S_+ is concentrated on the low-lying states.

In the calculations with $|g_A/g_V|$=1.25, the low-lying states contain from 20% to 77% of S_+. With increasing G_1^{01} from 7.5/A MeV by approximately 5% S_+ decreases by 3% and a part of the GT strength is shifted to the high-lying states.

According to our calculations with the separable p-h and p-p interactions, a satisfactory description of the experimental values of $\log \tilde{ft}$ with $|g_A/g_V|$ =1 and 1.25 has been obtained. With the new parameter G_1^{01} we get a correct description of the experimental data with the renormalisation of the constant g_A and without it. Our calculations show that from the available experimental data on the β^+ decays of neutron--deficit nuclei with A = 96 and 146-152 one cannot conclude that the constant g_A is renormalised considerably. We think that the effective constant g_A should not change when passing from one nucleus to another. Note that in some calculations, for instance, in ref.[26] medium dependence of g_A turns out to be roughly 5%.

5. Strength Functions of (n,p) Transitions

The Gamow-Teller resonance excited in (p,n) reactions is well studied experimentally. The model independent sum rule (1) contains the total strength function S_+ related to the 0^0 (n,p) cross section and β^+ decay.

Let us study now the influence of the p-h and p-p interactions on S_- and S_+. For the GT transitions we calculate the sums $\sum_i B^{(\pm)}(1^+_i)$ depending on the upper limit of the energy ω_i. The sums over all the states i are equal to $S_\pm$. The results of calculations in the RPA of $\sum_i B^{(+)}(1^+,i)$ and $\sum_i B^{(-)}(1^+,i)$ for ^{90}Zr are shown in figs. 1 and 2. In the calculations we

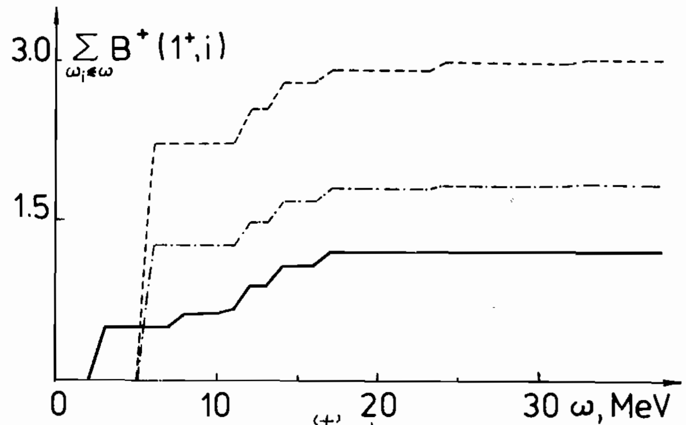

Fig. 1. Calculated sums $\sum_i B^{(+)}(1^+,i)$ as a function of the upper limit of ω_i for (n,p) transitions to ^{90}Zr.

Notation: dashed curve at $\varkappa_1^{01} = G_1^{01} = 0$;
dash-dotted curve at $\varkappa_1^{01} = -23/A$, $G_1^{01} = 0$;
solid curve at $\varkappa_1^{01} = -23/A$, $G_1^{01} = 7.5/A$.

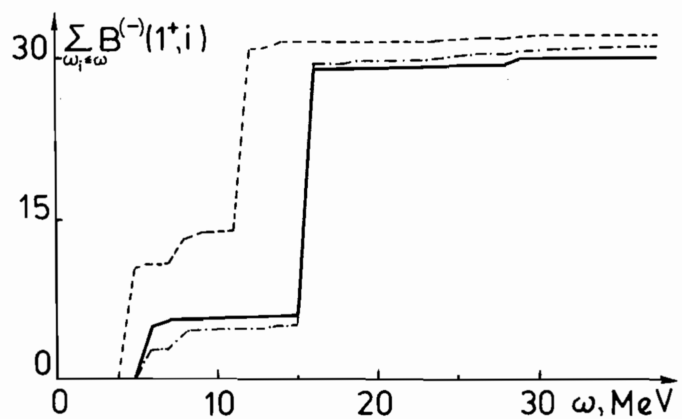

Fig. 2. Calculated sums $\sum_i B^{(-)}(1^+,i)$ as a function of the upper limit of ω_i for (p,n) transitions to ^{90}Zr.
Notation: As in fig. 1.

used a truncated space of single-particle states; therefore, at $\varkappa_1^{01} = G_1^{01} = 0$ we have $S_- - S_+ = 29$ instead of 30. The inclusion of the p-h interaction with $\varkappa_1^{01} = -23/A$ MeV diminishes S_+ 1.6 times. Inclusion of the p-p interaction with $G_1^{01} = 7.5/A$ MeV shifts a part of the strength to the energy less than 5 MeV and decreases S_+ 1.5 times, i.e. the p-h and p-p interactions decrease S_+ approximately 2.5 times. For $\sum_i B^{(-)}(1^+,i)$ the p-h interactions shift maximum of the GT resonance from 11 to 15 MeV and increase the strength at maximum, S_- decreasing by 4%. The inclusion of the p-p interaction decreases S_- by 3% more. The p-p interaction strongly influences $B^{(+)}(1^+,i)$ and S_+ slightly influences $B^{(-)}(1^+,i)$ and S_- .

Cross sections for ^{54}Fe (n,p)^{54}Mn have been measured in ref.[11] at small angles with the use of the charge-exchange facility at TRIUMF. This determination of the GT strength S_+ allows a full test of the sum rule (1). Their measurements give $S_+ = 3.8$. In ref.[27] $S_- = 7.8$ has been obtained from the ^{54}Fe(p,n)^{54}Co reaction. As a result, $S_- - S_+ = 4.0 \pm 2.1$. This is 67% of the sum rule value of 6, i.e. the quenching of the GT strength takes place. According to the calculations[28], $S_+ = 9.1$ for a two-particle, four-hole (2p-4h) model. The calculations [29] taking account of the 1p-1h configurations provide $S_+ = 9.4$ and more refined calculations give $S_+ = 7.4$. However, this still overestimates twice the experimental value.

We have calculated the S_+ for ^{54}Fe at $\varkappa_1^{01} = G_1^{01} = 0$ and $\varkappa_1^{01} = -23/A$ MeV, $G_1^{01} = 0$ and $\varkappa_1^{01} = -23/A$ MeV and $G_1^{01} = 7.5/A$ MeV. The results of calculations are shown in Table 4. The p-h RPA calculations of S_+ overestimate the experimental value almost twice. With the p-p interactions included, the S_+ becomes close to the experimental value $S_+ = 3.8$ obtained in ref.[11]. Note that for nuclei with small difference $N-Z$ the influence of the p-p interaction on S_+ is greater than in nuclei with large difference.

Interest in the strength functions of (n,p) transitions (see ref.[10]) stimulated us to calculate S_+ for ^{140}Ce, ^{120}Sn and ^{90}Zr, the fragmentation of the GT resonance (branch $\sigma t_{(-)}$) for which has been calculated in ref.[15]. It is seen from Table 4 that the calculations with the p-p interaction lead to a 1.5 - 2.0 decrease of S_+. Since a truncated space of single-particle states has been used, the sum rule (1) is not exhausted completely. The inclusion of the p-p interactions, as is seen from Table 4, does not lead to stronger deviations

Table 4. Effect of the p-h and p-p interactions on S_- and S_+

Target	$\varkappa_1^{01} A$	$G_1^{01} A$	S_-	S_+
^{140}Ce	0	0	73.4	2.7
	-23	0	72.2	1.1
	-23	7.5	71.0	0.5
^{120}Sn	0	0	60.3	2.7
	-23	0	59.2	1.5
	-23	7.5	58.0	0.8
^{90}Zr	0	0	32.1	3.0
	-23	0	30.8	1.9
	-23	7.5	29.9	1 2
^{54}Fe	0	0	16.4	10.3
	-23	0	12.3	6.6
	-23	7.5	10.3	4.2

from the sum rule (1) in comparison with $G_1^{01}=0$. It is seen from Table 4 that S_- is slightly influenced by the p-p interaction.

For nuclei far from stability, shown in Table 1, the p-p interactions taken into account diminish S_+ 2-4 times; the effect of the p-p interactions turned out to be stronger than in nuclei shown in Table 4, which confirms the conclusion on the relation between the neutron excess and influence of the p-p interactions.

6. Conclusion

The investigation within the QPNM has shown that the inclusion of the p-p interaction decreases the total GT strength S_+ 1.5 - 4.0 times. The p-p interactions influence considerably the integrated $\log \widetilde{ft}$ for the β^+ decays of neutron-deficit nuclei. As a result, a good description of the experimental values of $\log \widetilde{ft}$ is obtained under the assumption that $|g_A/g_V|$ =1.0 and 1.25.

The calculations, including the p-h and p-p interactions, of the S_+ strength and $\log \widetilde{ft}$ for the β^+ transitions at $|g_A/g_V|=1$ have been made with fixed constants $\varkappa_1^{01}$=-23A/MeV and G_1^{01}=7.5/A MeV. The effect of the p-p interaction is global in nature; it is independent of the detailed properties of the low-lying states populated in the β^+ decay.

The investigations have shown that the p-p interactions slightly influence the strength functions S_- manifesting themselves in the (p,n) reactions and β^- decay probabilities. The quenching of the GT resonance strength is not influenced by the p-p interactions.

Due to a strong effect of the p-p interaction on the β^+ decay probabilities, one cannot conclude unambiguously that the constant g_A of the axial-vector weak interaction is renormalised in nuclei. It would be important to find the constant G_1^{01} of the GT p-p interaction from other, apart from the β^+ decays, experimental data. Further experimental studies of the allowed and first forbidden β^+ and β^- transitions are needed for clarifying the renormalisation of the constant g_A in atomic nuclei. More exact calculations of the energies and wave functions of the states between which the β^+ transitions proceed are required as well.

The p-p as well as p-h interactions influence some nuclear characteristics. It is essential that the effect of the p-p interactions on many properties of spherical and deformed nuclei should further be studied.

References

1. V.G.Soloviev, Theory of Complex Nuclei (Pergamon Press, Oxford, 1976).
2. A.Arima and F.Iachello, Phys.Rev.Lett. 35 (1975) 1069.
   A.Arima and F.Iachello, Ann.Phys. 99 (1976) 253.
3. P.Vogel and M.R.Zirnbauer, Phys.Rev.Lett. 57 (1986) 3148.
4. G.D.Alkhazov, S.A.Artamonov, N.Ganbaatar et al., Izv. Akad. Nauk SSSR, ser. Fiz., 48 (1984) 913.
5. K.Ya.Gromov, Proc. Int. Symp. on IN-BEAM nuclear spectroscopy, ed. Zs.Dambradi, T.Fenyes (Akademiai Kiado, Budapest, 1984) p. 269.
6. G.D.Alkhazov, A.A.Bykov, V.D.Wittmann, F.V.Moroz, S.Yu.Orlov, V.E.Starodubsky and V.K.Tarasov, Yad.Fiz., 42 (1985) 1313.

7. P.Kleinheinz, K.Zuber, C.Conci, C.Protop, J.Zuber, C.F.Liang, P.Paris and J.Blomqvist, Phys.Rev.Lett. 55 (1985) 2664.
8. K.Zuber, C.F.Liang, P.Paris, J.Styczen et al., Z.Phys. - Atoms and Nuclei 327 (1987) 357.
9. G.D.Alkhazov, N.Ganbaatar, K.Ya.Gromov. V.I.Isakov et al. Yad.Fiz., 40 (1984) 554.
10. E.Vogt, Proc. Int. Nuclear Physics Conf., Harrogate U.R., ed. J.L.Durell, J.M.Irvine, T.P. Morrison, vol. 2, (Institute of Physics, Conf. Ser. Number 86, Bristol, 1986) p. 23.
    G.Gaarde, ibid., p. 173.
11. M.C.Vetterli, O.Hausser, W.P.Alford, D.Frekers et al., Phys.Rev.Lett. 59 (1987) 439.
12. V.G.Soloviev, Sov. J.Part. Nucl. 9 (1978) 343.
    L.A.Malov and V.G.Soloviev, Sov. J.Part. Nucl. 11 (1980) 111.
13. A.I.Vdovin and V.G.Soloviev, Sov. J.Part.Nucl. 14 (1983) 99.
    V.V.Voronov and V.G.Soloviev, Sov. J.Part.Nucl. 14 (1983) 583.
    A.I.Vdovin, V.V.Voronov, V.G.Soloviev and Ch.Stoyanov, Sov. J.Part. Nucl. 16 (1985) 105.
14. V.G.Soloviev, Progr.Part.Nucl.Physics, 19 (1987) 107.
15. V.A.Kuzmin and V.G.Soloviev, J.Phys. G : Nucl.Phys. 10 (1984) 1507.
16. V.Yu.Ponomarev, V.G.Soloviev, Ch.Stoyanov and A.I.Vdovin, Nucl.Phys. A323 (1979) 446.
17. V.A.Kuzmin and V.G.Soloviev, Joint Institute for Nuclear Research preprint E4-87-831 (Dubna, 1987).
18. K.Rykaczewski, I.S.Grant, R.Kirchner, C.Klepper et al., Z.Phys. - Atoms and Nuclei, 322 (1985) 263.
19. D.Cha, Phys.Rev., C27 (1983) 2269.

20. G.D.Alkhazov, A.A.Bykov, V.G.Wittmann, V.E.Starodubsky, S.Yu.Orlov, V.N.Panteleev, A.G.Polyakov and V.K.Tarasov, Nucl.Phys. A438 (1985) 482.
21. J.A.Winger, J.C.Hill, F.K.Wohn et al., Phys.Rev. C36 (1987) 758.
22. O.Civitarese, A.Faessler and T.Tomoda, Phys.Lett. B194 (1987) 11.
23. K.Grotz and H.V.Klapdor. Nucl.Phys. A460 (1986) 395.
24. G.D.Alkhazov, S.A.Artamonov, V.I.Isakov, K.A.Mezilev and Yu.N.Novikov, Phys.Lett. B198 (1987) 37.
25. B.A.Brown and B.H.Wildenthal, At.Data and Nucl.Data Tables 33 (1985) 347.
26. P.Hoodbhoy, J.Phys. G: Nucl.Phys. 13 (1987) L253.
27. J.Rapaport, T.Taddeucci, T.P.Welch, C.Gaarde, J.Larsen, D.J.Horen, E.Sugarbaker, P.Koncz, C.C.Foster, C.D. Goodman, C.A.Goulding and T.Masterson, Nucl.Phys. A410 (1983) 371.
28. S.D.Bloom and G.M.Fullea. Nucl.Phys. A440 (1985) 511.
29. K.Muto, Nucl.Phys. A451 (1986) 481.

Received by Publishing Department
on January 29, 1988.

Кузьмин В.А., Соловьев В.Г. E4-88-79

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

Исследовано влияние частично-частичного взаимодействия на вероятности гамов-теллеровских β^+-распадов и на силовые функции (n,p) переходов. Рассчитаны в RPA с сепарабельными частично-дырочными (p – h) и частично-частичными (p – p) взаимодействиями суммарные $\log \tilde{ft}$ -величины для ГТ распадов ^{152}Yb, ^{152,150}Er, ^{148,146}Dy и ^{96}Pd. Получено хорошее согласие с экспериментальными данными с константами $\kappa_1^{01} = 23/A$ МэВ и $G_1^{01} = 7{,}5/A$ МэВ при $|g_A/g_V| = 1$ и $G_1^{01} = 7{,}9/A$ МэВ при $|g_A/g_V| = 1{,}25$. Показано, что на имеющихся экспериментальных данных по β^+ распадам ядер, удаленных от полосы стабильности, нельзя сделать утверждение о сильной перенормировке в ядрах константы g_A аксиально-векторного слабого взаимодействия. Показано, что p–p взаимодействия оказывают сильное влияние на полную силу S_+(n,p) переходов путем уменьшения ее в 1,5 ÷ 3,0 раза. Для реакции ^{54}Fe(n, p)^{54}Mn рассчитанное значение $S_+ = 4{,}2$ согласуется с экспериментальным.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1988

Kuzmin V.A., Soloviev V.G. E4-88-79

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

The effect of the particle-particle interaction on the Gamow-Teller β^+ decay and strength functions of (n, p) transitions is studied. The integrated $\log \tilde{ft}$ values for the GT decays of ^{152}Yb, ^{152,150}Er, ^{146,148}Dy and ^{96}Pb are calculated in the RPA with separable particle-hole and particle-particle interactions. A good description of $\log \tilde{ft}$ is obtained with the constants $\kappa_1^{01} = -23/A$ MeV and $G_1^{01} = 7.5/A$ MeV at $|g_A/g_V| = 1$ and $G_1^{01} = 7.9/A$ MeV at $|g_A/g_V| = 1.25$. From the available experimental data on β^+ decay of nuclei far from stability one cannot conclude that the weak axial-vector constant g_A is strongly renormalised in nuclei. The particle-particle interaction is shown to influence strongly the total strength S_+ of (n, p) transitions by diminishing it (1.5-3.0) times. For the reaction ^{54}Fe (n, p) ^{54}Mn at forward angles the calculated value $S_+ = 4.2$ is in agreement with the experimental one.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1988