PARITY NONCONSERVATION AND THE REACTION $n + d \to \gamma + H_3$

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The purpose of this paper is to present the results of calculations of P-odd correlations in the capture of thermal neutrons by deuterons. These correlations are the result of weak interactions between the nucleons in the neutron-deuteron system and in tritium. The reaction $n + d \to \gamma + H_3$ was considered qualitatively in [1], where conjectures were made regarding relatively large effects of parity nonconservation in this reaction. We calculated the degree of circular polarization of the produced gamma quanta, P, and the asymmetry coefficients in the angular distribution of the gamma quanta, α_n and α_d. This asymmetry arises if polarized neutrons (α_n) or deuterons (α_d) are present in the initial state. In the calculations we took into account the weak interaction of the nucleons in tritium and in the nd system. The interaction amplitude of two nonrelativistic nucleons is characterized by five real weak constants g_0^0, g_0^1, g_0^2, g_1^0, and g_1^1, which describe the transitions between the S- and P-states. The lower index denotes the total angular momentum of the transition, and the upper index the change of the isospin in the transition. The amplitude of the interaction of the proton and of the neutron (1 - proton, 2 - neutron) is given by [2]

$$f_{pn}(\mathbf{k}', \mathbf{k}) = a_s(k)P_s + a_t(k)P_t + g_1^1 a_t(k)(\vec{\sigma}_1 + \vec{\sigma}_2)(\mathbf{k}' + \mathbf{k}) + \frac{1}{2}\{g_0^{pn} a_s(k) + g_1^0 a_t(k)\}(\vec{\sigma}_1 - \vec{\sigma}_2)(\mathbf{k}' + \mathbf{k}) + \frac{i}{2}\{g_0^{pn} a_s(k) - g_1^0 a_t(k)\}[\vec{\sigma}_1 \vec{\sigma}_2](\mathbf{k}' - \mathbf{k}). \quad (1)$$

A similar expression can be written for the amplitude of the interaction of identical nucleons, nn or pp:

$$f_{NN}(\mathbf{k}', \mathbf{k}) = a_s(k)P_s + \frac{1}{2} g_0^{NN} a_s(k)\{(\vec{\sigma}_1 - \vec{\sigma}_2)(\mathbf{k}' + \mathbf{k}) + i[\vec{\sigma}_1 \vec{\sigma}_2](\mathbf{k}' - \mathbf{k})\}. \quad (2)$$

In these formulas, $\vec{k}$ and $\vec{k}'$ are the initial and final momentum of nucleon 1 in the c.m.s., $a_{s,t}(k)$ are the amplitudes of the S-transitions in the singlet and triplet states, $P_{s,t}$ are the corresponding projection operators, and

$$g_0^{pn} = g_0^0 - 2g_0^2, \quad g_0^{nn} = g_0^0 - g_0^1 + g_0^2, \quad g_0^{pp} = g_0^0 + g_0^1 + g_0^2. \quad (3)$$

As seen from (1) and (2), the parity-nonconserving terms in the interaction amplitude of two nucleons have a resonant character, owing to the resonant factors $a_{s,t}(k)$. This makes it possible to include only paired nucleon interactions in the analysis of weak interactions in three-nucleon systems. To determine the wave functions of tritium and of the nd system, we used a method similar to that of [3] for the summation of nonrelativistic Feynman diagrams.

These wave functions were then used to calculate the circular polarization and the coefficients of angular asymmetry in the reaction $n + d \to \gamma + H_3$. The results of the calculations are:

$$P = (-0{,}7g_0^{pn} + 0{,}2g_0^{nn} - 0{,}4g_1^{0} - 1{,}7g_1^{1})m,$$
$$a_n = (-0{,}2g_0^{pn} - 1{,}0g_1^{nn} - 0{,}7g_1^{0} + 1{,}0g_1^{1})m, \qquad (4)$$
$$a_d = (0{,}2g_0^{pn} - 0{,}6g_0^{nn} - 0{,}2g_1^{0} + 1{,}2g_1^{1})m,$$

where m is the nucleon mass. It is hoped that the accuracy of these expressions is the same as the accuracy of the employed theory of zero nuclear-force action radius, i.e., about 30%. It follows from (4) that P, α_n, and α_d in the reaction $n + d \to \gamma + H_3$ have values on the order of gm. The absence of a reliable theory of weak nonleptonic interaction with $\Delta Y = 0$ does not make it possible to calculate the constant g_J^T. Different theoretical models make it possible only to estimate their order of magnitude. According to these estimates, $g_J^T m$ ranges from 10^{-5} to 10^{-7}, depending on the model [2], and consequently the values of the parameters P, α_n, and α_d lie in the same range. Experimental measurement of these parameters, together with measurement of of the analogous parameters in the reaction $n + p \to \gamma + d$, makes it possible to determine the constants g_J^T. This would resolve a number of fundamental problems in the theory of weak interactions [4].

It is of interest to compare the values of P and α_n in the reaction $n + d \to \gamma + H_3$ (I) with the values of these parameters in the reaction $n + p \to \gamma + d$ (II) [1, 2]. According to [2], in capture of neutrons by protons we have

$$P = (0{,}5g_0^{pn} - 0{,}2g_1^{0})m, \qquad (5)$$
$$a_n = 0{,}06g_1^{1}m.$$

Comparison of (4) and (5) leads to the conclusion that the degree of circular polarization of the γ quanta in both reactions is approximately the same, and the asymmetry parameter α_n in reaction I greatly exceed the analogous parameter in reaction II. This excess ranges from several times ten (if g_J^0 and g_J^1 are of the same order) to several hundred (say in octet intensification). However, it must be assumed that hopes for a larger absolute magnitude of the effects of parity nonconservation in reaction I [1] were apparently not fulfilled. This explains the negative result of measurements of α_n in reaction I [5]: $\alpha_n = (0.28 \pm 1.55) \times 10^{-4}$. As shown by our estimates above, to observe the effect the measurement accuracy must be raised by at least one order of magnitude.

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