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ISOTOPIC STRUCTURE OF PARITY NONCONSERVING NUCLEAR FORCES

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Blin-Stoyle and Feshbach [1] calculated the asymmetry, relative to the plane of polarization of the incident radiation, of nucleon emission in the $\gamma + d \rightarrow n + p$ reaction. This asymmetry is a result of the parity nonconserving weak interaction between nucleons, predicted by the V - A variant of the universal theory. The potential of the weak interaction in [1] corresponded to two-pion exchange [2], and its isotopic structure constituted a superposition of an isoscalar and an irreducible isotensor of second rank. Actually, however, only the isoscalar part makes a contribution to the amplitude of the considered process.

In this paper we estimate the possible contribution made to the same effect by the static isovector part of weak internucleon interaction, corresponding to a potential in the form

$$V(r) = V_1(r)(\sigma_1 + \sigma_2)(\mathbf{r}/r)[\tau_1 \times \tau_2]_0 \tag{1}$$

where $\mathbf{r}$ is the distance between the nucleons, and σ_1, σ_2, τ_1, and τ_2 are respectively the spin and isospin operators of nucleons 1 and 2.

A study of the isotopic selection rules in nuclear transitions which do not conserve parity is of interest from the point of view of SU(3) symmetry of elementary particles [3] which, under the assumption that there are no weak neutral currents, predicts an intensification of the isoscalar part compared with the isovector and isotensor parts.

The differential cross section of the process in question can be written in the form

$$\sigma(\theta,\varphi) = \sigma_0(\theta,\varphi)[1 + \gamma(\theta,\varphi)(\mathbf{Pe})(\mathbf{Ph})] \tag{2}$$

where σ_0 is the parity-conserving photodisintegration cross section, $\mathbf{P} = \mathbf{P}_1 - \mathbf{P}_2$ is the unit relative nucleon momentum, $\mathbf{e}$ and $\mathbf{h}$ are unit vectors in the direction of the electric and magnetic fields of the incident γ quantum, θ is the angle between the vectors $\mathbf{P}$ and $\mathbf{k}$ ($\mathbf{k} = \mathbf{e} \times \mathbf{h}$ is a unit vector in the direction of the incident radiation), and ζ is the angle between the reaction plane ($\mathbf{P}$, $\mathbf{k}$) and the plane ($\mathbf{h}$, $\mathbf{k}$).

The effect under consideration is due to interference between E1 and M1 transitions. The deuteron is in the state $^3S_1 + \alpha\, ^3P_1$, where the admixture of the $^3P_1$ state is due to the action of the parity nonconserving isovector potential of the weak interaction. It is easy to verify that the transitions $^3F_1 \to {}^3P_1$, $^3P_0$, $^3P_2$, (E1) and $^3P_1 \to {}^1P_1$ (M1) interfere with one another. The matrix element of the E1 transitions is small at γ-quantum energies near the threshold, and reaches a noticeable value at γ-quantum energies ϵ_γ of the order of or larger than $2\epsilon_d$ (ϵ_d is the deuteron binding energy).

The asymmetry of nucleon emission is defined by

$$\Delta(\theta,\varphi) = \frac{\sigma(\theta,\varphi) - \sigma(\theta,-\varphi)}{\sigma(\theta,\varphi) + \sigma(\theta,-\varphi)} = \gamma(\theta,P)(\mathbf{Pe})(\mathbf{Ph}) = \gamma_1 \cot\phi \tag{3}$$

In the energy region in question, as shown in [1], the coefficient γ_1 is practically independent of θ. Calculations with the aid of the potential (1) yield for γ_1 the following formula (in the zeroth approximation in the proton-neutron force radius):

$$\gamma_1 = \frac{16(\mu_1 - \gamma_2)[\cos(^1\delta_1 - {}^3\delta_1) + 3\cos(^1\delta_1 - {}^3\delta_2)]}{5/6 + (3/2)\cos(^3\delta_2 - {}^3\delta_1) + (2/3)\cos(^3\delta_2 - {}^3\delta_0)} \frac{I_M}{\epsilon_\gamma I_E} \tag{4}$$

where I_M and I_E are the radial matrix elements of the M1 and E1 transitions:

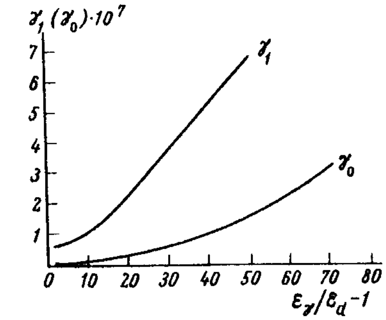
$$I_M = \int_0^\infty j_1(kr)V_1(r)R(r)r^2 dr, \qquad I_E = \int_0^\infty j_1(kr)R(r)r^3 dr$$

$j_1(kr)$ is a spherical Bessel function, $R(r)$ the deuteron wave function, $^1\delta_1$, $^3\delta_0$, $^3\delta_1$, and $^3\delta_2$ are the scattering phase shifts corresponding to the states $^1P_1$, $^3P_0$, $^3P_1$, and $^3P_2$, while μ_1 and μ_2 are the magnetic moments of the neutron and proton in nuclear magnetons.

We chose for a numerical estimate a potential corresponding to exchange of one charge pion

$$V_1(r) = g\frac{e^{-\mu r}}{r}(1 + \mu r^{-1})$$

where $1/\mu$ is the Compton wavelength of the pion ($\hbar = c = 1$). It is known that single-pion exchange (see [3,4]) is possible only if virtual strange particles participate in the nucleon weak-interaction process, i.e., only as a result of the existence of weak strangeness-nonconserving currents. In accordance with the theory of unitary symmetry of weak interaction [5], the numerical value of the constant g was chosen equal to approximately 1/15 of the analogous constant in the Blin-Stoyle potential. The expected asymmetry should be of the order of 10^{-6} - 10^{-7}.



The dependence of γ_1 on the energy is shown in the figure. The experimental values of the phases were taken from [6]. For comparison, the figure shows the curve from [1] for the analogous coefficient γ_0, corresponding to the isoscalar part of the Blin-Stoyle potential.

In conclusion the author is deeply grateful to I. F. Shapiro for suggesting the problem and for continuous interest in the work.

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CORRECTION

In the article by O. L. Lebedev et al. (JETP Letters v. 1, No. 2, Russian p. 16, translation p. 47, the following paragraph was omitted following Figs. 1 and 2:

In Fig. 2 the pulse duration reaches 80 nsec, and the corresponding pulse power is of the order of a megawatt. The amplitude of the oscillogram on Fig. 2 has been reduced by a factor 3×10^3 compared with Fig. 1 by using neutral filters placed ahead of the photomultiplier.

CORRECTION

In the article by B. L. Livshitz et al. (JETP Letters v. 1, no. 5, Russian p. 23, translation p. 136, the captions of Figs. 1 and 2 have been interchanged. In addition, the letters "a" and "b" on the photographs of Fig. 1 have been interchanged.