PARITY NONCONSERVATION IN THE FIRST ORDER IN THE WEAK-INTERACTION CONSTANT IN ELECTRON SCATTERING AND OTHER EFFECTS

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WE assume that besides the weak interaction that causes beta decay,

$$g(\bar{P}ON)(\bar{e}^{-}O\nu) + \text{Herm. conj.}, \qquad (1)$$

there exists an interaction

$$g(\bar{P}OP)(\bar{e}^{-}Oe^{-}) \qquad (2)$$

with $g \approx 10^{-49}$ and the operator $O = \gamma_\mu(1+i\gamma_5)$ characteristic[1] of processes in which parity is not conserved.*

Then in the scattering of electrons by protons the interaction (2) will interfere with the Coulomb scattering, and the nonconservation of parity will appear in terms of the first order in the small quantity g. Owing to this it becomes possible to test the hypothesis used here experimentally and to determine the sign of g.

The matrix element of the Coulomb scattering is of the order of magnitude e^2/k^2, where k is the momentum transferred ($\hbar = c = 1$). Consequently, the ratio of the interference term to the Coulomb term is of the order of gk^2/e^2. Substituting $g = 10^{-5}/M^2$, where M is the mass of the nucleon, we find that for $k \sim M$ the parity nonconservation effects can be of the order of 0.1 to 0.01 percent.

In the scattering of fast ($\sim 10^9$ ev) longitudinally polarized electrons through large angles by unpolarized target nuclei it can be expected that the cross-sections for right-hand and left-hand electrons (i.e., for electrons with $\boldsymbol{\sigma}\cdot\mathbf{p} > 0$ and $\boldsymbol{\sigma}\cdot\mathbf{p} < 0$) can differ by 0.1 to 0.01 percent. Such an effect is a specific test for an interaction not conserving parity.

A magnetized iron plate can served as a source of polarized electrons.[6] When electrons are ejected from it by ion or electron impacts (dynatron effect), photoelectric effect,[6] or as delta electrons, one can expect a polarization even larger than that corresponding to the ratio of the number of magnetization electrons to the total number of of electrons in the iron, since the inner electrons do not take much part in these processes. From thermoelectric emission or field emission one cannot expect an appreciable polarization of the emerging electrons, since the chemical potential of the electrons with spins parallel and antiparallel to the magnetization is evidently the same.

The interaction (2) leads to a displacement of the electron levels of different parities in the free atom.

In the hydrogen atom the probability of the metastable transition $2S_{1/2} \rightarrow 1S_{1/2}$, which appears on account of the admixture of $2P_{1/2}$ to the $2S_{1/2}$, still turns out to be even smaller that the transition probability on account of the magnetic moment of the electron, and is less than the probability of the two-quantum transition $2S \rightarrow 1S$ by a factor of more than 10^7. Finally, the interaction (2) leads to a rotation of the plane of polarization of visible light by any substance not containing molecules optically active in the ordinary sense of the words. The rotation of the plane of polarization also occurs because the weak interaction mixes atomic electronic states of different parity. A calculation of the effect gives an expression of the form

$$|n_{\text{right}} - n_{\text{left}}| \sim N_0 (a^4/\lambda) g |\psi_S(0)||\psi_P(0)|/(E_P - E_S), \qquad (3)$$

where n is the index of refraction for circularly polarized light; $N_0 \sim a^{-3}$ is the number density of the atoms; a is the linear dimension of an atom; λ is the wavelength of the light; $|\psi_S(0)| \sim 1/a^{3/2}$; in $|\psi_P(0)|$ there are nonvanishing "small components" χ, given by $\chi \sim (\hbar/2mc)\,\boldsymbol{\sigma}\,\text{grad}\,\varphi$, where φ are the "large components"; $|\psi_P(0)| \sim (\hbar/mc)\,a^{-5/2}$, so that

$$|n_{\text{right}} - n_{\text{left}}| \sim (g/a^3\Delta E_{SP})(\hbar/mc\lambda\!\!\!^{-}) \sim 10^{-20}. \qquad (4)$$

Rotation of the plane of polarization by 1 radian occurs in a length of the order $\lambda\!\!\!^{-}/10^{-20} = 10^{15}$ cm, so that even in the first order in g the effect obviously cannot be observed.

How plausible is the assumption that the interaction (2) exists? Let us regard νe^- as a doublet in isotopic space and denote by l_1 the two-component quantity ν, e^-. We denote by B (baryons) the two-component quantity P, N. The interaction that causes β decay is written

$$g(\bar{B}\tau_+OB)(\bar{l}_1\tau_-Ol_1) + g(\bar{B}\tau_-OB)(\bar{l}_1\tau_+Ol_1)$$
$$\equiv 2g(\bar{B}\tau_xOB)(\bar{l}_1\tau_xOl_1) + 2g(\bar{B}\tau_yOB)(\bar{l}_1\tau_yOl_1). \qquad (5)$$

It is natural to add to this formulation a term that complements the expression (5) to make the scalar product $\boldsymbol{\tau}_B\boldsymbol{\tau}_{l_1}$:

$$2g(\overline{B}\tau_z OB)(\overline{l}_1\tau_z O l_1)$$

$$= 2g[(\overline{P}OP) - (\overline{N}ON)][(\overline{\nu}O\nu) - (\overline{e^-}Oe^-)], \qquad (6)$$

l this term contains the interaction in which we ; interested here. In addition the formalism .ds to the conclusion that the sign of the inter- :ion will be different for the proton and the neu- n. For the μ-meson interactions one will have introduce another two-component quantity l_2, ısisting of ν, μ^-. Then in the scalar product $\tau l_1)(\overline{l}_2\tau l_2)$ there are no terms that would give ; decay $\mu^- \rightarrow 2e^- + e^+$, and the objection of ll-Mann and Feynman[1] falls to the ground.

Assumptions have been put forward about a ·ect interaction $g(\overline{e}^- O\nu)(\overline{\nu} Oe^-)$, which would ıd to a scattering of neutrinos by electrons,[1] d also about a weak interaction of four nucleons,[2] .ich leads to parity nonconservation in first order g in nuclear reactions and the stationary states nuclei. The four-nucleon interaction has as a nsequence that odd nuclei (spin $\neq 0$) will have "anapole" moment[3] proportional to g. The elec- ›magnetic interaction of the electron with the apole moment leads to parity nonconservation the order ge^2. Thus in the absence of a direct ak interaction of electrons with nucleons the ef- :ts considered above, caused by mixtures of atomic electron levels of different parities, do not vanish, but are weakened by a factor of about 100.

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*Such an interaction has been repeatedly discussed in the past in connection with the problem of the isotope shift of electron levels (I. E. Tamm). On an analogous interaction between the neutron and the electron, see references 4 and 5. New experimental possibilities arise in connection with the nonconservation of parity in the interaction (2).

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