PARITY NONCONSERVATION IN STRONG INTERACTIONS AND NUCLEAR FISSION

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RECENTLY, in connection with the discovery of nonconservation of parity in weak interactions, attempts have been made to determine the degree of nonconservation in strong interactions. We can expect the admixture of parity-nonconserving interaction in the nuclear forces to be of order $f^2/\hbar c \approx 10^{-14}$ if we include, in addition to the exchange of π mesons, the virtual exchange of leptons. Gell-Mann and Rosenfeld[1] found that under certain assumptions it is possible to have emission of a nucleon-antinucleon pair with the strong coupling constant $g/\sqrt{\hbar c}$, and the absorption of the pair by weak interaction with the weak coupling constant $f/\sqrt{\hbar c}$. The admixture of such a parity-nonconserving interaction into the strong interaction amounts to $\sim fg/\hbar c \approx 10^{-7}$. Within the framework of the universal Fermi interaction, a similar result is obtained for a four-fermion interaction and an interaction in which two fermions and two bosons participate.[2]

The possibility of observing experimentally the admixture of parity-nonconserving interaction results from the fact that selection rules hinder the parity-conserving transitions. Blin-Stoyle[3] investigated the possibility of observing a pseudoscalar admixture in nuclear γ transitions. A comparison of the computations with the experimental data shows that the admixture of nuclear states which do not conserve parity is $F \leq 10^{-4} - 10^{-5}$. An increase in accuracy of the measurements by $2 - 3$ orders of magnitude is required in order to reach the theoretical value $F \sim 10^{-7}$.

Further possibilities for detecting nonconservation of parity in strong interactions may be given by investigations of nuclear fission. The most important fact in this case is that the value of the fission threshold, according to the hypothesis of A. Bohr[4] and the data of Stokes et al,[5] depends on the spin and parity of the fissioning nucleus. If it turns out that the barrier for fission of a nucleus with nonconservation of parity is lower than the barrier for fission with conservation of parity, then the admixture of parity-nonconserving states, after passing through the barrier will be greater than the value F in the ratio of the barrier factors P_1 and P_2. The maximum enhancement can be obtained in the case of spontaneous fission, in which the ratio of the barrier penetrabilities is $\sim 10^{6 \cdot \Delta E}$, where ΔE is the difference in heights of the barriers in Mev. Thus in the case of spontaneous fission it would be sufficient to have a difference in barrier heights $\Delta E \geq 1$ Mev in order that $FP_1/P_2 \sim 1$.

A difference in barrier heights of this order was found by Stokes et al[5] in investigating the fission of even-even nuclei, and by Simmons and Henkel[6] in investigating nuclei with odd A. For odd nuclei the probability of spontaneous fission is, on the average, 10^{-4} of the probability for spontaneous fission of the neighboring even-even nuclei. This fact was explained by Newton[7] and Wheeler[8] as an effect of raising of the barrier with the spin and parity of the ground state above the ground state at the saddle point. To explain the smaller probability of spontaneous fission of nuclei with odd A, it was necessary to assume that this rise, the so-called "restricting energy," amounts to ~ 1 Mev.

Several effects may occur in experiments from nonconservation of parity in strong interactions:

1) Increase in fission probability because of the contribution of fission with nonconservation of parity. This effect can be observed only when one makes a comparison with theoretical calculations of fission probability. However, because there is no quantitative theory of fission, this effect cannot be detected.

2) Observation of the asymmetry in emergence of the light (or heavy) fragment along the direction of and opposite to the direction of the nuclear spin, i.e., an asymmetry of the form $1 + a\boldsymbol{\sigma}\cdot\mathbf{p}$, which is possible only when we have nonconservation of spatial parity. Such an asymmetry occurs as a result of the interference of states of one parity with states of the opposite parity and is maximal for $FP_1/P_2 \sim 1$.

One can suggest a mechanism for the appearance of spatial asymmetry. According to [9], in a sufficiently elongated nucleus the external nucleons with large angular momentum are located in the neighborhood of one of the ends, producing a pear-shaped deformation. We denote the wave functions of the states in which $\boldsymbol{\sigma}$ is directed along the two opposite directions relative to the "pear" by ψ_1 and ψ_2. If parity is conserved, two combinations of these states are possible: the even state $\psi_+ = \psi_1 + \psi_2$, and the odd state $\psi_- = \psi_1 - \psi_2$. If there is a weak parity violation, combinations of these functions must appear. In a nucleus with positive parity, we get $\psi = \psi_+ + F\psi_-$. After passing through the barrier, whose penetrabilities for the states ψ_+ and ψ_- are equal respectively to P_2 and P_1, we form a state

$$\psi = P_2\psi_+ + P_1F\psi_- = P_2\left[\left(1+\frac{P_1}{P_2}F\right)\psi_1 + \left(1-\frac{P_1}{P_2}F\right)\psi_2\right],$$

i.e., a state with a pear-shaped deformation which is correlated with the spin. An analogous result is obtained for a nucleus with negative parity.

The estimates given above for the values of P_1/P_2 and F show that the spatial asymmetry can be quite large in certain nuclei. An experiment for observing spatial asymmetry can be carried out with polarized nuclei which have a spin in the ground state and a relatively high probability for spontaneous fission:[10] Bk^{249} ($T_{sp.f.} = 6 \times 10^8$ yr), Cf^{249} ($T_{sp.f.} = 1.5 \times 10^9$ yr), Es^{253} ($T_{sp.f.} = 7 \times 10^5$ yr) and possibly Am^{241} ($T_{sp.f.} \geq 2 \times 10^{14}$ yr).[11]

3) The appearance of longitudinal polarization of secondary neutrons, associated with the fact that the direction of the spin of the fragments formed in fission may be correlated with the direction of motion of the fragments. The observation of longitudinal polarization of neutrons can be carried out with unpolarized nuclei.

4) The occurrence of circular polarization of γ quanta, associated with a possible transition of the mixture of even and odd wave functions in the fission fragment.

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TRANSVERSE POTENTIAL DIFFERENCE THAT IS EVEN WITH RESPECT TO THE MAGNETIC FIELD, OBSERVED IN TIN

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AT the present time there are only three papers dealing with the experimental study, in large magnetic fields, of the even e.m.f. (even relative to the magnetic field direction), which —like the Hall effect—appears in the plane perpendicular to the current; the experiments have been conducted on single crystals of gallium,[1] tin,[2] and copper.[3] In the last case this phenomenon is attributed to the motion of carriers in open trajectories.

We have carried out an investigation, which was described in [2], on cylindrical specimens of pure tin ($\rho_{290°K}/\rho_{4.2°K} = 60\,000$) of various orientations in fields up to 7 koe. The voltage proportional to the resistance due to inaccurate disposition of the contacts amounted to several percent of the measured effect.

The rotation diagram of the even voltage is given in the figure for one of the specimens— Sn-11; for comparison, the rotation diagram of the resistance in the magnetic field is given. (The quantity E_{qy} plotted in the diagram in the projection of the vector of the even electric field $\mathbf{E}_q$ on the y axis; the x and z axes are directed along the current $\mathbf{j}$ and field $\mathbf{H}$, respectively. Since $\mathbf{E}_q \perp \mathbf{H}$, it follows that E_{qy} coincides with $|\mathbf{E}_q|$ except in sign.) For directions leading to open trajectories, the even voltage attains a maximum (as in the case of copper[3]); it does not, however, disappear for intermediate directions of the magnetic field when there are no open trajectories (with the exception of the direction $\mathbf{H} \parallel$ proj.[001]).* A rotation dia-

*The symbol proj. [001] means the direction of the projection of the [001] axis in the plane of rotation of the magnetic field.