ON NEUTRAL LEPTON CURRENTS IN A NEW CP-ODD, $|\Delta S| = 1$, SUPERWEAK INTERACTION OF ELEMENTARY PARTICLES

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A simple model of a new CP-odd, $|\Delta S| = 1$, superweak interaction of elementary particles in the form of neutral currents (1) is proposed. The possible unitary and isotopic properties of this interaction are discussed for leptonic processes, and possible manifestations of it are considered for the case that neutral leptonic currents exist.

THE absence or at least the strong suppression of neutral leptonic currents l^0 in the known weak processes is an experimental fact. On the other hand, no theoretical principles are known at present which would exclude such currents from all interactions except the electromagnetic ones. The clear example of the latter possibly indicates that the absence of l^0 in the weak interactions represents an exception rather than the rule.[1)] In this case any "new" interaction of elementary particles should be tested for neutral currents.

Earlier, the author[4] has formulated the hypothesis that neutral leptonic currents l^0 take part in a new CP-odd superweak interaction of hadrons with $|\Delta S| = 1$.[5] Let us consider the simplest model for such an interaction. We assume that the phenomenological Lagrangian for this interaction, like the Lagrangian for the weak and electromagnetic interactions, has a current-current form with currents whose hadronic parts are components of the same vector and axial vector unitary octets as in the weak and electromagnetic interactions.[6] Hence

$$L_{CP=-1} = f\frac{G'}{\sqrt{2}} j_7 j^{u(0)}, \tag{1}$$

where f is a dimensionless coupling constant of the new interaction, G′ is the "Fermi constant" for the usual weak current-current interaction with strangeness violation $|\Delta S| = 1$, j_7 is the seventh component of the unitary octet of hadronic currents with CP = −1, and the current $j^{u(0)}$ includes the neutral hadronic current without strangeness violation with CP = +1, which can be a unitary singlet[7] or, under the preceding assumptions, is either the eighth or third component of the unitary octet, or a linear combination of them.

As can be seen immediately from (1), the nonleptonic CP-odd $|\Delta S| = 1$ processes must obey the strong $|\Delta T| = 1/2$ rule, i.e.,

$$w(K_2^0 \to \pi^0\pi^0)/w(K_2^0 \to \pi^+\pi^-) = 1/2. \tag{2}$$

if the hadronic part of the current $j^{u(0)}$ is a unitary singlet or the eighth component of an octet. However, the most recent experimental data[8] seem to indicate that Eq. (2) is not fulfilled. If these data are confirmed in the future, this means that the hadronic part of the current $j^{u(0)}$ includes the third component of the octet and is probably a linear combination of an isoscalar and the third component of an isovector. By assumption the current contains, besides the hadronic current already mentioned, also CP-even leptonic neutral currents of the form

$$l^0 = (\bar{e}\gamma_\alpha(1 \pm \gamma_5)e) + (\bar{\nu}\gamma_\alpha(1 \pm \gamma_5)\nu) + (\bar{\mu}\gamma_\alpha(1 \pm \gamma_5)\mu). \tag{3}$$

The coupling constant f can be estimated from the experimental data on the ratio of the probabilities for the decays $K_1^0 \to 2\pi$ and $K_2^0 \to 2\pi$.[5] Here the following circumstance must be taken into account. It is known that the existence of a symmetry of the strong interactions higher than the isotopic one can lead to a suppression of the $K \to 2\pi$ decays;[9] this effect may be different for CP-even and CP-odd processes. It is easy to show that if the hadronic currents participating in the usual weak interactions and in the superweak interaction (1) belong to the same unitary (V − A) octet, then

[1)]The elimination of l^0 by an appropriate choice of the isotopic structure of the weak currents with a corresponding definition of the violated isotopic properties of the leptons [1,2] or the Lagrangian of the weak interaction [3] cannot be regarded as universal.

all $K \to 2\pi$ decays ($K_1^0 \to 2\pi$, $K^+ \to \pi^+\pi^0$, $K_2^0 \to 2\pi$) are simultaneously forbidden in the limit of exact unitary symmetry of strong interactions. In this case one can obtain the estimate $f \sim 2 \times 10^{-3}$ from a comparison with the experimental data.[5] However, from a more general point of view one must evidently assume that hadronic currents of the two different unitary octets (V – A) and (V + A) take part in the weak[10] and superweak as well as the electromagnetic interactions. Then four cases are possible: 1) The $K \to 2\pi$ decays with CP = +1 and CP = –1 are simultaneously forbidden by unitary symmetry, 2) The $K \to 2\pi$ decays with CP = +1 and CP = –1 are simultaneously allowed by unitary symmetry, 3) The $K \to 2\pi$ with CP = +1 are allowed and the ones with CP = –1 are forbidden and the ones with CP = –1 are allowed. In cases 1) and 2) we find $f \sim 2 \times 10^{-3}$, in case 3) we find $f \sim \alpha = 1/137$, and in case 4) $f \sim 5 \times 10^{-4}$.

It is now important that, as is easy to see, in the model (1) the semileptonic decays with participation of neutral leptonic currents (in particular, $K^+ \to \pi^+e^+e^-$, $\pi^+\nu\tilde{\nu}$; $K_2^0 \to \pi^0e^+e^-$, $\pi^0\nu\tilde{\nu}$; $K_1^0 \to \mu^+\mu^-$) are allowed by unitary symmetry in all cases 1) to 4). Indeed, in the current-current Lagrangian (1) these decays are caused by the hadronic current j_7 with CP = –1, which is the seventh component of an octet independently of its Lorentz (V – A) or (V + A) structure. On the other hand, the hadronic current $q_\alpha K_1^0$ in the decay $K_1^0 \to \mu^+\mu^-$ is by definition also the seventh component of an octet, while the hadronic current $q_\alpha K_2^0\pi^0$ in the decay $K_2^0 \to \pi^0 l\tilde{l}$ contains the seventh component of an octet because of the presence of the part of the wave function of two octet mesons which is antisymmetric in the unitary variables.

This result allows us to make the following estimates[4, 11] for the leptonic decays of the K mesons owing to the superweak interaction (1):

$$w(K^+ \to \pi^+e^+e^-;\ \pi^+\nu\tilde{\nu})/w(K^+) \approx 2\cdot 10^{-7}, \quad (4)$$

$$w(K_2^0 \to \pi^0e^+e^-;\ \pi^0\nu\tilde{\nu})\ /\ w(K_2^0) \approx 10^{-6}, \quad (5)$$

$$w(K_1^0 \to \mu^+\mu^-)/w(K_1^0) \approx 4\cdot 10^{-8} \quad (6)$$

for the cases 1) and 2). In case 3) the estimates (4) to (6) are raised by an order of magnitude and have the value $\sim 2 \times 10^{-6}$, $\sim 10^{-6}$, and $\sim 4 \times 10^{-7}$, respectively, while for case 4) these estimates are lowered by an order of magnitude and yield $\sim 2 \times 10^{-8}$, $\sim 10^{-7}$, and $\sim 4 \times 10^{-9}$, respectively. It should be noted that in case 3) the estimates for the leptonic decays of K^+ and K_2^0 are at the threshold of the existing experimental data

$$w(K^+ \to \pi^+e^+e^-)/w(K^+) < 1{,}1\cdot 10^{-6}, \quad (7)$$

$$w(K_2^0 \to e^+e^-)/w(K_2^0) < 5\cdot 10^{-6}, \quad (8)$$

$$w(K_2^0 \to \mu^+\mu^-)\ /\ w(K_2^0) < (2 \div 8)\cdot 10^{-6}, \quad (9)$$

quoted in the report of Cabibbo.[12] An improvement in the statistical accuracy of these experimental data will evidently allow us to draw some critical conclusions regarding our hypothesis of neutral leptonic currents in the new CP-odd superweak interaction (1).

The CP-odd decay $K_1^0 \to e^+e^-$ is suppressed compared to the decay $K_1^0 \to \mu^+\mu^-$ by the factor $(m_e/m_\mu)^2$. It is interesting that the CP-even decay $K_2^0 \to \mu^+\mu^-$ is strictly forbidden with respect to the superweak interaction (1) and can only take place on account of the joint effect of the usual weak and electromagnetic interactions with the estimate $\sim 10^{-8}$ to 10^{-9}.[13] But if the decay $K_2^0 \to \mu^+\mu^-$ were allowed by the superweak interaction [this would be possible, for example, if together with the CP-odd current j_7, the CP-even current j_6 were also present in the superweak interaction (1)], then we would get the estimate $\sim 2 \times 10^{-4}$ to 2×10^{-6} for its relative probability, which is possibly already excluded by the available experimental data (9).

In conclusion we note that, as already pointed out by Ya. B. Zel'dovich, one cannot at present exclude the possibility that the law of leptonic charge conservation is violated by the new superweak interaction. In our model we can take this possibility into account by including in the CP-odd current j_7, together with the hadronic terms, also CP-odd nondiagonal leptonic terms of the form $(\bar{e}\gamma_\alpha(1 \pm \gamma_5)\mu) - (\bar{\mu}\gamma_\alpha(1 \pm \gamma_5)e)$. The inclusion of such terms would, in particular, give rise to $\mu^+ \to e^+ + e^- + e^+$ decays with a probability which is suppressed compared to the usual μ-decay by the factor $\sim f^2/20$. This suppression is in cases 1) and 2) equal to $\sim 10^{-7}$, in case 3) it is $\sim 10^{-6}$, and in case 4) it is $\sim 10^{-8}$. Hence, in case 3) this possibility is already definitely excluded by the present experimental data.[14]

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