STRANGE LEPTONS

Richard M. Weiner
Labirint 28, Bucharest, Rumania

(Received 19 September 1967)

The consequences of the following two assumptions are discussed: (1) There exist strange leptons; (2) strangeness is conserved in all semileptonic interactions. These hypotheses could explain the absence of neutral currents in semileptonic processes and the $\Delta S = \Delta Q$ rule without assuming that the weak current transforms like a SU(3) octet. We propose experiments, well within the reach of present possibilities, to test these assumptions.

One of the most interesting problems of weak interactions is that of neutral currents. This problem has two aspects: the existence of neutral currents (n.c.) and their experimental observation.

It has been suggested by Michel[1] that n.c. might exist, but in some cases their observation is inhibited by a selection rule. This happens, e.g., in leptonic processes where the decays $\mu \to e + \gamma$, $\mu \to 3e$ are not observed because muonic and electronic neutrinos are different particles and because the muonic and electronic quantum numbers are conserved. Along the same line of thought, in nonleptonic processes n.c. exist and are observed. This explains the $\Delta I = \frac{1}{2}$ rule[2] or the conjectured[3] octet enhancement.[4]

However, if we accept this point of view and the conventional hypothesis that leptonic, semileptonic, and nonleptonic interactions are described along a unique current-current scheme, the strong inhibition of n.c. in the semileptonic processes

$$K^+ \to \pi^+ + \mu^+ + \mu^-;\quad K^+ \to \pi^+ + e^+ + e^-;$$
$$K_L^{\,0} \to \mu^+ + \mu^-;\quad K_L^{\,0} \to e^+ + e^- \tag{1}$$

remains unexplained. The upper limits for these decays are 3×10^{-6} and 1.1×10^{-6} for K^+, and 1.6×10^{-6} and 1.8×10^{-5} for K^-, respectively.[5]

In this paper we should like to suggest that the nonobservation of n.c. in semileptonic processes is due to a similar cause to that acting in leptonic processes, i.e., a conservation law.

Semileptonic processes like (1) are usually considered to make part of the class $\Delta S \neq 0$ weak interactions, which includes also most of the nonleptonic processes and which does not conserve strangeness. We want to challenge this classification and assume that the nonconservation of strangeness occurs only in nonleptonic processes. Indeed, let us assume that in all semileptonic weak interactions strangeness is conserved and that the variation of strangeness in the hadronic current is compensated by a strange leptonic current, in the same way as the variation of charge ΔQ. Thus we also make the assumption that there exist strange leptons besides the conventional ones. These hypotheses are apparently shocking, but the present experimental situation in this field does not rule out this possibility. Moreover, as pointed out above, our assumptions satisfy the natural tendency towards an "economy of thought," because the divorce between nonleptonic and semileptonic interactions would be compensated by the new link between leptonic and semileptonic interactions. On the other hand, if the experimental evidence should fail to confirm our hypotheses, this in turn could be considered as an indirect, but independent, confirmation of the conventional theory. The need for such a confirmation is obvious.

It is highly intriguing that up to the present there are no proofs for the identity of leptons generated in $\Delta S = 0$ reactions with those emerging from $\Delta S \neq 0$ interactions. While the identity of electrons, e.g., from β decay, μ decay, and stable matter has been the subject of special experimental investigations, no such experiments have been performed for leptons generated by strange hadrons. This question is therefore of independent experimental interest. It is very well conceivable that some or all leptons have strange counterparts, although their respective masses might be nearly equal. A well-known example of two particles with (nearly) equal masses, but with quite different properties, is given by the two neutrinos ν_e, ν_μ.

We have analyzed three main possibilities which follow from the assumptions formulated above:

(i) There exist only neutral strange leptons.

A possible scheme for this case is given in Table I. Among others the following reactions are allowed (l stands for a lepton; here and in the following we assume μ-e universality throughout):

$$\pi^+ \to l^+ + \nu, \tag{2}$$

$$K^+ \to l^+ + \bar{\nu}^S, \tag{3}$$

$$\nu^S + p \to l^+ + Y^0, \tag{4}$$

$$\Sigma^- \to n + e^- + \nu^S, \tag{5}$$

$$K^+ \to \pi^+ + \bar{\nu}^S + \bar{\nu}, \tag{6}$$

while the reactions

$$\pi^+ \to l^+ + \nu^S (\bar{\nu}^S), \tag{7}$$

$$K^+ \to l^+ + \bar{\nu}(\nu), \tag{8}$$

$$\nu^S + N \to l + N, \tag{9}$$

$$\nu + N \to l + Y, \tag{10}$$

$$\Sigma^+ \to n + l^+ + \bar{\nu}^S (\nu^S, \nu, \bar{\nu}), \tag{11}$$

$$K \to \pi + l^+ + l^-, \tag{12}$$

are forbidden.

(ii) There exist only charged strange leptons l^S. Table II summarizes a possible assignment of quantum numbers for this case. The following reactions are now allowed:

$$K^+ \to l^{+S} + \bar{\nu}, \tag{13}$$

$$\nu + p \to l^{+S} + Y^0, \tag{14}$$

$$\Sigma^- \to n + l^{-S} + \nu, \tag{15}$$

while Reactions (7)-(12) and

$$\pi^+ \to l^{+S} + \nu(\bar{\nu}), \tag{16}$$

$$\Sigma^+ \to n + l^{+S} + \nu(\bar{\nu}), \tag{17}$$

$$\Sigma^+ \to n + l^+ + \nu(\bar{\nu}), \tag{18}$$

$$K^+ \to \pi^+ + l^{+S} + l^-, \tag{19}$$

$$K^+ \to \pi^+ + l^+ + l^{-S}, \tag{20}$$

$$K \to \pi + \text{neutrinos}, \tag{21}$$

$$l^{+S} + e^- \to \text{photons}, \tag{22}$$

$$l^{-S} + p \to \nu(\bar{\nu}) + n, \tag{23}$$

are forbidden.

Table I. Strange neutrinos (n = leptonic quantum number, S = strangeness).

	n	S
ν	1	0
$\bar{\nu}$	−1	0
ν^S	−1	−1
$\bar{\nu}^S$	1	1

Table II. Charged strange leptons.

	n	S
l^+	−1	0
l^-	1	0
l^{+S}	1	1
l^{-S}	−1	−1
ν	1	0
$\bar{\nu}$	−1	0

Table III. Neutral and charged strange leptons.

	n	S
ν	−1	0
$\bar{\nu}$	−1	0
ν^S	−1	−1
$\bar{\nu}^S$	1	1
l^+	−1	0
l^-	1	0
l^{+S}	1	1
l^{-S}	−1	−1

(iii) There exist both charged (l^S) and neutral (ν^S) strange leptons. A possible scheme for this case is represented in Table III. Reactions (2)-(6), (13)-(15), and

$$\pi^+ \to l^{+S} + \nu^S \tag{24}$$

are now allowed while Reactions (7)-(12) and (16)-(23) are forbidden. Experimentally, however, Reactions (4) and (14), e.g., will appear as partially inhibited, while Reactions (9), (10), (22), and (23) will appear as partially allowed, because strange leptons emerging from the decay of strange hadrons will always be mixed with nonstrange leptons (the K meson, e.g., decays now both via channel $l^S + \nu$ and channel

$l+\nu^S$). The degrees of inhibition or allowness of these reactions depend on the ratio

$$\eta\equiv(K\rightarrow l^S+\nu)/(K\rightarrow l+\nu^S).$$

With $\eta\ll1$ or $\eta\gg1$ we reobtain variants (i) and (ii), respectively.

From these three possible schemes two conclusions can be reached:

(a) Leptonic and strangeness quantum numbers n and S of strange leptons can be chosen in such a manner that some or all neutral currents in $\Delta S\neq0$ semileptonic reactions are forbidden because of n and S conservation. In particular, it is possible that only l^+l^- neutral currents which occur in Reactions (1) should be forbidden, while $\nu\bar{\nu}$ currents should be allowed. The search for the decay $K\rightarrow\pi+$neutrinos could help to distinguish between possibility (i), on the one hand, and possibilities (ii) and (iii), on the other hand.

(b) The $\Delta S=\Delta Q$ rule [inhibition of Reaction (11), e.g.] follows as a consequence of n and S conservation and does not necessitate the hypothesis that the weak hadronic current transforms like a SU(3) octet.

Some experimental consequences of the model put forward above are as follows:

(1) If there exist only strange neutrinos, neutrinos emerging from K_{e3}^- decay $K^-\rightarrow\pi^0+e^-+\nu_e^S$ can generate electrons only via the reaction

$$\nu_e^S+p\rightarrow e^++Y^0;$$

among others, the reaction

$$\nu_e^S+p\rightarrow e^++n$$

is forbidden. This last prediction is identical with that of the neutrino-flip hypothesis with hyperon production.[6] The experimental situation on this point is yet unclear.[7]

(2) Strange electrons do not annihilate with electrons in ordinary matter.[8]

(3) Strange muons are not captured by nuclei in ordinary matter, but decay freely.

All these consequences can be tested with present experimental techniques. Given the importance of the existence of strange leptons, experimentalists are invited to explore this "terra incognita" of particle physics.

Discussions with my colleagues are gratefully acknowledged. I am particularly indebted to E. M. Friedländer for suggesting variant (iii).

---

[1] F. C. Michel, Phys. Rev. 138, B408 (1965), and 156, 1608 (1967).

[2] T. D. Lee and C. N. Yang, Phys. Rev. 119, 1410 (1960); S. Oneda and J. C. Pati, Phys. Rev. 155, 1618 (1967); R. C. Brunet, Syracuse University Report No. 66-11, 1966 (unpublished); G. Murtaza and P. J. O'Donnell (to be published); G. S. Guralnik, V. S. Mathur, and L. K. Pandit, University of Rochester Report No. 875-148, 1966 (unpublished).

[3] Y. Hara, Y. Nambu, and J. Schechter, Phys. Rev. Letters 16, 380 (1966); Y. Yokoo, Progr. Theoret. Phys. (Kyoto) 35, 508 (1966); A. K. Mohanti, University of Rochester Report No. 875-182, 1967 (unpublished).

[4] This point of view is far from being shared unanimously and there are people who hope that the $\Delta I=\frac{1}{2}$ rule could be derived from considerations of currents algebra and other assumptions [cf., e.g., H. Sugawara, Phys. Rev. Letters 15, 870 (1965); M. Suzuki, Phys. Rev. Letters 15, 986 (1965)]. Leaving aside the objection that these assumptions (partial conservation of axial-vector currents, limit $m_\pi=0$, etc.) have yet to be proven, the present situation in this field, especially in what concerns p-wave processes [Y. Chiu, J. Schechter, and Y. Ueda, Phys. Rev. 150, 1201 (1966); L. Brown and Ch. Sommerfield, Phys. Rev. Letters 16, 751 (1966); Fayyazuddin and Riazuddin, Nuovo Cimento 47A, 222 (1967); L. Kisslinger, Phys. Rev. Letters 18, 861 (1967)], does not warrant such optimism. It seems that from charged currents alone one cannot obtain the $\Delta I=\frac{1}{2}$ rule.

[5] CERN Collaboration, Phys. Letters 24B, 194 (1967), and references therein.

[6] R. E. Marshak, C. Ryan, T. K. Radha, and K. Raman, Nuovo Cimento 32, 408 (1964).

[7] In a paper by R. R. Burns [Columbia University Report No. NEVIS 148, 1966 (unpublished)] experimental evidence against this prediction is reported. However, the confidence level of this experiment is low and we feel that no definite conclusion can yet be reached in this connection.

[8] Note added in proof.—If the electromagnetic interactions of strange charged leptons are the same as those of nonstrange leptons, they should be produced in pairs with the same cross section, in disagreement with experiment. This would constitute serious evidence against the existence of charged strange leptons, unless an alternative electromagnetic interaction can be found, which would suppress pair production. Possibilities are being investigated. I am very much indebted to Professor Harry J. Lipkin for this observation.