will be eigenstates of L with different eigenvalues. [From (1) it follows that for systems with $N=0$ the eigenvalues of L are ± 1.] From the assumed L conservation, K_1^0 and K_2^0 will decay into states with different L and will exhibit different lifetimes. Therefore K^0 and $\bar{K}^0$ shall be regarded as mixtures of K_1^0 and K_2^0 with coefficients, obtained from (4), which are still the same as for the case of absolute C conservation, discussed by Gell-Mann and Pais.[3]

A system of two pions will have $L=1$. [This can be seen as follows. In the limit $H_{\text{weak}}=0$, C and P are separately conserved and for a system of two pions, $L=CP=(-)^1(-)^1=1$ for every value 1 of the relative angular momentum. However, if H_{weak} is assumed to conserve L, the conclusion holds at any order in H_{weak}.] Therefore only the component with $L=1$ of the K^0 (or $\bar{K}^0$) mixture will be able to decay into two pions. It is known experimentally that the short-lived component decays into two pions. Therefore, if L is conserved, the long-lived component cannot decay into two pions. Decay into $e^-\pi^+\nu$ and $e^+\pi^-\bar{\nu}$ will not be forbidden for any of the two components on the basis of L conservation alone. The branching ratio for the decay of the long-lived component into $e^-\pi^+\nu$ and into $e^+\pi^-\bar{\nu}$ must be equal to unity if L conservation holds. (However, $e^-/e^+=1$ does not necessarily mean that T is conserved since this ratio also holds in the case that the mass difference between the long-lived and the short-lived component is negligible.[4] A $3\pi^0$ system with total angular momentum zero (for simplicity we confine the discussion to the case of spin zero for the K meson and we assume angular momentum conservation in weak interactions) will have $L=-1$. Therefore only the long-lived component will be able to decay into $3\pi^0$. For a $\pi^+\pi^-\pi^0$ system we denote by (l,l') the state for which l is the relative $\pi^+\pi^-$ angular momentum and l' the angular momentum of π^0 with respect to the $\pi^+\pi^-$ center of mass. The states of total angular momentum zero are (0,0), (2,2), $\cdots$, for which $L=-1$, and (1,1), (3,3), $\cdots$, for which $L=+1$. Decay into states of the first group will be forbidden for the short-lived component; decay into states of the second group will be forbidden for the long-lived one. Therefore decay into 3π would be very infrequent for the short-lived component, for which 2π decay is allowed, $3\pi^0$ decay would be forbidden, and $\pi^+\pi^-\pi^0$ decay without centrifugal barrier would also be forbidden. The decay curve for K^0 (or $\bar{K}^0$) would be the sum of two exponentials corresponding to the K_1^0 and K_2^0 lifetimes. However, an interference term may occur in the decay rate into a $e\pi\nu$ state with specified charges, in a similar way as discussed by Treiman and Sachs[5] for the case of absolute C conservation. Particular effects which depend only on the existence of the mixture as those discussed by Pais and Piccioni,[6] will occur in a similar way.

The foregoing conclusions follow from the assumption that L is conserved in weak interactions, which is equivalent to the assumption that weak interactions are invariant under time reversal. We have shown, in particular, that it follows from such an assumption that the long-lived component of the K^0 mixture must never decay into two pions, and that its branching ratio for decay into $e^-\pi^+\nu$ and into $e^+\pi^-\bar{\nu}$ must be unity. The first conclusion seems in agreement with the experiments so far.[7]

Note added in proof.—The author has been informed that results similar to those contained in the present letter have also been obtained by T. D. Lee and C. N. Yang (private communication).

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Charge Asymmetries in the Decay of Long-Lived Neutral *K*-Mesons

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It is known as a result of the experimental work of Lande *et al.*[1] that there exist two lifetimes (at least) among the neutral K-mesons. One is the familiar θ^0 lifetime of 1.5×10^{-10} sec, known for some time. The other is longer by a factor of 100 or more. This situation was predicted theoretically by Gell-Mann and Pais[2] and later explored theoretically by Pais and Piccioni,[3] Case,[4] Treiman and Sachs,[5] and Lee, Oehme, and Yang.[6] The two lifetimes arise because the neutral K-meson is different from its charge conjugate $\bar{K}$. The two states with definite lifetimes are then certain linear combinations of K and $\bar{K}$—call them K_1 and K_2. Experiments are at present underway in various laboratories to investigate possible charge asymmetries in the long-lived component K_2, i.e., asymmetries between

$$K_2\rightarrow e^+ + \pi^- + \nu$$

and

$$K_2\rightarrow e^- + \pi^+ + \nu;$$

and between

$$K_2\rightarrow \mu^+ + \pi^- + \nu$$

and

$$K_2\rightarrow \mu^- + \pi^+ + \nu.$$

We wish to point out in this note certain theoretical implications which the existence of such charge asymmetries would entail.

According to present ideas there are two possibilities. As is pointed out in reference 5, charge asymmetries can arise if the two lifetime components of a single kind of K, $\bar{K}$ complex interfere with each other. Suppose, for example, that charge asymmetries are observed after a time interval following K-meson production which is large compared to $1\ 5\times10^{-10}$ sec. Such charge asymmetries could not come about from $\theta_1-\theta_2$ interference. If they are caused by interference effects at all, there must be a second K, $\bar{K}$ complex whose two lifetime components both are comparable to or larger than the experimental time interval, i.e., there must exist a second neutral meson complex, call it τ, $\bar{\tau}$, different from θ, $\bar{\theta}$.

If the weak interactions are not invariant with respect to charge conjugation, there is another possibility. As has been pointed out by Lee, Oehme, and Yang,[6] noninvariance with respect to charge conjugation can lead to charge asymmetries in the long-lived component of a single K, $\bar{K}$ complex. The main point which we wish to make here is that this can occur only if time-reversal invariance is violated together with charge conjugation invariance.[7] This can easily be seen on the basis of the Lüders-Pauli theorem,[8] which states that a system is always invariant with respect to the product of space inversion P, charge conjugation C, and time reversal T. If a system is invariant with respect to T, it must then be invariant with respect to the product CP. In this case the two lifetime components K_1 and K_2 of a K, $\bar{K}$ complex would each be eigenstates of the operator CP. For a system involving only two independent momenta, such as the system (e,π,ν) arising from K-decay, a space inversion asymmetry is undetectable unless the spins of the particles are measured.[9] Thus if time reversal invariance holds, the system will appear to be charge conjugation invariant if spins are not measured. Conversely, detection of charge asymmetries would imply noninvariance with respect to time reversal.[10]

Thus, according to present ideas, if charge asymmetries are discovered in the long-lived component of K-meson decay, it means that either there are two different K-mesons or time-reversal invariance does not hold. It is possible to distinguish between these two possibilities experimentally by studying the time dependence of the asymmetry, i.e. the variation of the asymmetry as the detecting device is moved farther and farther from the K-meson source. The interference effect discussed in reference 5 is strongly dependent on time, so that if the first possibility discussed above holds, there should be time variations in the asymmetry. On the other hand, the charge asymmetries in the decay of a single lifetime component of a single meson are time independent.

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[7] After completion of this letter the authors learned in private communication from C. N. Yang and T. D. Lee that this fact was also known to them.
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[9] If the K-meson has a nonvanishing spin and if this spin is polarized, there may be differences in the angular distributions of (e^+,π^-,ν) and (e^-,π^+,ν) but the integrated transition rates will be the same.
[10] This can also be proved using the Weisskopf-Wigner method as discussed by Lee, Oehme, and Yang (reference 6). In the notation of their paper, there are no charge asymmetries if $|p|=|q|$ (see appendix of reference 6). Now it is easy to show that if time-reversal invariance holds, products of matrix elements of the form $H_{aj}H_{jb}$ are real. This then implies that Γ_{12} and M_{12} are real and hence that $p^2=q^2$ [see Eq. (30) of reference 6].

Theory of μ-Meson Decay with the Hypothesis of Nonconservation of Parity

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Lee and Yang[1] have proposed experiments for testing the nonconservation of parity in weak-coupling processes: the β decay of oriented Co^{60} nuclei and μ-meson decay. Those experiments have been completed[2] and they confirm the Lee and Yang hypothesis. In their paper,[1] these authors computed the decay rate for the β-decay experiment, but not for the μ-meson decay. We present here the result of theoretical computation for the latter phenomenon. If parity is not conserved in $\pi-\mu$ decay, the μ meson is then polarized.[1] This polarization is longitudinal in the π-meson restframe. Let $\mathbf{s}$ be a pseudovector in the direction of the μ-meson momentum, such that in the μ-meson rest frame $\mathbf{s}^2=1$. The μ-meson polarization is along $\pm\mathbf{s}$ with the degree of polarization $|\zeta|$ (where $-1\leq\zeta\leq1$). We shall choose the sign of ζ such that the μ-meson polarization is along $\zeta\mathbf{s}$ in its restframe. We use the usual β-decay Hamiltonian (with ordinary neutrino theory) for even and odd couplings with g_i and g_i' for their complex coupling constants ($i=1$ to 5; reality of the g_i and g_i' corresponds to invariance under time reversal). It is well known that a change in the order of the four fields in the interaction Hamiltonian preserving parity is equivalent to a relabeling of coupling