for forward scattering[4] into counter L is less than 1 mb and has been neglected.

The K^- lifetime may to a first approximation be calculated from the observed transmission t_0 measured by L with no hydrogen in the target, i.e.,

$$t_0 = e^{-d/\lambda},$$

where d is the separation of counters F and L, and λ is the mean decay distance related to the mean life τ by

$$\lambda = c\tau Pc/Mc^2,$$

where c is the velocity of light and P and M are the momentum and the mass, respectively, of the K^- meson. Several corrections are necessary. Because the empty hydrogen target was in place during the measurement, a correction must be made for attenuation in the windows and insulation of the target. This factor had been measured for antiprotons, for which the transmission was 0.90. Taking into account the relatively larger cross section for the interaction of antiprotons in matter at this momentum,[2] we estimate the transmission for K^- mesons of the empty target to be 0.95 ± 0.02. Counters L and F will detect the K^- decay products with a probability that depends on the kinematics of the decay and the position along the beam where the decay occurs. Since Counter L is larger than Counter F, this correction is equivalent to a reduction of the effective value of d. With the assumption that the decay modes are the same for the K^- and the K^+ meson,[5] we compute a correction for this effect of 9% to the counting rate of L and 3% to the rate of F. Therefore, we have made a net correction of -6% to the observed transmission. The uncertainty in the mean life from counting statistics is $\pm 13\%$, and an additional uncertainty of $^{+0}_{-6}\%$ comes from the possible contamination due to π^- mesons. The uncertainty in the K^- momentum contributes $\pm 5\%$. Combining the uncertainties, we find for the mean life of the K^- meson

$$\tau = (14.9_{-2.4}^{+2.2}) \times 10^{-9} \text{ second.}$$

Iloff *et al.*[6] obtain $(9.5_{-2.5}^{+3.6}) \times 10^{-9}$ sec, and a later measurement[7] gives $(10.2_{-1.9}^{+3.1}) \times 10^{-9}$ sec for the mean life of the K^- meson measured in emulsion experiments performed at a distance of one to two mean lives from the target. Because our experiment was performed at a distance of four mean lives from the target, our greater value for the measured mean life is in the direction expected if there is a long-life component in the K^- decay. However, the uncertainties are such that both K^- lifetime measurements are consistent with a single value for the K^- lifetime of $(12 \text{ or } 13) \times 10^{-9}$ sec, or about the same as that obtained for the K^+ lifetime.[8,9]

From the measured K^- mean life and the observed yield (Fig. 1) of K^- mesons relative to π's at Counter F, we find that the ratio of K^- mesons to π^- mesons produced with momentum 0.9 Bev/c in the forward direction by 6-Bev protons on a 6-inch beryllium target is about 1 to 150.

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K^0 Decay Modes and the Question of Time Reversal of Weak Interactions*

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Recent experiments[1] have shown the existence of weak interactions which violate conservation of parity (P) and invariance under charge conjugation (C). It is not known so far whether invariance under time reversal (T) is also violated in weak interactions. We shall assume that C, P, and T are conserved in strong and electromagnetic interactions and we shall derive some physical consequences—to be compared with experiment—of the assumption that weak interactions are invariant under time reversal.

From the Lüders-Pauli theorem,[2] if T is conserved the product CP (which we shall denote by L) is also conserved, and the reverse also holds. Let us assume that L is conserved in strong and electromagnetic interactions and also in weak interactions. For systems of strongly interacting particles and for the usual theories, the operator L must satisfy the equations

$$LL^\dagger = 1, \quad L^\dagger = (-)^N L, \tag{1}$$

$$LP - (-)^N PL = 0, \quad LC - (-)^N CL = 0, \tag{2}$$

$$[L,Q]_+ = 0, \quad [L,N]_+ = 0, \quad [L,S]_+ = 0, \tag{3}$$

where Q, N, and S are the operators for the charge, for the heavy particle number, and for the strangeness, respectively. We may expect selection rules due to conservation of L for systems with $Q=0$, $N=0$. A K^0 meson, and a $\bar{K}^0$ meson, will not be eigenstates of L, but the superpositions

$$K_1^0 = (K^0 + \bar{K}^0)/\sqrt{2} \quad \text{and} \quad K_2^0 = (K^0 - \bar{K}^0)/\sqrt{2} \tag{4}$$

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, $L=CP=(-)^l(-)^l=1$ for every value l 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

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

and

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

and between

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

and

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