CALCULATION OF THE K_1 AND K_2 MASS DIFFERENCE

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A number of interesting results were recently obtained with the aid of current algebra and the hypothesis of the partially conserved axial current. In particular, Suzuki [1] obtained for the ratio of the matrix elements of the $K \to 2\pi$ and $K \to 3\pi$ transitions a value that agrees with the experimental data within about 15%.

In this paper we obtain, under the same assumptions, the connection between the matrix elements of the $K \to \pi$ and $K \to 2\pi$ transitions, so that we can calculate the contribution of the π-meson pole diagram to the mass difference of K_1 and K_2. When added to the contribution of the η-meson state (the $K \to \pi$ and $K \to \eta$ decays are related with the aid of SU(3) symmetry [2,3]) this leads to $\Delta m \equiv m_1 - m_2 = 0.75\Gamma_1$.

The matrix element of the $K_1 \to 2\pi^0$ decay is transformed as follows·

$$\begin{aligned} \langle \pi^0\pi^0 | H(0) | K_1 \rangle &= \int dx\, e^{ipx} (p^2 - \mu^2) \langle \pi^0 | T\, H(0) \phi^3(x) | K_1 \rangle \approx \\ &\approx c\mu^2 \langle \pi^0 | [Q^3(0), H(0)] | K_1 \rangle = [(c\mu^2)/2] \langle \pi^0 | H(0) | K_2 \rangle . \end{aligned} \tag{1}$$

Here $Q^3(0) = \int d^3x a_0^3(x, 0)$ and we have made the substitution $\varphi^\alpha = c\partial_\mu a_\mu^\alpha$, where $c = -[g/M\mu^2 g_A]$. The commutator $[Q^3(0), H(0)^{\Delta S=-1}] = \frac{1}{2}H(0)^{\Delta S=-1}$ which we have used [1] corresponds to the usual assumptions concerning the current algebra and the $(V - A)(V - A)$ structure of the weak-interaction Hamiltonian. It is also assumed that only the isospinor part of H contributes to the transitions in question. We hope that the matrix elements change little when the pion momenta are altered by an amount on the order of m/2 (m is the K meson mass).

The virtual π^0 and η states are possible only for the K_2 meson. Their contribution to the mass difference of K_1 and K_2 is [3]

$$2m\Delta m = | \langle \pi^0 | H(0) K_2 \rangle |^2 \left(\frac{1}{\mu^2 - m^2} + \frac{1}{3} \frac{1}{m_\eta^2 - m^2} \right). \tag{2}$$

We have used here the relation $\langle \eta | H | K_2 \rangle = (1/\sqrt{3}) \langle \pi^0 | H | K_2 \rangle$, which follows from SU(3) symmetry [2,3]. Expressing Δm with the aid of (1) in terms of experimentally known quantities, we find

$$\frac{\Delta m}{\Gamma_1} = \frac{16\pi}{3(c\mu^2)^2} \frac{m}{|\underline{p}|} \left(\frac{1}{\mu^2 - m^2} + \frac{1}{3} \frac{1}{m_\eta^2 - m^2} \right) = 1{,}0 \pm 0{,}1. \tag{3}$$

It is known, however, that the ratio $\Gamma(K \to 3\pi)/\Gamma(K \to 2\pi)$ obtained by Suzuki [1] is smaller than the experimental value by 20 - 30%. In our case it is natural to choose the constant c such as to make this ratio agree with the experimental value. Then

$$\frac{\Delta m}{\Gamma_1} = 0{,}75 \pm 0{,}1. \tag{4}$$

Experiment yields [4]

$$\frac{\Delta m}{\Gamma_1} = 0{,}44 \pm 0{,}06. \tag{5}$$

Equation (2) was used to calculate the mass difference in [3]. However, the estimate used there for the matrix element of the $K \to \pi$ transition leads to a Δm value smaller than experimental by one order of magnitude. Calculation of the pion contribution to the mass difference [5], using for the $K \to \pi$ transition an estimate based on the pole model of the $K \to 3\pi$ decay, yields $\Delta m/\Gamma_1 = -2.2$. For some unexplained reason, however, the estimates using the same K-decay model led in [6] to the results of [3].

The question arises of the role of other virtual states. Thus, one should have taken into account the X-meson pole. If the $K \to X$ transition is of the same order as $K \to \pi$, then the contribution of the X meson to Δm is of the order of $0.5\Gamma_1$. As to the contribution of the bipion states, various estimates [7-9] give a range from $-1.6\Gamma_1$ to $1.5\Gamma_1$. In our opinion, the negative values are more probable. It can be hoped that owing to the larger masses of the remaining states they have little effect on Δm. In addition, many of them change the masses of both K_1 and K_2, so that their contributions may cancel out in part [7].

Our result (4) gives therefore only the order of magnitude of the mass difference of the neutral K mesons.

In conclusion, let us discuss the pole model of the $K_2 \to 2\pi$ decay [2], in which knowledge of the $K \to \pi$ transition is also necessary. Assuming that the process proceeds via decay of virtual π^0 and η mesons, we can obtain [2]

$$\Gamma_{2\gamma} = |\langle\pi^0|H|K_2\rangle|^2 \left(\frac{1}{\mu^2 - m^2} + \frac{1}{3}\,\frac{1}{m_\eta^2 - m^2}\right)^2 \left(\frac{m}{\mu}\right)^3 \Gamma_{\pi^0}. \tag{6}$$

Using the previous value of the $K \to \pi$ transition amplitude, we get

$$R = \frac{\Gamma_{2\gamma}}{\Gamma_2} = (4{,}4 \pm 1{,}2)\cdot 10^{-4}. \tag{7}$$

(We have assumed [10] that $\tau_{\pi^0} = (0.74 \pm 0.105) \times 10^{-16}$ sec.) Experiment yields [11]

$$R = (1.3 \pm 0.6) \times 10^{-4}.$$

The contribution of the X meson to this process is not clear, since the $X \to 2\pi$ decay has not been observed experimentally.

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CIRCULAR POLARIZATION OF γ QUANTA FROM Ta^{181}

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Measurement of the circular polarization of the γ quanta emitted by unpolarized nuclei makes it possible to determine the admixture of weak nucleon-nucleon interaction in nuclear processes. A convenient object for research of this type is the 482-keV γ transition in Ta^{181}, which is excited in β decay of Hf^{181}. We have shown in an earlier paper [1] that the circular polarization of this transition is smaller than $\approx 2 \times 10^{-5}$. In this paper we report new measurements of the circular polarization of the Ta^{181} γ quanta with the aid of a procedure proposed in [2] and developed subsequently in [1] and [3].

The Hf^{181} source was obtained by irradiating in a neutron flux $\approx 10^{15}$ cm^{-2}sec^{-1} (in an SM-2 reactor) tablets of HfO_2 prepared from the separated isotope Hf^{180} (95% enrichment) and mixed with magnesium oxide. The use of the separated isotope makes it possible to eliminate the Hf^{175} admixture, which decays via K capture with emission of positively polarized internal bremsstrahlung. The activity of the Hf^{181} source at the start of the measurements was $\approx$500 Curie.

The experimental effect was determined by calculating $\delta = 2(J_1 - J_2)/(J_1 + J_2)$, where $J_{1,2}$ are the intensities of the registered γ quanta corresponding to opposite directions of polarimeter magnetization. The measurement results are given in Table 1.

The data indicate the presence of a certain effect $\delta = -(2.9 \pm 0.4) \times 10^{-7}$, which corresponds to a polarization $P = -6 \times 10^{-6}$. The measurements were made with lead absorbers of varying thickness (see [3]) and with an interval of 60 days between runs II and III. We see that, within the limit of statistical errors, the effect is independent of both absorber thickness and time. This excludes the possibility of the effect being due to bremsstrahlung in β decay of Hf^{181}, or due to any admixture of some β activity.

We used Sc^{46} and Bi^{82} as control sources of unpolarized γ quanta (unhindered E2 and E1 transitions). The results of measurements with these sources are also listed in Table 1. Other control experiments were carried out in the same manner as in [1] and [3].