POSSIBLE RADIATIVE DECAYS OF HEAVY MESONS WITH VIOLATION OF CHARGE CONJUGATION SYMMETRY

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The radiative decays of f^0, B, A_1 and A_2 mesons are considered in relation to the hypothesis of Bernstein, Feinberg, and Lee of a possible non-conservation of C in the electromagnetic interactions of hadrons. A confirmation of this hypothesis would be provided by observation of the decays $f^0 \to \pi^0\gamma$ or $A_2^0 \to \pi^0\gamma$, for which the rates are estimated to be of the order of a few per cent of the decay rates from strong interactions. Of particular interest would be a measurement of the ratio of the decay rates $A_2^0 \to \pi^0\gamma$ and $A_2^+ \to \pi^+\gamma$, which could serve as a measure of the C violation in electromagnetic interactions.

1. The paper by Bernstein, Feinberg, and Lee[1] puts forward the suggestion that the electromagnetic interactions of hadrons violate charge-conjugation invariance so that the electromagnetic current I_μ would consist of two parts

$$I_\mu = J_\mu + K_\mu,$$
$$CJ_\mu C^{-1} = -J_\mu, \qquad CK_\mu C^{-1} = K_\mu,$$

where C is the charge-conjugation operator.

In the present note we wish to draw attention to the fact that a study of the radiative decays of the heavy mesons f^0(1250), A_1(1070), A_2(1310) or B(1220)[2] could be very useful as a test of the validity of this hypothesis, or, if the existence of K_μ is confirmed by other evidence, of the selection rules for K_μ in respect of isotopic and unitary spin.

The G parity is known for all the listed mesons and equals +1 for f^0 and B, and −1 for A_1 and A_2. Since the isotopic spin of A_1, A_2, and B is unity and that of f^0 is zero, the charge parity of f^0, A_1, and A_2 is positive and that of B negative. The discovery of the decays

$$f^0 \to \pi^0 + \gamma, \tag{1}$$

$$A_2^0 \to \pi^0 + \gamma, \tag{2}$$

$$A_1^0 \to \pi^0 + \gamma, \tag{3}$$

$$B^0 \to \rho^0 + \gamma \tag{4}$$

would imply non-conservation of charge parity in the electromagnetic decays of hadrons.

Reaction (1) is possible if K_μ contains transitions with $\Delta T = 1$, whereas reactions (2)—(4) could take place for any isotopic spin content of the current K_μ. By comparing the relative suppression of reaction (2) with, for example, the decay $\eta^0 \to \pi^0 e^+ e^-$, which would be forbidden by unitary symmetry[3] if K_μ transformed by the octet representation of SU(3), one could obtain information about the transformation properties of K_μ under the SU(3) group.

2. The quantum numbers of f^0 and A_2 ($J^P = 2^+$) are fairly definitely established, and we shall consider the possible electromagnetic decays of these mesons in somewhat greater detail.

Because of the conservation of space parity the matrix element of the reactions (1) and (2) can be described by a single unknown constant g_t ($t = f^0, A_2^0$), and is of the form

$$M = eg_t \varepsilon_{\alpha\beta\gamma\delta} A_\alpha q_\beta k_\gamma \varphi_{\delta\rho} q_\rho, \tag{5}$$

where φ_0 is the wave function for the particle of spin 2, q and k are the four-momenta of γ and t respectively, A_α is the vector potential of the electromagnetic field and $e = \sqrt{\alpha}$.

The matrix elements of the reaction

$$A_2^\pm \to \pi^\pm + \gamma, \tag{6}$$

which is not forbidden by the conservation of charge parity, and of the strong decay $A_2 \to \rho\pi$ have a similar structure.

It would be of particular interest to measure the ratio of the rates for the decays (2) and (6) which depend on the coupling constant g_n for charge violating coupling and the constant g_c for charge parity conserving coupling; it can serve as a measure of the violation of charge parity in electromagnetic interactions;

$$\frac{W(A_2^0 \to \pi^0\gamma)}{W(A_2^\pm \to \pi^\pm\gamma)} = \frac{g_n^2}{g_c^2 + g_n^2}$$

The rate of the process (6) can be estimated by means of the pole term in the γ decay of ρ^0. The coupling constant for the decay of $A_2^{\pm}$ into ρ^0 and $\pi^{\pm}$ can be found from the known width of the A_2 meson, and the constant of the $\rho^0 - \gamma$ decay can be estimated from the decay rate of ρ^0 into e^+e^-[4]. The ratio R comes out to be

$$R = W(A_2^{\pm} \rightarrow \pi^{\pm}\gamma) \, / \, W(A_2^{\pm} \rightarrow \pi^{\pm}\rho^0) \approx 2.5\%. \quad (7)$$

If we simply use the similarity of matrix elements of the decay (2) and of $A_2 \rightarrow \rho\pi$ and assume that R is $\alpha|\mathbf{p}_\gamma|^5 \, |\mathbf{p}_\rho|^{-5}$ we obtain a similar magnitude

$$R = 6\%. \quad (8)$$

If the charge-parity-violating part of the electromagnetic interactions of hadrons does not contain any additional small factor, as is assumed by Bernstein, Feinberg, and Lee, the rates of the reactions (1) and (2) should also amount to a few per cent of the strong decays $f^0 \rightarrow 2\pi$, and $A_2 \rightarrow \rho\pi$.

If the estimates (7) and (8) of the rate of the decay (2) are valid the experimental verification of the violation of C parity in the decays f^0 and A_2^0 would seem to be possible in the near future.

3. The possible decay of vector mesons with violation of charge parity

$$\omega^0 \rightarrow \rho^0 + \gamma, \qquad \varphi^0 \rightarrow \rho^0 + \gamma, \qquad \varphi^0 \rightarrow \omega^0 + \gamma \quad (9)$$

has been discussed in the literature[1,5]. According to the estimates given in these papers the rate of the transition $\omega^0 \rightarrow \rho^0\gamma$ is negligible ($\sim 10^{-3}\%$) and the decay width for $\varphi^0 \rightarrow \rho^0\gamma$ and $\varphi^0 \rightarrow \omega^0\gamma$ represents 2.5 and 1.9% of the total width, respectively.

One must, however, take into account that the production cross section of f^0 is about 13 times larger than the cross section for the formation of φ^0 (0.4 and 0.3 millibarn at $p_L \sim 4$ GeV[6]). Furthermore if K_μ transforms according to the $\{35\}$ representation of SU(6) the decay (9) is suppressed. For this reason a search for the radiative decays (1) and (2) may be more promising from the experimental point of view than the study of the corresponding decays of the vector mesons.

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