NONLEPTONIC DECAYS OF BARYONS AND THE EIGHTFOLD WAY*

Yasuo Hara†
California Institute of Technology, Pasadena, California
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It has been shown[1,2] that the decays $K_1^0 \to 2\pi$ are forbidden in the limit of unitary symmetry[3,4] under the following assumptions: (i) The nonleptonic weak interaction is a component of an octet, or some mechanism selectively enhances the contribution of the octet part of the interaction. (ii) The interaction is formed from a sum of products of weak currents and their Hermitian conjugates $[G_1J_{1\mu}^+J_{1\mu}+(G_2J_{2\mu}^+J_{2\mu}+\cdots)]$. (iii) The interaction is PC invariant.[5] Here, we would like to show that under the same assumptions we can also prove the following facts: (i) If we make the pole approximation for the nonleptonic weak decays of strange baryons, we have to include poles due to octet baryon resonances (B_8^*). (ii) The parity-violating amplitudes of the γ decays $\Sigma^+\to p+\gamma$ and $\Xi^-\to\Sigma^-+\gamma$ are zero.

Since the matrix elements of the parity-nonconserving nonleptonic weak interaction between octet baryons have been shown[2] to vanish in the limit of unitary symmetry, the pole model of Feldman, Mathews, and Salam[6] for the nonleptonic weak decay of the strange baryons gives us no asymmetry. Thus, in order to obtain asymmetry, we have to include poles due to baryon resonances and meson resonances. However, observed meson resonances do not contribute to the parity-violating amplitudes since the matrix elements corresponding to the process "$\bar{B}+B\to$ (meson with spin ≥ 1) $\to$ p-v spurion and pion" can be shown to vanish in the limit of unitary symmetry.[7] We thus have to consider baryon resonances in order to obtain asymmetry. At present, a unitary singlet, a unitary decuplet, and unitary octets of baryon resonances are presumed to exist.[8] In Table I their contributions to various amplitudes are shown. Since $\alpha(\Xi^-)$ is known not to be equal to zero experimentally, we see that we have to consider at least one of the octets of baryon resonances to have nonzero $\alpha(\Xi^-)$. We probably have to include poles due to the unitary decuplet and singlet baryon resonances if we wish to consider octet baryon resonances. The inclusion of these poles makes the pole model very complicated. However, if $d_0/f_0=d_1/f_1=\cdots=D_0/F_0=D_1/F_1=\cdots$, and if there are no decuplets of meson resonances, the relation

$$-B(\Lambda\to p+\pi^-)-2B(\Xi^-\to\Lambda+\pi^-)=\sqrt{3}B(\Sigma^+\to p+\pi^0) \quad (1)$$

is found to hold for parity-conserving amplitudes. This relation, which is compatible with experimental evidence, has been derived by Sugawara[9]

Table I. The contributions from various poles. The notation $A(\Lambda\to p+\pi^-)$ $[B(\Lambda\to p+\pi^-)]$ represents the parity-violating (parity-conserving) part of the amplitude of the $\Lambda\to p+\pi^-$ decay, and $A,B(\Lambda\to p+\pi^-)=-\sqrt{2}A,B(\Lambda\to n+\pi^0)$, $A,B(\Sigma^+\to p+\pi^0)=[A,B(\Sigma^+\to n+\pi^+)-A,B(\Sigma^-\to n+\pi^-)]/\sqrt{2}$, and $A,B(\Xi^-\to\Lambda+\pi^-)=-\sqrt{2}A,B(\Xi^0\to\Lambda+\pi^0)$. The notations B_i^* represent i-fold baryon resonances and M_8^* represent meson resonance octets. The ratio d_i/f_i is the d/f ratio for the (octet baryon B_8) - (ith baryon resonance octet $B_{8,i}^*$) - (octet ps-meson) coupling ($B_{8,0}^*=B_8$). The ratio D_i/F_i (D_i'/F_i') is the d/f ratio for $B_8-B_{8,i}^*$ - [parity-conserving (parity-violating) spurion] coupling, and d_i'/f_i' is that of the B_8-B_8 - (ith meson resonance octet) coupling ($D_0'=F_0'=0$). Contributions from M_1^* are zero.

	From all B_1^*	From all B_{10}^*	From ith B_8^*	From ith M_8^*
$6^{1/2}A(\Lambda\to p+\pi^-)$	0	$-\frac{1}{2}C$	$d_i(-3D_i'+F_i')+f_i(D_i'-3F_i')$	0
$6^{1/2}B(\Lambda\to p+\pi^-)$	0	$-\frac{1}{2}D$	$-d_i(D_i+5F_i)-f_i(D_i-3F_i)$	$d_i'-3f_i'$
$A(\Sigma^+\to n+\pi^+)$	A	$-\frac{1}{4}C$	$-\frac{4}{3}d_iD_i'$	0
$B(\Sigma^+\to n+\pi^+)$	B	$\frac{1}{12}D$	$2(d_i-f_i)(D_i+F_i)-\frac{4}{3}d_iD_i$	0
$A(\Sigma^-\to n+\pi^-)$	A	$-\frac{5}{12}C$	$(d_i+f_i)(D_i+F_i)-\frac{4}{3}d_iD_i'$	0
$B(\Sigma^-\to n+\pi^-)$	B	$\frac{7}{12}D$	$(d_i+f_i)(D_i+F_i)-\frac{4}{3}d_iD_i$	$d_i'+f_i'$
$6^{1/2}A(\Xi^-\to\Lambda+\pi^-)$	0	0	$d_i(3D_i'+F_i')+f_i(D_i'+3F_i')$	0
$6^{1/2}B(\Xi^-\to\Lambda+\pi^-)$	0	D	$d_i(-D_i+5F_i)+f_i(D_i+3F_i)$	$d_i'+3f_i'$

and by Lee[10] on the basis of R invariance. It is interesting that the d/f ratio for $\bar{B}_8 B_8 PS_8$ coupling (d_0/f_0) has been found[11] to be nearly equal to the d/f ratio for $\bar{B}_8 B_8{}^* PS_8$ coupling (d_1/f_1).

The parity-violating parts of the amplitudes of the γ decays of the strange baryons can be written as

$$\{a(\bar{B}_2{}^3 O_\alpha B_1{}^1 - \bar{B}_1{}^1 O_\alpha B_3{}^2) + b(\bar{B}_1{}^3 O_\alpha B_2{}^1 - \bar{B}_1{}^2 O_\alpha B_3{}^1)$$
$$+ c(\bar{B}_2{}^1 O_\alpha B_1{}^3 - \bar{B}_3{}^1 O_\alpha B_1{}^2)$$
$$+ d(\bar{B}_1{}^1 O_\alpha B_2{}^3 - \bar{B}_3{}^2 O_\alpha B_1{}^1)\} A_\alpha, \quad (2)$$

making use of the tensor notation,[12] where[13] $\bar{B} O_\alpha B = \bar{B}\gamma_5 \sigma_{\alpha\beta} B \partial_\beta$ and $A_1{}^1$ should be read as $A_1{}^1 - \frac{1}{2}(A_2{}^2 + A_3{}^3)$. From the invariance of the interaction[5] under the exchange of the indices 2 and 3, we find $a = -d$ and $b = c = 0$. Since the configurations $\bar{\Xi}^- \Sigma^-$ $(= \bar{B}_1{}^3 B_2{}^1)$ and $\bar{\Sigma}^+ p$ $(= \bar{B}_2{}^1 B_1{}^3)$ are not found in the first and fourth terms in the bracket of (2), the parity-violating amplitudes of the γ decays, $\Sigma^+ \to p + \gamma$ and $\Xi^- \to \Sigma^- + \gamma$, are zero in the limit of unitary symmetry and their asymmetry parameters are zero. This will be checked by experiments in the future.

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†On leave of absence from Physics Department, Tokyo University of Education, Tokyo, Japan.

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[5]Assumption (ii) can be replaced by the following: (ii') The interaction is invariant under the exchange of the indices 2 and 3, when matrices are written in terms of tensor notations. [See S. Okubo, Progr. Theoret. Phys. (Kyoto) 27, 947 (1962).] This corresponds to the assumption (a) of Cabibbo (reference 1).

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[7]For example, the amplitude for "$\bar{B} + B \to$ vector meson $\to$ p-v-spurion and pion" process is proportional to $\bar{\psi}(p')\gamma_\mu \psi(p)(p'-p)_\mu$ and vanishes in the limit of the unitary symmetry.

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UNITARY SYMMETRY MODEL OF WEAK INTERACTIONS*

Bunji Sakita
University of Wisconsin, Madison, Wisconsin
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In this note we present a model of weak interactions based on unitary symmetry of strong interactions[1] and on the V-A theory of weak interactions. The basic assumption made here is that the weak interaction currents of strongly interacting particles, J_μ, have positive RC conjugation parity,

$$RCJ_\mu (RC)^{-1} = J_\mu, \quad (1)$$

where R and C are the R-conjugation and charge-conjugation operator, respectively.[2]

We first consider the representation of J_μ as a sum of baryon-antibaryon products in the octet model of unitary symmetry in which baryons (mesons) are members of the "8" representation of the SU(3) group. Therefore, J_μ is expressed by a direct product of two octets which has the well-known decomposition into the direct sum "1" + "8_s" + "27" + "8_a" + "10" + "10*". Under the interchange of two octets in the product, the first three representations ("1", "8_s", "27") are symmetric while the last three ("8_a", "10", "10*") are antisymmetric. If we divide J_μ into a vector (V) and an axial-vector part (A), we expect from the assumption (1) that the V current and the A current have different SU(3) coupling schemes because of their different properties under charge conjugation. RC conjugation gives the interchange of two octets in the product with a minus sign for the V and with a plus sign for the A. The permissible candidates for representation of J_μ are