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Nonleptonic Decays in Right-Handed Current Models

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Abstract

It is shown that, contrary to the arguments recently made, the right-handed current models (even with a current $\bar{c}_R\gamma_\mu d_R$) have no obvious disagreement with experiment in weak nonleptonic decays of hadrons.

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We point out in this note that some of the recent arguments[1] on nonleptonic decays in right-handed current models of weak interactions are incomplete and the conclusions drawn are unwarranted. We present here a more complete treatment to demonstrate that the right-handed current models do not lead to any obvious disagreement with existing experimental data in nonleptonic decays (including radiative weak decays). We have in mind the right-handed current $\bar{c}_R\gamma_\mu d_R$ suggested by de Rujula et al.[2] and incorporated into the six-quark vector model;[3] this is also the model criticized in Ref. 1. We are here not concerned with whether the neutral current is pure vector but only to investigate if the $\Delta I = 1/2$ rule can originate from a right-handed current $\bar{c}_R\gamma_\mu d_R$ or not. A mechanism for sufficient enhancement of the $\Delta I = 1/2$ part, despite the presence of $c\bar{c}$ terms, has been suggested by Fritzsch and Minkowski.[4]

An important observation to make is that in the model at hand the parity-violating (p.v.) nonleptonic decay Hamiltonian contains a term transforming like λ_7 while the parity-conserving one transforms purely like λ_6. In fact, the λ_7 term is dominant if the new interaction is to account for $\Delta I = 1/2$ dominance. Hence, unlike the standard left-handed current model, the right-handed current models allow both the $K \to 2\pi$ decays <u>and</u> the p.v. octet baryon pole transitions in the SU(3) symmetric limit. This alters the conclusion previously reached for nonleptonic hyperon decays.

Let us see this in detail. With $H^{p.v.} \sim \lambda_7$, octet baryon pole transitions are SU(3)-allowed so that we have to retain, in the standard current algebra calculation, the equal-time commutators of p.c. amplitudes <u>and</u> also Born terms (or octet baryon pole terms) of p.v. amplitudes.[5] As will become apparent, it is not justified to ignore the latter on the basis of the energy denominators appearing in the form of sums of two baryon masses instead of differences.[6] For simplicity we take $H^{p.v.}$ to be pure λ_7 and ignore all boson pole transitions. Now it was observed some years ago[7] that if d/f ratios of pseudoscalar meson-baryon coupling and of the p.v. octet baryon pole transitions are taken to be identical and equal to about $\sqrt{3}$, the p.v. Born terms transform effectively as $[(\bar{B}B)_{8_F}\pi]_8$ and fit the experimental data crudely up to an overall constant. The equality of the d/f ratios is also appealing from the viewpoint of a p.v. spurion annihilating into the vacuum through the K_1^o tadpole especially since the latter is also an allowed transition. We have therefore assumed this equality in our fit. The d/f ratio and the overall magnitude of the p.c. octet pole transitions have been adjusted to fit the experimentally-observed amplitudes of hyperon decays. The results are shown in Table I. Except for the parity-violating $\Lambda \to p\pi^-$ amplitude being off by more than a factor of two, seven other amplitudes are reproduced to within 25%. Including either a small amount of λ_6 term in $H^{p.v.}$ or the boson pole transitions[5] would improve the fit considerably. The main thing to notice is that signs of the asymmetry parameters are reproduced correctly contrary to the claim in Ref. 1. By the same token the relative signs of $\Delta I = 3/2$ to $\Delta I = 1/2$ amplitudes would also be correctly reproduced. However, it is fair to remark here that even the simplest calculation (such as this) of the hyperon decays in the right-handed current model involves two more parameters than the standard left-handed current model.

Next we use the octet baryon pole transition strengths fixed above to calculate weak radiative hyperon decays such as $\Sigma^+ \to p\gamma$, $\Xi^o \to \Lambda\gamma$, and $\Xi^o \to \Sigma^o\gamma$. The Born diagrams are calculable without any further parameters provided the magnetic moments of octet baryons are known. To this, the short distance singularity (SDS) contribution has to be added. The SDS contribution alone, in the model under discussion, would yield the asymmetry parameter $\alpha = -1$ for all radiative hyperon decays.[8] The recent measurement[9] of α for the decay $\Xi^o \to \Lambda^o\gamma$ indicates that SDS contribution does not dominate. Hence, we have to take the Born terms, calculated as indicated above, into account. We have adjusted the d/f ratio and the magnitude of the SDS term to fit the decay rate and the asymmetry parameter of $\Sigma^+ \to p\gamma$. It turns out then, that not only the decay rate and asymmetry parameter of $\Xi^o \to \Lambda^o\gamma$ are reproduced, but also the decay rate of $\Xi^o \to \Sigma^o\gamma$ is close to the measured value. The results are shown in Table II.

We now turn to K-decays. Golowich and Holstein[1] point out that if the $\Delta I = 1/2$ contribution comes from RHC contribution containing $\bar{c}_R \gamma_\mu d_R$ and $\Delta I = 3/2$ from the standard LHC contribution, then the relative signs of $\Delta I = 3/2$ to $\Delta I = 1/2$ amplitudes[10] in $K \to 3\pi$ come out to be wrong. However this result obtains in a model of chiral symmetry breaking[10] in which $\lambda = 0$, where λ is defined by

$$<K^m|\sigma(0)|K^n> = -\frac{1}{2}\lambda\ \delta^{mn} m_\pi^2 .$$

In the Gell-Mann-Oakes-Renner model[11] of chiral symmetry breaking, on the other hand, $\lambda = 1$.[12] Then the $\Delta I = 1/2$ amplitudes have no term that survives in the limit of all pions being soft, and their signs are determined by higher order terms in pion momenta. The $\Delta I = 3/2$ amplitudes also have two free parameters[10] and consequently the relative signs of $\Delta I = 1/2$ and $3/2$ amplitudes are no longer fixed in terms of $K \to 2\pi$ amplitudes.

Summarizing, we find that models with right-handed currents like $\bar{c}_R \gamma_\mu d_R$ are consistent with nonleptonic weak decays, but that this explanation of the $\Delta I = 1/2$ rule is necessarily accompanied by more parameters and a subsequent loss of predictive power. About the possibly large K_S-K_L mass difference that may arise, we have nothing to add to the comments made by de Rujula et al.[3]

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References and Footnotes

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Table I. Fit of nonleptonic hyperon decays. The d/f ratios are 1.70 for both the p.v. baryon pole transitions and the pseudoscalar meson baryon couplings, and -0.80 for the p.c. baryon pole transitions. The relative magnitude of p.c. and p.v. pole transitions is chosen such that the ratio of their f couplings is given by $F^{pv}/F^{pc} = -0.90$. The magnitude of F^{pc} is fixed as $F^{pc} = -6.1 \times 10^{-5}$ MeV. The first and second columns are dimensionless amplitudes of the equal-time commutators and Born terms respectively. Units are 10^{-7} and 10^{-6} for p.v.(S) and p.c.(P) amplitudes respectively.

	ETC	Born	Theory	Experiment
$S(\Lambda^0_-)$	2.88	-11.14	-8.26	-3.28
$P(\Lambda^0_-)$	-0.55	-2.20	-2.75	-2.25
$S(\Sigma^+_+)$	0	3.17	3.17	4.23
$P(\Sigma^+_+)$	0	0.42	0.42	0
$S(\Sigma^-_-)$	-5.78	8.76	2.98	4.28
$P(\Sigma^-_-)$	-0.20	0.09	-0.11	-0.16
$S(\Xi^-_-)$	-4.98	8.88	3.90	4.52
$P(\Xi^-_-)$	0.15	-1.91	-1.76	-1.49

Table II. Fit of radiative hyperon decays. Units are 10^{-10} MeV^{-1} for both p.v. and p.c. amplitudes. Figures in parentheses are measured values. The magnetic moments of p, Σ^+, and Λ are taken from the tabulation of the Particle Data Table. For the magnetic moments of Ξ^0, Σ^0, and Σ^0-Λ, SU(3) is assumed for them after $1/(2m_i)$ is factored out for each baryon i. Experimental values for $\Xi^0 \to \Lambda\gamma$ and $\Xi^0 \to \Sigma\gamma$ are taken from Ref. 9.

	Born	SDS	Theory
$S(\Sigma^+ \to p\gamma)$	0.46	-1.70	-1.29
$S(\Sigma^+ \to p\gamma)$	-0.56	1.70	1.19
$S(\Xi^0 \to \Lambda\gamma)$	-0.61	0.62	0.013
$P(\Xi^0 \to \Lambda\gamma)$	1.78	-0.62	1.16
$S(\Xi^0 \to \Sigma^0\gamma)$	0.31	1.08	1.39
$P(\Xi^0 \to \Sigma^0\gamma)$	3.70	-1.08	2.62

	Decay Rate	Asymmetry Parameter α
$\Sigma^+ \to p\gamma$	$1.03(1.02) \times 10^{-10}$ MeV	$-1.00(-1.03^{+0.52}_{-0.42})$
$\Xi^0 \to \Lambda\gamma$	$2.45(3.10) \times 10^{-10}$ MeV	$0.02(0.22 \pm 0.34)$
$\Xi^0 \to \Sigma^0\gamma$	$3.68(4.9) \times 10^{-10}$ MeV	0.82 (?)

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