PHYSICAL REVIEW D VOLUME 3, NUMBER 5 1 MARCH 1971

Isospin Structure of the Nonleptonic Weak Hamiltonian

C. H. ALBRIGHT*†
Institute for Atomic Research and Department of Physics, Iowa State University, Ames, Iowa 50010

AND

R. J. OAKES‡
Department of Physics, Northwestern University, Evanston, Illinois 60201
(Received 31 August 1970)

The isospin structure of the nonleptonic weak Hamiltonian is investigated under the assumption that the interaction can be constructed from the products of charged and neutral $V-A$ octet currents. It is shown that quite generally, in addition to the well-known $\Delta S=\pm1$, $\Delta I=\frac{1}{2}$ selection rule, a pure $\Delta S=0$, $\Delta I=0$ selection rule can be obtained. However, if charged currents, e.g., the Cabibbo current, occur in the interaction, then neither a pure $\Delta S=0$, $\Delta I=1$ nor a pure $\Delta S=0$, $\Delta I=2$ selection rule is possible. The implications for parity-violating effects in strangeness-conserving nuclear processes are discussed.

THE nonleptonic weak interactions are usually assumed to be described, at least phenomenologically, by an interaction Hamiltonian constructed from the products of octet $V-A$ hadron currents. An attractive example is the form due to Cabibbo[1] in which only charged $V-A$ hadron currents enter. The Cabibbo form consists of a strangeness-conserving piece having the selection rules $\Delta S=0$, $\Delta I=0$, 1, 2, and a strangeness-changing piece having the selection rules $\Delta S=\pm1$, $\Delta I=\frac{1}{2}, \frac{3}{2}$.

Here we investigate the isospin structure in the more general case, including neutral currents.[2] We emphasize the relations between the selection rules and their experimental implications. In particular, it is shown that in strangeness-conserving processes the pure selection rule $\Delta S=0$, $\Delta I=1$ or $\Delta S=0$, $\Delta I=2$ cannot obtain unless the charged currents are absent. However, even if charged currents do enter, e.g., the Cabibbo current, a $\Delta S=0$, $\Delta I=0$ rule is still possible. The experimental implications are discussed, and the parity-violating effects in the radiative capture by protons of polarized neutrons are found to be particularly interesting experimental tests.

We write the Hamiltonian in the form

$$H=\frac{G}{\sqrt{2}}\sum_{\alpha,\beta} G^{(\alpha\beta)}J_\lambda{}^{(\alpha)}J_\lambda{}^{(\beta)}, \tag{1}$$

where G is the Fermi constant, $J=V-A$, and the summation extends over the $SU(3)$ indices α, $\beta=1\pm i2$, 3, $4\pm i5$, $6\pm i7$, and 8. To insure CPT invariance and Hermiticity, the coupling coefficients must satisfy

$$G^{(\alpha\beta)}=G^{(\beta\alpha)}=G^{(\alpha^*\beta^*)*}, \tag{2}$$

and obviously many must vanish by charge conservation. If time-reversal invariance is assumed, the $G^{(\alpha\beta)}$ also can be chosen real.

In general, this interaction can contain pieces with the following selection rules:

$$\Delta S=0,\quad \Delta I=0,\,1,\,2;$$
$$\Delta S=\pm1,\quad \Delta I=\tfrac{1}{2},\,\tfrac{3}{2};$$
$$\Delta S=\pm2,\quad \Delta I=1.$$

The $\Delta S=\pm2$ processes, which seem to be absent experimentally, can be eliminated by requiring

$$G^{(6\pm i7,6\pm i7)}=0. \tag{3}$$

As is well known, the $\Delta S=\pm1$, $\Delta I=\frac{3}{2}$ processes, which are considerably suppressed experimentally relative to the $\Delta S=\pm1$, $\Delta I=\frac{1}{2}$ processes, can be eliminated by requiring

$$G^{(3,6\pm i7)}=-G^{(1\mp i2,4\pm i5)}. \tag{4}$$

This condition, Eq. (4), for the $\Delta S=\pm1$, $\Delta I=\frac{1}{2}$ rule to be an exact property of the nonleptonic interaction can be satisfied in a nontrivial manner only if *both* charged and neutral currents are present in the interaction.

In the case of the $\Delta S=0$ processes, the $\Delta I=0$, 1, and 2 pieces can be eliminated by the following conditions:

No $\Delta S=0$, $\Delta I=2$:

$$G^{(33)}=2G^{(1\pm i2,1\mp i2)}; \tag{5}$$

No $\Delta S=0$, $\Delta I=1$:

$$G^{(38)}=0, \tag{6a}$$

$$G^{(6\pm i7,6\mp i7)}=G^{(4\pm i5,4\mp i5)}; \tag{6b}$$

No $\Delta S=0$, $\Delta I=0$:

$$G^{(88)}=0, \tag{7a}$$

$$G^{(33)}=-4G^{(1\pm i2,1\mp i2)}, \tag{7b}$$

$$G^{(6\pm i7,6\mp i7)}=-G^{(4\pm i5,4\mp i5)}. \tag{7c}$$

* Permanent address: Northern Illinois University, DeKalb, Ill. 60115.
† Work performed in part in the Ames Laboratory of the U. S. Atomic Energy Commission, Contribution No. 2841.
‡ Research supported by the Air Force Office of Scientific Research, Office of Aerospace Research, United States Air Force, under AFOSR Grant No. 69-1761.
[1] N. Cabibbo, Phys. Rev. Letters 10, 531 (1963); 12, 62 (1964).
[2] For a general discussion of weakly coupled neutral currents, cf. C. H. Albright and R. J. Oakes, Phys. Rev. D 2, 1883 (1970).

From Eqs. (5)–(7), the following conclusions regarding the $\Delta S=0$ nonleptonic interaction can be drawn:

(1) If $G^{(1\pm i2,1\mp i2)}\neq 0$, then the pure selection rule $\Delta S=0$, $\Delta I=1$ is *not* possible.

(2) If $G^{(4\pm i5,4\mp i5)}\neq 0$, then the pure selection rule $\Delta S=0$, $\Delta I=2$ is *not* possible.

(3) If both $G^{(1\pm i2,1\mp i2)}\neq 0$ and $G^{(4\pm i5,4\mp i5)}\neq 0$, as in the Cabibbo form of the interaction, then neither pure $\Delta S=0$, $\Delta I=1$ nor pure $\Delta S=0$, $\Delta I=2$ is possible; however, a pure $\Delta S=0$, $\Delta I=0$ rule, which essentially corresponds to the schizon model of Lee and Yang,[3] is possible.

Assuming the correctness of the Cabibbo form for the charged current part of the interaction and imposing the selection rules $\Delta S=\pm 1$, $\Delta I=\frac{1}{2}$ [Eq. (4)] and $\Delta S=0$, $\Delta I=0$ [Eqs. (5) and (6)], one can write uniquely the simplest form of the nonleptonic weak Hamiltonian as

$$H=(G/\sqrt{2})\times\tfrac{1}{2}[\{J^{(+)},J^{(+)\dagger}\}+\{J^{(0)},J^{(0)\dagger}\}], \quad (8)$$

where

$$J^{(+)}=\cos\theta\,(V-A)^{(1+i2)}+\sin\theta\,(V-A)^{(4+i5)} \quad (9)$$

and

$$J^{(0)}=\cos\theta\,(V-A)^{(3)}-\sin\theta\,(V-A)^{(6+i7)}. \quad (10)$$

Additional neutral currents $J^{(8)}$ and $J^{(6\pm i7)}$ can be coupled with arbitrary coefficients $G^{(88)}$ and $G^{(8,6\pm i7)}$, if one admits a more complicated form than (8).

The present information bearing on the isospin structure of the strangeness-conserving part of $H_{\rm NL}$ is obtained from parity-violation experiments in nuclear physics.[4] The circular polarization of γ rays from unoriented nuclei suggests a parity violation which may involve both $\Delta I=0$ and 1 weak transitions. Calculations indicate that the results are consistent with the $\Delta I=1$ part suppressed by at least $\sin^2\theta$, as in the Cabibbo scheme with charged currents alone. A pure $\Delta I=0$ transition enters in the α decay of $^{16}O^*\to {}^{12}C+\alpha$, where a parity violation must occur for the process to proceed from the 2^- level of ^{16}O to the 0^+ ground state of ^{12}C. A preliminary result of $(1.8\pm0.8)\times10^{-10}$ eV has been obtained by Hättig *et al.* for the width of this 2^- level.[5]

More precise information should ultimately be obtained by a study of polarized neutron capture on protons in the reaction $n+p\to d+\gamma$. Danilov[6] and Tadić[7] have shown that here the circular polarization of the capture photons depends only on the $\Delta I=0$ and 2 components of H, while the asymmetry of the photons with respect to the direction of polarization of the captured neutrons depends only on the $\Delta I=1$ component of H. Our results show that a circular polarization of the capture photons must be observed while the asymmetry may in fact vanish, as would be the case if the pure $\Delta S=0$, $\Delta I=0$ rule obtains. A preliminary result reported by Lobashov[8] and co-workers for the circular polarization is $-(1.8\pm0.9)\times10^{-6}$.

Finally, Henley[9] has pointed out that the circular polarization in the γ decays of ^{18}F and ^{10}B is particularly sensitive to the $\Delta S=0$, $\Delta I=1$ part of the weak interaction. Hence the effect should be suppressed if the $\Delta S=0$, $\Delta I=0$ rule is the correct one.

To summarize, present data indicate the presence of at least a $\Delta I=0$ part in the strangeness-conserving weak interaction thus precluding both pure $\Delta S=0$, $\Delta I=1$ and pure $\Delta S=0$, $\Delta I=2$ selection rules in agreement with our analysis. It is therefore tempting to postulate a *pure* $\Delta S=0$, $\Delta I=0$ selection rule, in addition to the $\Delta S=\pm1$, $\Delta I=\frac{1}{2}$ rule for the nonleptonic weak interaction. While all data are consistent with this hypothesis, we stress the importance of experimental tests, particularly searches for $\Delta S=0$, $\Delta I=1$ parity-violating effects as discussed above.

One of us (C. H. A) wishes to thank Professor S. B. Treiman for a remark which led to this investigation. He also wishes to thank Professor R. H. Good, Jr. and Professor D. J. Zaffarano for the kind hospitality extended to him at Ames Laboratory during the course of this work.

[3] T. D. Lee and C. N. Yang, Phys. Rev. **119**, 1410 (1960).

[4] For excellent reviews, see R. J. Blin-Stoyle, in Proceedings of the CERN Topical Conference on Weak Interactions, 1969 (unpublished); B. H. J. McKellar and D. Hamilton, in *High Energy Physics and Nuclear Structure*, edited by S. Devons (Plenum, New York, 1970); E. M. Henley, Ann. Rev. Nucl. Sci. **19**, 367 (1969).

[5] H. Hättig, K. Hünchen, and H. Wäffler, Phys. Rev. Letters **25**, 941 (1970).

[6] G. S. Danilov, Phys. Letters **18**, 40 (1965).

[7] D. Tadić, Phys. Rev. **174**, 1694 (1968).

[8] V. M. Lobashov, A. E. Egorov, D. M. Kaminker, V. A. Nazarenko, L. F. Saenko, L. M. Smotritskii, G. I. Kharkevich, and V. A. Khyaz'kov, Zh. Eksperim. i Teor. Fiz. Pis'ma v Redaktsiyu **11**, 124 (1970) [Soviet Phys. JETP Letters **11**, 76 (1970)].

[9] E. M. Henley, Phys. Letters **28B**, 1 (1968).