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Weak radiative decays of hyperons: Quarks, $SU(6)_W$, and vector-meson dominance

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Quark-model, $SU(6)_W$, and vector-dominance-model (VDM) methods are simultaneously used to investigate weak radiative decays of hyperons. The use of the VDM helps in the identification of the origin of the quark-model violation of the Hara theorem: besides the $\bar{u}_1\sigma_{\mu\nu}\gamma_5 q^\nu u_2 A^\mu$ term the $A_\mu J_V^\mu$ "contact" photon-quark interaction generates an *additional* contribution which is *effectively* equivalent to a nonvanishing $\bar{u}_1\gamma_5\gamma_\mu u_2 A^\mu$ photon-hadron coupling. Our approach provides a $SU(6)_W$-based symmetry connection between radiative and nonleptonic hyperon decays. As a result, a parameter-free symmetry prediction for asymmetries and branching ratios in weak radiative hyperon decays is obtained. The $\Sigma^+\to p\gamma$ decay asymmetry is found to be large and negative ($\alpha\simeq -0.6$).

I. INTRODUCTION

Since the experimental discovery in 1969 of a large asymmetry in the weak radiative decay $\Sigma^+\to p\gamma$ (Ref. 1; later also Ref. 2), its explanation has constituted a constant challenge for theorists. Indeed, according to the well-known Hara theorem[3] the parity-violating amplitude of this decay and hence the corresponding asymmetry parameter were expected to vanish in the limit of exact $SU(3)_F$ symmetry. The observed large violation of the Hara theorem was thus in direct conflict with the elsewhere well-established small size of the $SU(3)_F$-symmetry-breaking effects.

Various models and different physical mechanisms were considered appropriate for the description of the weak radiative decays of hyperons.[4–18] Some of the proposed solutions of the $\Sigma^+\to p\gamma$ asymmetry problem were fairly orthodox (e.g., Ref. 9) while others suggested the introduction of exotic currents,[5] gluonic corrections,[17] etc. Developments took a turn in 1983 when Kamal and Riazuddin[19] thoroughly reconsidered the problem within the framework of the quark model. The astonishing result of their calculations was that in the quark model—even in the limit of $SU(3)_F$ symmetry—the Hara theorem is still violated. This means that at least one of the assumptions used in the proof of the Hara theorem is not satisfied in the quark model and one has to identify which one it is. When discussing this question, Kamal and Riazuddin (KR) blamed Hara's assumption of the λ_6 form of the weak spurion. Below it is argued, however, that the origin of the quark-model breakdown of the Hara theorem is different.

Following the KR paper further attempts to predict asymmetries and branching ratios in weak radiative hyperon decays were made within the framework of the quark model.[20] As a result, new sets of theoretical predictions were added to those obtained earlier. All these various alternatives are in strong disagreement among themselves

TABLE I. Theoretical asymmetries, and branching ratios in units of 10^{-3} (underlined entries were used as input in calculations).

Calculated asymmetries					
Transition	Ref. 9	Ref. 13 solution A	Ref. 13 solution B	Ref. 20 QCD eff.	Ref. 20 long distance
$\Sigma^+\to p\gamma$	$-0.80(^{+0.32}_{-0.19})$	$-\underline{0.5}$	$-\underline{0.5}$	-0.56	-0.55
$\Sigma^0\to n\gamma$	-0.98	$+0.76$	-0.26		
$\Lambda\to n\gamma$	-0.49	-0.87	$+0.25$	-0.51	-0.52
$\Xi^0\to\Lambda\gamma$	-0.78	-0.96	-0.45	$+1.0$	$+0.74$
$\Xi^0\to\Sigma^0\gamma$	-0.96	-0.3	-0.99	$+0.97$	$+0.81$
$\Xi^-\to\Sigma^-\gamma$	?	-0.87	$+0.56$	$+1.00$	-0.44

Calculated branching ratios						
Transition	Ref. 9	Ref. 13 solution A	Ref. 13 solution B	Ref. 20 QCD eff.	Ref. 20 long distance	Ref. 7
$\Sigma^+\to p\gamma$	$0.92(^{+0.26}_{-0.14})$	$\underline{1.24}$	$\underline{1.24}$	0.99	1.35	$\underline{1.24}$
$\Lambda\to n\gamma$	0.62	5.97	1.70	0.36	1.66	22.0
$\Xi^0\to\Lambda\gamma$	3.0	1.80	1.36	0.29	0.57	4.0
$\Xi^0\to\Sigma^0\gamma$	7.2	1.48	0.23	4.58	4.06	9.1
$\Xi^-\to\Sigma^-\gamma$	?	1.20	1.20	$\underline{0.23}$	$\underline{0.23}$	11.0

(see Table I for a few examples). In fact, the results are so strongly model dependent that one cannot even talk of a "middle-ground" alternative. The reason for this state of affairs is the lack of a real understanding as to what a symmetry prediction should be (and the resulting absence of such a prediction from Table I). Indeed, as it is now clear from the calculations of Kamal and Riazuddin[19] there seem to exist not one but *two* "symmetry predictions": one following from the Hara theorem and the other given by the quark model. This is clearly unacceptable.

In the past the interest in weak radiative decays of hyperons was partially triggered by hope that the treatment of photon emission should be considerably simpler than that of pions. It is, therefore, somewhat surprising that while the "more complicated" pionic weak decays of hyperons possess a satisfactory symmetry description formulated in the SU(3) language [which assumes the hadron-pole model for parity-conserving (PC) amplitudes and admits slightly different f/d ratios for parity-violating (PV) and PC amplitudes, see, e.g., Ref. 21] their "simpler" radiative weak decays are not understood in this way. Such an understanding could be achieved if a symmetry connection between the pion and photon couplings to hadrons could be established. In fact such a connection is provided by the idea of vector-meson dominance (vector-dominance model, VDM). This well-established idea from the physics of the 1960s states that the coupling of a photon to hadrons can be calculated from the knowledge of that of vector mesons. Since the transverse ρ mesons and the pion belong to the same multiplet of the $SU(2)_W$ group (which governs the symmetry of hadron vertices) the description of radiative weak decays of hyperons should—by symmetry requirements—be related closely to that of pionic weak hyperon decays. The main objective of this paper is to provide the relevant symmetry prediction and to clarify the quark-model breakdown of the Hara theorem in light of the VDM. One of the particular results of our combined $VDM+SU(6)_W$ symmetry approach is the explanation of the observed large and negative asymmetry of the $\Sigma^+\to p\gamma$ radiative weak decay.

The symmetry approach of this paper describes all radiative weak hyperon decays in terms of parameters determined from weak nonleptonic hyperon decays and thus without free parameters. It is, of course, a different problem to explain in the framework of QCD why the f/d, etc., parameters in nonleptonic hyperon decays have the experimentally observed values. Such questions are of no interest to us in this paper, however, since our main concern is to obtain a reliable symmetry-based prediction. In the following we shall, therefore, refrain from any discussion of possible QCD effects and complications.

The paper is organized as follows. In Sec. II the idea of vector-meson dominance is recalled and shown to indicate that the PV amplitude of radiative weak hyperon decays can be calculated through the VDM-based prescription characterized by a nonvanishing $F_1(q^2=0)\bar{u}\gamma_\mu\gamma_5 u A^\mu$ photon-hadron coupling. Then, the question of the gauge invariance of the VDM prescription is briefly discussed leading to the explanation of the origin of the quark-model violation of the Hara theorem. The symmetry approach connecting the weak pionic decays of hyperons with the weak amplitudes for vector-meson emission from baryons is discussed in Sec. III. In that section the relevant symmetry formulas are given and the relationship between the quark- and hadron-level approaches to PC amplitudes is briefly indicated. In Sec. IV the parameters of the model are extracted from the weak nonleptonic hyperon decays. Section V contains the sought symmetry predictions for the weak radiative hyperon decays. Our main results are restated in Sec. VI.

II. VECTOR-MESON DOMINANCE, GAUGE INVARIANCE, AND THE VIOLATION OF THE HARA THEOREM

The idea of vector-meson dominance (vector-dominance model, VDM) is nearly thirty years old but its usefulness is still being corroborated anew in present elementary-particle physics (see, e.g., Ref. 22). The VDM states that the coupling of photon to hadrons may be obtained by first calculating the vector-meson coupling and then performing the substitution (here for the ρ meson)

$$\rho_\mu \to \frac{e}{g_\rho} A_\mu \ , \tag{2.1}$$

where $e^2/(4\pi)=\frac{1}{137}$ and $g_\rho=f_{\rho NN}=5.0$ with analogous formulas for other vector mesons (see, e.g., Ref. 23).

The most general parity-violating coupling of vector mesons to spin-$\frac{1}{2}$ baryons is given by

$$\bar{u}_1\gamma_5[F_1(q^2)\gamma_\mu+i\sigma_{\mu\nu}q^\nu F_2(q^2)+q_\mu F_3(q^2)]u_2\epsilon_V^\mu \ . \tag{2.2}$$

For a general U-spin-singlet vector meson there is absolutely no reason why the form factor $F_1(q^2)$ should vanish at $q^2=0$. The VDM effective prescription (2.1) indicates then that the *effective* $F_1(q^2=0)$ does not vanish for photons either. Since the $\bar{u}_1\gamma_\mu\gamma_5 u_2$ term has $C=P=+1$ (for identical incoming and outgoing baryons) the relevant coupling of Σ^+ and p must be symmetrical under the $\Sigma^+\leftrightarrow p$ interchange, in accordance with the λ_6 form of the spurion used in the derivation of the Hara theorem. In short, the VDM prescription indicates that it is the other assumption of Hara, that of the *effective* presence of the $F_2(0)$ term only, that in general need not be satisfied.

There remains, however, a question of how the above statement can be compatible with gauge invariance which seems to require the vanishing of $F_1(q^2)$ for real photons (see, e.g., Ref. 15). In the VDM language that question is replaced by the question of how the photon–vector-meson coupling

$$e(m_V^2/g_V)V\cdot A \tag{2.3}$$

[that leads to prescription (2.1)] can be compatible with gauge invariance. The latter question is answered at length in Ref. 24 where it is shown how the presence of two explicitly gauge-invariant terms $F_{\mu\nu}V^{\mu\nu}$ and $A_\mu J_V^\mu$ in the Lagrangian is equivalent to a gauge-invariant combination of coupling (2.3) and the gauge-noninvariant photon mass term

$$-\tfrac{1}{2}(e/g_\rho)^2 m_\rho^2 A_\mu^2 \ . \tag{2.4}$$

To first order in e, the mass term (2.4) may be neglected and the *effective* V-γ coupling (2.3) results in the VDM prescription (2.1). Consequently, the *effective* vector-meson-mediated $\bar{u}\gamma_u\gamma_5 u A^\mu$ coupling need not vanish.

In the equivalent formulation using explicitly gauge-invariant couplings $F_{\mu\nu}V^{\mu\nu}$ and $A_\mu J_V^\mu$ the vector-meson-mediated photon-hadron $\bar{u}\gamma_\mu\gamma_5 u A^\mu$ coupling duly vanishes at $q^2=0$. (Note that also the standard $\bar{u}\sigma_{\mu\nu}q^\nu\gamma_5 u A^\mu$ term vanishes if complete VDM holds.) However, the contribution from the $A_\mu J_V^\mu$ "contact" term (with J_V^μ constructed from quarks) does not. The latter coupling is what has been considered in the quark-model calculations of Kamal and Riazuddin. Proper description of photon-hadron interactions requires taking both contributions into account. The Hara theorem is thus violated because it does not consider the "contact" $A_\mu J_V^\mu$ photon-quark interaction.

It should also be stressed that prescription (2.1) is not only theoretically legitimate but practically very *useful,* as various calculations confirm. Therefore, in the following we shall deal with transverse vector mesons in place of photons and only at the end of our considerations shall we utilize Eq. (2.1).

III. THE SYMMETRY APPROACH

As is well known the transverse vector and pseudoscalar mesons (of a given flavor content) belong to the same triplet of the $SU(2)_W$ group. The idea of using the $SU(2)_W$ [in reality $SU(6)_W$] group to the description of both the weak pionic decays of hyperons and the related couplings of vector mesons to baryons has already been exploited by McKellar and Pick[25] who followed the original work of Ref. 26. The interrelation of the $SU(6)_W$ and quark-model schemes has been discussed thoroughly by Desplanques, Donoghue, and Holstein[27] who have demonstrated explicitly how the quark model underlies and unites previous [i.e., SU(3), current algebra, and $SU(6)_W$] approaches to the description of parity-violating nuclear forces. Their quark-model technique of calculating the relevant meson-baryon-baryon parity-violating (baryon-baryon parity-conserving) amplitudes is utilized in this work to determine all the necessary couplings. Results of these calculations are given below in a compact SU(3)-invariant form. For the parity-conserving amplitudes we use a hadron-level pole model which was found fairly successful in describing PC amplitudes in weak nonleptonic hyperon decays. Connection between this hadron-level model and the quark-level calculations shall be indicated briefly later on.

A. Parity-violating amplitudes

The SU(3)-symmetry structure of the weak amplitudes describing octet-pseudoscalar-meson coupling to octet baryons is conveniently described in the spurion language. In the 1960s the PV spurion was assumed to be the λ_6 member of the SU(3) octet ($\Delta I=\frac{1}{2}$ rule). In the quark model this $\Delta I=\frac{1}{2}$ assumption is a consequence of the (anti)symmetry of baryon wave functions.[28] From the above four octets one can form nine SU(3)-invariant combinations:

$$\begin{aligned}
&J_1=\mathrm{Tr}(SB_f^T M^T B_i), \quad J_2=\mathrm{Tr}(SB_i M^T B_f^T)\ ,\\
&J_3=\mathrm{Tr}(SB_f^T B_i M^T), \quad J_4=\mathrm{Tr}(SB_i B_f^T M^T)\ ,\\
&J_5=\mathrm{Tr}(SM^T B_f^T B_i), \quad J_6=\mathrm{Tr}(SM^T B_i B_f^T)\ ,\\
&J_7=\mathrm{Tr}(SB_f^T)\,\mathrm{Tr}(B_i M^T), \quad J_8=\mathrm{Tr}(SB_i)\,\mathrm{Tr}(B_f^T M^T)\ ,\\
&J_9=\mathrm{Tr}(SM^T)\,\mathrm{Tr}(B_i B_f^T)\ ,
\end{aligned} \tag{3.1}$$

where T denotes transposition, $S=\lambda_6$, and M, B_i, B_f are the standard meson and baryon matrices (see, e.g., the Appendix of Ref. 29).

Coefficients A_k of the most general SU(3)-invariant form

$$\sum A_k J_k \tag{3.2}$$

are determined by the considered model (we use A,B for PV and PC amplitudes, respectively). Since there exists one linear relation among nine traces (3.1) ($\sum_1^6 J_k=\sum_7^9 J_k$) one of the coefficients A_k (B_k) is left undetermined and can be chosen at will.[30]

The $SU(6)_W$-symmetry approach to the parity-violating amplitudes[27] allows the determination of the values of coefficients A_k for the different $SU(6)_W$ diagrams presented in Figs. 1(a)–1(c). The $\Delta S=1$ weak nonleptonic

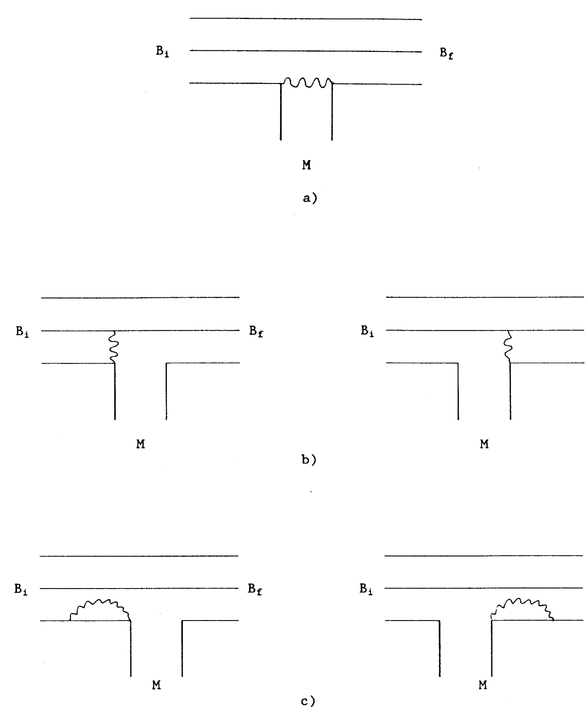

FIG. 1. $SU(6)_W$ quark-line diagrams.

parity-violating Hamiltonian may in general be decomposed into two parts:

$$H^{\rm PV}(\Delta S=1)=x_L H_L^{\rm PV}(\Delta S=1)+x_T H_T^{\rm PV}(\Delta S=1) \; ; \quad (3.3)$$

the first one (H_L) describes the effect of currents along the direction of decay momentum, while the other (H_T) includes currents perpendicular to it. Scale parameters x_L, x_T depend on the type of diagram in question and we have $x_L(x_T)=a_L(a_T), b_L(b_T), 0(c_T)$ for Figs. 1(a), 1(b), 1(c), respectively.[27] In $SU(6)_W$ the parameters x_L and x_T are unrelated. They are related by the quark model[27] so that we have only one parameter corresponding to Fig. 1(b):

$$b \equiv b_T = -b_L \; . \quad (3.4)$$

For pseudoscalar mesons, Fig. 1(a) does not contribute[27] and relation (3.4) ensures the $\Delta I=\frac{1}{2}$ rule in nonleptonic decays. In the vector-meson sector the colored-quark model provides a relation between a_L and a_T (Ref. 27) which is different from (3.4):

$$a_L = \tfrac{1}{3} a_T \equiv -a \; . \quad (3.5)$$

The relative size of the three remaining parameters $a, b, c \equiv c_T$ is left undetermined by symmetry considerations. Consequently, the actual values of coefficients $A_k \equiv A_k^M(x)$ depend on the type of diagram considered (i.e., $x=a$, b, or c) and on the type of meson in question (i.e., whether it is pseudoscalar or a vector meson: $M=P$ or V).

Calculation along the lines presented in Ref. 27 gives, for pseudoscalar mesons,

$$A_k^P(a)=0 \quad (\text{for all } k) \; ; \quad (3.6a)$$

$$\begin{aligned} A_1^P(b)&=A_2^P(b)=A_4^P(b)=A_6^P(b)\\ &=-A_7^P(b)=-A_8^P(b)=-A_9^P(b) \; ,\\ A_3^P(b)&-A_1^P(b)=A_1^P(b)-A_5^P(b)=-b/2 \; ; \end{aligned} \quad (3.6b)$$

$$\begin{aligned} &A_1^P(c)=A_2^P(c)=-A_7^P(c)=-A_8^P(c)=-A_9^P(c) \; ,\\ &A_4^P(c)=A_5^P(c), \quad A_6^P(c)=A_3^P(c) \; ,\\ &A_1^P(c)-A_3^P(c)=A_5^P(c)-A_1^P(c)=-c/6, \quad (c\equiv c_T) \; . \end{aligned} \quad (3.6c)$$

In (3.6) we may set $A_1^P(b)=A_1^P(c)=0$. For the b-type diagrams the resulting SU(3) structure is then

$$-\operatorname{Tr}([P^T,S]\{B_i,B_f^T\}-[P^T,S][B_i,B_f^T])\frac{b}{4} \; ; \quad (3.7a)$$

i.e., we obtain $f/d=-1$. For the c-type diagrams one obtains a pure f-type coupling:

$$-\operatorname{Tr}([P^T,S][B_i,B_f^T])\frac{c}{6} \; . \quad (3.7b)$$

For vector mesons we shall first consider the b- and c-type diagrams. It may be checked that the $\Delta I=\frac{1}{2}$ rule is satisfied for these diagrams for the same reason as in the case of pseudoscalar mesons and that the PV spurion is still $S=\lambda_6$. The resulting A_k coefficients are

$$\begin{aligned} &A_2^V(b)=A_4^V(b)=A_6^V(b), \quad A_7^V(b)=A_8^V(b) \; ,\\ &A_1^V(b)-A_2^V(b)=A_1^V(b)+A_9^V(b)=-\frac{4}{3\sqrt{2}}b \; ,\\ &A_3^V(b)-A_1^V(b)=\frac{1}{\sqrt{2}}b \; ,\\ &A_1^V(b)+A_7^V(b)=-\frac{2}{3\sqrt{2}}b \end{aligned} \quad (3.8a)$$

and

$$\begin{aligned} &A_1^V(c)=A_2^V(c)=-A_7^V(c)=-A_8^V(c) \; ,\\ &A_3^V(c)=A_5^V(c), \quad A_4^V(c)=A_6^V(c) \; ,\\ &A_3^V(c)-A_1^V(c)=-\frac{1}{9\sqrt{2}}c,\\ &A_4^V(c)-A_1^V(c)=-\frac{5}{9\sqrt{2}}c \; ,\\ &A_9^V(c)+A_1^V(c)=\frac{2}{9\sqrt{2}}c \; . \end{aligned} \quad (3.8b)$$

Setting $A_9^V(b)=0$ and $A_1^V(c)=0$ we get the following SU(3) structure for the vector-meson couplings due to Figs. 1(b) and 1(c):

$$\begin{aligned}(-4\operatorname{Tr}(SB_f^TV^TB_i)-\operatorname{Tr}(\{S,V^T\}B_f^TB_i)\\ +2[\operatorname{Tr}(SB_f^T)\operatorname{Tr}(B_iV^T)\\ +\operatorname{Tr}(SB_i)\operatorname{Tr}(B_f^TV^T)])/(3\sqrt{2})b\end{aligned} \quad (3.9a)$$

and

$$\begin{aligned}(-\operatorname{Tr}(\{S,V^T\}B_f^TB_i)-5\operatorname{Tr}(\{S,V^T\}B_iB_f^T)\\ +2\operatorname{Tr}(SV^T)\operatorname{Tr}(B_iB_f^T))/(9\sqrt{2})c \; .\end{aligned} \quad (3.9b)$$

The origin of the difference in the SU(3)-symmetry structure of the pseudoscalar- and vector-meson parity-violating amplitudes [as seen in (3.6)–(3.9)] can be traced back to the fact that the parity-violating couplings $\bar{u}_1 u_2 P$ and $\bar{u}_1\gamma_\mu\gamma_5 u_2 V^\mu$ are not related by an $SU(2)_W$ transformation[31] but by the quark model only.

In Table II(a) we gathered the couplings of the neutral members of meson octets [corresponding to (3.6)–(3.9)] which are of interest to us. In Table II(b) we listed the relevant couplings of the nonoctet ω^0 vector meson which—in addition to those of ρ^0 and ω_8— are needed in the calculation of weak radiative hyperon decays when the photon coupling to strange quark is suppressed by a factor

$$\epsilon \simeq m_q(\text{nonstrange})/m_q(\text{strange}) \simeq \tfrac{2}{3} \; .$$

From Eqs. (3.9) or Table II(a) it may be checked that the coupling of the U-spin-singlet transverse vector meson to $B_i=\Sigma^+$, $B_f=p$ does *not* vanish. Thus, the Hara theorem is violated. Note that the breakdown of the Hara theorem comes not only from two-quark interactions which are described by reduced matrix ele-

TABLE II. Weak PV amplitudes for (a) neutral-octet-meson emission from baryons and (b) ω^0 emission.

(a)

Process	SU(3) formula	$M=P$ b	$M=P$ c	$M=V$ b	$M=V$ c	$M=V$ a
$\Sigma^+\to p\pi^0$ (ρ^0)	$(A_1-A_3)/\sqrt{2}$	$\frac{1}{2\sqrt{2}}$	$-\frac{1}{6\sqrt{2}}$	$-\frac{1}{2}$	$\frac{1}{18}$	$-\frac{2}{9}$
$\Sigma^+\to p\eta_8$ (ω_8)	$(A_1+A_3-2A_5)/\sqrt{6}$	$-\frac{3}{2\sqrt{6}}$	$\frac{1}{2\sqrt{6}}$	$-\frac{1}{2\sqrt{3}}$	$\frac{1}{18\sqrt{3}}$	$-\frac{2}{9\sqrt{3}}$
$\Lambda\to n\pi^0$ (ρ^0)	$(2A_4-A_1-A_3)/(2\sqrt{3})$	$\frac{1}{4\sqrt{3}}$	$-\frac{1}{4\sqrt{3}}$	$\frac{5}{6\sqrt{6}}$	$-\frac{1}{2\sqrt{6}}$	$\frac{2}{\sqrt{6}}$
$\Lambda\to n\eta_8$ (ω_8)	$(A_1+A_3)/6+A_7$ $+(2A_2+2A_6-A_4-A_5)/3$	$-\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2\sqrt{2}}$	$-\frac{1}{6\sqrt{2}}$	$\frac{2}{3\sqrt{2}}$
$\Sigma^0\to n\pi^0$ (ρ^0)	$(A_1+A_3)/2+A_7$	$-\frac{1}{4}$	$\frac{1}{12}$	$-\frac{1}{6\sqrt{2}}$	$-\frac{1}{18\sqrt{2}}$	$\frac{2}{9\sqrt{2}}$
$\Sigma^0\to n\eta_8$ (ω_8)	$(2A_5-A_1-A_3)/(2\sqrt{3})$	$\frac{3}{4\sqrt{3}}$	$-\frac{1}{4\sqrt{3}}$	$\frac{1}{2\sqrt{6}}$	$-\frac{1}{18\sqrt{6}}$	$\frac{2}{9\sqrt{6}}$
$\Xi^0\to\Sigma^0\pi^0$ (ρ^0)	$(A_2+A_4)/2+A_8$	0	$-\frac{1}{12}$	$\frac{2}{3\sqrt{2}}$	$-\frac{5}{18\sqrt{3}}$	$\frac{10}{9\sqrt{2}}$
$\Xi^0\to\Sigma^0\eta_8$ (ω_8)	$(2A_6-A_2-A_4)/(2\sqrt{3})$	0	$\frac{1}{4\sqrt{3}}$	0	$-\frac{5}{18\sqrt{6}}$	$\frac{10}{9\sqrt{6}}$
$\Xi^0\to\Lambda\pi^0$ (ρ^0)	$(2A_3-A_2-A_4)/(2\sqrt{3})$	$-\frac{1}{2\sqrt{3}}$	$\frac{1}{4\sqrt{3}}$	$-\frac{1}{3\sqrt{6}}$	$\frac{1}{6\sqrt{6}}$	$-\frac{2}{3\sqrt{6}}$
$\Xi^0\to\Lambda\eta_8$ (ω_8)	$(A_2+A_4)/6+A_8$ $+(2A_1+2A_5-A_3-A_6)/3$	$\frac{1}{2}$	$-\frac{1}{4}$	$-\frac{1}{3\sqrt{2}}$	$\frac{1}{18\sqrt{2}}$	$-\frac{2}{9\sqrt{2}}$
$\Xi^-\to\Sigma^-\pi^0$ (ρ^0)	$(A_2-A_4)/\sqrt{2}$	0	$\frac{1}{6\sqrt{2}}$	0	$\frac{5}{18}$	$-\frac{10}{9}$
$\Xi^-\to\Sigma^-\eta_8$ (ω_8)	$(A_2+A_4-2A_6)/\sqrt{6}$	0	$-\frac{1}{2\sqrt{6}}$	0	$\frac{5}{18\sqrt{3}}$	$-\frac{10}{9\sqrt{3}}$
$p\to p(K^0)$ (K^{*0})	A_3+A_9	$-\frac{1}{2}$	$\frac{1}{6}$	$-\frac{1}{3\sqrt{2}}$	$\frac{1}{9\sqrt{2}}$	$-\frac{8\sqrt{2}}{9}$

(b)

Process	b	c	a
$\Sigma^+\to p\omega^0$	$-\frac{1}{6}$	$-\frac{1}{18}$	$-\frac{2}{9}$
$\Lambda\to n\omega^0$	$+\frac{1}{2\sqrt{6}}$	$+\frac{1}{2\sqrt{6}}$	$\left[\frac{2}{3}\right]^{1/2}$
$\Sigma^0\to n\omega^0$	$+\frac{1}{6\sqrt{2}}$	$+\frac{1}{18\sqrt{2}}$	$\frac{\sqrt{2}}{9}$
$\Xi^0\to\Sigma^0\omega^0$	0	$+\frac{5}{18\sqrt{2}}$	$\frac{5\sqrt{2}}{9}$
$\Xi^0\to\Lambda\omega^0$	$-\frac{1}{3\sqrt{6}}$	$-\frac{1}{6\sqrt{6}}$	$-\frac{1}{3}\left[\frac{2}{3}\right]^{1/2}$
$\Xi^-\to\Sigma^-\omega^0$	0	$-\frac{5}{18}$	$-\frac{10}{9}$

ments b (as originally calculated by Kamal and Riazuddin) but also from the c-type single-quark $SU(6)_W$ diagrams.

For the a-type diagrams the $\Delta I=\frac{1}{2}$ rule does not hold in the colored quark model. The $\Delta I=\frac{1}{2}$ rule would be recovered if the relevant reduced matrix elements corresponding to the contributions from longitudinal (a_L) and transverse (a_T) pieces of the weak Hamiltonian were equal and opposite in sign as it happens in the quark model for b-type diagrams. This is, however, not the case [see Eq. (3.5)]. Consequently, we cannot use (3.1). Rather than writing the general SU(3)-invariant coupling appropriate in this case we chose to tabulate [Tables II(a) and II(b)] those neutral-vector-meson couplings which are relevant for our purposes ($a\equiv -a_L$).

B. Parity-conserving amplitudes

For the description of parity-conserving amplitudes we shall use the pole model which was fairly successful in the weak nonleptonic hyperon decays. In general, poles in both baryon and meson channels are expected to contribute. It is well known, however, that the contribution of meson poles in pionic decays of hyperons is small.[9,21] We shall, therefore, neglect the meson-pole contribution for the time being and only at the end of our calculations shall we try to see whether its inclusion can further improve the agreement of our predictions with experiment.

There are two possible ways of treating quark indices in the pole model. We may either keep the identity of quarks in the intermediate state or we may not. The first alternative corresponds more closely to performing the calculations at the quark level (i.e., "inside" hadrons of the bag model) or at the "planar" hadronic level of the so-called unitarized quark model (UQM; discussed extensively elsewhere[29,32]). At this level of the UQM the equal-splitting rule holds for the members of ground-state baryon octet and, consequently, the Lee-Sugawara rule for PC amplitudes is exact. In the second alternative it is the baryon state with properly (anti)symmetrized quarks that propagates in the intermediate state. When the PC B-B' amplitudes are estimated from the PV B-$B'P$ ones and the (nonrelativistic) quark model is used for the description of the $BB'M$ coupling the two alternatives lead to the same SU(3)-symmetry structure of the parity-conserving amplitudes. This indicates a connection between quark level and hadron level approaches to PC amplitudes (see also Ref. 15). In practice, however, it is the second alternative that is phenomenologically more successful as it is able to provide us with a better description of weak nonleptonic hyperon decays. The reason is that in the second alternative we may somewhat relax our assumptions and allow the f/d and F/D coupling ratios (the former describing PC weak process, the latter meson emission) to be slightly different from our previous PV estimates (for f/d) and quark-model [$SU(6)_W$] predictions (for F/D). Such small changes in these ratios and in the overall strength of the PC amplitudes are crucial in obtaining a satisfactory description of pionic decays of hyperons. In fact, if just F/D is kept at its quark-model/$SU(6)_W$ value of $\frac{2}{3}$ while the f/d ratio and the overall scale parameter are considered as free parameters the best *overall* description of PC amplitudes of nonleptonic hyperon decays for some processes still differs from the experimental amplitudes by a factor of 2 or more. Since in this paper we are concerned strictly with the symmetry predictions we shall not attempt any explanation of these ratios. However, it should be obvious from the above that a *reliable* prediction for the weak radiative decays of hyperons may come from the second alternative only.

The resulting formulas for vector-meson-emission PC amplitudes are given in Table III (baryon symbols stand for their masses). For pseudoscalar mesons the formulas of Table III should be divided by $-\sqrt{2}$ with obvious correspondences: $\pi\to\rho$, etc. Unlike the case of PV amplitudes, for PC amplitudes the obtained SU(3) structures of P and V emissions are identical. Since SU(3)-symmetry breaking in vertices is not understood anyway[33,34]—and we are interested in the most general SU(3) structure of the model only—all factors of $(m_B+m_{B''})/(m_B+m_{B'})$ modifying somewhat the resulting expressions for the pionic decays were put equal to their SU(3) value, i.e. to 1 [for a related question of a more rigorous description of SU(3)-symmetry breaking in hyperon semileptonic decays see Ref. 35].

As in the case of parity-violating amplitudes, the obtained SU(3) structure of PC amplitudes may be written with the help of nine invariant couplings J_k (3.1) though this time with a different spurion ($S=\lambda_7$):

$$\sum B_k J_k \ . \tag{3.10}$$

In Table III we included also the amplitudes involving a nonoctet vector meson (ω^0) since they are needed for a realistic estimate of the PC amplitudes of the weak radiative decays of hyperons in the SU(3)-symmetry-breaking case (see Sec. V). In these amplitudes the contribution from the strong-interaction vertex contains a piece whose SU(3) structure is $\mathrm{Tr}(M)\mathrm{Tr}(B_i B_f^T)$. The S parameter describes the strength of this SU(3)-invariant coupling. The Zweig rule requires $S=F-D$. This equality is maintained also when F and D are shifted from their $SU(6)_W$ values of $\frac{2}{3}$ and 1.

When (for simplicity) equal splitting is assumed for octet baryons, the octet-meson emission amplitudes in Table III are equivalent (up to a factor) to

$$\begin{aligned} &B_1=B_2=-B_9 \ ,\\ &B_1-B_3=B_5-B_1=(-f+d)(-F+D) \ ,\\ &B_1-B_6=B_4-B_1=(f+d)(F+D) \ ,\\ &B_1+B_7=-(B_1+B_8)=4dD/3 \end{aligned} \tag{3.11}$$

and we may set $B_9=0$.

Formulas for the first alternative (i.e., quarks inside hadrons or "planar" level of UQM) are obtained from Table III and Eq. (3.11) by first setting $F/D=\frac{2}{3}$ and then choosing $f=-d$ for b-type diagrams and $d=0$ for c-type diagrams.

TABLE III. Weak PC amplitudes for vector-meson emission from baryons.

Process	Hadron-pole model formula
$\Sigma^+ \to p\rho^0$	$-(-f+d)(-F+D)\frac{1}{N-\Sigma}$
$\Sigma^+ \to p\omega_8$	$\sqrt{3}(-f+d)(-F+D)\frac{1}{N-\Sigma}$
$\Sigma^+ \to p\omega^0$	$(-f+d)[3(-F+D)+2S]\frac{1}{N-\Sigma}$
$\Lambda \to n\rho^0$	$-\sqrt{2/3}(-f+d)D\frac{1}{N-\Sigma}-\frac{1}{\sqrt{6}}(3f+d)(F+D)\frac{1}{N-\Lambda}$
$\Lambda \to n\omega_8$	$\frac{1}{3\sqrt{2}}(3f+d)(3F+D)\frac{1}{N-\Lambda}$
$\Lambda \to n\omega^0$	$\frac{1}{\sqrt{6}}(3f+d)\left[3F-\frac{5}{3}D-2S\right]\frac{1}{N-\Lambda}$
$\Sigma^0 \to n\rho^0$	$-\frac{1}{\sqrt{2}}(-f+d)(F+D)\frac{1}{N-\Sigma}-\frac{2}{3\sqrt{2}}(3f+d)D\frac{1}{N-\Lambda}$
$\Sigma^0 \to n\omega_8$	$-\sqrt{3/2}(-f+d)(-F+D)\frac{1}{N-\Sigma}$
$\Sigma^0 \to n\omega^0$	$-\frac{1}{\sqrt{2}}(-f+d)[3(-F+D)+2S]\frac{1}{N-\Sigma}$
$\Xi^0 \to \Sigma^0\rho^0$	$-\frac{2}{3\sqrt{2}}(3f-d)D\frac{1}{\Lambda-\Xi}-\frac{1}{\sqrt{2}}(f+d)(F-D)\frac{1}{\Sigma-\Xi}$
$\Xi^0 \to \Sigma^0\omega_8$	$\sqrt{3/2}(f+d)(F+D)\frac{1}{\Sigma-\Xi}$
$\Xi^0 \to \Sigma^0\omega^0$	$\frac{1}{\sqrt{2}}(f+d)(F+D)\frac{1}{\Sigma-\Xi}$
$\Xi^0 \to \Lambda\rho^0$	$\frac{2}{\sqrt{6}}(f+d)D\frac{1}{\Sigma-\Xi}+\frac{1}{\sqrt{6}}(3f-d)(F-D)\frac{1}{\Lambda-\Xi}$
$\Xi^0 \to \Lambda\omega_8$	$-\frac{1}{3\sqrt{2}}(3f-d)(3F-D)\frac{1}{\Lambda-\Xi}$
$\Xi^0 \to \Lambda\omega^0$	$-\frac{1}{3\sqrt{6}}(3f-d)(3F-D)\frac{1}{\Lambda-\Xi}$
$\Xi^- \to \Sigma^-\rho^0$	$(f+d)(F+D)\frac{1}{\Sigma-\Xi}$
$\Xi^- \to \Sigma^-\omega_8$	$-\sqrt{3}(f+d)(F+D)\frac{1}{\Sigma-\Xi}$
$\Xi^- \to \Sigma^-\omega^0$	$-(f+d)(F+D)\frac{1}{\Sigma-\Xi}$

IV. WEAK NONLEPTONIC HYPERON DECAYS AND MODEL PARAMETERS

We may now proceed to the determination of model parameters. For parity-violating amplitudes we have three parameters: a, b, c. The latter two (b,c) may be extracted from the experimental data on weak nonleptonic decays of hyperons. This procedure leads to [see Table IV(a)]

$$b=-5.0,\quad c=12.0 \tag{4.1}$$

which corresponds to $f/d=-1+2c/(3b)=-2.6$.

The value of a is not accessible in this way. We utilize the theoretical estimate given by McKellar and Pick[25] for a_T,

$$a_T=-\frac{c}{4}\ , \tag{4.2}$$

which together with (3.5) gives

$$a\equiv -a_L=\frac{c}{12}\ . \tag{4.3}$$

The PC amplitudes are also described by three parameters: F/D, f/d, and the overall normalization factor C. From the semileptonic decays we take $F=0.43$, $D=0.82$, and consequently $F/D=0.52$. A proper description of the experimental data on PC amplitudes of pionic hyperon decays requires then [see Table IV(b)]

$$f/d=-1.9,\quad C=-30.0\ . \tag{4.4}$$

The symmetry description of nonleptonic hyperon decays given in Table IV differs from experimental data by up to 20%. Provided that the theoretical understanding of nonoctet contribution from the a-type diagrams is correct, this is, therefore, the accuracy we expect from our symmetry predictions for weak radiative decays.

V. WEAK RADIATIVE DECAYS: PREDICTIONS

Expressing the photon couplings through those of vector mesons

$$\gamma=\frac{1}{\sqrt{2}}\rho^0+\frac{1}{3\sqrt{2}}\omega^0-\tfrac{1}{3}\epsilon\phi \tag{5.1}$$

(where $\epsilon\simeq\frac{2}{3}$) and using $\omega^0=\sqrt{3}\omega_8+\sqrt{2}\phi$ we determine

TABLE IV. Hyperon nonleptonic decays. The amplitudes A,B in units of 10^{-7}.

(a)

Amplitude	Quark model Eq. (3.6) (or Table II)	Data (from Ref. 21)	Eq. (3.6) $b=-5$ $c=12$
$A(\Sigma_0^+)$	$\frac{1}{2\sqrt{2}}\left[b-\frac{c}{3}\right]$	-3.27	-3.18
$A(\Sigma_+^+)$	0	0.13	0.0
$A(\Sigma_-^-)$	$-\frac{1}{2}\left[b-\frac{c}{3}\right]$	4.27	4.50
$A(\Lambda_0^0)$	$\frac{1}{4\sqrt{3}}(b-c)$	-2.37	-2.46
$A(\Lambda_-^0)$	$-\frac{1}{2\sqrt{6}}(b-c)$	3.25	3.47
$A(\Xi_0^0)$	$-\frac{1}{2\sqrt{3}}\left[b-\frac{c}{2}\right]$	3.43	3.18
$A(\Xi_-^-)$	$\frac{1}{\sqrt{6}}\left[b-\frac{c}{2}\right]$	-4.51	-4.49

(b)

Amplitude	Pole-model expression [Table III or Eq. (3.11) with scale parameter C]	Data (from Ref. 21)	Pole model $f/d=-1.9$ $C=-30$
$B(\Sigma_0^+)$	$\frac{1}{\sqrt{2}}\left[\frac{f}{d}-1\right]\left[1-\frac{F}{D}\right]C$	26.6	29.5
$B(\Sigma_+^+)$	$-\frac{4}{3}C$	42.4	40.0
$B(\Sigma_-^-)$	$\left[\left[\frac{f}{d}-1\right]\frac{F}{D}-\left[3\frac{f}{d}+1\right]\Big/3\right]C$	-1.44	-1.76
$B(\Lambda_0^0)$	$-\frac{1}{2\sqrt{3}}\left[\frac{f}{d}+3+\left[3\frac{f}{d}+1\right]\frac{F}{D}\right]C$	-15.8	-11.7
$B(\Lambda_-^0)$	$\frac{1}{\sqrt{6}}\left[\frac{f}{d}+3+\left[3\frac{f}{d}+1\right]\frac{F}{D}\right]C$	22.1	16.5
$B(\Xi_0^0)$	$\frac{1}{2\sqrt{3}}\left[\left[3\frac{f}{d}-1\right]\frac{F}{D}+3-\frac{f}{d}\right]C$	-12.3	-12.2
$B(\Xi_-^-)$	$-\frac{1}{\sqrt{6}}\left[\left[3\frac{f}{d}-1\right]\frac{F}{D}+3-\frac{f}{d}\right]C$	16.6	17.3

TABLE V. Weak radiative hyperon decays: comparison of symmetry predictions with experiment.

Transition	A	$\bar{B}$	α	Branching ratio (10^{-3})	Experimental data (Ref. 36) α	Experimental data (Ref. 36) Branching ratio (10^{-3})
$\Sigma^+\to p\gamma$	$+2.54$	-0.78	-0.56	0.90	-0.83 ± 0.13	1.24 ± 0.08
$\Sigma^0\to n\gamma$	-0.13	-4.21	$+0.06$			
$\Lambda\to n\gamma$	-2.92	-1.32	$+0.75$	3.21		1.02 ± 0.33
$\Xi^0\to\Lambda\gamma$	$+1.23$	$+1.70$	$+0.95$	2.06	$+0.41\pm0.26$	1.1 ± 0.2
$\Xi^0\to\Sigma^0\gamma$	-2.78	$+2.18$	-0.97	3.49		<70
$\Xi^-\to\Sigma^-\gamma$	$+1.57$	-0.32	-0.40	0.36		0.23 ± 0.1

from Tables II and III the structure of both the PV and PC amplitudes for weak radiative decays of hyperons:

$$\begin{aligned}
A(\Sigma^+\to p\gamma)&=-\frac{5+\epsilon}{9\sqrt{2}}b+\frac{1+\epsilon}{27\sqrt{2}}c-\frac{4\sqrt{2}}{27}a\ ,\\
A(\Sigma^0\to n\gamma)&=-\tfrac{1}{18}(1-\epsilon)b-\frac{1+\epsilon}{54}c+\tfrac{4}{27}a\ ,\\
A(\Lambda\to n\gamma)&=\frac{3+\epsilon}{6\sqrt{3}}b-\frac{1+\epsilon}{6\sqrt{3}}c+\frac{4}{3\sqrt{3}}a\ ,\\
A(\Xi^0\to\Lambda^0\gamma)&=-\frac{2+\epsilon}{9\sqrt{3}}b+\frac{1+\epsilon}{18\sqrt{3}}c-\frac{4}{9\sqrt{3}}a\ ,\\
A(\Xi^0\to\Sigma^0\gamma)&=\tfrac{1}{3}b-\tfrac{5}{54}(1+\epsilon)c+\tfrac{20}{27}a\ ,\\
A(\Xi^-\to\Sigma^-\gamma)&=\frac{5}{27\sqrt{2}}(1+\epsilon)c-\frac{40}{27\sqrt{2}}a\ ;
\end{aligned}\tag{5.2a}$$

$$\begin{aligned}
B(\Sigma^+\to p\gamma)&=\frac{\sqrt{2}}{3}\left[\frac{f}{d}-1\right](1-\epsilon)\left[\frac{F}{D}-1\right]C\ ,\\
B(\Sigma^0\to n\gamma)&=\tfrac{4}{3}C-\frac{1}{3}\left[\frac{f}{d}-1\right](1-\epsilon)\left[\frac{F}{D}-1\right]C\ ,\\
B(\Lambda\to n\gamma)&=\frac{4}{3\sqrt{3}}C\\
&\quad+\frac{1}{3\sqrt{3}}\left[3\frac{f}{d}+1\right](1-\epsilon)\left[\frac{F}{D}+\frac{1}{3}\right]C\ ,\\
B(\Xi^0\to\Lambda^0\gamma)&=-\frac{4}{3\sqrt{3}}C\\
&\quad-\frac{1}{9\sqrt{3}}\left[3\frac{f}{d}-1\right](1-\epsilon)\left[3\frac{F}{D}-1\right]C\ ,\\
B(\Xi^0\to\Sigma^0\gamma)&=-\tfrac{4}{3}C+\frac{1}{3}\left[\frac{f}{d}+1\right](1-\epsilon)\left[\frac{F}{D}+1\right]C\ ,\\
B(\Xi^-\to\Sigma^-\gamma)&=-\frac{\sqrt{2}}{3}\left[\frac{f}{d}+1\right](1-\epsilon)\left[\frac{F}{D}+1\right]C\ .
\end{aligned}\tag{5.2b}$$

As can be seen from Eqs. (5.2), it is the parity-conserving and not the parity-violating amplitude of the $\Sigma^+\to p\gamma$ transition that vanishes in the SU(3) limit $\epsilon\to 1$ (see also Ref. 9). Putting in (5.2) $c=a=0$, $F/D=\frac{2}{3}$, and $f/d=-1$ we reproduce the quark-model results of Ref. 20 for two-quark interactions (with X of Ref. 20 equal zero). The essential differences between the quark-model calculations of Ref. 20 and our approach are (1) a different treatment of single-quark diagrams which in our approach are determined by symmetry considerations, (2) a different treatment of quark momenta, and (3) the inclusion of deviations from quark-model predictions for F/D in PC amplitudes. The f/d ratios in PC and PV amplitudes and their relative size are fixed by known nonleptonic hyperon decays. In particular, due to the inclusion of the experimental scale factor in PC $Y_i\to Y_f\pi$ amplitudes, the size of PC $Y_i\to Y_f\gamma$ amplitudes estimated in this way is larger than might be naively expected. Thus, the SU(3) suppression of the $\Sigma^+\to p\gamma$ PC amplitude is not really operative. This results in a relatively large asymmetry parameter $\alpha(\Sigma^+\to p\gamma)$.

Asymmetry parameters $\alpha(Y_i\to Y_f\gamma)$ are calculated from

$$\alpha=\frac{2A\bar{B}}{A^2+\bar{B}^2}\ ,\tag{5.3}$$

where

$$\bar{B}=\frac{m_i-m_f}{m_i+m_f}B$$

and branching ratios are given by

$$R(Y_i\to Y_f\gamma)=\left[\frac{e}{g_\rho}\right]^2\frac{1}{4\pi m_i}k_\gamma(E_f+m_f)\times(A^2+\bar{B}^2)/\sum_f\Gamma(Y_i\to Y_f\pi)\ ,\tag{5.4}$$

where the first factor comes from the VDM prescription (2.1).

The resulting asymmetries and branching ratios are presented in Table V where a reasonable agreement between the symmetry prediction and the experimental data is seen. In particular, (1) the predicted asymmetry of the $\Sigma^+\to p\gamma$ decay is large and negative and (2) the obtained $\Xi^-\to\Sigma^-\gamma$ branching ratio is of the right magnitude. Inspection of Table V and Eq. (5.2a) shows that the (correct) size of the $\Xi^-\to\Sigma^-\gamma$ branching ratio is set by a nonvanishing contribution from the c-type $SU(6)_W$ diagram. In the valence-quark model (which has been employed by Kamal and Riazuddin) c vanishes.[27] The nonzero value of c observed in nonleptonic hyperon decays may be attributed to the contribution from sea quarks.[37] As already remarked the SU(3) suppression of the $\Sigma^+\to p\gamma$ PC amplitude is compensated for by a larger overall size of PC amplitudes, required by symmetry connection with nonleptonic hyperon decays. Incidentally, the agreement of Table V in connection with the VDM idea indicates also that the vector-meson–nucleon PV amplitudes seem to be given correctly by the symmetry prescription.

TABLE VI. K^*-pole contribution.

Transition	Amplitude
$\Sigma^+\to p\gamma$	$-\frac{8}{27\sqrt{2}}\kappa$
$\Sigma^0\to n\gamma$	$+\frac{4}{27}\kappa$
$\Lambda\to n\gamma$	$+\frac{4}{3\sqrt{3}}\kappa$
$\Xi^0\to\Lambda\gamma$	$-\frac{4}{9\sqrt{3}}\kappa$
$\Xi^0\to\Sigma^0\gamma$	$+\frac{20}{27}\kappa$
$\Xi^-\to\Sigma^-\gamma$	$-\frac{40}{27\sqrt{2}}\kappa$

The only way by which symmetry predictions of Table V may still be modified is through the introduction of the K^*-pole contribution which may differ in size from an analogous term in nonleptonic decays due to an additional contribution from type-a diagrams (with K^*-pole inserted). The pattern of this contribution is given in Table VI. To see what its influence on the predictions of Table V can be we shall consider its size as a free parameter κ (which turns out to be positive in the pole model). The resulting dependence of the asymmetries and branching ratios on κ is shown in Figs. 2(a) and 2(b). The allowed range of κ is restricted by the requirement that the $\Xi^- \to \Sigma^- \gamma$ branching ratio should not deviate too far from experimental data. In this region of parameter space only the asymmetries of the $\Lambda \to n\gamma$ and $\Xi^- \to \Sigma^- \gamma$ decays depend significantly on κ. The $\Sigma^+ \to p\gamma$ decay asymmetry remains relatively stable around -0.7 ± 0.1.

VI. CONCLUSIONS

In this paper weak radiative hyperon decays were investigated in a symmetry approach. The basic ingredients of the approach were the $SU(6)_W$ symmetry supplied with some quark-model results, the experimental knowledge of nonleptonic hyperon decays and the idea of vector-meson dominance. The latter helped in the identification of the origin of the quark-model breakdown of the Hara theorem. Using VDM the "contact" $A_\mu J_\mu^V$ interaction of the quark model was shown to induce an *effective* $\bar{u}\gamma_\mu\gamma_5 u A^\mu$ photon-hadron coupling. Thus, the original Hara assumption of the pure $\bar{u}_1 \sigma_{\mu\nu}\gamma_5 q^\nu u_2 A^\mu$ form of the photon-hadron coupling appears invalid in the quark model: one has to take the "contact" interaction into account as well.

The symmetry/VDM approach enabled us to determine a connection between the weak radiative and nonleptonic decays of hyperons. Using the experimental knowledge of the latter we were able to predict the asymmetries and branching ratios of the former. In particular we obtained a large negative asymmetry parameter for the $\Sigma^+ \to p\gamma$ decay. Given the quality of our description of nonleptonic hyperon decays our symmetry predictions for the branching ratios of weak radiative hyperon decays are expected to deviate by $\sim$30–40% from reality. In fact, our predictions are within a factor of 2 from the experimental data. The least reliable ingredients of our approach are present theoretical understanding of the a-type diagrams and a possibility of a non-negligible contribution from the K^* pole. In the quark-model language both of them correspond to a single-quark transition. Further theoretical studies on the relationship between the symmetry considerations of this paper and the explicit quark-model calculations as well as an improvement in the accuracy of experiments are needed. Only then shall we finally know whether some new physics really manifests itself in the weak radiative decays of hyperons.

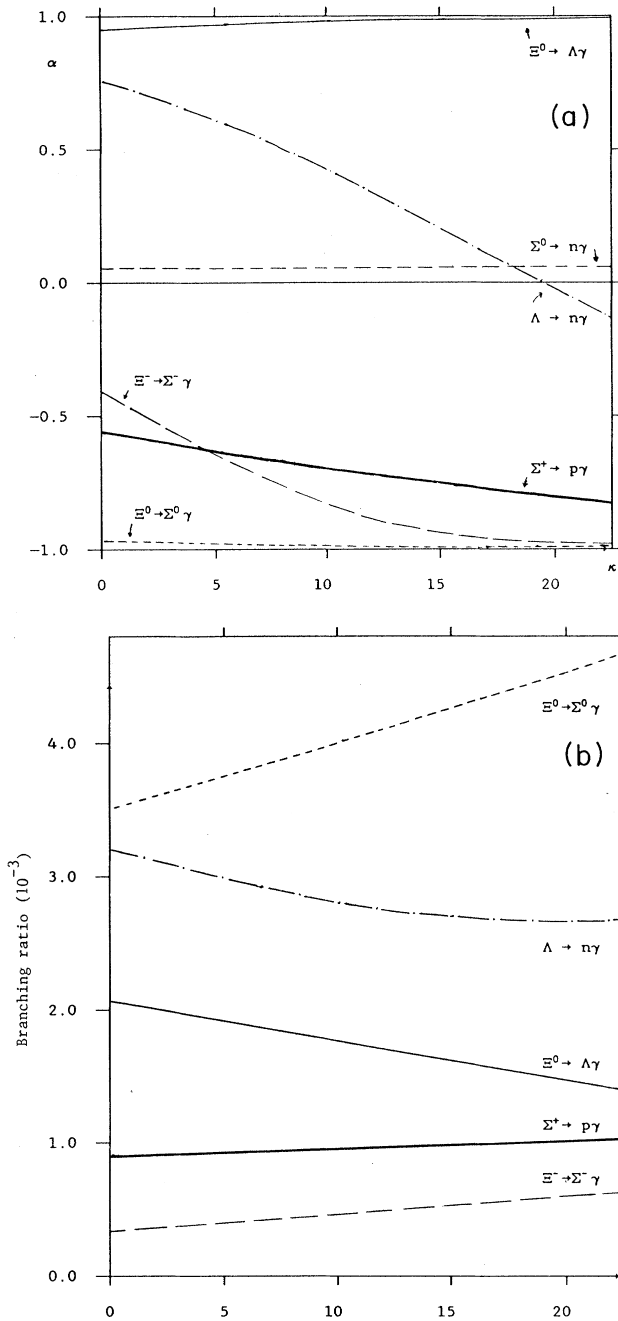

FIG. 2. Dependence on the size of K^*-pole contribution of (a) asymmetries and (b) branching ratios of radiative hyperon decays.

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