Pramāṇa, Vol. 8, No. 1, 1977, pp. 56–67. © Printed in India.

Parity violating non-leptonic decays of hyperons and of charmed baryons in SU (8)

RAMESH C VERMA and M P KHANNA
Department of Physics, Panjab University, Chandigarh 160014

MS received 21 June 1976; in revised form 13 August 1976

Abstract. The parity violating non-leptonic decays of hyperons and of charmed baryons are discussed in the framework of SU (8) symmetry. Several relations in addition to the ones obtained earlier by using SU (4) symmetry and $\underline{20}''$-dominance, are obtained. The assumption of $\underline{20}''$-dominance at the SU (4) level is no longer required for explaining the non-leptonic decays of $1/2^+$ baryons.

Keywords. Non-leptonic decays; SU (8) symmetry.

1. *List of symbols*:

Subscript A	antisymmetric
$B(n)$	SU (3) baryon multiplet of dimension n.
c	charm quantum number
CP	charge conjugation and parity
G	weak coupling constant
H_w	weak decay Hamiltonian
$H_0^{(720)}$	weak decay Hamiltonian corresponding to 720 representation
$H_{1,2,3,4}^{(1232)}$	weak decay Hamiltonian corresponding to 1232 representation
J and J^+	GIM type weak hadronic currents
$P(n)$	SU (3) meson multiplet of dimension n.
S	strangeness quantum number
Subscript s	symmetric
SU (n)	n dimensional unitary symmetry group
θ	Cabibbo angle
p, n, λ, p'	four fundamental quarks (p type, n type, strange quark, charm quark, respectively)
ϵ_{ij} and $\epsilon_{\alpha\beta\rho\delta}$	Levi-Civita symbols
χ_{ijk} and $\chi_{(i,s)}$	wave functions for spin 3/2 and 1/2 respectively
Superscript Bar, * and +	conjugation.

enlargement of SU (3) to SU (6) is known to have given useful information about several properties of the uncharmed particles including their non-leptonic decays (Rosen and Pakvasa 1964; Babu 1965; Kawarabayashi 1965). Therefore, it is reasonable to expect that SU (8) symmetry considerations may give new insight into the properties of both charmed and uncharmed baryons. In this paper, we discuss the parity violating (pv) non-leptonic decays of these particles assuming SU (8) to be the symmetry group of strong interactions. For the weak Hamiltonian we adopt the GIM scheme (Glashow *et al* 1970) (section 2).

We are able to obtain many new relations among the various decay amplitudes in addition to all the relations derived earlier by using SU (4) symmetry and $\underline{20}''$-dominance (Iwasaki 1975; Gupta 1976). We also find that if we treat SU (4) as a subgroup of SU (8) we no longer have to assume $\underline{20}''$-dominance in order to explain the pv decays of charmed and uncharmed baryons ($1/2^+$). This is because $\underline{84}$ representation of SU (4) subgroup of SU (8) does not contribute to these dacays.

For the S-wave decays of uncharmed baryons we obtain the following relations among the decay amplitudes:

$$\Lambda^0_- : \Sigma^+_0 : \Xi^-_- = 1 : -\sqrt{3} : 2 \tag{1.1}$$

$$\Sigma^+_+ = 0. \tag{1.2}$$

We also obtain the relations imposed by the $\triangle I = \frac{1}{2}$ rule. Relation (1.1) is not new. It has been shown to be a consequence of SU (4) symmetry but with the assumption of $\underline{20}''$-dominance. Relation (1.2) cannot be obtained from SU(4) alone, however, it has been obtained by using SU (6) symmetry considerations. Relation (1.1) agrees with experiment within $\sim 40\%$. Relation (1.2) is a well known experimental result.

For Ω^- decays, we assume $\underline{20}''$-dominance at the SU (4) level. We find that the pv decays of the type $\Omega^- \to \Xi^* + \pi$ are forbidden, while $\Omega^- \to \Xi + \pi$ and $\Omega^- \to \Lambda + K^-$ are allowed. In fact all pv decays of the type $3/2^+ \to 3/2^+ + 0^-$ are found to be forbidden. SU (4) symmetry together with $\underline{20}''$-dominance forbids the pv-decays $3/2^+ \to 3/2^+ + 0^-$. SU (4) symmetry used along with current algebra forbids $\Omega^- \to \Xi^+ + \pi$ also (Khanna 1976). On the other hand in SU (6), the assumption of $\underline{35}$-dominance leads to the vanishing of $\Omega^- \to \Lambda + K^-$. The uncharmed baryons ($\frac{1}{2}^+$) decays and the Ω^- decays are discussed in section (3.1).

In section (3.2) we discuss the pv-non-leptonic decays of the charmed baryons. These are three channels of charm changing ($\triangle C = -1$) non-leptonic decays of charmed particles (Altarelli *et al* 1975 *a*) corresponding to the different modes of change in strangeness, *viz.*, $\triangle S = 0, +1, -1$. The predominant decay mode is the $\triangle C = \triangle S = -1$ decay mode, the amplitude of this mode being larger than that of the $\triangle C = 0$ decay mode by a factor of $\cot\theta$ (θ is the Cabibbo angle). Hence it is expected that the charmed particles will decay faster than the uncharmed ones. SU (8) symmetry forbids many of the charm-changing decays. We derive relations among these decay amplitudes at both the SU (4) and SU (8) level. These are recorded in section (3.2).

2. *Tensors corresponding to representations of symmetry groups*;

$B_{ABC} \equiv$ 120 representation of SU (8)
$\bar{B}^{ABC} \equiv 120^*$ do.
$M^A_B \equiv 63$ do.
$T^{[A,B]}_{[C,D]} \equiv 720$ do.
$T^{(A,B)}_{(C,D)} \equiv 1232$ do.

} *A*, *B*, *C*, *D* as indices run from 1 to 8.

$D_{\alpha\beta\gamma} \equiv$ 20 representation of SU (4)
$N^{[\alpha,\beta]}_{\gamma} \equiv 20'$ do.
$P^{\alpha}_{\beta} \equiv 15$ do.
$V^{\alpha}_{\beta} \equiv 15 \oplus 1$ do.
$T^{[\alpha,\beta]}_{[\gamma,\delta]} \equiv 20''$ do.
$T^{(\alpha,\beta)}_{(\gamma,\delta)} \equiv 84$ do.

} α, β, γ, δ run from 1 to 4.

3. Symbols for the decay modes of hyperons.

$\Lambda^0_- =\rangle\ \Lambda^0 \to P + \pi^-$

$\Lambda^0_0 =\rangle\ \Lambda^0 \to N + \pi^0$

$\Xi^-_- =\rangle\ \Xi^- \to \Lambda + \pi^-$

$\Xi^0_0 =\rangle\ \Xi^0 \to \Lambda + \pi^0$

$\Sigma^+_0 =\rangle \Sigma^+ \to P + \pi^0$

$\Sigma^+_+ =\rangle \Sigma^+ \to N + \pi^+$

$\Sigma^-_- =\rangle \Sigma^- \to N + \pi^-$

1. Introduction

Recently, there have been indications that strong interactions may be invariant under the group SU(4) that accommodates charmed particles in addition to the usual uncharmed ones. Non-leptonic decays of both charmed and uncharmed baryons have been discussed in literature using the SU (4) symmetry framework (Iwasaki 1975; Altarelli *et al* 1975 (*a* and *b*); Kingsley *et al* 1975). In these papers, in addition to SU (4) symmetry, $\underline{20}''$-dominance of the weak interaction Hamiltonian is assumed. This assumption is the SU (4) equivalent of the well-known octet-dominance phenomenon at the SU (3) level. Application of the spin-unitary symmetry independence hypothesis (Gürsey and Radicatti 1964) now, should lead to the enlargement of the symmetry group SU (4) to SU (8). Similar

2. The Hamiltonian

In describing weak non-leptonic decays we make the following assumptions: (*a*) the symmetry group of the strong interactions is SU (8), (*b*) weak interaction Hamiltonian H_w conserves *CP*, (*c*) H_w has the current x current form and is symmetric, *i.e.*, H_w can be written as:

$$H_w = G/(2\sqrt{2})(JJ^+ + J^+J) \tag{2.1}$$

where J and J^+ are the GIM type weak hadronic currents, which transform as the adjoint representation of the symmetry group of the hadrons.

In SU (4), the currents can be written as:

$$J = \bar{p}n\cos\theta + \bar{p}\lambda\sin\theta - \bar{p}'n\sin\theta + \bar{p}'\lambda\cos\theta \tag{2.2 a}$$

$$J^+ = \bar{n}p\cos\theta + \bar{\lambda}p\sin\theta - \bar{n}p'\sin\theta + \bar{\lambda}p'\cos\theta \tag{2.2 b}$$

(The Dirac matrices in the definitions of J and J^+ have been omitted). And the effective hamiltonian for various non-leptonic decay modes may be written as:

$$H_w^{\Delta C=0,\,\Delta S=-1} = \sin\theta\cos\theta\,(\bar{p}\lambda\bar{n}p - \bar{p}'\lambda\bar{n}p' + \text{h.c.}) \tag{2.3 a}$$

$$H_w^{\Delta C=\Delta S=-1} = \cos^2\theta\,(\bar{p}n\bar{\lambda}p' + \text{h.c.}) \tag{2.3 b}$$

$$H_w^{\Delta C=-\Delta S=-1} = -\sin^2\theta\,(\bar{p}\lambda\bar{n}p' + \text{h.c.}) \tag{2.3 c}$$

$$H_w^{\Delta C=-1,\,\Delta S=0} = \sin\theta\cos\theta\,(\bar{p}\lambda\bar{\lambda}p' - \bar{p}n\bar{n}p' + \text{h.c.}). \tag{2.3 d}$$

If the symmetry group of strong interactions is SU (8), the GIM hadronic currents should transform like $\underline{63}$ representation of SU (8) (assumption c). Then, the weak Hamiltonian transforms as:

$$\underline{63}\otimes\underline{63} = \underline{1}\oplus\underline{63}_s + \underline{63}_A\oplus\underline{720}\oplus\underline{945}\oplus\underline{945}^*\oplus\underline{1232}. \tag{2.4}$$

Because of the symmetric nature of H_w, only symmetric representations in the direct product (2.4) contribute; *i.e.*,

$$H_w \sim \underline{1}\oplus\underline{63}_s\oplus\underline{720}\oplus\underline{1232}. \tag{2.5}$$

It is a highly specific property of the weak interactions in the GIM model that the bilinear in currents do not contain any adjoint representation, so $\underline{63}_s$ must be absent. The singlet cannot contribute to strangeness changing and/or charm changing decays. So the H_w transforms as:

$$H_w \sim \underline{720}\oplus\underline{1232}. \tag{2.6}$$

Equivalently, in case of SU (4), H_w transforms as:

$$H_w \sim \underline{20}''\oplus\underline{84}. \tag{2.7}$$

The obvious generalization of $\underline{20}''$-dominance at SU (4) level to SU (8), is $\underline{720}$-dominance. That implies neglecting $\underline{1232}$ part of the weak interaction Hamiltonian. However, if $\underline{1232}$ part of H_w is neglected, CP-invariance makes all pv-non-leptonic decays of charmed and uncharmed baryons zero. Therefore we adopt the viewpoint that in SU (8) framework both $\underline{720}$ and $\underline{1232}$ representations contribute to the weak interaction Hamiltonian and at the SU (4) level $\underline{20}''$ dominance may be assumed if needed.

In classifying the particles in SU (8) multiplets, we put $1/2^+$ and $3/2^+$ baryons in the $(\underline{20}', \underline{2})$ and $(\underline{20}, \underline{4})$ components of the totally symmetric representation $\underline{120}$ of SU (8) (Kobayashi *et al* 1972), generated in the direct product:

$$\underline{8} \otimes \underline{8} \otimes \underline{8} = \underline{56} \oplus \underline{120} \oplus \underline{168} \oplus \underline{168}. \tag{2.8}$$

Pseudoscalar mesons are placed in $(\underline{15}, \underline{1})$ component of the adjoint representation $\underline{63}$ of SU $(\underline{8})$, generated in the direct product:

$$\underline{8} \otimes \underline{8}^* = \underline{63} \oplus \underline{1}. \tag{2.9}$$

Particle contents of the different SU (4) multiplets are the following:

$$\underline{20}: \quad \underline{10}_0 \, (\Delta^{\substack{++\\+\\0\\-}} \; \Sigma^{*\substack{+\\0\\-}} \; \Xi^{*\substack{0\\-}} \; \Omega^-)$$

$$\underline{6}_1 \, (\Sigma_1^{*\substack{++\\+\\0}} \; \Xi_1^{*\substack{+\\0}} \; \Omega_1^{*0})$$

$$\underline{3}_2 \, (\Xi_2^{*\substack{++\\+}} \; \Omega_2^{*+})$$

$$\underline{1}_3 \, (\Omega_3^{*++})$$

$$\underline{20}: \quad \underline{8}_0 \, (N^{\substack{+\\0}} \; \Sigma^{\substack{+\\0\\-}} \; \Lambda^0 \; \Xi^{\substack{0\\-}})$$

$$\underline{6}_1 \, (\Sigma_1^{\substack{++\\+\\0}} \; \Xi_1^{\substack{+\\0}} \; \Omega_1^0)$$

$$\underline{3}_1^* \, (\Lambda_1'^{+} \; \Xi_1^{\substack{+\\0}})$$

$$\underline{3}_2 \, (\Xi_2^{\substack{++\\+}} \; \Omega_2^+)$$

$$\underline{15}: \quad \underline{8}_0 \, (K^{\substack{+\\0}} \; \pi^{\substack{+\\0\\-}} \; \eta^0 \; \overline{K^{\substack{+\\0}}})$$

$$\underline{3}_{-1} \, (\overline{D^{\substack{+\\0}}} \; F^-)$$

$$\underline{3}_1^* \, (D^{\substack{+\\0}} \; F^+)$$

$$\underline{1}_0 \, (\eta'^0)$$

where the subscripts denote the charm of the SU (3) multiplets,

3. Parity violating non-leptonic decays

Consider the direct product $\bar{B} \otimes B \otimes M$, *i.e.*,

$$\underline{120}^* \otimes \underline{120} \otimes \underline{63} = \underline{1} \oplus 4(\underline{63}) \oplus \underline{720} \oplus 2(\underline{945})$$
$$\oplus\, 2(\underline{945^*}) \oplus 4(\underline{1232}) \oplus 3(\underline{13104}) \oplus 2(\underline{17920})$$
$$\oplus\, 2(\underline{17920^*}) \oplus \underline{24255} \oplus \underline{94500}$$
$$\oplus\, \underline{174636} \oplus \underline{174636^*} \oplus \underline{318500}. \qquad (3.1)$$

In general we must take $(\underline{20}'', \underline{1})$ component of every representation appearing in this direct product. But as discussed in section 2, in the GIM model, weak Hamiltonian transforms like $\underline{720}$ and $\underline{1232}$ representations only.

The various pieces of the nonleptonic weak Hamiltonian transforming as $\underline{720}$ and $\underline{1232}$ can be written as:

$$H_0^{(720)} = \bar{B}^{ABC'} B_{ABC}\, M_D^{D'}\, T^{[C,D]}_{[C',D']}$$
$$H_1^{(1232)} = \bar{B}^{ABC'} B_{ABC}\, M_D^{D'}\, T^{(C,D)}_{(C',D')}$$
$$H_2^{(1232)} = \bar{B}^{AC'D'} B_{ABC}\, M_D^{B}\, T^{(C,D)}_{(C',D')}$$
$$H_3^{(1232)} = \bar{B}^{ABC'} B_{ACD}\, M_B^{D'}\, T^{(C,D)}_{(C',D')}$$
$$H_4^{(1232)} = \bar{B}^{A'C'D'} B_{ACD}\, M_{A'}^{A}\, T^{(C,D)}_{(C',D')} \qquad (3\cdot 2)$$

where A, B, C are SU (8) indices running from 1 to 8.

B_{ABC} and M_B^A are tensors corresponding to the $\underline{120}$ and $\underline{63}$ representations of SU (8) respectively.

The SU (4) $\times$ SU (2) substructure of B_{ABC} and M_B^A is given by [The Greek letters α, β, γ, etc. indicate SU (4) indicate; and the Roman letters i, j, k, etc. indicate SU (2) indices]

$$B_{ABC} = \chi_{ijk}\, D_{\alpha\beta\gamma} + \frac{1}{6\sqrt{2}} [\epsilon_{ij}\, \chi_k\, \epsilon_{\alpha\beta\rho\delta}\, N_\gamma^{[\rho\delta]} + \epsilon_{jk}\chi_i\, \epsilon_{\beta\gamma\rho\delta}\, N_\alpha^{[\rho\delta]}$$
$$+\, \epsilon_{ki}\chi_j\, \epsilon_{\gamma\alpha\rho\delta}\, N_\beta^{[\rho\delta]}] \qquad (3.3\,a)$$

and

$$M_B^A = \delta_j^i\, P_\beta^\alpha + i\, \vec{\sigma}_j^i \cdot \hat{q}\, V_\beta^\alpha \qquad (3.3\,b)$$

where the following definitions have been used:

(1) $\chi_{111} = \psi_{3/2}$, $\chi_{112} = (1/\sqrt{3})\, \psi_{1/2}$, $\chi_{122} = (1/\sqrt{3})\, \psi_{-1/2}$, $\chi_{222} = \psi_{-3/2}$

where ψ_α are the normed wave-functions for $S = 3/2$, $S_z = \alpha$.

(2) χ_i's are normed spin-1/2 wave functions.

(3) $D_{\alpha\beta\gamma}$, $N_\gamma^{[\alpha,\beta]}$, P_β^α and V_β^α are tensors (Kobayashi *et al* 1972) representing $\underline{20}$, $\underline{20}'$, $\underline{15}$, $\underline{15} \oplus \underline{1}$, representations of SU (4) group respectively.

(4) ϵ_{ij} and $\epsilon_{\alpha\beta\rho\delta}$ are the Levi-Civita symbols for SU (2) and SU (4) respectively.

3.1. *Decays of the hyperons*

From CP invariance, only $CP = -1$ combination $(H_2^{(1232)} - H_3^{(1232)})$ can contribute to the parity violating decays. No contributions arise from $H_0^{(720)}$, $H_1^{(1232)}$ $H_4^{(1232)}$, the $CP = +1$ pieces. On taking $(H^{[2,1]}_{[3,1]} - H^{[2,4]}_{[3,4]})$ projection of the Hamiltonian, a straightforward calculation yields the following relations among decay amplitudes.

$$\sqrt{3/2}\ \Xi^-_- = \sqrt{3}\ \Xi^0_0 = \sqrt{6}\ \Lambda^0_- = -\sqrt{12}\ \Lambda^0_0 = -\sqrt{2}\ \Sigma^+_0 = \Sigma^-_- \tag{3.4 a}$$

and

$$\Sigma^+_+ = 0. \tag{3.4 b}$$

Clearly these decays satisfy $\triangle I = \frac{1}{2}$ rule and the relation (1.1) and (1.2).

So far we have not assumed $\underline{20}''$-dominance. On making that assumption, we also get

$$A\,(\Omega^- \rightarrow \Xi^* + \pi) = 0. \tag{3.5}$$

In fact we see that all *pr* decays of the type $3/2^+ \rightarrow 3/2^+ + 0^-$ are forbidden. The SU (4) symmetry together with $\underline{20}''$-dominance also gives this result. It is not necessary to use SU (8) to get it.

3.2. *Decays of charmed baryons*

We take the weak Hamiltonian transforming like $(\underline{20}'', \underline{1})$ and $(\underline{84}, \underline{1})$ components of both $\underline{720}$ and $\underline{1232}$ representations. For $\triangle C \neq 0$ decays, it transforms like $6 \oplus 6^*$ under SU (3) symmetry group (Altarelli *et al* 1975 *a* and *b*). In the considerations of mass spectrum of the charmed baryons it is found (Kobayashi *et al* 1972; Gupta 1976) that decays like $\Sigma_1 \rightarrow \Lambda_1'^+ \pi$, $\Xi_1' K$; $\Xi_1 \rightarrow \Xi_1' \pi$, $\Lambda_1'^+ \bar{K}$; $\Omega_1 \rightarrow \Xi_1' K$ will be strong decays. While strong decays of other charmed baryons [B (3) and B (3*)] will depend upon the masses of charmed mesons. There are large number of probable weak decay modes of these charmed baryons [B (3) and B (3*)]. These are given in tables 1 and 2 respectively. We have calculated the decay amplitudes for *pv* decays, first, using SU (4) symmetry. Later, additional relation are obtained in SU (8) symmetry framework.

Using SU (4) symmetry and $\underline{20}''$-dominance we get the following relations:

$$\begin{aligned} 0 &= c_1 = c_2 = c_7 = c_{10} = c_{11} = c_{20} = c_{23} = c_{29} \\ &= b_5 = b_{12} = b_{13} = b_{15} = b_{16} = b_{17} = b_{18} = b_{19} = b_{33} = b_{35} = b_{39} \\ &= a_5 = a_6 = a_8 = a_9 = a_{10} = a_{11} = a_{14} = a_{19} = a_{21} = a_{22} \end{aligned} \tag{3.6}$$

Table 1

Decaying particle	$\Delta C = -\Delta S = -1$	$\Delta C = -1, \Delta S = 0$	$\Delta C = \Delta S = -1$
a) $B(3) \to B(6) + P(9)$			
Ω_2^+	$a_1 = \Xi_1^0 + K^+$	$b_1 = \Omega_1^0 + K^+$	$c_1 = \Omega_1^0 + \pi^+$
	$a_2 = \Xi_1^+ + K^0$	$b_2 = \Xi_1^0 + \pi^+$	$c_2 = \Xi_1^+ + \bar{K}^0$
	$a_3 = \Sigma_1^0 + \pi^+$	$b_3 = \Xi_1^+ + \pi^0$	
	$a_4 = \Sigma_1^+ + \pi^0$	$b_4 = \Xi_1^+ + \eta$	
	$a_5 = \Sigma_1^+ + \eta$	$b_5 = \Xi_1^+ + \eta'$	
	$a_6 = \Sigma_1^+ + \eta'$	$b_6 = \Sigma_1^+ + \bar{K}^0$	
	$a_7 = \Sigma_1^+ + \pi^-$	$b_7 = \Sigma_1^{++} + K^-$	
Ξ_2^+	$a_8 = \Sigma_1^0 + K^+$	$b_8 = \Xi_1^0 + K^+$	$c_3 = \Omega_1^0 + K^+$
	$a_9 = \Sigma_1^+ + K^0$	$b_9 = \Xi_1^+ + K^0$	$c_4 = \Xi_1^0 + \pi^+$
		$b_{10} = \Sigma_1^0 + \pi^+$	$c_5 = \Xi_1^+ + \pi^0$
		$b_{11} = \Sigma_1^+ + \pi^0$	$c_6 = \Xi_1^+ + \eta$
		$b_{12} = \Sigma_1^+ + \eta$	$c_7 = \Xi_1^+ + \eta'$
		$b_{13} = \Sigma_1^+ + \eta'$	$c_8 = \Sigma_1^+ + \bar{K}^0$
		$b_{14} = \Sigma_1^{++} + \pi$	$c_9 = \Sigma_1^{++} + K^-$
Ξ_2^{++}	$a_{10} = \Sigma_1^+ + K^+$	$b_{15} = \Xi_1^+ + K^+$	$c_{10} = \Xi_1^+ + \pi^+$
	$a_{11} = \Sigma_1^{++} + K^0$	$b_{16} = \Sigma_1^+ + \pi^+$	$c_{11} = \Sigma_1^{++} + \bar{K}^0$
		$b_{17} = \Sigma_1^{++} + \pi^0$	
		$b_{18} = \Sigma_1^{++} + \eta$	
		$b_{19} = \Sigma_1^{++} + \eta'$	
b) $B(3) \to B(3^*) + P(9)$			
Ω_2^+	$a_{12} = \Xi_1'^0 + K^+$	$b_{20} = \Xi_1'^0 + \pi^+$	$c_{12} = \Xi_1'^+ + \bar{K}^0$
	$a_{13} = \Xi_1'^+ + K^0$	$b_{21} = \Xi_1'^+ + \pi^0$	
	$a_{14} = \Lambda_1'^+ + \pi^0$	$b_{22} = \Xi_1'^+ + \eta$	
	$a_{15} = \Lambda_1'^+ + \eta$	$b_{23} = \Xi_1'^+ + \eta'$	
	$a_{16} = \Lambda_1'^+ + \eta'$	$b_{24} = \Lambda_1'^+ + \bar{K}^0$	
Ξ_2^+	$a_{17} = \Lambda_1'^+ + K^0$	$b_{25} = \Xi_1'^0 + K^+$	$c_{13} = \Xi_1'^0 + \pi^+$
		$b_{26} = \Xi_1'^+ + K^0$	$c_{14} = \Xi_1'^+ + \pi^0$
		$b_{27} = \Lambda_1'^+ + \pi^0$	$c_{15} = \Xi_1'^+ + \eta$
		$b_{28} = \Lambda_1'^+ + \eta$	$c_{16} = \Xi_1'^+ + \eta'$
		$b_{29} = \Lambda_1'^+ + \eta'$	$c_{17} = \Lambda_1'^+ + \bar{K}^0$
Ξ_2^{++}	$a_{18} = \Lambda_1'^+ + K^+$	$b_{30} = \Xi_1'^+ + K^+$	$c_{18} = \Xi_1'^+ + \pi^+$
		$b_{31} = \Lambda_1'^+ + \pi^+$	
c) $B(3) \to B(8) + P(3^*)$			
Ω_2^+	$a_{19} = \Sigma^0 + F^+$	$b_{32} = \Xi^0 + F^+$	$c_{19} = \Xi^0 + D^+$
	$a_{20} = \Lambda + F^+$	$b_{33} = \Sigma^0 + D^+$	
	$a_{21} = N + D^+$	$b_{34} = \Lambda + D^+$	
	$a_{22} = P + D^0$	$b_{35} = \Sigma^+ + D^0$	
Ξ_2^+	$a_{23} = N + F^+$	$b_{36} = \Sigma^0 + F^+$	$c_{20} = \Xi^0 + F^+$
		$b_{37} = \Lambda + F^+$	$c_{21} = \Sigma^0 + D^+$
		$b_{38} = N + D^+$	$c_{22} = \Lambda + D^+$
		$b_{39} = P + D^0$	$c_{23} = \Sigma^+ + D^0$
Ξ_2^{++}	$a_{24} = P + F^+$	$b_{40} = \Sigma^+ + F^+$	$c_{24} = \Sigma^+ + D^+$
		$b_{41} = P + D^+$	

Table 2

$B(3^*) \rightarrow B(8) + P(9)$

Decaying particle	$\Delta C = -\Delta S = -1$	$\Delta C = -1, \Delta S = 0$	$\Delta C = \Delta S = -1$
$\Lambda_1'^+$	$a_{25} = N + K^+$	$b_{42} = N + \pi^+$	$c_{25} = P + \bar{K}^0$
	$a_{26} = P + K^0$	$b_{43} = P + \pi^0$	$c_{26} = \Sigma^+ + \pi^0$
		$b_{44} = P + \eta$	$c_{27} = \Sigma^+ + \eta$
		$b_{45} = P + \eta'$	$c_{28} = \Sigma^+ + \eta'$
		$b_{46} = \Sigma^+ + K^0$	$c_{29} = \Lambda + \pi^+$
		$b_{47} = \Lambda + K^+$	$c_{30} = \Sigma^0 + \pi^+$
		$b_{48} = \Sigma^0 + K^+$	$c_{31} = \Xi^0 + K^+$
$\Xi_1'^+$	$a_{27} = N + \pi^+$	$b_{49} = P + \bar{K}^0$	$c_{32} = \Sigma^+ + \bar{K}^0$
	$a_{28} = P + \pi^0$	$b_{50} = \Sigma^+ + \pi^0$	$c_{33} = \Xi^0 + \pi^+$
	$a_{29} = P + \eta$	$b_{51} = \Sigma^+ + \eta$	
	$a_{30} = P + \eta'$	$b_{52} = \Sigma^+ + \eta'$	
	$a_{31} = \Sigma^+ + K^0$	$b_{53} = \Lambda + \pi^+$	
	$a_{32} = \Lambda + K^+$	$b_{54} = \Sigma^0 + \pi^+$	
	$a_{33} = \Sigma^0 + K^+$	$b_{55} = \Xi^0 + K^+$	
$\Xi_1'^0$	$a_{34} = P + \pi^-$	$b_{56} = P + K^-$	$c_{34} = \Sigma^+ + K^-$
	$a_{35} = N + \pi^0$	$b_{57} = N + \bar{K}^0$	$c_{35} = \Lambda + \bar{K}^0$
	$a_{36} = N + \eta$	$b_{58} = \Sigma^+ + \pi^-$	$c_{36} = \Sigma^0 + \bar{K}^0$
	$a_{37} = N + \eta'$	$b_{59} = \Lambda + \pi^0$	$c_{37} = \Xi^0 + \pi^0$
	$a_{38} = \Lambda + K^0$	$b_{60} = \Lambda + \eta$	$c_{38} = \Xi^0 + \eta$
	$a_{39} = \Sigma^0 + K^0$	$b_{61} = \Lambda + \eta'$	$c_{39} = \Xi^0 + \eta'$
	$a_{40} = \Sigma^- + K^+$	$b_{62} = \Sigma^0 + \pi^0$	$c_{40} = \Xi^- + \pi^+$
		$b_{63} = \Sigma^0 + \eta$	
		$b_{64} = \Sigma^0 + \eta'$	
		$b_{65} = \Sigma^- + \pi^+$	
		$b_{66} = \Xi^0 + K^0$	
		$b_{67} = \Xi^- + K^+$	

$$-\Sigma_+^+ \cot\theta = c_3 = \sqrt{2}\, c_4 = 2c_5 = 2/\sqrt{3}\, c_6 = -\sqrt{2}\, c_8 = c_9 = c_{19} = -\sqrt{2}\, c_{21} = \sqrt{6}\, c_{22} = c_{24} = -\sqrt{6}\, c_{31} = -\sqrt{6}\, c_{34} \quad (3.7)$$

$$\Sigma_+^+ = b_1 = b_2 = 2b_3 = 2\sqrt{3}b_4 = -\sqrt{2}b_6 = b_7 = -\sqrt{2}b_8 = \sqrt{2}b_9 = -b_{10} = -b_{11} = -b_{14} = b_{32} = -\sqrt{3/2}\, b_{34} = -\sqrt{2}b_{36} = \sqrt{6}b_{37} = b_{38} = b_{40} = b_{41} = 2b_{47} = -\sqrt{6}b_{56} = \sqrt{6}b_{58} \quad (3.8)$$

$$\Sigma_+^+ \tan\theta = -\sqrt{2}a_1 = \sqrt{2}a_2 = -a_3 = -a_4 = -a_7 = -\sqrt{3/2}\, a_{20} = a_{23} = a_{24} = \sqrt{6}\, a_{27} = \sqrt{12}\, a_{28} = \sqrt{6}a_{34} = -\sqrt{12}a_{35} \quad (3.9)$$

$$\Lambda_-^0 \cot\theta = -1/2\, c_{12} = -1/2\, c_{18} = -c_{25} = 1/\sqrt{2}\, c_{26} = -1/\sqrt{2}c_{30} = \sqrt{2/3}\, c_{35} = -\sqrt{2}\, c_{36} = -c_{40} \quad (3.10)$$

$$\Lambda_-^0 = 1/\sqrt{2}\, b_{27} = -1/2\, b_{30} = 1/2\, b_{31} = b_{42} = \sqrt{2}\, b_{43} = -b_{55} = 1/2\, b_{57} = b_{65} = -1/2\, b_{66} = b_{67} \quad (3.11)$$

$$\Lambda_-^0 \tan\theta = -1/2\, a_{17} = -1/2\, a_{18} = a_{31} = \sqrt{2/3}\, a_{32} = \sqrt{2}a_{33} = \sqrt{2/3}\, a_{38} = -\sqrt{2}\, a_{39} = a_{40} \quad (3.12)$$

$$(2\,\Lambda_-^0 + \Sigma_+^+/\sqrt{6})\cot\theta = c_{13} = -c_{17} = -\sqrt{6}\,c_{38}$$

$$(2\sqrt{2}\,\Lambda_-^0 + \Sigma_+^+/2\sqrt{3})\cot\theta = c_{14} = -\sqrt{3}\,c_{15}$$

$$(2\Lambda_-^0/\sqrt{6} - \Sigma_+^+/3)\cot\theta = -c_{27} = \sqrt{2/3}\;c_{32} = -\sqrt{2/3}\;c_{33}$$

$$(2\Lambda_-^0/\sqrt{3} + 4\Sigma_+^+/3\sqrt{2})\cot\theta = c_{28} = c_{39}$$

$$(\sqrt{2}\,\Lambda_-^0 - \Sigma_+^+/2\sqrt{3})\cot\theta = c_{37}$$

$$(4\Lambda_-^0/\sqrt{3} + 4\Sigma_+^+/3\sqrt{2}\cot\theta = c_{16} \tag{3.13}$$

$$(2\Lambda_-^0 + \Sigma_+^+/\sqrt{6}) = \sqrt{6}\,b_{22} = -b_{46} = -\sqrt{2}\,b_{48} = b_{49}$$

$$2\Lambda_-^0/\sqrt{6} - \Sigma_+^+/3 = (1/2)\sqrt{2}\,b_{23} = b_{28} = (1/2)\sqrt{2}\,b_{29} = -2/\sqrt{3}\,b_{50}$$
$$= 2/\sqrt{3}\,b_{54}$$

$$(\Lambda_-^0 + \Sigma_+^+/\sqrt{6}) = -\sqrt{6}\,b_{51} = \sqrt{2/3}\,b_{53} = -2/\sqrt{3}\,b_{59} = -2\,b_{60}$$
$$= 2b_{62} = 2/\sqrt{3}\,b_{63}$$

$$(2\Lambda_-^0/\sqrt{6} - 2\,\Sigma_+^+/3) = 2b_{44} = 1/\sqrt{2}\,b_{45} = -1/\sqrt{2}\,b_{52} = -1/\sqrt{3}\,b_{61} = b_6$$

$$(2\Lambda_-^0 - \Sigma_+^+/\sqrt{6}) = b_{20} = \sqrt{2}\,b_{21} = b_{25}$$

$$(4\Lambda_-^0 - \Sigma_+^+/\sqrt{6}) = -b_{24} = -b_{26} \tag{3.14}$$

$$(\Lambda_-^0 + \Sigma_+^+/\sqrt{6})\tan\theta = a_{25} = a_{26}$$

$$(2\Lambda_-^0 - \Sigma_+^+/\sqrt{6})\tan\theta = a_{12} = -a_{13}$$

$$(2\Lambda_-^0/\sqrt{3} - 4\,\Sigma_+^+/3\sqrt{2})\tan\theta = -a_{30} = -a_{37}$$

$$(4\Lambda_-^0/\sqrt{3} - 4\,\Sigma_+^+/3\sqrt{2})\tan\theta = a_{16}$$

$$(4\Lambda_-^0/\sqrt{6} + \Sigma_+^+/6)\tan\theta = -a_{24} = -a_{36}$$

$$(8\Lambda_-^0/\sqrt{6} - \Sigma_+^+/3)\tan\theta = a_{15}. \tag{3.15}$$

SU (8) symmetry considerations (without 20″-dominance) give following relations in addition to above results:

(1) The decay amplitudes in (3.7), (3.8) and (3.9) vanish.

(2) $\Lambda_-^0\cot\theta = (1/2)\sqrt{2}\,c_{14} = \sqrt{3}/4\,c_{16} = -1/2\,c_{17} = -\sqrt{3/2}\,c_{27}$
$= \sqrt{3/2}\,c_{28} = 1/\sqrt{2}\,c_{37}$

(3) $\Lambda_-^0 = \sqrt{3/2}\,b_{22} = 1/2\,b_{25} = -1/4\,b_{26} = \sqrt{3/2}\,b_{28} = \sqrt{6}\,b_{44} = -\sqrt{6}\,b_{51}$

(4) $\Lambda_-^0\tan\theta = -1/2\,a_{13} = \sqrt{3/32}\,a_{26} = \sqrt{3}/4\,a_{16} = a_{25} = -\sqrt{3/8}\,a_{24}$
$= -\sqrt{3}/2a_{30}.$ (3.16)

It is interesting to note that SU (8) symmetry forbids all charm changing non-leptonic decays of the following types:

$$B(3) \to B(6) + P(9)$$

$$\to B(8) + P(3^*).$$

That so many decay amplitudes vanish is a specific result of SU (8) symmetry. It may be pointed out that all charm changing decays are now expressed in terms of only two parameters: the Γ^0_- decay amplitude and the Cabibbo angle θ.

4. Conclusion

Considering SU (8) to be the symmetry group of strong interactions, we are able to reproduce all the relations among *pv* non-leptonic decay amplitudes that have been derived earlier by using SU (4) symmetry together with the assumption of $\underline{20}''$-dominance. We do not have to make this latter assumption for the non-leptonic decays of baryons ($1/2^+$). In addition we get the experimentally well satisfied result $\Sigma^+_+ = 0$; and new relations among the charm changing non-leptonic decay amplitudes. Even though in our calculations we have throughout assumed the GIM scheme, we wish to point out that the result $\Sigma^+_+ = 0$ and the vanishing of decay amplitudes in relations (3.7), (3.8) and (3.9) are the explicit consequences of SU (8) symmetry alone. We also note that SU (8) symmetry considerations, naturally account for the contributions coming from $\underline{84}$ representation of the sub-group SU (4), as far as *pv* decays of $1/2^+$ baryons (charmed and uncharmed) are concerned. But if $\underline{20}''$-dominance is also assumed, SU (8) symmetry further forbids the decays of the type $\Omega^- \to \Xi^* + \pi$. In fact we regain the result obtained from SU (4) symmetry and assumption of $\underline{20}''$-dominance, *viz.*, all decays of the type $3/2^+ \to 3/2^+ + 0^-$ are forbidden.

Because SU (8) symmetry is valid only in the static limit, we have not considered the parity conserving decays of baryons. For describing these decays $SU(8)_w$ symmetry has to be used. The discussions of the parity conserving decays will be taken up elsewhere.

Acknowledgements

We are thankful to J K Bajaj for interesting discussions and for reading the manuscript. RCV gratefully acknowledges the financial support given by CSIR, New Delhi.

References

Altarelli G, Cabibbo N and Maiani L 1975 *a* *Nucl. Phys.* **B88** 285
Altarelli G, Cabibbo N and Maiani L 1975 *b* *Phys. Lett.* **57 B** 277
Babu P 1965 *Phys. Rev. Lett.* **14** 166
Glashow S L, Illoupoulos I and Maiani L 1970 *Phys. Rev.* **D 2** 1285

Gupta V 1976 *Pramāṇa* **7** 277; (preprint) Nonleptonic weak decays of charmed baryons and Present understanding of the new hadrons. III HEP symposium, Bhubaneswar (1976)
Gürsey F and Radicatti L A 1964 *Phys. Rev. Lett.* **13** 173
Iwasaki Y 1975 *Phys. Rev. Lett.* **34** 1407
Kawarabayashi K 1965 *Phys. Rev. Lett.* **14** 86
Khanna M P 1976 *Phys. Rev.* **D** (to be published).
Kingsley R L, Treiman S B, Wilczek F and Zee A 1975 *Phys. Rev.* **D 11** 1919
Kobayashi M, Nakagawa M and Nitto H 1972 *Prog. Theor. Phys.* **47** 982
Rosen S P and Pakvasa S 1964 *Phys. Rev. Lett.* **13** 773