Pramāṇa, Vol. 9, No. 6, December 1977, pp. 643-652, © Printed in India.

Adjoint representation admixture to weak nonleptonic decays in SU(4) and SU(8)

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MS received 25 June 1977; revised 2 September 1977

Abstract. In order to remove some of the unsatisfactory features of the GIM model, we consider $\underline{15}$-admixture in SU(4). $\Delta C = \pm \Delta S$ decays remain unaffected. Lee-Sugawara sum-rule is obtained. $\underline{15}$-admixture is extended then to $\underline{63}$-admixture in SU(8). The most general Hamiltonian ($H_w \sim \underline{63} \oplus \underline{720} \oplus \underline{1232}$) in SU(8) is found to give Lee-Sugawara relation and $\Sigma_+^+ = 0$ for S-wave decays of uncharmed baryons. Decay amplitude relations for $\Delta C = -1$, $\Delta S = 0$ mode are obtained.

Keywords. Nonleptonic weak decays; SU(4) and SU(8) symmetries; $\underline{15}$ and $\underline{63}$-admixtures to weak interaction.

1. Introduction

Weak nonleptonic decays have been discussed by many authors in SU(4) charm scheme (Altarelli *et al* 1975; Einhorn and Quigg 1975; Iwasaki 1975; Kohara 1976; Matsuda 1976). In previous papers (Verma and Khanna 1977 a, b) we have discussed nonleptonic weak decays of baryons in the framework of SU(8) symmetry, assuming standard GIM model (Glashow *et al* 1970) of weak interactions. But there are a number of experimental results which do not agree with GIM model: (1) SU(4) predicted (Iwasaki 1975) ratios $\Lambda^0_- : \Sigma^+_0\, \Xi_-^- = 1 : -\sqrt{3} : 2$ for s-wave amplitudes have large discrepancy of about 40% with the experimental values; (2) $P \rightarrow 2P$ type nonleptonic decays are forbidden by $\underline{20}''$ dominance in SU(4) (Iwasaki 1975) where P is a pseudo scalar meson; (3) All the s-wave decays of the type $3/2^+ \rightarrow 3/2^+ + 0^-$ are not allowed in the GIM model (Verma and Khanna 1977a) in the framework of SU(4) and SU(8), while recent observed mass values (Cazzoli *et al* 1975; Knapp *et al* 1976) of charmed particles suggest that some of the charmed isobars (e.g. Ω_3^{*++} ($C = 3$) may be expected to decay only through weak interaction; (4) Standard GIM model (with the assumption of sextet dominance) predicts low bounds (Branco *et al* 1976) for the decay $D \rightarrow PP$ to be 8%. But experimental values are observed to be high.

These facts seem to suggest a considerable admixture of the adjoint representation (Hayashi *et al* 1973) which is prevented in the GIM model. This $\underline{15}$-admixture may be expected to arise (Shin-Mura 1976) from the large symmetry breaking of SU(4) even in the case of GIM model, as cancellation of $\underline{15}$ may not be complete owing to the large mass difference between charmed and uncharmed quarks. Recently $\underline{15}$-admixture has also been proposed in many models (Branco *et al* 1976; Bajaj and Kapoor 1977) of weak interactions.

In SU(4) framework, then weak Hamiltonian transforms like:

$$H_w \sim \underline{15} \oplus \underline{20}''. \tag{1}$$

With this Hamiltonian we have 15-parameters to express the nonleptonic decays of baryons ($1/2^+$), *CP*-invariance reduces these to five for *S*-wave decays. We get Lee-Sugawara sum rule for hyperon-decays. Because the number of parameters is still large, we do not derive any relation among the various $\triangle C \neq 0$ decays. Instead we give contributions coming from $\underline{15}$-admixture in tables 1 and 2. Contributions from $\underline{20}''$ representation has already been given by Verma and Khanna (1977a).

In section 3 we study the whole problem in SU(8). $\underline{15}$-admixture there leads to $\underline{63}$-admixture. In SU(8) we have considered the most general symmetric Hamiltonian $H_w \sim \underline{63} \oplus \underline{720} \oplus \underline{1232}$. Without assuming dominance of any representation even at the SU(4) sub level, we are able to obtain the Lee-Sugawara sum rule and $\Sigma_+^+ = 0$ for the *pv* decays of uncharmed baryons. $\triangle C = \pm \triangle S$ decay modes remain unaffected by $\underline{63}$-admixture and hence are not considered. All other decay amplitudes are expressed in terms of only two parameters.

Four independent parameters are required to describe *p*-wave decays in $SU(8)_w$. It simply gives us freedom to adjust the parameters to get Lee-Sugawara sum rule and $\Sigma_-^- = 0$ without being forced to take $\Sigma_+^+ = 0$. Amplitudes for *p*-wave decays are given in table 3.

Nonleptonic decays of the type $3/2^+ \to 3/2^+ + 0^-$ are also discussed in SU(8). Various decays of Ω_3^{*++} are compared with decay modes of Ω^- in table 4.

2. Weak hamiltonian and decay amplitudes in SU(4)

In order to describe $B(1/2^+) \to B'(1/2^+) + P(0^-)$ decays, consider the direct product:

$$\underline{20}^{*\prime} \otimes \underline{20}' \otimes \underline{15} = 2(\underline{1}) \oplus 9(\underline{15}) \oplus 6(\underline{20}'') \oplus \underline{35} \oplus \underline{35}^* \oplus 7(\underline{45})$$

$$\oplus\, 7(\underline{45}^*) \oplus 7(\underline{84}) \oplus \underline{105} \oplus 7(\underline{175}) \oplus 3(\underline{256}) \oplus 3(\underline{256}^*)$$

$$\oplus\, \underline{280} \oplus \underline{280}^* \oplus \underline{300} \oplus \underline{729}$$

CP-invariant *pv*-weak Hamiltonian transforming like 15 can be written as:

$$H_w^{15} \sim b_1(\bar{B}^i_{[j,k]}\, B^{[j,m]}_i\, p^e_m\, H^k_e - \bar{B}^i_{[j,m]}\, B^{[j,e]}_i\, p^m_k\, H^k_e)$$

$$+\, b_2(\bar{B}^m_{[i,j]}\, B^{[i,j]}_k\, p^e_m\, H^k_e - \bar{B}^e_{[i,j]}\, B^{[i,j]}_m\, p^m_k\, H^k_e)$$

$$+\, b_3(\bar{B}^j_{[i,m]}\, B^{[i,e]}_k\, p^m_j\, H^k_e - \bar{B}^e_{[i,k]}\, B^{[i,j]}_m\, p^m_j\, H^k_e) \tag{2}$$

where $B^{[i,j]}_k$ and P^i_j are tensors representing $\underline{20}'$ and $\underline{15}$ multiplets respectively. H^k_e, tensor for suprion, belongs to the representation 15. In SU(4), GIM weak Hamiltonian is given by:

$$H_w^{20''} \sim \cos\theta \sin\theta \begin{pmatrix} 21 & -24 \\ 31 & -34 \end{pmatrix} + \cos\theta \sin\theta \begin{pmatrix} 13 & -12 \\ 43 & -42 \end{pmatrix}$$

$$(\triangle C{=}0,\ \triangle S{=}{-}1) \qquad (\triangle C{=}{-}1,\ \triangle S{=}0)$$

$$+ \cos^2\theta \begin{pmatrix} 31 \\ 24 \end{pmatrix} + \sin^2\theta \begin{pmatrix} 12 \\ 34 \end{pmatrix}$$

$$(\triangle C{=}\triangle S{=}{-}1)\ (\triangle C{=}{-}\triangle S{=}{-}1). \tag{3}$$

It is clear that ($\triangle C = \triangle S = -1$) is Cabibbo enhanced mode and the others are Cabibbo suppressed. 15-admixture enhances ($\triangle C = -1,\ \triangle S = 0) \sim T_4^1$ and ($\triangle C = 0,\ \triangle S = -1) \sim T_3^2$ modes only. Other two modes ($\triangle C = \pm \triangle S = -1$) remain unaffected.

Following amplitudes are obtained for the different decays modes from the 15-component in SU(4). We have given the decay amplitudes of the SU(3) multiplets $B(3)^*$ and $B(3)$ only. $B(6)$ baryons are expected to decay (Kobayashi *et al* 1972) into $B(3)^*$ and a pseudoscalar meson through strong and/or electromagnetic interactions.

2.1. ($\triangle C = 0,\ \triangle S = -1$) *mode*

We obtain Lee-Sugawara sum rule i.e. $\sqrt{3}\,\Sigma_0^+ - \Lambda_-^0 = -2\,\Xi_-^-$ $\triangle C = 0$ decays of the type $B(3) \rightarrow B(6) + P(3^*)$ and $B(3^*) \rightarrow B(8) + P(3^*)$ are forbidden energetically.

2.2. ($\triangle C = -1,\ \triangle S = 0$) *mode*

We see in SU(4), that weak Hamiltonian $H_w \sim \underline{15} \oplus \underline{20}''$ expresses the *s*-wave decay amplitudes in terms of five parameters. Thus SU(4) gives no useful relations to compare with experiment. In the next section we consider the whole problem in SU(8) symmetry.

3. SU(8) symmetry framework

In SU(8) symmetry, it has been shown (Verma and Khanna 1977a, b) that, in the GIM model of weak Hamiltonian ($H_w \sim \underline{720} \oplus \underline{1232}$), 20″-dominance cannot be

Table 1. ($\triangle C = 0,\ \triangle S = -1$) mode

$B(8) \rightarrow B(8) + P(8)$		$B(3)/B(3^*) \rightarrow B(3)/B(3^*) + P(8)$	
Λ_-^0	$(b_2 - 2b_3)/\sqrt{6}$	$\Omega_2^+ \rightarrow \Xi_2^+ + \pi^0$	$b_2/\sqrt{2}$
Λ_0^0	$-(b_2 - 2b_3)/2\sqrt{3}$	$\Xi_2^{++} + \pi^-$	$-b_2$
Ξ_-^-	$(2b_2 - b_3)/\sqrt{6}$	$\Xi'^0_1 \rightarrow \Lambda'^+_1 + \pi^-$	$(b_1 - 5b_2 + b_3)/6$
Ξ_0^0	$(2b_2 - b_3)/2\sqrt{3}$	$\Xi'^+_1 \rightarrow \Lambda'^+_1 + \pi^0$	$(b_1 - 5b_2 + b_3)/6\sqrt{2}$
Σ_0^+	$-b_2/\sqrt{2}$		
Σ_+^+	$-b_1$		
Σ_-^-	$-b_1 + b_2$		

Table 2a. ($\Delta C = -1$, $\Delta S = 0$) mode: $B(3) \rightarrow B(6) + P(9)$

Decaying particle Ω_2^+		Ξ_2^+		Ξ_2^{++}	
$\Omega_1^0 + K^+$	$b_1 + b_3$	$\Xi_1^+ + K^0$	$(b_1 + b_3)/\sqrt{2}$	$\Xi_1^+ + K^+$	$b_3/\sqrt{2}$
$\Xi_1^0 + \pi^+$	$(b_1 + b_3)/\sqrt{2}$	$\Xi_1^0 + K^+$	$-b_1/\sqrt{2}$	$\Sigma_1^+ + \pi^+$	$b_3/\sqrt{2}$
$\Xi_1^+ + \pi^0$	$(b_1 + b_3)/2$	$\Sigma_1^0 + \pi^+$	$(b_1 + b_3)$	$\Sigma_1^{++} + \pi^0$	$-b_2/\sqrt{2}$
$\Xi_1^+ + \eta$	$(3b_1 + b_3)/2\sqrt{3}$	$\Sigma_1^+ + \pi^0$	$(b_1 + b_3)/2$	$\Sigma_1^{++} + \eta'$	$-b_3/\sqrt{6}$
$\Xi_1^+ + \eta'$	$2b_3/\sqrt{6}$	$\Sigma_1^+ + \eta$	$b_3/2\sqrt{3}$	$\Sigma_1^{++} + \eta'$	$-2b_3/\sqrt{3}$
$\Sigma_1^+ + \bar{K}^0$	$-b_1/\sqrt{6}$	$\Sigma_1^+ + \eta'$	$2b_3/\sqrt{6}$		
$\Sigma_1^{++} + K^-$	b_1	$\Sigma_1^{++} + \pi^-$	b_1		

Table 2b. $B(3) \rightarrow B(3^*) + P(9)$

Decaying particle Ω_2^+		Ξ_2^+		Ξ_2^{++}	
$\Xi_1'^0 + \pi^+$	$-(b_1 - 2b_2 + b_3)/\sqrt{6}$	$\Xi_1'^0 + K^+$	$(b_1 - 2b_2 + b_3)/\sqrt{6}$	$\Xi_1'^+ + K^+$	$-(2b_2 - b_3)/\sqrt{6}$
$\Xi_1'^+ + \pi^0$	$-(b_1 - 2b_2 + b_3)/2\sqrt{3}$	$\Xi_1'^+ + K^0$	$-b_1/\sqrt{6}$	$\Lambda_1'^+ + \pi^+$	$(2b_2 - b_3)/\sqrt{6}$
$\Xi_1'^+ + \eta$	$(b_1 + 2b_2 - b_3)/6$	$\Lambda_1'^+ + \pi^0$	$(-2b_2 + b_3)/2\sqrt{3}$		
$\Xi_1'^+ + \eta'$	$-(\sqrt{2/3})(2b_1 - 2b_2 + b_3$	$\Lambda_1'^+ + \eta$	$(2b_1 - 2b_2 + b_3)/6$		
$\Lambda_1'^+ + \bar{K}^0$	$b_1/\sqrt{6}$	$\Lambda_1'^+ + \eta'$	$(2b_1 - 2b_2 + b_3(\sqrt{2}/3)$		

Table 2c. B(3) $\rightarrow B(8) + P(3^*)$

Decaying particle Ω_2^+		Ξ_2^+		Ξ_2^{++}	
$\Lambda + D^+$	$2b_1/\sqrt{6}$	$N + D^+$	b_1	$P + D^+$	$-b_1$
$\Sigma^0 + D^+$	0	$P + D^0$	0	$\Sigma^+ + F^+$	b_1
$\Sigma^+ + D^0$	0	$\Lambda + F^+$	$b_1/\sqrt{6}$		
$\Xi^0 + F^+$	b_1	$\Sigma^0 + F^+$	$-b_1/\sqrt{2}$		

Table 2d. $B(3^*) \rightarrow B(8) + P(9)$

Decaying particle $\Lambda_1'^+$		$\Xi_1'^+$		$\Xi_1'^0$	
$N + \pi^+$	$-(b_2 - 2b_3)/\sqrt{6}$	$P + \bar{K}^0$	$-b_1/\sqrt{6}$	$P + K^-$	$-b_1/\sqrt{6}$
$P + \pi^0$	$-(b_2 - 2b_3)/2\sqrt{3}$	$\Sigma^+ + \pi^0$	$(b_1 - b_2 + 2b_3)/2\sqrt{3}$	$N + \bar{K}^0$	$-2b_1/\sqrt{6}$
$P + \eta$	$(2b_1 - b_2 + 2b_3)/6$	$\Sigma^+ + \eta$	$-(b_1 + b_2 - 2b_3)/6$	$\Lambda + \pi^0$	$(b_1 + b_2 - 2b_3)/6\sqrt{2}$
$P + \eta'$	$(2b_1 - b_2 + 2b_3)(\sqrt{2}/3)$	$\Sigma^+ + \eta'$	$(2b_1 - b_2 + 2b_3)(\sqrt{2}/3)$	$\Lambda + \eta$	$(b_1 + b_2 - 2b_3)/6\sqrt{6}$
$\Sigma^+ + K^0$	$-b_1/\sqrt{6}$	$\Lambda + \pi^+$	$-(b_1 + b_2 - 2b_3)/6$	$\Lambda + \eta'$	$-(2b_1 - b_2 + 2b_3)3\sqrt{3}$
$\Lambda + K^+$	$-(b_1 - 2b_2 + 4b_3)/\sqrt{6}$	$\Sigma^0 + \pi^+$	$-(b_1 - b_2 + 2b_3)/2\sqrt{3}$	$\Sigma^0 + \pi^0$	$(b_1 + b_2 - 2b_3)/2\sqrt{6}$
$\Sigma^0 + K^+$	$-b_1/2\sqrt{3}$	$\Xi^0 + K^+$	$-(b_2 - 2b_3)/\sqrt{6}$	$\Sigma^0 + \eta$	$(b_1 + b_2 - 2b_3)/6\sqrt{2}$
				$\Sigma^0 + \eta'$	$-(2b_1 - b_2 + 2b_3)/3$
				$\Sigma^- + \pi^+$	$-(2b_1 - b_2 + 2b_3)/\sqrt{6}$
				$\Sigma^+ + \pi^-$	$-b_1/\sqrt{6}$
				$\Xi^0 + K^0$	$-2b_1/\sqrt{6}$
				$\Xi^- + K^+$	$(2b_1 - b_2 + 2b_3)/\sqrt{6}$

simply generalized to $\underline{720}$-dominance, as it predicts vanishing amplitudes for *s*-wave decays. These decay amplitudes can be obtained from the $\underline{1232}$ part of the weak Hamiltonian (Verma and Khanna 1977a, b). Now if $\underline{63}$-contributions are taken into account for the weak Hamiltonian, ($\triangle C = 0$, $\triangle S = -1$) and ($\triangle C = -1$, $\triangle S = 0$) decay modes can be generated, even without considering $\underline{1232}$ part. In this case SU(6) result (Rosen and Pakvasa 1964; Babu 1965; Suzuki 1965; Kawarabayashi 1965) $\Lambda_-^0 : \Sigma_0^+ : \Xi_-^- = 1 : -1/\sqrt{3} : 1$ is reproduced for the decays of octet baryons. Cabibbo enhanced decay mode ($\triangle C = \triangle S = -1$) is still forbidden in SU(8). Hence we consider the most general Hamiltonian for these decays. i.e.

$$H_w \sim \underline{63} \oplus \underline{720} \oplus \underline{1232} \tag{4}$$

$\underline{720}$ and $\underline{1232}$ components of weak Hamiltonian have been described by Verma and Khanna (1977a, b). $\underline{63}$ component of weak Hamiltonian can be written as:

$$\begin{aligned} H_1^{63} &\sim \bar{B}^{ABC} \; B_{ABC} \; M_D^{D'} \; H_{D'}^{D} \\ H_2^{63} &\sim \bar{B}^{ABD'} \; B_{ABC} \; M_D^{C} \; H_{D'}^{D} \\ H_3^{63} &\sim \bar{B}^{ABC} \; B_{ABD} \; M_C^{D'} \; H_{D'}^{D} \\ H_4^{63} &\sim \bar{B}^{ABD'} \; B_{ACD} \; M_B^{C} \; H_{D'}^{D} \end{aligned} \tag{5}$$

(Notations used to describe to H_w^{63} are given in Verma and Khanna 1977). The first component H_1^{63} cannot contribute to charm changing and strangeness changing decays. *CP*-invriance further gives:

$$\begin{aligned} &H_3^{63} = -H_2^{63}; \qquad H_4^{63} = 0 \qquad \text{for } s\text{-wave} \\ &H_3^{63} = H_2^{63} \qquad\qquad\qquad\quad \text{for } p\text{-wave} \end{aligned} \tag{6}$$

In general, weak Hamiltonian eq. (4) contains nine parameters, but *CP*-invariance reduces these to two for *s*-wave decays.

3.1. ($\triangle C = 0$, $\triangle S = -1$) *decay amplitude relations*

We obtain the following results:

$$\sqrt{3}\,\Sigma_0^+ - \Lambda_-^0 = -2\,\Xi_-^-$$

$$\text{and} \qquad \Sigma_+^+ = 0 \tag{7}$$

for uncharmed baryonic decays.
For charmed baryonic *pv* decays, we get:

$$\sqrt{2}\,\langle \Omega_2^+ | \Xi_2^+ \pi^0 \rangle = -\langle \Omega_2^+ | \Xi_2^{++} \pi^- \rangle = \sqrt{2/3}\,(5\Lambda_-^0 - 4\,\Xi_-^-)$$

$$\sqrt{2}\langle \Xi'^{+}_{1} \mid \Lambda'^{+}_{1}\,\pi^{0}\rangle = \langle \Xi_{1}'^{0} \mid \Lambda'^{+}_{1}\,\pi^{-}\rangle = -1/\sqrt{6}\,(\Lambda_{-}^{0}+\Xi_{-}^{-}). \tag{8}$$

Notice that most general symmetric weak Hamiltonian gives Lee-Sugawara sum rule as well as $\Sigma_{+}^{+} = 0$ for the parity violating decays of octet baryons.

3.2. ($\triangle C = -1$, $\triangle S = 0$) *decay amplitude relations in pv mode*

We obtain:

$$\begin{aligned} 0 = \Sigma_{+}^{+} &= \langle \Xi_{1}'^{0} \mid PK^{-}\rangle = \langle \Xi_{1}'^{0} \mid \Sigma^{+}\pi^{-}\rangle = \langle \Xi_{2}^{++} \mid PD^{+}\rangle = \langle \Xi_{2}^{++} \mid \Sigma^{+}F^{+}\rangle \\ &= \langle \Xi_{2}^{+} \mid \Xi_{1}^{+}K^{0}\rangle = \langle \Xi_{2}^{+} \mid \Sigma_{1}^{++}\pi^{-}\rangle = \langle \Xi_{2}^{+} \mid PD^{0}\rangle = \langle \Xi_{2}^{+} \mid ND^{+}\rangle \\ &= \langle \Xi_{2}^{+} \mid \Lambda F^{+}\rangle = \langle \Xi_{2}^{+} \mid \Sigma^{0}F^{+}\rangle = \langle \Omega_{2}^{+} \mid \Sigma_{1}^{+}\bar{K}^{0}\rangle = \langle \Omega_{2}^{+} \mid \Sigma_{1}^{++}K^{-}\rangle \\ &= \langle \Omega_{2}^{+} \mid \Lambda D^{+}\rangle = \langle \Omega_{2}^{+} \mid \Sigma^{0}D^{+}\rangle = \langle \Omega_{2}^{+} \mid \Sigma^{+}D^{0}\rangle = \langle \Omega_{2}^{+} \mid \Xi^{0}F^{+}\rangle \end{aligned} \tag{9}$$

$$\begin{aligned} \Xi_{-}^{-} &= -\langle \Xi_{2}^{++} \mid \Xi_{1}'^{+}K^{+}\rangle = \langle \Omega_{2}^{+} \mid \Xi_{1}'^{0}\pi^{+}\rangle = \sqrt{2}\,\langle \Omega_{2}^{+} \mid \Xi_{1}'^{+}\pi^{0}\rangle \\ &= \sqrt{6}\,\langle \Omega_{2}^{+} \mid \Xi_{1}'^{+}\eta\rangle = \sqrt{3}/2\,\langle \Omega_{2}^{+} \mid \Xi_{1}'^{+}\eta'\rangle \end{aligned} \tag{10}$$

$$\begin{aligned} \Lambda_{-}^{0} &= -\sqrt{2}\,\langle \Xi_{1}'^{+} \mid \Sigma^{+}\pi^{0}\rangle = -\sqrt{6}\,\langle \Xi_{1}'^{+} \mid \Sigma^{+}\eta\rangle = -\sqrt{3}/2\,\langle \Xi_{1}'^{+} \mid \Sigma^{+}\eta'\rangle \\ &= \sqrt{2}\,\langle \Xi_{1}'^{+} \mid \Sigma^{0}\pi^{+}\rangle = -\langle \Xi_{1}'^{+} \mid \Xi^{0}K^{+}\rangle = 2\,\langle \Xi_{1}'^{0} \mid \Sigma^{0}\pi^{0}\rangle \\ &= 2\sqrt{3}\,\langle \Xi_{1}'^{0} \mid \Sigma^{0}\eta\rangle = 3/\sqrt{6}\,\langle \Xi_{1}'^{0} \mid \Sigma^{0}\eta'\rangle = \langle \Xi_{1}'^{0} \mid \Sigma^{-}\pi^{+}\rangle \end{aligned} \tag{11}$$

$$\begin{aligned} 2(\Xi_{-}^{-}-\Lambda_{-}^{0}) &= -\langle \Lambda'^{+}_{1} \mid \Sigma^{+}K^{0}\rangle = -\sqrt{2}\,\langle \Lambda'^{+}_{1} \mid \Sigma^{0}K^{+}\rangle = \langle \Xi'^{+}_{1} \mid P\bar{K}^{0}\rangle \\ &= \langle \Xi_{1}'^{0} \mid N\bar{K}^{0}\rangle \\ &= -\langle \Xi_{1}'^{0} \mid \Xi^{0}K^{0}\rangle = -1/2\,\langle \Xi_{2}^{+} \mid \Xi'^{+}_{1}K^{0}\rangle = -1/2\,\langle \Omega_{2}^{+} \mid \Lambda'^{+}_{1}\bar{K}^{0}\rangle \end{aligned} \tag{12}$$

$$\begin{aligned} (\Xi_{-}^{-}-2\Lambda_{-}^{0}) &= \sqrt{3}\,\langle \Xi_{2}^{++} \mid \Xi_{1}^{+}K^{+}\rangle = \sqrt{3}\,\langle \Xi_{2}^{++} \mid \Sigma_{1}^{+}\pi^{+}\rangle \\ &= -\sqrt{3}/2\,\langle \Xi_{2}^{++} \mid \Sigma_{1}^{++}\pi^{0}\rangle \\ &= -3\,\langle \Xi_{2}^{++} \mid \Sigma_{1}^{++}\eta\rangle = -3/\sqrt{8}\,\langle \Xi_{2}^{++} \mid \Sigma_{1}^{++}\eta'\rangle = \sqrt{3}\,\langle \Xi_{2}^{+} \mid \Xi_{1}^{0}K^{+}\rangle \\ &= \sqrt{3/2}\,\langle \Xi_{2}^{+} \mid \Sigma_{1}^{0}\pi^{+}\rangle = \sqrt{6}\,\langle \Xi_{2}^{+} \mid \Sigma_{1}^{+}\pi^{0}\rangle = 3\sqrt{2}\,\langle \Xi_{2}^{+} \mid \Sigma_{1}^{+}\eta\rangle \\ &= 3/2\,\langle \Xi_{2}^{+} \mid \Sigma_{1}^{+}\eta'\rangle \end{aligned}$$

$$=\sqrt{3/2}\,\langle\Omega_2^+\,|\,\Omega_1^0 K^+\rangle = \sqrt{3}\,\langle\Omega_2^+\,|\,\Xi_1^0\pi^+\rangle = \sqrt{6}\,\langle\Omega_2^+\,|\,\Xi_1^+\pi^0\rangle$$

$$= 3\sqrt{2}\,\langle\Omega_2^+\,|\,\Xi_1^+\,\eta\rangle = 3/2\,\langle\Omega_2^+\,|\,\Xi_1^+\eta'\rangle = -\sqrt{3/2}\,\langle\Lambda_1'^+\,|\,\Lambda K^+\rangle \tag{13}$$

$$(2\Xi-3\Lambda_-^0) = \langle\Lambda_1'^+\,|\,N\pi^+\rangle = \sqrt{2}\,\langle\Lambda_1'^+\,|\,P\pi^0\rangle = \sqrt{6}\,\langle\Lambda_1'^+\,|\,P\eta\rangle$$

$$=\sqrt{3}/2\,\langle\Lambda_1'^+\,|\,P\eta'\rangle = \langle\Xi_1'^0\,|\,\Xi^-\,K^+\rangle \tag{14}$$

$$(3\Xi_-^- -4\Lambda_-^0) = -\langle\Xi_2^{++}\,|\,\Lambda_1'^+\pi^+\rangle = \langle\Xi_2^+\,|\,\Xi_1'^0\,K^+\rangle$$

$$= \sqrt{2}\,\langle\Xi_2^+\,|\,\Lambda_1'^+\pi^0\rangle = \sqrt{6}\,\langle\Xi_2^+\,|\,\Lambda_1'^+\eta\rangle$$

$$= \sqrt{3}/2\,\langle\Xi_2^+\,|\,\Lambda_1'^+\eta'\rangle \tag{15}$$

$$(4\Xi_-^- -5\Lambda_-^0) = \sqrt{6}\,\langle\Xi_1'^+\,|\,\Lambda\,\pi^+ = -2\sqrt{3}\,\langle\Xi_1'^0\,|\,\Lambda\,\pi^0\rangle$$

$$= -6\,\langle\Xi_1'^0\,|\,\Lambda\eta'\rangle = -3/\sqrt{2}\,\langle\Xi_1'^0\,|\,\Lambda\eta'\rangle\quad. \tag{16}$$

Inclusion of 63 admixture does not affect decay amplitudes of other modes. In SU(8), one can fix the ratio of 15-contributions to 20″-contributions from the experimental values of two amplitudes. Most general Hamiltonian eq. (4) forbids $B(3)\to B(8)+P(3^*)$ decay mode completely.

3.3. *Parity conserving decays of uncharmed baryons*

In $SU(8)_w$ considerations 63-admixture seems to improve the state of parity conserving decays also. We obtain the following amplitudes from the most general Hamiltonian eq. (4).

It is interesting to point out that though *CP*-invariant *pc* weak Hamiltonian contains seven parameters, only four contributions are independent. The most

Table 3. $B(8)\to B'(8)+\pi$

p-Wave decay amplitude	Most general Hamiltonian $H_W \sim \underline{63}\oplus\underline{720}\oplus\underline{1232}$	When Lee-Sugawara sum rule and $\Sigma_-^- = 0$ are imposed
Λ_-^0	$(6a_1+9a_2+3a_3+a_4)/\sqrt{6}$	$-(9a'_1+a'_2)/\sqrt{6}$
Λ_0^0	$-(6a_1+9a_2+3a_3+a_4)/\sqrt{12}$	$(9a'_1+a'_2)/\sqrt{12}$
Ξ_-^-	$(3a_1+3a_2+2a_3)/\sqrt{6}$	$-(6a'_1+5a'_2)/\sqrt{6}$
Ξ_0^0	$(3a_1+3a_2+2a_3)/\sqrt{12}$	$-(6a'_1+5a'_2)/\sqrt{12}$
Σ_0^+	$(4a_1+a_2+a_3+a_4)/\sqrt{2}$	$(a'_1+3a'_2)/\sqrt{2}$
Σ_+^+	$5a_1+a_4$	$a'_1+3a'_2$
Σ_-^-	$a_1-a_2-a_3$	0

general Hamiltonian gives no relation as such, but one has a freedom to adjust the parameters. In column 3 of table 3 we give the amplitudes after imposing the Lee-Sugawara sum rule and $\Sigma_-^-=0$.

4. Nonleptonic decays of the type $(3/2^+\rightarrow 3/2^+ + 0^-)$

Parity violating decays of the type $3/2^+\rightarrow 3/2^+ + 0^-$ now can occur in nature via $\underset{\sim}{15}$-admixture. Recent observations (Cazzoli *et al* 1975; Knapp *et al* 1976) made in search of charmed particles suggests the mass spectrum (Hendry and Lichtenberg 1976; Gupta 1976; Verma and Khanna 1977c) of charmed isobars, which indicate that $\Omega_3^{*++}(C=3)$ cannot decay through electromagnetic or strong interactions. All other charmed isobars may decay strongly and/or electromagnetically. Hence *pv* decays of Ω_3^{*++} are expected to be observed.

Amplitudes are obtained for the various decays $(3/2^+\rightarrow 3/2^+ + 0^-)$ of Ω_3^{*++} and Ω^- from SU(4) weak Hamiltonian $(H_w \sim 15 \oplus 20'')$;

$$H_w^{15} = d_1\ \bar{D}^{ije}\, D_{ijm}\, P_k^m\, H_e^k$$

$$+ d_2\ \bar{D}^{ijm}\ D_{ijk}\, P_m^e\, H_e^k$$

$$+ d_3\, \bar{D}^{ink}\, D_{ime}\, P_n^m\, H_e^k$$

$$H_w^{20''} = d_4\ \bar{D}^{ijk}\, D_{ijm}\, P_n^e\, H_{[k,\ e]}^{[m,\ n]}$$

CP invariance gives:

$$d_1 = -d_2;\ d_3 = d_4 = 0 \text{ for } s\text{-wave}$$

$$d_1 = d_2 \text{ for } p\text{-wave.}$$

In table 4, decay amplitudes are expressed in terms of *C*'s which are simple functions of *d*'s.

In SU(8) most general Hamiltonian eq. (4) gives identical results.

5. Discussion and conclusion

In order to remove the discrepancies present in the results obtained in the GIM model, we have considered the $\underset{\sim}{15}$-admixture in the SU(4) framework. Many recent models of weak interaction suggest this representation to be included in the weak Hamiltonian. The $\underset{\sim}{15}$-admixture may be expected to arise through the symmetry breaking mechanism even in the case of GIM model. $\triangle C = \pm \triangle S$ decay modes do not get any contribution from $\underset{\sim}{15}$-weak Hamiltonian. Lee-Sugawara relation is reproduced for parity violating decays of uncharmed hyperons. We do not obtain

Table 4. $B(3/2^+) \rightarrow B(3/2^+) + P(0^-)$

Decay mode	Decay	s-Wave	p-Wave
$(\triangle C=0, \triangle S=-1)$	$\Omega^- \rightarrow \Xi^{*-}+\pi^0$	$-C_0/\sqrt{6}$	$(C_1-C_2)/\sqrt{6}$
	$\Xi^{*0}+\pi^-$	$C_0/\sqrt{3}$	$-(C_1-C_2)/\sqrt{3}$
$(\triangle C=\triangle S=-1)$	$\Omega_3^{*++} \rightarrow \Xi_2^{*++}+\bar{K}^0$	0	$-C_1/\sqrt{3}\cot\theta$
	$\Omega_2^{*+}+\pi^+$	0	$C_1/\sqrt{3}\cot\theta$
$(\triangle C=-\triangle S=-1)$	$\Omega_3^{*++} \rightarrow \Xi_2^{*+}+K^+$	0	$C_1/\sqrt{3}\tan\theta$
	$\Xi_2^{*++}+K^0$	0	$-C_1/\sqrt{3}\tan\theta$
$(\triangle C=-1, \triangle S=0)$	$\Omega_3^{*++} \rightarrow \Omega_2^{*+}+K^+$	$C_0/\sqrt{3}$	$-(C_1-C_2)/\sqrt{3}$
	$\Xi_2^{*+}+\pi^+$	$C_0/\sqrt{3}$	$(C_1+C_2)/\sqrt{3}$
	$\Xi_2^{*++}+\pi^0$	$C_0/\sqrt{6}$	$(C_1+C_2)/\sqrt{6}$
	$\Xi_2^{*++}+\eta$	$C_0/3\sqrt{2}$	$-(C_1-C_2)/\sqrt{2}$
	$\Xi_2^{*++}+\eta'$	$2C_0/3$	$-(2C_2+3C_3)/6$
$(\triangle C=-1, \triangle S=0)$	$\Omega_3^{*++} \rightarrow \Xi_1^{*+}+F^+$	0	$C_3/\sqrt{6}$
	$\Sigma_1^{*+}+D^+$	0	$C_3/\sqrt{6}$
	$\Sigma_1^{*++}+D^0$	0	$C_3/\sqrt{3}$

any relation among $\triangle C = -1$, $\triangle S = 0$ decay amplitudes, as the H_w^{15} introduces three more parameters. Parity conserving non-leptonic weak decays are not considered in SU(4), since they involve ten parameters.

In SU(8) symmetry considerations, 15-admixture is extended to 63-admixture. The most general Hamiltonian eq. (4) here gives interesting results. We are able to get $\Sigma_+^+ = 0$ and Lee-Sugawara relation for parity violating decays of uncharmed baryons. Notice that even at the SU(4) sublevel (in the SU(4) $\otimes$ SU(2) structure of SU(8)) we have included all the symmetric representations; 15, 20″ and 84. Most general Hamiltonian expresses $\triangle C = -1$, $\triangle S = 0$ decays in terms of two parameters only. We have obtained relations among $\triangle C = -1$, $\triangle S = 0$ decay amplitudes for $B(3)$ and $B(3^*)$ baryons. It is to be noticed that $B(3) \rightarrow B(8) + P(3^*)$ decays are completely forbidden. Parity conserving decays of uncharmed baryons are expressed in terms of only four independent parameters in SU(8) with most general weak Hamiltonian ($H_w \sim 63 \oplus 720 \oplus 1232$). Though no relation other than $\triangle I = 1/2$ rule can be obtained as such we can yet adjust the parameters freely to obtain the Lee-Sugawara sum rule and $\Sigma_-^- = 0$. We have neglected the 84-contributions at SU(4) sub level, in the study of p-wave decays and $3/2^+ \rightarrow 3/2^+ + 0^-$ decays. Some s-wave decays, $3/2^+ \rightarrow 3/2^+ + 0^-$ which vanish in 20″ dominance of the weak Hamiltonian, can now occur through the adjoint representation. SU(4) and SU(8) give identical relations for these decays.

Acknowledgement

One of us (RCV) wishes to thank Council of Scientific and Industrial Research, New Delhi for financial support.

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