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Charm changing weak decays $1/2^+ \rightarrow 3/2^+ + 0^-/\gamma$ in SU(4) and SU(8)$_w$

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Abstract. Weak decay modes ($1/2^+ \rightarrow 3/2^+ + 0^-/\gamma$) of charmed baryons are studied. Relations among the various decay amplitudes are derived in isospin, SU(3), SU(4) and SU(8)$_w$ symmetries. Sextet dominance in SU(3) forbids $B(3) \rightarrow D(10) + P(3^*)$ decays. 20$''$ dominance in SU(4) specifies all the decays in terms of Ω^- decays. Weak decays of Ω_3^{*++} and Ω^- are also discussed. SU(8)$_w$ symmetry predicts α $(\Omega\bar{k}) = 0$, which is consistent with the experimental value.

Keywords. Weak nonleptonic decays; charmed baryons; SU(4) and SU(8)$_w$.

1. Introduction

Weak nonleptonic decays of the type $B(1/2^+) \rightarrow B(1/2^+)+P(0^-)$ have been discussed in higher symmetry frameworks (Iwasaki 1975; Altarelli *et al* 1975; Gupta 1976a; Verma and Khanna 1977 a, b; Karino 1977). In this paper we wish to discuss the weak mesonic and radiative decays: $B(1/2^+) \rightarrow B(3/2^+)+P(0^-)/\gamma$. The charmed quark being the heaviest among the four quarks, the decays would be allowed in the charm changing mode. In the next section, we comment on the possible masses of the charmed baryons. We note that $B(6)$ multiplet can decay to $B(3^*)$ via strong and/or electromagnetic interactions and so their weak decays are not expected to be interesting. We study the weak decays of $B(3^*)$ and $B(3)$ in the channels: $B(3^*) \rightarrow D(10)+P(9)$; $B(3) \rightarrow D(6)+P(9)$ and $B(3) \rightarrow D(10)+P(3^*)$ allowed energetically. Weak Hamiltonian is described in §3. $\triangle C=\triangle S=-1$ mode is Cabibbo-enhanced. From among the Cabibbo suppressed modes

$$\triangle C=-1,\ \triangle S=0 \text{ and } \triangle C=-\triangle S=-1$$

the $\triangle C=-1$, $\triangle S=0$ mode may be enhanced due to the SU(4) 15-admixture. (Verma and Khanna 1977c). So the decays corresponding to $\triangle C=-\triangle S=-1$ are not discussed. In § 4 several decay amplitude relations are obtained in the SU(2), SU(3) and SU(4) symmetries assuming the GIM model of weak interaction. $H_w^{\triangle C=\triangle S}$ obeys $\triangle I=1$ selection rule. The $\triangle C=-1$, $\triangle S=0$ Hamiltonian contains both the $\triangle I=1/2$ and $\Delta I=3/2$ pieces but we assume $\triangle I=1/2$ enhancement. In SU(3) we obtain sum rules with and without sextet dominance. SU(4) symmetry relates the decays in different channels of $B(3)$ and $B(3^*)$ multiplets. CP invariance further

Table 1. Masses of charmed baryon isomultiplets in SU(4)

$1/2^+$	Multiplets	Mass GeV	$3/2^+$	Multiplets	Mass GeV
$B(6)$	Σ_1	2·50 (input)	$D(6)$	Σ_1^*	2·50 (input)
	Ξ_1	2·69		Ξ_1^*	2·65
	Ω_1	2·88		Ω_1^*	2·80
$B(3)$	Ξ_2	3·75	$D(3)$	Ξ_2^*	3·77
	Ω_2	4·00		Ω_2^*	3·92
$B(3^*)$	Λ'_1	2·26 (input)	$D(1)$	Ω_3^*	5·04
	Ξ_1'	2·49			

relates these decays with those of Ω^-. $D(3/2^+) \rightarrow B(1/2^+) + P(0^-)$ decays of Ω_3^{*++} ($C=3$) singlet are also discussed. In §5 we study all these processes in spin symmetry considerations. Adjoint representation admixture to weak decays is considered in § 6. Summary and conclusion are given in the last section.

2. Mass spectrum of the charmed baryons

Various mass relations have been obtained in quark models and in the frameworks of SU(4) and SU(8) (Hendry and Lichtenberg 1975; Lichtenberg 1975; Franklin 1975; Verma and Khanna 1977d). Experimentally a state has been observed (Cazzoli *et al* 1975; Knapp *et al* 1976) at 2·26 GeV decaying to Λ and 3π. Another state decaying to the first one and a pion has also been observed at 2·5 GeV. Taking the first state to be $\Lambda_1'^+$ and second state to be (i) Σ_1^{*0} $(3/2^+)$ or (ii) Σ_1^0 $(1/2^+)$ following mass spectrum can be obtained (Gupta 1976b).

We see that $B(6)$ can decay to $B(3^*)$ and pseudo-scalar meson/photon through strong/electromagnetic interactions (Kobayashi *et al* 1972; Gupta 1976c). The remaining charmed multiplets $B(3^*)$ and $B(3)$ may decay through weak interaction via $B(3^*) \rightarrow D(10) + P(9)$, $B(3) \rightarrow D(6) + P(9)$ and $B(3) \rightarrow D(10) + P(3^*)$ channels. These decay modes would be allowed in mass spectrum of charmed baryons as predicted by de Rujula *et al* 1975.

In the $J^P=3/2^+$ charmed isobars, Ω_3^{*++} seems to be stable against the strong electromagnetic decays $D(3/2^+) \rightarrow B(1/2^+) + P(0^-)/\gamma$. Therefore the weak decays of Ω_3^{*++} would be interesting and we shall discuss them too.

3. Weak decay Hamiltonian

In a current$\otimes$current model, SU(4) weak Hamiltonian H_w transforms like $15 \otimes 15$.

Since H_w behaves like $[J, J^\dagger]_+$, SU(4) weak Hamiltonian is reduced to:

$$
\begin{aligned}
H_w \sim 15:&\ \ (3+3^*) \quad + \quad (8+1) \\
&\quad |\triangle C| = 1 \qquad \triangle C = 0 \\
+\,20'':&\ \ (6+6^*) \quad + \quad 8 \\
&\quad |\triangle C| = 1 \qquad C = 0 \\
+\,84:&\ \ (3+3^*+15+15^*) + (27+8+1) \\
&\qquad |\triangle C| = 1 \qquad\qquad \triangle C = 0
\end{aligned}
\tag{1}
$$

where SU(3) decomposition is given in brackets. GIM model forbids $H_w{}^{15}$ to contribute. However $\triangle C = \pm \triangle S$ decay modes do not occur in 15 representation of SU(4) and $\triangle C = -1$, $\triangle S = 0$ mode may get enhanced through possible 15-admixture (Branco *et al* 1976; Bajaj and Kapoor 1977; Shin-Mura 1976). We discuss $\triangle C = \triangle S = -1$ and $\triangle C = -1$, $\triangle S = 0$ decays only.

3.1. *Isospin selection rule*

$\triangle C = \triangle S = -1$ decays satisfy $\triangle I = 1$ selection rule while $\triangle C = -1$, $\triangle S = 0$ decays contain both the $\triangle I = 1/2$ and $3/2$ pieces. We obtain relations among the decay amplitudes assuming $\triangle I = 1/2$ enhancement.

3.2. *SU(3) framework*

In SU(3) we first obtain amplitude relations by assuming sextet dominance which follows from 20″ dominance in SU(4). Here we notice that $B(3) \rightarrow D(10) + P(3^*)$ decays are forbidden totally since the direct product $(10^* \times 3 \times 3)$ does not contain sextet representation. Similarly all the decays involving η' are also forbidden. These decays can arise through 15 component of 84. Sum rules are also obtained for the SU(3) weak Hamiltonian $H_w{}^{6^*+15}$.

3.3. *SU(4) framework*

SU(4) symmetry relates all the three channels $B(3^*) \rightarrow D(10) + P(9)$, $B(3) \rightarrow D(6) + P(9)$ and $B(3) \rightarrow D(10) + P(3^*)$. 20″ dominant weak Hamiltonian has the following parts:

$$H_w{}^{20''} = a_1/2 \quad \epsilon_{abmn} \quad D^{cep} \quad B^{[m,n]}_{p} \quad P^{d}_{e} \quad H^{[a,b]}_{[c,d]} \tag{2a}$$

$$+ \, a_2/2 \quad \epsilon_{apmn} \quad D^{cep} \quad B^{[m,n]}_{e} \quad P^{d}_{b} \quad H^{[a,b]}_{[c,d]} \tag{2b}$$

Table 2. ($\triangle C = \triangle S = -1$) decay amplitudes

2.1 $B(3^*) \to D(10) + P(9)$

	Decay		$H_w^{20''}$	H_w^{84}
A_1	$\Lambda_1'^+ \to$	$\Xi^{*0}K^+$	$a_1/3\surd 2$	$b_2/\surd 2 + b_5/\surd 2$
A_2		$\Sigma^{*0}\pi^+$	$a_1/6$	$b_2/2 - b'_3/6 + b_5/2$
A_3		$\Sigma^{*+}\pi^0$	$a_1/6$	$b_2/2 - b'_3/6 + b_5/2$
A_4		$\Sigma^{*+}\eta$	$a_1/2\surd 3$	$b_2/2\surd 3 + b_3'/6\surd 3 - b_5/2\surd 3$
A_5		$\Sigma^{*+}\eta'$	0	$b_2/2\surd 6 - b_3'/3\surd 6 + b_5/\surd 6 + b_4/2\surd 6$
A_6		$\triangle^{++}K^-$	$-\ a_1/\surd 6$	$3b_5/\surd 6$
A_7		$\triangle^+\bar{K}^0$	$-\ a_1/3\surd 2$	$b_5/\surd 2$
A_8	$\Xi_1'^+ \to$	$\Xi^{*0}\pi^+$	0	$-\ b'_3/3\surd 2$
A_9		$\Sigma^{*+}\bar{K}^0$	0	$b_3'/3\surd 2$
A_{10}	$\Xi_1'^0 \to$	Ω^-K^+	$a_1/\surd 6$	$3b_5/\surd 6$
A_{11}		$\Xi^{*-}\pi^+$	$a_1/3\surd 2$	$b_5/\surd 2$
A_{12}		$\Xi^{*0}\pi^0$	$a_1/6$	$-\ b_3'/6 + b_5/2$
A_{13}		$\Xi^{*0}\eta$	$a_1/2\surd 3$	$-\ b_2/\surd 3 + b_3'/6\surd 3 - b_5/2\surd 3$
A_{14}		$\Xi^{*0}\eta'$	0	$b_2/2\surd 6 - b_3'/3\surd 6 + b_5/\surd 6 + b_4/2\surd 6$
A_{15}		$\Sigma^{*+}K^-$	$-\ a_1/3\surd 2$	$b_2/\surd 2 + b_5/\surd 2$
A_{16}		$\Sigma^{*0}\bar{K}^0$	$-\ a_1/6$	$b_2/2 - b_3'/6 + b_5/2$

$b_3' = b_3 - b_4$

2.2 $B(3) \to D(6) + P(9)$

	Decay		$H_w^{20''}$	H_w^{84}
A_{17}	$\Xi_2^+ \to$	$\Omega_1^{*0}K^+$	$a_1/\surd 3$	$b_5/\surd 3$
A_{18}		$\Xi_1^{*0}\pi^+$	$a_1/\surd 6 - a_2/\surd 6$	$b_1/\surd 6 + b_5/\surd 6$
A_{19}		$\Xi_1^{*+}\pi^0$	$a_1/2\surd 3$	$-\ b_3/2\surd 3 + b_5/2\surd 3$
A_{20}		$\Xi_1^{*+}\eta$	$a_1/2$	$b_3/6 - b_5/6$
A_{21}		$\Xi_1^{*+}\eta'$	0	$b_3/2\surd 2 - b_3/3\surd 2 + 5b_4/6\surd 2 + b_5/3\surd 2$
A_{22}		$\Sigma_1^{*++}K^-$	$-\ a_1/\surd 3$	$b_5/\surd 3$
A_{23}		$\Sigma_1^{*+}\bar{K}^0$	$-\ a_1/\surd 6 + a_2/\surd 6$	$b_1/\surd 6 + b_5/\surd 6$
A_{24}	$\Xi_2^{++} \to$	$\Xi_1^{*+}\pi^+$	$-\ a_2/\surd 6$	$b_1/\surd 6 + b_3/\surd 6$
A_{25}		$\Sigma_1^{*++}\bar{K}^0$	$a_2/\surd 3$	$b_1/\surd 3$
A_{26}	$\Omega_2^+ \to$	$\Omega_1^{*0}\pi^+$	$-\ a_2/\surd 3$	$b_1/\surd 3$
A_{27}		$\Xi_1^{*+}\bar{K}^0$	$a_2/\surd 6$	$b_1/\surd 6 + b_3/\surd 6$

2.3 $B(3) \to D(10) + P(3^*)$

	Decay		$H_w^{20''}$	H_w^{84}
A_{28}	$\Xi_2^+ \to$	$\Xi^{*0}F^+$	0	$b_2/\surd 3$
A_{29}		$\Sigma^{*0}D^+$	0	$b_2/\surd 6 + b_4/\surd 6$
A_{30}		$\Sigma^{*+}D^0$	0	$b_2/\surd 3$
A_{31}	$\Xi_2^{++} \to$	$\Sigma^{*+}D^+$	0	$b_4/\surd 3$
A_{32}	$\Omega_2^+ \to$	$\Xi^{*0}D^+$	0	$b_4/\surd 3$

CP invariance expresses the decay amplitudes in terms of those of Ω^-. We also consider the weak Hamiltonian $H_w^{20''+84}$, where H_w^{84} has the following pieces:

$$\begin{aligned} H_w^{84} = & - b_1/2 \quad \epsilon_{eamn} \quad D^{epc} \quad B_p^{[m,n]} \quad P_b^d \quad H_{(c,d)}^{(a,b)} \\ & - b_2/4 \quad \epsilon_{apmn} \quad D^{ecd} \quad B_b^{[m,n]} \quad P_e^p \quad H_{(c,d)}^{(a,b)} \\ & + b_3/4 \quad \epsilon_{apmn} \quad D^{ecd} \quad B_e^{[m,n]} \quad P_b^p \quad H_{(c,d)}^{(a,b)} \\ & - b_4/4 \quad \epsilon_{eamn} \quad D^{ecd} \quad B_p^{[m,n]} \quad P_b^p \quad H_{(c,d)}^{(a,b)} \\ & - b_5/2 \quad \epsilon_{apmn} \quad D^{epc} \quad B_b^{[m,n]} \quad P_e^d \quad H_{(c,d)}^{(a,b)}. \end{aligned} \tag{3}$$

In the tables 2 to 5 we have given contributions to the weak decays, from different components of SU(4) weak Hamiltonian.

4. Decay amplitude relations

4.1. $\triangle C = \triangle S = -1$ *decay mode*

$\triangle C = \triangle S$ decays of $1/2^+$ baryons are denoted by set of amplitudes A's in tables 2. A_1 to A_{16} describe the decays of $B(3^*)$ multiplet. A_{17} to A_{27} and A_{28} to A_{32} represents the decays of $C=2$ multiplet in the channels: $B(3) \rightarrow D(6) + P(9)$ and $B(3) \rightarrow D(10) + P(3^*)$ respectively.

(*a*) *Isospin selection rule*

$H_w^{\triangle C = \triangle S}$ satisfies a $\triangle I = 1$ selection rule which gives

$$A_3 = A_2 \tag{4a}$$

$$(\sqrt{3})\, A_7 = A_6 \tag{4b}$$

$$A_{11} - (\sqrt{2})\, A_{12} = A_8 \tag{4c}$$

$$A_{15} - (\sqrt{2})\, A_{16} = A_9 \tag{4d}$$

$$A_{18} - (\sqrt{2})\, A_{19} = A_{24} \tag{4e}$$

$$A_{22} - (\sqrt{2})\, A_{23} = - A_{25} \tag{4f}$$

$$A_{30} - (\sqrt{2})\, A_{29} = - A_{31}. \tag{4g}$$

(b) SU(3) framework

In addition to the relations (4) of isospin, sextet dominance gives:

$$0 = A_5 = A_8 = A_9 = A_{14} = A_{21} = A_{28} = A_{29} = A_{30} = A_{31} = A_{32} \quad (5a)$$

$$(\sqrt{2})\, A_{11} = A_{10} \quad (5b)$$

$$(\sqrt{3})\, A_1 = (\sqrt{6})\, A_2 = (\sqrt{2})\, A_4 = -A_6 = A_{10} = -(\sqrt{3})\, A_{15} \quad (5c)$$

$$A_{17} = 2A_{19} = (2/\sqrt{3})\, A_{20} = -A_{22} \quad (5d)$$

$$-(\sqrt{2})\, A_{24} = A_{25} = -A_{26} = (\sqrt{2})\, A_{27}. \quad (5e)$$

Notice that the decays $B(3) \rightarrow D(10)+P(3^*)$ are forbidden.
Inclusion of H_w^{15} maintains (4) and (5b), other relations are modified to:

$$A_1 = (\sqrt{2})\, A_2 - A_8 \quad (6a)$$

$$(3\sqrt{2})\, A_4 = (\sqrt{6})\, A_2 - 2A_6 - (2\sqrt{3})\, A_8 \quad (6b)$$

$$A_5 = A_{14} = 1/6\, [(\sqrt{6})\, A_2 + A_6 + (\sqrt{3})\, A_8)] \quad (6c)$$

$$A_9 = -A_8 \quad (6d)$$

$$6A_{13} = -(4\sqrt{3})\, A_2 + (\sqrt{6})\, A_8 - (2\sqrt{6})\, A_6 + (3\sqrt{6})\, A_{11} \quad (6e)$$

$$(\sqrt{6})\, A_{16} = (\sqrt{6})\, A_2 + A_6 - (\sqrt{3})\, A_{11} \quad (6f)$$

$$A_{17} = 2A_{19} + (\sqrt{2})\, A_{24} - A_{26} \quad (6g)$$

$$(\sqrt{2})\, A_{18} - A_{17} = A_{26} \quad (6h)$$

$$(\sqrt{3})\, A_{20} = A_{19} - A_{22} + (\sqrt{2})\, A_{24} - A_{26} \quad (6i)$$

$$(2\sqrt{2})\, A_{23} = 2A_{22} + A_{25} - A_{26} \quad (6j)$$

$$(\sqrt{2})\, A_{27} - A_{25} = (\sqrt{2})\, A_{24} - A_{26} \quad (6k)$$

$B(3) \rightarrow D(10+P(3^*)$ may arise through H_w^{15} and obey the relations

$$A_{32} = A_{31} \quad (6l)$$

$$A_{30} = A_{28} \quad (6m)$$

$$(\sqrt{2})\, A_{29} - A_{30} = A_{31}. \quad (6n)$$

(c) SU(4) framework

In SU(4), the different channels get related. 20″ dominance, in addition to (4) and (5) gives:

$$(\sqrt{3})\, A_2 = A_{19} \tag{7}$$

while the total SU(4) weak Hamiltonian (20″+84) satisfies (4), (5b) and (6). In addition we get:

$$(\sqrt{2})\, A_{24} - A_{26} = -\,(\sqrt{6})\, A_8 \tag{8a}$$

$$(3\sqrt{2})\, A_{19} = -\,A_6 + (3\sqrt{3})\, A_8 + (2\sqrt{3})\, A_{11} \tag{8b}$$

$$(3/\sqrt{2})\, A_{22} = 2A_6 - (\sqrt{3})\, A_{11} \tag{8c}$$

$$\sqrt{3/2}\, A_{30} = (\sqrt{2})\, A_2 - A_8 - A_{11}. \tag{8d}$$

Relations obtained till now are valid for both the parity conserving (pc) and the parity violating (pv) modes. In SU(4) symmetry, *CP* invariance relates these decays ($1/2^+ \to 3/2^+ + 0^-$) with ($3/2^+ \to 1/2^+ + 0^-$) decays. 20″ dominance completely specify these decays in terms of Ω^- decay amplitudes through the relations:

$$A_2 = -\,(1/2\sqrt{6})\, \Omega^-_K \cot\theta \tag{9a}$$

$$A_{24} = -\,(1/\sqrt{6})\, \Omega^-_- \cot\theta \tag{9b}$$

for pc mode.
Parity violating (*d*-wave) decays are expected to have very small amplitudes due to large centrifugal barrier. However, pv decays are also related in similar manner as (9), except that now minus sign is to be replaced by plus. Inclusion of 84 does not lead to any useful relations.

4.2. $\triangle C = -1,\ \triangle S = 0$ *decay mode*

These decays of $1/2^+$ baryons are denoted by *B*'s in tables 3.1 to 3.3. B_1 to B_{23} describes the weak decays of $B(3^*)$ multiplet. B_{24} to B_{42} and B_{43} to B_{51} represent the decay amplitudes in the channels $B(3) \to D(6) + P(9)$ and $B(3) \to D(10) + P(3^*)$ respectively.

(a) Isospin selection rule

Assuming $\triangle I = 1/2$ dominance, we obtain:

$$-\,(\sqrt{2})\, B_1 = B_2 \tag{10a}$$

$$(\sqrt{6})\, B_3 = (\sqrt{3})\, B_4 = -\,(\sqrt{2})\, B_7 \tag{10b}$$

Table 3. ($\Delta C=-1$, $\Delta S=0$) decay amplitudes

3.1. $B(3^*)\to D(10)+P(9)$

	Decay	$H_w^{20''}$	H_w^{84}	H_w^{15}
B_1	$\Lambda_1'^{+}\to\Sigma^{*0}K^+$	$a_1/6$	$b_2/2+b_3'/6+b_5/2$	$C_3/6-c_4/3$
B_2	$\Sigma^{*+}K^0$	$-a_1/3\sqrt{2}$	$b_3'3\sqrt{2}+b_5/\sqrt{2}$	$-C_3/3\sqrt{2}+2C_4/3\sqrt{2}$
B_3	$\Delta^0\pi^+$	$a_1/3\sqrt{2}$	$b_2/\sqrt{2}-b_3'/3\sqrt{2}+b_5/\sqrt{2}$	$C_3/3\sqrt{2}-2C_4/3\sqrt{2}$
B_4	$\Delta^+\pi^0$	$a_1/3$	$b_2/2-b_3'/6$	$C_3/3-2C_4/3$
B_5	$\Delta^+\eta$	0	$b_2/2\sqrt{3}+b_3'/6\sqrt{3}+b_5/\sqrt{3}$	0
B_6	$\Delta^+\eta'$	0	$b_2/2\sqrt{6}-b_3'/3\sqrt{6}+b_5/\sqrt{6}+b_4/2\sqrt{6}$	0
B_7	$\Delta^{++}\pi^-$	$-a_1/\sqrt{6}$	$3b_5/\sqrt{6}$	$-C_3/\sqrt{6}+2C_4/\sqrt{6}$
B_8	$\Xi'^{+}\to\Xi^{*0}K^+$	$a_1/3\sqrt{2}$	$b_2/\sqrt{2}-b_3'/3\sqrt{2}+b_5/\sqrt{2}$	$-C_3/3\sqrt{2}+2C_4/3\sqrt{2}$
B_9	$\Sigma^{*0}\pi^+$	$a_1/6$	$b_2/2+b_3'/6+b_5/2$	$-C_3/6+C_4/3$
B_{10}	$\Sigma^{*+}\pi^0$	$a_1/6$	$b_2/2+b_5/2$	$-C_3/6+C_4/3$
B_{11}	$\Sigma^{*+}\eta$	$a_1/2\sqrt{3}$	$b_2/2\sqrt{3}-b_3'/3\sqrt{3}-b_5/2\sqrt{3}$	$-C_3/2\sqrt{3}+C_4/\sqrt{3}$
B_{12}	$\Sigma^{*+}\eta'$	0	$b_2/2\sqrt{6}-b_3'/3\sqrt{6}+b_5/\sqrt{6}+b_4/2\sqrt{6}$	0
B_{13}	$\Delta^{++}K^-$	$-a_1/\sqrt{6}$	$3b_5/\sqrt{6}$	$C_3/\sqrt{6}-2C_4/\sqrt{6}$
B_{14}	$\Delta^+\bar{K}^0$	$-a_1/3\sqrt{2}$	$-b'_3/3\sqrt{2}+b_5/\sqrt{2}$	$C_3/3\sqrt{2}-2C_4/3\sqrt{2}$
B_{15}	$\Xi_1'^{0}\to\Xi^{*-}K^+$	$2a_1/3\sqrt{2}$	$2b_5/\sqrt{2}$	0
B_{16}	$\Xi^{*0}K^0$	$-a_1/3\sqrt{2}$	$b_2/\sqrt{2}+b_3'/3\sqrt{2}+b_5/\sqrt{2}$	$-C_3/3\sqrt{2}+2C_4/3\sqrt{2}$
B_{17}	$\Sigma^{*-}\pi^+$	$2a_1/3\sqrt{2}$	$2b_5/\sqrt{2}$	0
B_{18}	$\Sigma^{*0}\pi^0$	$a_1/2\sqrt{2}$	$-b_2/2\sqrt{2}-b_3'/6\sqrt{2}+b_5/2\sqrt{2}$	$C_3/6\sqrt{2}-C_4/3\sqrt{2}$
B_{19}	$\Sigma^{*0}\eta$	$a_1/2\sqrt{6}$	$-b_2/2\sqrt{6}-b_3'/6\sqrt{6}+b_5/2\sqrt{6}$	$-C_3/2\sqrt{6}+C_4/\sqrt{6}$
B_{20}	$\Sigma^{*0}\eta'$	0	$b_2/2\sqrt{3}-b_3'/3\sqrt{3}+b_5/\sqrt{3}+b_4/2\sqrt{3}$	0
B_{21}	$\Sigma^{*+}\pi^-$	$a_1/3\sqrt{2}$	$b_2/\sqrt{2}+b_5/\sqrt{2}$	$-C_3/3\sqrt{2}+2C_4/3\sqrt{2}$
B_{22}	Δ^+K^-	$-a_1/3\sqrt{2}$	$b_2/\sqrt{2}+b_5/\sqrt{2}$	$C_3/3\sqrt{2}-2C_4/3\sqrt{2}$
B_{23}	$\Delta^0\bar{K}^0$	$-a_1/3\sqrt{2}$	$b_2/\sqrt{2}-b_3'/3\sqrt{2}+b_5/\sqrt{2}$	$C_3/3\sqrt{2}-2C_4/3\sqrt{2}$

$b_3'=b_3-b_4$

3.2. $B(3) \to D(6)\,P(9)$

	Decay	$H_w^{20'}$	H_w^{84}	H_w^{15}
B_{24}	$\Xi_2^+ \to \Xi_1^{*0}K^+$	$a_1/\sqrt{6} + a_2/\sqrt{6}$	$-b_1/\sqrt{6} + b_5/\sqrt{6}$	$C_2/\sqrt{6}$
B_{25}	$\Xi_1^{*+}K^0$	$-a_1/\sqrt{6}$	$-b_3/\sqrt{6} + b_5/\sqrt{6}$	$-C_3/\sqrt{6} + C_4/\sqrt{6}$
B_{26}	$\Sigma_1^{*0}\pi^+$	$a_1/\sqrt{3} - a_2/\sqrt{3}$	$b_1/\sqrt{3} + b_5/\sqrt{3}$	$C_2/\sqrt{3}$
B_{27}	$\Sigma_1^{*+}\pi^0$	$a_1/\sqrt{3} - a_2/2\sqrt{3}$	$-b_1/2\sqrt{3} - b_3/2\sqrt{3}$	$C_2/2\sqrt{3} + C_3/2\sqrt{3} - C_4/2\sqrt{3}$
B_{28}	$\Sigma_1^{*+}\eta$	$a_2/2$	$b_1/2 + b_3/6 + b_5/3$	$C_2/6 - C_3/6 + C_4/6$
B_{29}	$\Sigma_1^{*+}\eta'$	0	$b_2/2\sqrt{2} - b_3/3\sqrt{2} + 5b_4/6\sqrt{2} + b_5/3\sqrt{2}$	$C_1/2\sqrt{2} + C_2/6\sqrt{2} - C_3/6\sqrt{2} + 2C_4/3\sqrt{2}$
B_{30}	$\Sigma_1^{*++}\pi^-$	$-a_1/\sqrt{3}$	$b_5/\sqrt{3}$	$-C_3/\sqrt{3} + C_4/\sqrt{3}$
B_{31}	$\Xi_2^{++} \to \Xi_1^{*+}K^+$	$a_2/\sqrt{6}$	$-b_1/\sqrt{6} - b_3/\sqrt{6}$	$C_2/\sqrt{6} - C_3/\sqrt{6} + C_4/\sqrt{6}$
B_{32}	$\Sigma_1^{*+}\pi^+$	$-a_2/\sqrt{6}$	$b_1/\sqrt{6} + b_3/\sqrt{6}$	$C_2/\sqrt{6} - C_3/\sqrt{6} + C_4/\sqrt{6}$
B_{33}	$\Sigma_1^{*++}\pi^0$	$-a_2/\sqrt{6}$	$-b_1/\sqrt{6}$	$C_2/\sqrt{6} - C_3/\sqrt{6} + C_4/\sqrt{6}$
B_{34}	$\Sigma_1^{*++}\eta$	$a_2/\sqrt{2}$	$b_1/\sqrt{2}$	$C_2/3\sqrt{2} - C_3/3\sqrt{2} + C_4/3\sqrt{2}$
B_{35}	$\Sigma_1^{*++}\eta'$	0	0	$C_1/2 + C_2/6 - C_3/6 + 2C_4/3$
B_{36}	$\Omega_2^+ \to \Omega_1^{*0}K^+$	$-a_1/\sqrt{3} + a_2/\sqrt{3}$	$-b_1/\sqrt{3} - b_5/\sqrt{3}$	$C_2/\sqrt{3}$
B_{37}	$\Xi_1^{*0}\pi^+$	$-a_1/\sqrt{6} - a_2/\sqrt{6}$	$-b_1/\sqrt{6} - b_5/\sqrt{6}$	$C_2/\sqrt{6}$
B_{38}	$\Xi_1^{*+}\pi^0$	$-a_1/2\sqrt{3} - a_2/2\sqrt{3}$	$-b_1/2\sqrt{3} - b_5/2\sqrt{3}$	$C_2/2\sqrt{3}$
B_{39}	$\Xi_1^{*+}\eta$	$-a_1/2 + a_2/2$	$-b_1/6 + b_3/3 + b_5/6$	$C_2/6 + C_3/3 - C_4/3$
B_{40}	$\Xi_1^{*+}\eta'$	0	$b_2/2\sqrt{2} - b_3/3\sqrt{2} + 5b_4 6\sqrt{2} + b_5/3\sqrt{2}$	$C_1/2\sqrt{2} + C_2/6\sqrt{2} - C_3/6\sqrt{2} + 2C_4/3\sqrt{2}$
B_{41}	$\Sigma_1^{*++}K^-$	$a_1/\sqrt{3}$	$-b_5/\sqrt{3}$	$-C_3/\sqrt{3} + C_4/\sqrt{3}$
B_{42}	$\Sigma_1^{*+}\bar{K}^0$	$a_1/\sqrt{6}$	$b_3/\sqrt{6} - b_5\sqrt{6}$	$-C_3/\sqrt{6} + C_4/\sqrt{6}$

3.3 $B(3) \to D(10) + P(3^*)$

Decay			$H_w^{20''}$	H_w^{84}	H_w^{15}
B_{43}	$\Xi_2^+ \to$	$\Sigma^{*0}F^+$	0	$b_2/\sqrt{6} - b_4/\sqrt{6}$	$-C_4/\sqrt{6}$
B_{44}		$\Delta^0 D^+$	0	$b_2/\sqrt{3} + b_4/\sqrt{3}$	$-C_4/\sqrt{3}$
B_{45}		$\Delta^+ D^0$	0	$b_2/\sqrt{3}$	$-C_4/\sqrt{3}$
B_{46}	$\Xi_2^{++} \to$	$\Sigma^{*+}F^+$	0	$-b_4/\sqrt{3}$	$-C_4/\sqrt{3}$
B_{47}		$\Delta^+ D^+$	0	$b_4/\sqrt{3}$	$-C_4/\sqrt{3}$
B_{48}		$\Delta^{++} D^0$	0	0	$-C_4$
B_{49}	$\Omega_2^+ \to$	$\Xi^{*0}F^+$	0	$-b_2/\sqrt{3} - b_4/\sqrt{3}$	$-C_4/\sqrt{3}$
B_{50}		$\Sigma^{*0}D^+$	0	$-b_2/\sqrt{6} + b_4/\sqrt{6}$	$-C_4/\sqrt{6}$
B_{51}		$\Sigma^{*+}D^0$	0	$-b_2/\sqrt{3}$	$-C_4/\sqrt{3}$

$$0 = B_5 = B_6 \tag{10c}$$

$$B_9 = B_{10} = (\sqrt{2})\,(B_{17} - B_{18}) \tag{10d}$$

$$(1/\sqrt{3})\,B_{13} = B_{14} = B_{22} = B_{23} \tag{10e}$$

$$B_8 = B_{15} + B_{16} \tag{10f}$$

$$2B_{18} + B_{22} = B_{17} \tag{10g}$$

$$(\sqrt{2})\,B_{19} = B_{11} \tag{10h}$$

$$(\sqrt{2})\,B_{20} = B_{12} \tag{10i}$$

$$B_{24} + B_{25} = B_{31} \tag{10j}$$

$$B_{26} - 2B_{27} = B_{30} \tag{10k}$$

$$B_{26} - B_{27} = (1/\sqrt{2})\,B_{32} \tag{10l}$$

$$(\sqrt{2})\,B_{28} = B_{34} \tag{10m}$$

$$(\sqrt{2})\,B_{29} = B_{35} \tag{10n}$$

$$B_{32} = B_{33} \tag{10o}$$

$$B_{37} = (\sqrt{2})\,B_{38} \tag{10p}$$

$$B_{41} = (\sqrt{2})\,B_{42} \tag{10q}$$

$$(\sqrt{2})\,B_{43} = B_{46} \tag{10r}$$

$$B_{44} = B_{45} = B_{47} = (1/\sqrt{3})\,B_{48} \tag{10s}$$

$$(\sqrt{2})\,B_{50} = B_{51}. \tag{10t}$$

(b) SU(3) frame work

In SU(3), sextet dominance of weak Hamiltonian, in addition to (10), yields:

$$0 = B_{12} = B_{20} \tag{11a}$$

$$0 = B_{29} = B_{35} = B_{40} = B_{43} = B_{44} = B_{45} = B_{46} = B_{47} = B_{48}$$
$$= B_{49} = B_{50} = B_{51} \tag{11b}$$

$$(1/\sqrt{2})B_8 = B_9 = (1/\sqrt{3})B_{11} = (2/\sqrt{6})B_{19} = -(1/\sqrt{2})B_{14} = -(1/\sqrt{6})B_{13}$$
$$= -(1/\sqrt{2})B_{22} = -(1/\sqrt{2})B_{23} \tag{11c}$$

$$B_1 = (1/2)B_4 = -(1/\sqrt{2})B_{10} = (1/\sqrt{2})B_{21} \tag{11d}$$

$$(\sqrt{2})\ B_1 = B_8 \tag{11e}$$

$$B_{17} = B_{15} \tag{11f}$$

$$(\sqrt{3})\ B_{19} = B_{18} \tag{11g}$$

$$B_{32} = -B_{31} \tag{11h}$$

$$B_{34} = -(\sqrt{3})\ B_{33} \tag{11i}$$

$$B_{36} = -B_{26} \tag{11j}$$

$$B_{37} = -B_{24} \tag{11k}$$

$$B_{42} = -B_{25} \tag{11l}$$

$$B_{41} = -B_{30} \tag{11m}$$

$$(\sqrt{2})B_{38} = B_{37} \tag{11n}$$

$$(\sqrt{2})B_{25} = B_{30} \tag{11o}$$

$$-(2/\sqrt{6})\ B_{28} = B_{33} = B_{32} \tag{11p}$$

$$\sqrt{2}(B_{24} + B_{32}) = -B_{30} \tag{11q}$$

$$(2/\sqrt{3})B_{39} = -B_{26} = B_{30} - (\sqrt{2})\ B_{32}. \tag{11r}$$

Note that $B(3) \rightarrow D(10) + P(3^*)$ are forbidden. $\triangle C = -1$, $\triangle S = 0$ decays are Cabibbo suppressed and are related to $\triangle C = \triangle S = -1$ as:

$$B_4 = -2A_2 \tan\theta \tag{12a}$$

$$B_{32} = -A_{24} \tan\theta \tag{12b}$$

$$B_{30} = 2\ A_{19} \tan\theta. \tag{12c}$$

In the presence of H_w^{15} component in SU(3), relations (11f) to (11m) are valid. Other relations are modified to:

$$(\sqrt{2})B_1 + B_2 = -(1/2)B_3 + (1/\sqrt{3})B_7 + (3/\sqrt{2})B_9 \tag{13a}$$

$$(2\sqrt{2})B_4 = 2B_3 - (2/\sqrt{3})B_7 \tag{13b}$$

$$B_6 = (1/\sqrt{2})B_{20} = B_{12} \tag{13c}$$

$$(2\sqrt{2})B_{10} = B_3 + (\sqrt{2})B_9 \tag{13d}$$

$$B_8 + B_{14} = (3/2)B_3 + (1/\sqrt{3})B_7 - (1/\sqrt{2})B_9 \tag{13e}$$

$$B_2 + B_{14} = (2/\sqrt{3})B_7 \tag{13f}$$

$$(\sqrt{2})B_{19} - B_{11} = -(1/\sqrt{6})B_3 + (1/3\sqrt{2})B_7 - (1/\sqrt{3})B_9 + (3/2\sqrt{2})B_{17} \tag{13g}$$

$$B_{23} - B_{14} = B_{16} - B_2 = (1/2)B_3 + (1/\sqrt{2})B_9 - (1/2)B_{17} \tag{13h}$$

$$\sqrt{3}\,(B_{23} - B_{22}) = (\sqrt{3})B_{14} - B_{13} = \sqrt{6}(B_{10} - B_9) \tag{13i}$$

$$2B_{21} = B_3 + (2/\sqrt{3})B_7 + (\sqrt{2})B_9 - B_{17} \tag{13j}$$

$$B_{40} = -B_{29} \tag{13k}$$

$$-B_{37} = 2(B_{25} + B_{32}) \tag{13l}$$

$$(\sqrt{2})B_{43} - B_{46} = B_{45} = -B_{51} \tag{13m}$$

$$-B_{46} = B_{47} = B_{44} - B_{45} \tag{13n}$$

$$B_{48} = 0 \tag{13o}$$

$$B_{50} = -B_{43} \tag{13p}$$

$$B_{49} = -B_{44} \tag{13q}$$

$\triangle C = -1$, $\triangle S = 0$ decays are related to $\triangle C = \triangle S = -1$ as:

$$B_7 = -A_6 \tan\theta \tag{14a}$$

$$B_{17} = -2A_{11} \tan\theta \tag{14b}$$

$$(\sqrt{2})B_7 - B_3 = 2A_8 \tan\theta \tag{14c}$$

$$B_{45} = A_{30} \tan\theta \tag{14d}$$

$$B_{47} = A_{31} \tan\theta \tag{14e}$$

(c) *SU*(4) *symmetry*

20″ dominance maintains relations (10), (11) and (12) and gives

$$B_{30} = -(\sqrt{3})\, B_4. \tag{15}$$

Weak Hamiltonian (20″+84) obeys relations (11f to 11m), (13) and (14). In addition it gives:

$$(\sqrt{3})\, B_{45} = (1/\sqrt{2})B_3 + B_9 - (1/\sqrt{2})B_{17} \tag{16a}$$

$$B_{26} - (\sqrt{2})\,(B_{32} + B_{25}) = (3/\sqrt{6})B_{17} - (\sqrt{2})\, B_7 \tag{16b}$$

$$B_{30} = -\,(1/\sqrt{6})B_{17} + (2\sqrt{2}/3)B_7 \tag{16c}$$

$$(\sqrt{2})\, B_{25} - B_{30} = (3/\sqrt{6})B_3 - (\sqrt{3})\, B_9. \tag{16d}$$

Relations (10) to (16) are valid for both the pv and pc decays. *CP* invariance with 20″ dominance relates these decay with Ω^- decays as:

$$B_4 = \pm\, (1/\sqrt{6})\, \Omega^{-}_{K} \tag{17a}$$

$$(\sqrt{6})\, B_{32} = \pm\, \Omega^{-}_{-} \tag{17b}$$

where + and − sign stand for pc and pv modes respectively.

4.3. $B(1/2^+) \rightarrow D(3/2^+) + \gamma$ *decays*

We have discussed the charm changing weak radiative decays of the type $B(1/2^+) \rightarrow B(1/2^+)+\gamma$ elsewhere (Verma *et al* 1977). The decays $B(1/2^+) \rightarrow D(3/2^+)+\gamma$ can be calculated from the weak Hamiltonian (2) but in this case $P_b{}^a$ should be replaced by photon transforming as $15 \oplus 1$. It is to be noted that singlet component of photon gives null contribution here. Moreover, the second term (2b) of weak Hamiltonian does not contribute to these decays. We obtain the following relation for Cabibbo-enhanced mode ($\triangle C = \triangle S$).

$$M\,(\Lambda_1{}'^{+} \rightarrow \Sigma^{*+}\, \gamma) = M\,(\Xi'^{0}{}_1 \rightarrow \Xi^{*0}\, \gamma) = (1/\sqrt{3})\, M\,(\Xi_2{}^{+} \rightarrow \Xi_1{}^{*+}\, \gamma). \tag{18}$$

Relation is valid for both the pc and pv modes, since Hamiltonian (2) is independent of the behaviour of Hamiltonian under charge conjugation. It only relates these decay with $D(3/2^+) \rightarrow B(1/2^+)+\gamma$, out of which $\Omega^- \rightarrow \Xi^- + \gamma$ is observable. But the decay $\Omega^- \rightarrow \Xi^- \gamma$ obtains contribution only from (2b) part of weak Hamiltonian.

4.4. $\Omega_3{}^{*++}$ *decays*

Most of the charmed isobars may decay through strong and or electromagnetic interactions. Only $\Omega_3{}^{*++}$ (C=3) singlet is expected to decay via weak interaction

Table 4. Ω_3^{*++} decays ($\triangle C = \triangle S = -1$ mode)

Decay product	$H_w^{20''}$	H_w^{84}
A_{33} $\Xi_1^+D^+$	0	$-(\sqrt{2})b_5$
A_{34} $\Xi_1'^+D^+$	$-2/\sqrt{6}\,a_1$	0
A_{35} $\Xi_2^{++}\overline{K^0}$	a_2	b_1
A_{36} $\Omega_2^+\pi^+$	a_2	b_1

Table 5. Ω_3^{*++} decays ($\triangle C = -1$, $\triangle S = 0$ mode)

Decay product	$H_w^{20''}$	H_w^{84}	H_w^{15}
B_{52} $\Xi_1^+F^+$	0	$-(\sqrt{2})\,b_5$	$C_5/\sqrt{2}$
B_{53} $\Sigma_1^+D^+$	0	$(\sqrt{2})\,b_5$	$C_5/\sqrt{2}$
B_{54} $\Sigma_1^{++}D^0$	0	0	$-C_5$
B_{55} $\Xi_1'^+F^+$	$-2a_1/\sqrt{6}$	0	$-C_5/\sqrt{6}$
B_{56} $\Lambda_1'^+D^+$	$-2a_1/\sqrt{6}$	0	$C_5/\sqrt{6}$
B_{57} $\Omega_2^+K^+$	$-a_2$	b_1	C_1
B_{58} $\Xi_2^+\pi^+$	a_2	$-b_1$	C_1
B_{59} $\Xi_2^{++}\pi^0$	$a_2/\sqrt{2}$	$b_1/\sqrt{2}$	$C_1/\sqrt{2}$
B_{60} $\Xi_2^{++}\eta$	$-2a_2/\sqrt{6}$	$-3b_1/\sqrt{6}$	$C_1/\sqrt{6}$
B_{61} $\Xi_2^{++}\eta'$	0	0	$1/(2\sqrt{2})(C_1 - 3C_2 - 3C_3)$

through the channel $D(1) \rightarrow B(6)/B(3^*)+P(3^*)$ and $B(3)+P(9)$. Sextet dominance forbids $D(1) \rightarrow B(6)+P(3^*)$ processes. Various amplitudes are given in tables 4 and 5.

(a) $\triangle C=\triangle S=-1$ *decays*

Here $\triangle I=1$ selection rule gives no relation. Sextet dominance leads to:

$$A_{33} = 0 \tag{19a}$$

$$A_{35} = A_{36} \tag{19b}$$

(b) $\triangle C=-1$, $\triangle S=0$ *decays*

$\triangle I=1/2$ selection rule gives:

$$-(\sqrt{2})\,B_{53} = B_{54} \tag{20a}$$

$$B_{55} = B_{56} \tag{20b}$$

$$(\sqrt{2})\,B_{59} = B_{58} \tag{20c}$$

Sextet dominance further gives:

$$0 = B_{52} = B_{53} = B_{54} = B_{61} \tag{21a}$$

$$-B_{57} = B_{58} = (\sqrt{2})\,B_{59} = -\sqrt{3/2}\,B_{60} \tag{21b}$$

$$B_{58} = -A_{36}\tan\theta \tag{21c}$$

$$B_{56} = -A_{34}\tan\theta \tag{21d}$$

$H_w^{6^*+15}$ maintains (20b) and (21d). In addition it yields:

$$0 = B_{54} = B_{61} \tag{22a}$$

$$B_{52} = B_{53} \tag{22b}$$

$$(2\surd 6)\, B_{60} = -\, (5\surd 2)\, B_{59} + B_{58} \tag{22c}$$

$$B_{53} = A_{33} \tan\theta \tag{22d}$$

$$(\surd 2)\, B_{59} = -\, A_3 \tan\theta_6 \tag{22e}$$

SU(4) with 20″ dominance, in addition to (19), (20) and (21) gives:

$$A_{36} = \Omega^-_{-} \cot\theta \tag{23a}$$

$$A_{34} = \Omega^-_{K} \cot\theta. \tag{23b}$$

Relations (19) to (23) are valid for both the pv and pc modes.

5. $SU(8)_W$ Considerations

Since ordinary SU(8) is valid only in the static limit, we employ $SU(8)_w$ symmetry (Horn *et al* 1965; Carter *et al* 1965; Lipkin and Meshkov 1965) to discuss these decays. Here GIM weak Hamiltonian transforms like 720 and 1232 representations. Weak Hamiltonian is described in detail in Verma and Khanna (1977a and b). In $SU(4)\times SU(2)_w$ structure it can immediately be seen that pc Hamiltonian transforms as (20″, 1) and (84,1) components of 720 and 1232 representations and pv Hamiltonian as (20″, 3) and (84, 3) components.

If 720 dominance is assumed (as an extension of 20″ dominance in SU(4)), all the pv decays of charmed and uncharmed baryons are forbidden. In the pc mode $B(3^*) \to D(10)+P(9)$; $B(3) \to D(10)+P(3^*)$ and $B(1/2^+) \to D(3/2^+)+\gamma$ and $\Omega^- \to \Lambda K^-$ modes are not allowed. But $\Omega^- \to \Lambda K^-$ is an observed decay hence 1232 part of weak Hamiltonian must be included as in the case of nonleptonic decays $1/2^+ \to 1/2^+ + 0^-$ (Verma and Khanna 1977a). Now if 20″ dominance is assumed at the SU(4) sublevel of $SU(8)_w$ all the results obtained in SU(4) are reproduced. PV decays $B\,(1/2^+) \to D(3/2^+)+P(0^-)$ still remain forbidden since 1232 does not contain (20″,3) component. Total GIM weak Hamiltonian (including 84 at SU(4) level) yields (4), (5b), (6), (8), (11f) to (11m), (13), (16) and (22). In addition we obtain:

(i) *pc decays*

$$A_6 = -\, (\surd 3) A_{11} \tag{24a}$$

$$B_{17} = -\, (2/\surd 3) B_7 \tag{24b}$$

$$(\surd 2) B_{25} - B_{26} = \surd 2[(\surd 2) B_{30} - B_{32}] \tag{24c}$$

$$0 = A_{33} = B_{52} = B_{53} = B_{54} \tag{24d}$$

(ii) *pv decays*

$$A_6 = (\sqrt{3})A_{11} \tag{24e}$$

$$B_{17} = (2/\sqrt{3})B_7 = B_8 - (\sqrt{2})B_9 \tag{24f}$$

$$B_{26} = B_{30} = (\sqrt{2})(B_{25} + B_{32}) \tag{24g}$$

$$0 = B_{33} = B_{34} = B_{45} = B_{48} = B_{51}. \tag{24h}$$

We notice that Ω^- decays and $\Omega_3^{*++} \to B(3) + P(9)$ and $B(3^*) + P(3^*)$ are forbidden in pv mode, $\Omega_3^{*++} \to B(6) + P(3^*)$ decays vanish in pc mode. Thus assymmetry parameters for Ω^- modes (Ω_-^-, Ω_0^- and Ω_k^-) vanish.

6. Adjoint representation admixture to weak decays

We have considered elsewhere (Verma and Khanna 1977c) adjoint representation admixture to weak Hamiltonian in SU(4) and SU(8) for $B(1/2^+) \to B(1/2^+) + P(0^-)$ decays. This admixture may be expected to arise from the large symmetry breaking even in the case of GIM model (Shin-Mura 1976 Igarashi and Shin Mura 1977) 15-admixture in SU(4) has also been proposed in the models of weak interactions (Branco *et al* 1976; Bajaj and Kapoor 1977).

In SU(4), 15-weak Hamiltonian can be written as

$$\begin{aligned} H_w^{15} &= \tfrac{1}{2}C_1 \quad \epsilon_{admn} \quad D^{abc} \quad B_b^{[m,n]} \quad P_f^d \quad H_c^f \\ &+ \tfrac{1}{2}C_2 \quad \epsilon_{afmn} \quad D^{abe} \quad B_b^{[m,n]} \quad P_e^c \quad H_c^f \\ &+ \tfrac{1}{2}C_3 \quad \epsilon_{efmn} \quad D^{abc} \quad B_a^{[m,n]} \quad P_b^e \quad H_c^f \\ &+ \tfrac{1}{2}C_4 \quad \epsilon_{abmn} \quad D^{aec} \quad B_f^{[m,n]} \quad P_e^b \quad H_c^f. \end{aligned} \tag{25}$$

H_w^{15} does not contain $\triangle C = \pm \triangle S$ decays and so $\triangle C = -1$, $\triangle S=0$ mode gets enhanced. H_w^{15} obeys the $\triangle I=1/2$ selection rule, hence the relations (10) and (20) are maintained. At the SU(3) level weak Hamiltonian transforms like triplet component of H_w^{15}. Neglecting 15 component at the SU(3) level, $H_w^{3+6^*}$ obeys (11a), (11c), (11d) and (11f). In addition we get:

$$B_{35} = (\sqrt{2})B_{29} = (\sqrt{2})B_{40} \tag{26a}$$

$$B_{25} = B_{32} - (1/\sqrt{2})B_{26} \tag{26b}$$

$$(\sqrt{6})B_{28} = 2B_{31} - B_{32} \tag{26c}$$

$$B_{31} - B_{32} = B_{36} - B_{37} \tag{26d}$$

$$B_{41} = -(\sqrt{2})B_{37} + (\sqrt{2})B_{32}. \tag{26e}$$

The $B(3) \to D(10) + P(3^*)$ and $\Omega_3^{*++} \to B(6) + P(3^*)$, forbidden by sextet dominance, now arise through triplet component and obey:

$$(\sqrt{2}) B_{43} = B_{44} = B_{45} = B_{46} = B_{47} = (1/\sqrt{3}) B_{48} = B_{49}$$

$$= (\sqrt{2}) B_{50} = B_{51} \tag{27a}$$

$$B_{53} = B_{52} \tag{27b}$$

$$3B_{57} - B_{58} = (2\sqrt{6}) B_{60}. \tag{27c}$$

In SU(4) symmetry $H_w^{15+20''}$, in addition to SU(3) results gives:

$$B_{26} - (\sqrt{2})\, B_{37} = \sqrt{6}\,(B_3 + \sqrt{2}\, B_9) \tag{28a}$$

$$B_{57} = \Omega_-^-. \tag{28b}$$

All these relations (26) to (28) are valid for pv and pc modes. Most general Hamiltonian $H_w^{15+20''+84}$ does not lead to any useful relations:

In $SU(8)_w$ symmetry, 15-admixture is extended to 63 admixture (Verma and Khanna 1977c). Neglecting 84 component at the SU(4) sublevel, SU(8) weak Hamiltonian $(63 + 720 + 1232)$ gives (11a), (11c), (11d), (11f), (26), (27) and (28). In addition it yields:

(i) *pc decays*

$$B_{48} = B_{54} = 3\,[(1/\sqrt{2})\, B_3 - B_9] = (\sqrt{3}/2)\,(B_{26} + (\sqrt{2})\, B_{37} - 2\sqrt{2}\, B_{32}) \tag{29a}$$

$$\sqrt{6}\,(B_{32} - B_{31}) = 2\Omega_-^- \tag{29b}$$

$$\sqrt{3}\,(B_3 + (3\sqrt{2})\, B_9) = 2\Omega_K^-. \tag{29c}$$

(ii) *pv decays*

Decays of the type $B(3^*) \to D(10) + P(9)$ and $B(3) \to D(10) + P(3^*)$ are forbidden and can arise only through 84 component of 1232 Hamiltonian. $B(3) \to D(6) + P(9)$ decays are expressed in terms of one parameter obeying:

$$0 = \Omega_K^- = B_{25} = B_{30} = B_{41} = B_{42} \tag{30a}$$

$$- \Omega_-^- = (\sqrt{2})\, B_{24} = B_{26} = 2B_{27} = (2\sqrt{3})\, B_{28} = (4/\sqrt{6}) B_{29}$$

$$= (\sqrt{2})\, B_{31} = (\sqrt{2})\, B_{32} = (\sqrt{2})\, B_{33} = (\sqrt{6})\, B_{34} = (2\sqrt{3})\, B_{35}$$

$$= B_{36} = (\sqrt{2})\, B_{37} = 2B_{38} = (2\sqrt{3})\, B_{39} = (2\sqrt{6})\, B_{40}. \tag{30b}$$

It may be noted that most general $SU(8)_w$ Hamiltonian (including 84 at the SU(4) level) forbids $\Omega^- \to \Lambda K^-$ decay in pv mode. The parity violating $\Omega^- \to \Xi\pi$ decays can occur only through the 63 admixture. Hence $SU(8)_w$ symmetry alone predicts asymmetry parameter $\alpha(\Omega^- \to \Lambda K^-)$ to be zero. It is to be compared with the experimental value (Kocher and Wernhard 1974).

$$\alpha(\Omega^- \to \Lambda K^-) = 0{\cdot}66^{+0{\cdot}36}_{-0{\cdot}30} \quad \text{from 15 events.}$$

7. Summary and conclusions

In this paper we have discussed weak decay modes of $J^p = 1/2^+$ baryons other than the modes $B(1/2^+) \to B(1/2^+) + P(0^-)/\gamma$. Mass spectrum of charmed baryons suggests that the charm changing decays $B(1/2^+) \to D(3/2^+) + P(0^-)/\gamma$ are allowed energetically. The charm changing decays of $1/2^+$ baryons to $3/2^+$ isobars are interesting to study as they involve a large number of decay products which can be observed experimentally. Only parity conserving decays (p-wave) will be important, because parity violating (d-wave) decays are expected to be suppressed due to centrifugal barrier. Assuming GIM model of weak Hamiltonian we obtain several relations among the amplitudes of $B(3^*) \to D(10) + P(9)$; $B(3) \to D(6) + P(9)$ and $B(3) \to D(10) + P(3^*)$ decays in the SU(2), SU(3) and SU(4) frameworks. Full $H_w^{\Delta C = \Delta S}$ obey $\Delta I = 1$ selection rule, $H_w^{\Delta C = -1, \Delta S = 0}$ contains both $\Delta I = 1/2$ and $3/2$ pieces and $\Delta I = 1/2$ dominance is assumed. At SU(3) level, sextet dominance forbids $B(3) \to D(10) + P(3^*)$ decays. SU(4) symmetry relates different decay modes of $B(3)$ and $B(3^*)$ multiplets. *CP* invariance with 20″ dominance completely specify all these decays in terms of Ω^- decay amplitudes. We have considered the 15-admixture to weak Hamiltonian. This enhances the $\Delta C = -1$, $\Delta S = 0$ decays and satisfy $\Delta I = 1/2$ rule. We have also studied these charm changing processes in $SU(8)_w$ considerations. We observe that in the GIM model 720 dominance forbids all the pv decays, hence both the 720 and 1232 representations should be included in the weak Hamiltonian. Since the experimental data regarding the charmed baryons and their decays are meagre we are at present unable to decide about the structure of weak Hamiltonian.

Note added in Proof

Recently in a CERN experiment, (Gaillard 1978) the assymetry parameter for $\Omega^- \to \Lambda K^-$ decay is observed to be $\alpha(\Omega_K^-)_\Lambda = 0{\cdot}06 \pm 0{\cdot}14$, which is consistent with zero, the value predicted by $SU(8)_w$ symmetry.

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List of Symbols

SU(4) *Tensors*

$B_a^{[m,n]}$	20′ multiplet of $1/2^+$ baryons
D_{abc}	20 multiplet of $3/2^+$ baryons
P_b^a	15 multiplet of 0^- mesons

$H_b{}^a$	15 component of weak Hamiltonian
$H_{[c,d]}^{[a,b]}$	20″ component of weak Hamiltonian
$H_{(c,d)}^{(a,b)}$	84 component of weak Hamiltonian
ϵ_{abmn}	Levi-Civita symbol for SU(4)
$\Omega_-{}^-$	decay amplitude for the decay $\Omega^- \to \Xi^0\pi^-$
$\Omega_K{}^-$	decay amplitude for the decay $\Omega^- \to \Lambda K^-$

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