

### 33. SU(3) ISOSCALAR FACTORS AND REPRESENTATION MATRICES

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The most commonly used SU(3) isoscalar factors, corresponding to the singlet, octet, and decuplet content of  $8 \otimes 8$  and  $10 \otimes 8$ , are shown at the right. The notation uses particle names to identify the coefficients, so that the pattern of relative couplings may be seen at a glance. We illustrate the use of the coefficients below. See J.J. de Swart, Rev. Mod. Phys. **35**, 916 (1963) for detailed explanations and phase conventions.

A  $\sqrt{\phantom{x}}$  is to be understood over every integer in the matrices; the exponent 1/2 on each matrix is a reminder of this. For example, the  $\Xi \rightarrow \Omega K$  element of the  $10 \rightarrow 10 \otimes 8$  matrix is  $-\sqrt{6}/\sqrt{24} = -1/2$ .

Intramultiplet relative decay strengths may be read directly from the matrices. For example, in decuplet  $\rightarrow$  octet + octet decays, the ratio of  $\Omega^* \rightarrow \Xi \bar{K}$  and  $\Delta \rightarrow N\pi$  partial widths is, from the  $10 \rightarrow 8 \times 8$  matrix,

$$\frac{\Gamma(\Omega^* \rightarrow \Xi \bar{K})}{\Gamma(\Delta \rightarrow N\pi)} = \frac{12}{6} \times (\text{phase space factors}). \quad (33.1)$$

Including isospin Clebsch-Gordan coefficients, we obtain, e.g.,

$$\frac{\Gamma(\Omega^{*-} \rightarrow \Xi^0 K^-)}{\Gamma(\Delta^+ \rightarrow p\pi^0)} = \frac{1/2}{2/3} \times \frac{12}{6} \times p.s.f. = \frac{3}{2} \times p.s.f. \quad (33.2)$$

Partial widths for  $8 \rightarrow 8 \otimes 8$  involve a linear superposition of  $8_1$  (symmetric) and  $8_2$  (antisymmetric) couplings. For example,

$$\Gamma(\Xi^* \rightarrow \Xi\pi) \sim \left( -\sqrt{\frac{9}{20}} g_1 + \sqrt{\frac{3}{12}} g_2 \right)^2. \quad (33.3)$$

The relations between  $g_1$  and  $g_2$  (with de Swart's normalization) and the standard  $D$  and  $F$  couplings that appear in the interaction Lagrangian,

$$\mathcal{L} = -\sqrt{2} D \text{Tr}(\{\bar{B}, B\}M) + \sqrt{2} F \text{Tr}([\bar{B}, B]M), \quad (33.4)$$

where  $[\bar{B}, B] \equiv \bar{B}B - B\bar{B}$  and  $\{\bar{B}, B\} \equiv \bar{B}B + B\bar{B}$ , are

$$D = \frac{\sqrt{30}}{40} g_1, \quad F = \frac{\sqrt{6}}{24} g_2. \quad (33.5)$$

Thus, for example,

$$\Gamma(\Xi^* \rightarrow \Xi\pi) \sim (F - D)^2 \sim (1 - 2\alpha)^2, \quad (33.6)$$

where  $\alpha \equiv F/(D + F)$ . (This definition of  $\alpha$  is de Swart's. The alternative  $D/(D + F)$ , due to Gell-Mann, is also used.)

The generators of SU(3) transformations,  $\lambda_a$  ( $a = 1, 8$ ), are  $3 \times 3$  matrices that obey the following commutation and anticommutation relationships:

$$[\lambda_a, \lambda_b] \equiv \lambda_a \lambda_b - \lambda_b \lambda_a = 2i f_{abc} \lambda_c \quad (33.7)$$

$$\{\lambda_a, \lambda_b\} \equiv \lambda_a \lambda_b + \lambda_b \lambda_a = \frac{4}{3} \delta_{ab} I + 2d_{abc} \lambda_c, \quad (33.8)$$

where  $I$  is the  $3 \times 3$  identity matrix, and  $\delta_{ab}$  is the Kronecker delta symbol. The  $f_{abc}$  are odd under the permutation of any pair of indices, while the  $d_{abc}$  are even. The nonzero values are

$1 \rightarrow 8 \otimes 8$

$$(A) \rightarrow (N\bar{K} \ \Sigma\pi \ \Lambda\eta \ \Xi K) = \frac{1}{\sqrt{8}} (2 \ 3 \ -1 \ -2)^{1/2}$$

$8_1 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix} \rightarrow \begin{pmatrix} N\pi & N\eta & \Sigma K & \Lambda K \\ N\bar{K} & \Sigma\pi & \Lambda\pi & \Sigma\eta & \Xi K \\ N\bar{K} & \Sigma\pi & \Lambda\eta & \Xi K \\ \Sigma\bar{K} & \Lambda\bar{K} & \Xi\pi & \Xi\eta \end{pmatrix} = \frac{1}{\sqrt{20}} \begin{pmatrix} 9 & -1 & -9 & -1 \\ -6 & 0 & 4 & 4 & -6 \\ 2 & -12 & -4 & -2 \\ 9 & -1 & -9 & -1 \end{pmatrix}^{1/2}$$

$8_2 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix} \rightarrow \begin{pmatrix} N\pi & N\eta & \Sigma K & \Lambda K \\ N\bar{K} & \Sigma\pi & \Lambda\pi & \Sigma\eta & \Xi K \\ N\bar{K} & \Sigma\pi & \Lambda\eta & \Xi K \\ \Sigma\bar{K} & \Lambda\bar{K} & \Xi\pi & \Xi\eta \end{pmatrix} = \frac{1}{\sqrt{12}} \begin{pmatrix} 3 & 3 & 3 & -3 \\ 2 & 8 & 0 & 0 & -2 \\ 6 & 0 & 0 & 6 \\ 3 & 3 & 3 & -3 \end{pmatrix}^{1/2}$$

$10 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{pmatrix} \rightarrow \begin{pmatrix} N\pi & \Sigma K \\ N\bar{K} & \Sigma\pi & \Lambda\pi & \Sigma\eta & \Xi K \\ \Sigma\bar{K} & \Lambda\bar{K} & \Xi\pi & \Xi\eta \\ \Xi\bar{K} \end{pmatrix} = \frac{1}{\sqrt{12}} \begin{pmatrix} -6 & 6 \\ -2 & 2 & -3 & 3 & 2 \\ 3 & -3 & 3 & 3 \\ 12 \end{pmatrix}^{1/2}$$

$8 \rightarrow 10 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix} \rightarrow \begin{pmatrix} \Delta\pi & \Sigma K \\ \Delta\bar{K} & \Sigma\pi & \Sigma\eta & \Xi K \\ \Sigma\pi & \Xi K \\ \Sigma\bar{K} & \Xi\pi & \Xi\eta & \Omega K \end{pmatrix} = \frac{1}{\sqrt{15}} \begin{pmatrix} -12 & 3 \\ 8 & -2 & 3 & 2 \\ -9 & 6 \\ 3 & -3 & -3 & 6 \end{pmatrix}^{1/2}$$

$10 \rightarrow 10 \otimes 8$

$$\begin{pmatrix} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{pmatrix} \rightarrow \begin{pmatrix} \Delta\pi & \Delta\eta & \Sigma K \\ \Delta\bar{K} & \Sigma\pi & \Sigma\eta & \Xi K \\ \Sigma\bar{K} & \Xi\pi & \Xi\eta & \Omega K \\ \Xi\bar{K} & \Omega\eta \end{pmatrix} = \frac{1}{\sqrt{24}} \begin{pmatrix} 15 & 3 & -6 \\ 8 & 8 & 0 & -8 \\ 12 & 3 & -3 & -6 \\ 12 & -12 \end{pmatrix}^{1/2}$$

$abc$	$f_{abc}$	$abc$	$d_{abc}$	$abc$	$d_{abc}$
123	1	118	$1/\sqrt{3}$	355	1/2
147	1/2	146	1/2	366	-1/2
156	-1/2	157	1/2	377	-1/2
246	1/2	228	$1/\sqrt{3}$	448	$-1/(2\sqrt{3})$
257	1/2	247	-1/2	558	$-1/(2\sqrt{3})$
345	1/2	256	1/2	668	$-1/(2\sqrt{3})$
367	-1/2	338	$1/\sqrt{3}$	778	$-1/(2\sqrt{3})$
458	$\sqrt{3}/2$	344	1/2	888	$-1/\sqrt{3}$
678	$\sqrt{3}/2$				

The  $\lambda_a$ 's are

$$\lambda_1 = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad \lambda_2 = \begin{pmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad \lambda_3 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\lambda_4 = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix} \quad \lambda_5 = \begin{pmatrix} 0 & 0 & -i \\ 0 & 0 & 0 \\ i & 0 & 0 \end{pmatrix} \quad \lambda_6 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

$$\lambda_7 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{pmatrix} \quad \lambda_8 = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -2 \end{pmatrix}$$

Equation (33.7) defines the Lie algebra of SU(3). A general  $d$ -dimensional representation is given by a set of  $d \times d$  matrices satisfying Eq. (33.7) with the  $f_{abc}$  given above. Equation (33.8) is specific to the defining 3-dimensional representation.