ELECTROMAGNETIC MASS SPLITTINGS AND THE BARYON OCTET MASS FORMULA

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A B S T R A C T

It is shown that in order to take into account the electromagnetic mass shifts of the baryons in testing the baryon octet mass formula, the mean mass of each baryon isospin multiplet may be used.

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One of the most impressive predictions of the approximate SU_3 symmetry of strong interactions is the Gell-Mann-Okubo formula [1),2)] relating the masses of particles within an SU_3 multiplet. In particular, the baryon octet mass formula is valid to the same order as the observed electromagnetic splittings in each isotopic spin multiplet. This raises the problem of how to test correctly the accuracy of this formula, because it is obtained in terms of baryon masses without including the electromagnetic contributions. Let us define a characteristic deviation δm to the baryon octet mass formulae by

$$\delta m \equiv N + \Xi - 1/2(3\Lambda + \Sigma) \tag{1}$$

where N, Ξ, Λ and Σ are the masses of the corresponding baryons when the electromagnetic interactions are switched off. We shall derive below two relations, Eqs. (3) and (4), for δm in terms of baryon masses which include the electromagnetic shifts obtained in the limit of exact SU_3 symmetry. The accuracy of the Coleman-Glashow relation [3)] for the electromagnetic mass splittings among the baryon isospin multiplets justifies the substitution of the <u>observed</u> baryon masses in relations (3) or (4) to obtain δm.

Since the electromagnetic interaction transforms like a scalar under U-spin [4)], the electromagnetic mass shifts δB of the baryons in a U-spin multiplet are all equal in the limit of exact SU_3 symmetry. Furthermore, there is no electromagnetic mixing among states with the same charge but different U-spin. Setting $Y_o = \frac{\sqrt{3}}{2}\Lambda + 1/2\,\Sigma^o$ and $Z^o = 1/2\,\Lambda - \frac{\sqrt{3}}{2}\Sigma^o$ for the $U = 1,\ U_3 = 0$ and $U = 0,\ U_3 = 0$ states respectively, we have [3),5)]

$$\delta \Sigma^+ = \delta P$$

$$\delta \Sigma^- = \delta \Xi^-$$

$$\delta Y^0 = \frac{\sqrt{3}}{2} (\Sigma|\delta|\Lambda) + \frac{1}{4}(3\delta\Lambda + \delta\Sigma^0) = \delta N = \delta \Xi^0$$

$$(Y^0|\delta|Z^0) = -\frac{1}{2}(\Sigma|\delta|\Lambda) + \frac{\sqrt{3}}{4}(\delta\Lambda - \delta\Sigma^0) = 0$$

(2)

where $(\Sigma|\delta|\Lambda)$ denotes the Σ-Λ electromagnetic mass mixing [6]. If we set $B^q = B + \delta B^q$ for the corresponding baryon mass, where B is the mass without electromagnetic interaction, and the superscript q is the charge, we obtain by combining Eqs. (1) and (2).

$$\delta m = \Sigma^0 - \Sigma^+ + P^+ + \Xi^0 - \frac{1}{2}(3\Lambda^0 + \Sigma^0) \qquad (3)$$

or alternatively

$$\delta m = \frac{1}{2}(P^+ + N^0) + \frac{1}{2}(\Xi^- + \Xi^0) - \frac{1}{2}(3\Lambda^0 + \Sigma^+ + \Sigma^- - \Sigma^0) \qquad (4)$$

Substituting the observed mean baryon masses [7], we find $\delta m = -12.4$ MeV and -12.9 from Eqs. (3) and (4) respectively [8]. Note that Eq. (4) is nearly equivalent to substituting the mean mass of each isospin baryon multiplet in Eq. (1) because the Σ hyperon mass relation

$$\Sigma^0 = \frac{1}{2}(\Sigma^+ + \Sigma^-) \qquad (5)$$

is very well satisfied. However, Eq. (5) cannot be derived on symmetry arguments alone [9].

Similar considerations can be applied to include the effect of the electromagnetic interaction in the GMO mass formula for other multiplets of SU_3. For triangular representations (for example the decuplet of baryon resonances) the equal mass spacing rule should simply be applied to states with the same electric charge.

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6) R.H. Dalitz and F. von Hippel (Oxford preprint) have discussed the evidence for the $\Sigma\Lambda$ electromagnetic mixing.

7) We have used baryon mass values given by M. Roos, Phys. Letters 8, 1 (1964).

8) S. Okubo (Rochester preprint) has concluded that the baryon octet mass formula ought to be tested among the neutral members of the octet, in disagreement with our result.

9) A very crude argument for this relation is obtained from the two triplet bound state model of the baryons : J. Schwinger, Phys. Rev. Letters 12, 237 (1963), F. Gursey, T.D. Lee and M. Nauenberg, Phys. Rev. (to be published). Let the $I = 1/2$ component of the fundamental fermion triplet have electromagnetic mass shifts δm_1 and δm_2 for $I_3 = 1/2$ and $-1/2$ respectively, and correspondingly $\delta\mu_1$ and $\delta\mu_2$ for the boson triplet. If we assume that the baryon electromagnetic mass shifts are simply the sum of the shifts of their components (justified in the case of weak binding) we obtain $\delta\Sigma^+ = \delta m_1 + \delta\mu_2$, $\delta\Sigma^- = \delta m_2 + \delta\mu_1$ and $\delta\Sigma^0 = 1/2(\delta m_1 + \delta m_2 + \delta\mu_1 + \delta\mu_2)$ leading to Eq. (5). The relations given in Eq. (2) are also readily obtained in this manner, if we note that the electromagnetic mass shift δm_0 and $\delta\mu_0$ of the $I = 0$ member of the fermion and boson triplets satisfies the condition $\delta m_0 = \delta m_2$ and $\delta\mu_0 = \delta\mu_2$ respectively. A similar argument has been proposed by G. Zweig (CERN preprint).