Progress of Theoretical Physics, Vol. 48, No. 3, September 1972

A Two-Body Baryon Model

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(Received February 28, 1972)

Baryons and mesons are constructed on the assumption that their constituent particles are the $\frac{1}{2}^+$ triplet and the 1^+ sextet. Our model is a modification of the quark-diquark model of Lichtenberg, and improves on the quark model in the following points: (1) Constituent particles need not obey para-statistics but only the normal spin-statistics relation. (2) In the quark model there is the dynamical difficulty that Q, QQ, $QQQQ$, $\cdots$ are so heavy that they cannot be observed while QQQ, $Q\bar{Q}$ are so light. Our model does not have such difficulties. (3) Even in the para-quark model we must consider why only $SU(6)$ symmetric states are observed. In our model we need not consider the symmetry of the wave function.

Following our model we have tried to classify and assign the baryon resonances. The strong decay rates of the baryon resonances are also calculated.

§ 1. Introduction

After the successes of $SU(3)$, Gell-Mann[1] and Zweig[2] proposed the quark model which achieved considerable success in hadron physics.[3),4)] But many serious difficulties remained in the quark model. The quarks themselves have not been observed in spite of great efforts by many experimentalists.[5] It is said that the quarks are so heavy that we cannot produce them by present accelerators. In the same way states composed of QQ, $QQQQ$, $QQ\bar{Q}$, $\cdots$ are not observed also, thus these states must also have masses more than, say, several GeV. On the other hand the mass of the π-meson constructed as $Q\bar{Q}$ is only 0.14 GeV and the nucleon made of QQQ is only 0.94 GeV. The quarks in spite of their spin $\frac{1}{2}$ do not obey Fermi statistics but obey parastatistics. To make matters worse, parastatistics alone is not sufficient to make only the $SU(6)$ symmetric states and to eliminate the mixed and antisymmetric states. We must make the assumption that the latter are of very high energies.[6]

Several years ago, Lichtenberg et al.[7)~12)] proposed a two-body baryon model composed of the triplet fermions and the sextet mesons (later they added the triplet mesons to make an $SU(6)$ multiplet) and computed magnetic moments, and electromagnetic mass differences of hadrons. But in their model, almost the same difficulties as in the quark model are involved. Let us modify their model to avoid their difficulties.

We assume that baryons are composite systems of the triplet $\frac{1}{2}^+$ fermions Q and the sextet axial vector bosons Q' and that mesons are $Q\bar{Q}$ systems. The basic assumptions of this model are stated in § 2. In § 3 energy spectrum predicted from our model are presented and the known baryon resonances are assigned in this scheme. Further the properties of spin-spin forces and the spin-orbit forces are discussed. In § 4 the strong decay rates of baryons are calculated using the static approximation. Agreement with experiment is satisfactory.

§ 2. Basic assumptions

Let us introduce an $SU(3)$ triplet (Q) and a sexet (Q') and their quantum numbers are:

Table I.

triplet (quark) strong charge=1

	Q_p	Q_n	Q_λ
charge	y	$y-1$	$y-1$
hypercharge	$2y-1$	$2y-1$	$2y-2$
baryon number	$1-b$	$1-b$	$1-b$

sextet (diquark) strong charge=−1

	Q_{pp}	Q_{pn}	Q_{nn}	$Q_{p\lambda}$	$Q_{n\lambda}$	$Q_{\lambda\lambda}$
charge	$2-y$	$1-y$	$-y$	$1-y$	$-y$	$-y$
hypercharge	$2-2y$	$2-2y$	$2-2y$	$1-2y$	$1-2y$	$-2y$
baryon number	b	b	b	b	b	b

Here the suffixes of Q and Q' show that they transform in the same way as the quarks p, n and λ in $SU(3)$. We do not specify the parameters y and b here. Therefore the charges and the baryon numbers have flexibility. For example, we can let them to be both integers and multiples of one third of the electron charge. In the former case efforts to seek the fractionally charged particles prove in vain. The spin-parities are $J^P=\frac{1}{2}^+$ for the quarks and $J^P=1^+$ for the diquarks. Notice that the absolute parity of the diquarks has no meaning in the same way as that of the quarks. Parities indicated above should be regarded as definitions for convenience.

Suppose that the quarks (Q) have "strong charge" $g=1$, the diquarks (Q') have $g=-1$, and two particles of which strong charges are the same (or opposite) sign interact repulsively (or attractively). Strong charge of an anti-particle is opposite sign of that of the particle. We assume that strong binding forces are of short range and "universal". That is, their properties depend only on the strong charge. And we assume, as usual, that this force is so strong that the heavy mass of a quark plus a diquark or a quark plus an anti-quark is almost canceled by the binding energy. Suppose quarks and diquarks are very heavy and as such have not yet been discovered. As for two-body systems, the pairs that can make a bound state (i.e., interact attractively) are $Q\bar{Q}$, QQ' and $Q'\bar{Q}'$. It is natural to consider that many-body systems more than three do not have low energy bound systems which are not observed until now. The $Q\bar{Q}$ bound states have the same states as the ordinary quark model. For $l=0$, 1 (l is the orbital angular momentum) they can explain experimental boson spectrum well.[4),13)] The QQ' bound states are $3\times 6=8+10$ and their ground states (S-states) are $\frac{1}{2}^+$ baryons and $\frac{3}{2}^+$ baryon resonances. As a whole, baryons are heavier than bosons by about 1 GeV. Assuming that they are caused by the mass differences between Q and Q', we may conclude that Q' are heavier than Q by about 1 GeV. In the same way the $Q'\bar{Q}'$ bound states would have masses of about 2 GeV. And $Q'\bar{Q}'$ bosons*) are $6\times\bar{6}=1+8+27$. But the well-known bosons of $l=0, 1$ $Q\bar{Q}$ states have masses below 1.5 GeV.

§ 3. Baryon states (QQ')

Let us examine the baryon states (QQ' bound states) in more detail. Our model predicts the following states.

Table II.**)

$$l=0 \begin{cases} \{\frac{1}{2}^+, 10\},\ \{\frac{3}{2}^+, 10\}^{(*)} \\ \{\frac{1}{2}^+, 8\}^{(*)},\ \{\frac{3}{2}^+, 8\} \end{cases}$$

$$l=1 \begin{cases} \{\frac{1}{2}^-, 10\},\ \{\frac{3}{2}^-, 10\},\ \{\frac{5}{2}^-, 10\} \\ \{\frac{1}{2}^-, 10\}^{(*)},\ \{\frac{3}{2}^-, 10\}^{(*)} \\ \{\frac{1}{2}^-, 8\}^{(*)},\ \{\frac{3}{2}^-, 8\}^{(*)},\ \{\frac{5}{2}^-, 8\}^{(*)} \\ \{\frac{1}{2}^-, 8\}^{(*)},\ \{\frac{3}{2}^-, 8\}^{(*)} \end{cases}$$

$$l=2 \begin{cases} \{\frac{3}{2}^+, 10\},\ \{\frac{5}{3}^+, 10\} \\ \{\frac{1}{2}^+, 10\}^{(*)},\ \{\frac{3}{2}^+, 10\}^{(*)},\ \{\frac{5}{2}^+, 10\}^{(*)},\ \{\frac{7}{2}^+, 10\}^{(*)} \\ \{\frac{3}{2}^+, 8\}^{(*)},\ \{\frac{5}{2}^+, 8\}^{(*)} \\ \{\frac{1}{2}^+, 8\},\ \{\frac{3}{2}^+, 8\},\ \{\frac{5}{2}^+, 8\},\ \{\frac{7}{2}^+, 8\} \end{cases}$$

Here we used the notation {spin parity, $SU(3)$ multiplet}. Let us attempt to assign baryon resonances[4)] in this scheme. We do not consider doubtful states because they cause a confusion. The assignments of the $l=0, 1$ states are shown in Tables III and IV in the case of our model and of the quark model, respectively.

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*) They are the bound states of two bosons. Here we think diquarks are not elementary particles having no spacial extension but particles with inner structure. That is, the $Q'\bar{Q}'$ bound states are similar to the ^{4}He made from two bosons ^{2}H. If we want to know what states can be made from $Q'\bar{Q}'$ bound states, we must know the internal structure. We do not discuss about it here. Lichtenberg et al.[7)~12)] considered mainly the case that the diquarks are the bound states of the two quarks.

**) The states with the asterisk (*) appear also in the symmetric quark model, i.e., in the $SU(6)$ classification. They are {56} for $l=0$, 2 and {70} for $l=1$. The states that appear in the symmetric quark model and not appear in our model are $\{\frac{1}{2}^-, 1\}$ and $\{\frac{3}{2}^-, 1\}$ for $l=1$.

For the $l \geq 2$ states the resonances are not well known and are difficult to assign. We mention only the N resonances. In the $SU(6)$ (or the symmetric quark model) classification, $N(1470)\frac{1}{2}^+$ and $N(1780)\frac{1}{2}^+$ are assigned to the first radially excited state and the second radially excited state, respectively. In our model $N(1470)\frac{1}{2}^+$ is the $l=2$ state and $N(1780)\frac{1}{2}^+$ is the radially excited state or $N(1470)\frac{1}{2}^+$ is the radially excited state and $N(1780)\frac{1}{2}^+$ is the $l=2$ state.

Perhaps the most important problem of our model is where $\{\frac{3}{2}^+, 8\}$ and $\{\frac{1}{2}^+, 10\}$ of an S-state are. So we must discuss the spin dependent forces besides the major strong binding forces between $Q\bar{Q}$ or QQ'. Suppose the spin-spin

Table III. Proposed assignment of baryon resonances in our model.

l	total spin	$\{J^P, SU_3\}$	N or Δ	Λ	Σ	Ξ	Ω
0	$\frac{1}{2}$	$\{\frac{1}{2}^+, 8\}$	$N(940)$	$\Lambda(1115)$	$\Sigma(1190)$	$\Xi(1320)$?	—
	$\frac{3}{2}$	$\{\frac{3}{2}^+, 8\}$	$N(1860)$				—
	$\frac{1}{2}$	$\{\frac{1}{2}^+, 10\}$	$\Delta(1910)$	—			
	$\frac{3}{2}$	$\{\frac{3}{2}^+, 10\}$	$\Delta(1236)$	—	$\Sigma(1385)$	$\Xi(1530)$	$\Omega(1673)$?
1	$\frac{1}{2}$	$\{\frac{1}{2}^-, 8\}$	$N(1535)$	$\Lambda(1405)$			—
	$\frac{1}{2}$	$\{\frac{3}{2}^-, 8\}$	$N(1520)$	$\Lambda(1520)$	$\Sigma(1670)$		—
	$\frac{3}{2}$	$\{\frac{1}{2}^-, 8\}$	$N(1700)$	$\Lambda(1670)$			—
	$\frac{3}{2}$	$\{\frac{3}{2}^-, 8\}$		$\Lambda(1690)$			—
	$\frac{3}{2}$	$\{\frac{5}{2}^-, 8\}$	$N(1670)$	$\Lambda(1830)$	$\Sigma(1765)$		—
	$\frac{1}{2}$	$\{\frac{1}{2}^-, 10\}$		—			
	$\frac{1}{2}$	$\{\frac{3}{2}^-, 10\}$		—			
	$\frac{3}{2}$	$\{\frac{1}{2}^-, 10\}$	$\Delta(1650)$	—	$\Sigma(1750)$		
	$\frac{3}{2}$	$\{\frac{3}{2}^-, 10\}$	$\Delta(1670)$	—			
	$\frac{3}{2}$	$\{\frac{5}{2}^-, 10\}$		—			

Table IV. Assignment of baryon resonances in the ordinary quark model.

l	total spin	$\{J^P, SU_3\}$	N or Δ	Λ	Σ	Ξ	Ω
0	$\frac{1}{2}$	$\left\{\frac{1}{2}^-, 8\right\}$	$N(940)$	$\Lambda(1115)$	$\Sigma(1190)$	$\Xi(1320)$?	—
	$\frac{3}{2}$	$\left\{\frac{3}{2}^-, 10\right\}$	$\Delta(1236)$	—	$\Sigma(1385)$	$\Xi(1530)$	$\Omega(1673)$?
1	$\frac{1}{2}$	$\left\{\frac{1}{2}^-, 1\right\}$	—	$\Lambda(1405)$	—	—	—
	$\frac{3}{2}$	$\left\{\frac{3}{2}^-, 1\right\}$	—	$\Lambda(1520)$	—	—	—
	$\frac{1}{2}$	$\left\{\frac{1}{2}^-, 8\right\}$	$N(1535)$	$\Lambda(1670)$			—
	$\frac{1}{2}$	$\left\{\frac{3}{2}^-, 8\right\}$	$N(1520)$	$\Lambda(1690)$	$\Sigma(1670)$		—
	$\frac{3}{2}$	$\left\{\frac{1}{2}^-, 8\right\}$	$N(1700)$				—
	$\frac{3}{2}$	$\left\{\frac{3}{2}^-, 8\right\}$					—
	$\frac{3}{2}$	$\left\{\frac{5}{2}^-, 8\right\}$	$N(1670)$	$\Lambda(1830)$	$\Sigma(1765)$		—
	$\frac{1}{2}$	$\left\{\frac{1}{2}^-, 10\right\}$	$\Delta(1650)$	—	$\Sigma(1750)$		
	$\frac{1}{2}$	$\left\{\frac{3}{2}^-, 10\right\}$	$\Delta(1670)$	—			

forces between QQ' are

$$H_{S-S} \propto -(\boldsymbol{F}_1 \cdot \boldsymbol{F}_2)(\boldsymbol{s}_1 \cdot \boldsymbol{s}_2), \tag{3·1}$$

where $\boldsymbol{s}_1$ and $\boldsymbol{s}_2$ are the spin operators of Q and Q' respectively, and

$$(\boldsymbol{s}_1 \cdot \boldsymbol{s}_2) = \begin{cases} -1 & \text{for } |\boldsymbol{s}_1 + \boldsymbol{s}_2| = \frac{1}{2}, \\ \frac{1}{2} & \text{for } |\boldsymbol{s}_1 + \boldsymbol{s}_2| = \frac{3}{2}. \end{cases} \tag{3·2}$$

$\boldsymbol{F}_1$ and $\boldsymbol{F}_2$ are the $SU(3)$ generators of Q and Q' respectively, and

$$(\boldsymbol{F}_1 \cdot \boldsymbol{F}_2) = \begin{cases} -5 & \text{for } \{8\}, \\ 4 & \text{for } \{10\}. \end{cases} \tag{3·3}$$

Such forces can be generated by the exchange of a vector octet.[16] Suppose that the masses are described in the following formula:

$$M = A - B(\boldsymbol{F}_1 \cdot \boldsymbol{F}_2)(\boldsymbol{s}_1 \cdot \boldsymbol{s}_2). \tag{3·4}$$

Using the $N(938)$ and the $\Delta(1236)$ to fix A and B we obtain

$$A = 1436\ \text{MeV}\,,$$
$$B = 100\ \text{MeV}\,. \tag{3·5}$$

Then (3·4) predicts that the mass of the N belonging to $\{\frac{3}{2}^+, 8\}$ is 1686 MeV and that of the Δ belonging to $\{\frac{1}{2}^+, 10\}$ is 1836 MeV. Experimentally the $\frac{3}{2}^+N$ is 1860 MeV (1770∼1900 MeV) and the $\frac{1}{2}^+\Delta$ is 1910 MeV (1780∼1935 MeV) and they are nearly right positions as expected. But if we consider that the transition rate to a lower state emitting a meson is proportional to $|\langle f|e^{i\mathbf{k}\cdot\mathbf{r}}|i\rangle|^2$, the transition probability of an S-state to a ground state is much larger than that of a D-state. The decay widths of the particles located around the 1700 MeV region are from 50 MeV to 400 MeV and if an S-state locates near here, it must have a very large width ($\gtrsim$500 MeV) and it seems very difficult to observe it. Considering these situations we feel the following assignments are better. $N(1860)\,\frac{3}{2}^+$ and $\Delta(1920)\,\frac{1}{2}^+$ are the $l=2$ states and the S-states are not yet observed.

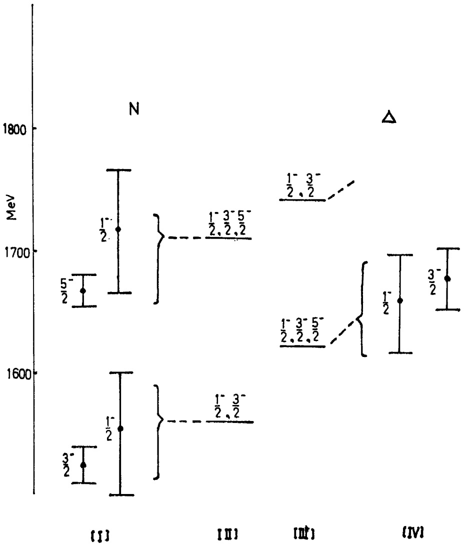

Fig. 1. Columns [II] and [III] show the theoretical values of the mass spectra of $l=1$ N and Δ resonances, respectively. Corresponding experimental values[14] are shown in columns [I] and [IV], respectively.

For the P states neglecting the L-S force, put

$$A = 1660\ \text{MeV}\,,$$
$$B = 20\ \text{MeV}. \tag{3·6}$$

Then (3·4) predicts all the masses of the Δ and N resonances correctly as a whole. Comparison with the experimental data is shown in Fig. 1.

Incidentally we comment on the spin-orbit force for the $l=1$ states. Define

$$\boldsymbol{J} = \boldsymbol{l} + \boldsymbol{S}\,,$$
$$\boldsymbol{S} = \boldsymbol{s}_1 + \boldsymbol{s}_2\,. \tag{3·7}$$

Then

$$\begin{aligned} \boldsymbol{l}\cdot\boldsymbol{S} &= -1 \quad \text{for } |\boldsymbol{l}+\boldsymbol{S}| = \tfrac{1}{2}\,,\ |\boldsymbol{S}| = \tfrac{1}{2}\,, \\ &= \tfrac{1}{2} \quad \text{for } |\boldsymbol{l}+\boldsymbol{S}| = \tfrac{3}{2}\,,\ |\boldsymbol{S}| = \tfrac{1}{2}\,, \\ &= -\tfrac{5}{2} \quad \text{for } |\boldsymbol{l}+\boldsymbol{S}| = \tfrac{1}{2}\,,\ |\boldsymbol{S}| = \tfrac{3}{2}\,, \\ &= -1 \quad \text{for } |\boldsymbol{l}+\boldsymbol{S}| = \tfrac{3}{2}\,,\ |\boldsymbol{S}| = \tfrac{3}{2}\,, \\ &= \tfrac{3}{2} \quad \text{for } |\boldsymbol{l}+\boldsymbol{S}| = \tfrac{5}{2}\,,\ |\boldsymbol{S}| = \tfrac{3}{2}\,. \end{aligned} \tag{3·8}$$

If we assume that the spin-orbit force and the spin-spin force contribute to the $l=1$ state, the mass of an $l=1$ baryon is

$$M = a\boldsymbol{l}\cdot\boldsymbol{S} + b\boldsymbol{s}_1\cdot\boldsymbol{s}_2 + M_0 . \qquad (3\cdot 9)$$

For the $l=1$ Λ resonances put

$$M_0 = 1665\ \text{MeV},$$
$$a = 20\ \text{MeV}, \qquad (3\cdot 10)$$
$$b = 210\ \text{MeV}.$$

The result is compared with the experiment in Fig. 2. All of the resonances are located near the expected places. There are slight discrepancies for the states Λ (1690) and Λ (1520), but they have the same spin parity $\frac{3}{2}^-$ and can mix with each other by small forces we have not yet discussed. This is the reason why they approached each other. From these analyses we notice that for the S-states the spin-spin forces are very strong and for the P-states they are rather weak. The spin-spin forces between $Q\bar{Q}$ have similar properties. The π-ρ mass difference (the spin-spin forces for the S-states) is 630 MeV. However for the $l=1$ excited states, i.e., A_2, B, A_1 and δ (or π_N), their mass splittings can be explained only by the L-S forces and the spin-spin forces are considered to be nearly zero. These facts mean that the spin-spin forces between $Q\bar{Q}$ and between QQ' are strong only at short distance but weak in the outer region.

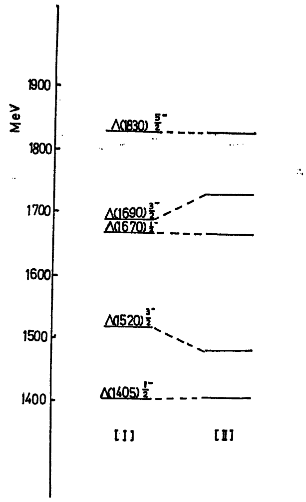

Fig. 2. The column [I] shows the experimental values[14] of $l=1$ Λ resonances. The column [II] shows corresponding theoretical values.

§ 4. Strong decay processes

Let us compute the strong decay rates of the hadrons using the static approximation as was done in the quark model.[17)~19)] π-quark interaction is then

$$\frac{f_q}{m_\pi}\boldsymbol{k}\cdot\boldsymbol{\sigma}\boldsymbol{\tau}\cdot\boldsymbol{\pi}, \qquad (4\cdot 1)$$

where $\boldsymbol{k}$ is the momentum of the emitted π. π-diquark interaction is in the relativistic form

$$-\frac{f'}{m_\pi}\varepsilon_{ijk}\varepsilon_{\alpha\beta\gamma\delta}\partial_\alpha\bar{\alpha}_\beta{}^i\partial_\gamma\alpha_\delta{}^j\pi^k, \qquad (4\cdot 2)$$

$$\frac{f''}{m_\pi}i\varepsilon_{\mu\nu\kappa\sigma}\partial_\mu\bar{\beta}_\nu\boldsymbol{\tau}\partial_\kappa\beta_\sigma\cdot\boldsymbol{\pi}, \qquad (4\cdot 3)$$

where $\alpha_\mu{}^i$, $\beta_\mu{}^i$ are field operators for the diquarks, that is,

$$\boldsymbol{\alpha}=\begin{pmatrix} Q_{pp} \\ Q_{pn} \\ Q_{nn} \end{pmatrix}, \qquad \beta=\begin{pmatrix} Q_{p\lambda} \\ Q_{n\lambda} \end{pmatrix}. \tag{4·4}$$

In the exact $SU(3)$ limit, $f'=-2f''$ holds. In the static limit, (4·2) and (4·3) tend to

$$-\frac{f'}{m_\pi}\frac{1}{2}\boldsymbol{k}\cdot\boldsymbol{J}i\bar{\boldsymbol{\alpha}}\times\boldsymbol{\alpha}\cdot\boldsymbol{\pi}\,, \tag{4·2'}$$

$$-\frac{f''}{m_\pi}\frac{1}{2}\boldsymbol{k}\cdot\boldsymbol{J}\boldsymbol{\tau}\cdot\boldsymbol{\pi}\,, \tag{4·3'}$$

where

$$J_x=\frac{1}{\sqrt{2}}\begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}, \qquad J_y=\frac{1}{\sqrt{2}}\begin{pmatrix} 0 & -i & 0 \\ i & 0 & -i \\ 0 & i & 0 \end{pmatrix},$$

$$J_z=\begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{pmatrix}, \tag{4·5}$$

$$i\bar{\boldsymbol{\alpha}}\times\boldsymbol{\alpha}\cdot\boldsymbol{\pi}=(\bar{Q}_{nn}Q_{nn}-\bar{Q}_{pp}Q_{pp})\pi^0+(\bar{Q}_{pn}Q_{pp}-\bar{Q}_{nn}Q_{pn})\pi^- + (\bar{Q}_{pp}Q_{pn}-\bar{Q}_{pn}Q_{nn})\pi^+. \tag{4·6}$$

Using the hypothesis of additivity in the quark model a relation

$$f_q=\frac{3}{5}f_\pi\,, \qquad \frac{f_\pi^2}{4\pi}=0.082 \tag{4·7}$$

is obtained,[18] where f_π is the π-N coupling constant. In the same way in our model we can derive

$$f_q+2f'=9f_\pi\,. \tag{4·8}$$

Now let us compute the decay rates of the processes baryon→baryon+π, assuming that one baryon state makes a transition to another state emitting a π. Using the static approximation the decay rates of these processes are given by

$$\Gamma=\frac{k}{2\pi}|m|^2_{\mathrm{av}}\frac{E_{\mathrm{f}}}{M_{\mathrm{i}}}\,, \tag{4·9}$$

where $|m|^2_{\mathrm{av}}$ means the square of the matrix element averaged over the initial spin states and summed over the final spin states. E_{f} is the energy of the final baryon and M_{i} is the mass of the initial baryon resonance. The value $|m|^2_{\mathrm{av}}$ for each process is given in Table V.

Using the experimental values[14] of the decay rates given in Table V we obtain the following relations between coupling constants:

Table V.

	$\Gamma^{\exp}$ (MeV)	$\lvert m\rvert^2_{\mathrm{av}}$
$\Delta\to N\pi$	116±6	$\frac{(f'+8f_q)^2k^2}{108m_\pi^2}$
$\Sigma^*\to\Sigma\pi$	3.6±1.0	$\frac{(4f_q+f'+f'')^2k^2}{81m_\pi^2}$
$\Sigma^*\to\Lambda\pi$	32.7±2.7	$\frac{(4f_q-f'')^2k^2}{54m_\pi^2}$
$\Xi^*\to\Xi\pi$	7.3±1.7	$\frac{(4f_q-f'')^2k^2}{54m_\pi^2}$

$$|f'+8f_q|=12.6\pm0.3\,, \tag{4·10}$$
$$|4f_q+f''+f'|=4.46\pm0.52\,, \tag{4·11}$$
$$|4f_q-f''|=5.40\pm0.21\,, \tag{4·12}$$
$$|4f_q-f''|=4.11\pm0.45\,. \tag{4·13}$$

In the exact $SU(3)$ limit, i.e., $f'=-2f''$ these equations tend to

$$|4f_q-f''|=6.30\pm0.15\,, \tag{4·10a}$$
$$|4f_q-f''|=4.46\pm0.52\,, \tag{4·11a}$$
$$|4f_q-f''|=5.40\pm0.21\,, \tag{4·12a}$$
$$|4f_q-f''|=4\cdot11\pm0.45\,. \tag{4·13a}$$

From these equations we find nearly equal values for $|4f_q-f''|$. Taking an average of them we obtain

$$|4f_q-f''|\approx5\,. \tag{4·14}$$

From (4·8) and (4·14) one gets

$$f_q\approx0.75\,,\qquad f'\approx4.1\,, \tag{4·15}$$
$$f_q\approx-1.9\,,\qquad f'\approx5.5\,. \tag{4·16}$$

In the quark model, $f_q\approx0.6$ is obtained and the value of f_q of (4·15) is almost equal to this.

§ 5. Conclusion

The baryon mass spectrum is conventionally explained on the basis of the three-body model, but it can also be explained on the basis of a two-body model not incompatible with the present experimental data. The latter has the advantage that the number of predicted states is much smaller than that in the former. Further we need not use a parastatistics trick. The decay rates of baryon→

baryon$+\pi$ obtained in the two-body model using the static approximation are satisfactory.

Remaining computations of the hadronic weak decays and of the electromagnetic properties of hadrons etc., are now in progress and will be discussed in a subsequent paper.

Acknowledgements

The author would like to thank Professor Y. Yamaguchi for valuable comments. He is also grateful to Professor M. Konuma for informing him of the papers of Lichtenberg and the references.

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