angle θ, and (ii) the $SU(3)$ symmetry-breaking parameter b, are too important to be ignored. Therefore, it is hoped that detailed experimental data with small errors will soon be available on all the $\gamma N \rightarrow PB$ reactions at high energies ($E_\gamma \geqslant 5$ GeV). Also, calculations are in progress on other particle reactions to explore the importance of θ and b.

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Vector-Meson Production in Meson-Nucleon Collisions in a Quark Model

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In an $SU(3)$-symmetric quark model, the production of vector mesons in high-energy $PN \rightarrow VB$ collisions is investigated in the crossed t channel. We assume that the physical baryon octet is given by $\mathbf{8}$(physical) $\equiv \mathbf{8}' \cos\theta + \mathbf{8} \sin\theta$, where $\mathbf{8}$ and $\mathbf{8}'$ octets arise from $\mathbf{3}\otimes\bar{\mathbf{3}}$ and $\mathbf{3}\otimes\mathbf{6}$, respectively. It is found that the value $\theta = 20°$, which leads to predictions in reasonable agreement with the available data on high-energy meson-baryon scattering and the photoproduction of pseudoscalar mesons, is also consistent with the available data on vector-meson production. Also, independently of the mixing angle θ, a number of sum rules are obtained.

I. INTRODUCTION

THERE exist many versions of the quark model; quite often the quark-model predictions are in sharp disagreement with the experimental data.[1] However, we have found that all the available data on high-energy meson-baryon scattering and on high-energy photoproduction of pseudoscalar mesons are consistent with the predictions of our $SU(3)$-symmetric quark model.[2,3] Therefore, in this paper, we would like to investigate in our simple quark model the high-energy processes of the type

$$P + N \rightarrow V + B, \tag{1}$$

where P stands for the pseudoscalar meson, N stands for the nucleon (neutron n or proton p), V stands for the vector meson (singlet as well as the octet), and B stands for the baryon (both the octet and the decuplet). At the present time, a reasonable amount of data is available on these reactions and more data are being obtained.[4,5]

Calculations using quark models[5,6] and also the peripheral-exchange model[7] have been performed on these reactions. In these quark-model calculations, the spin couplings have been ignored, with the result that several of the predictions are in disagreement with the data. Also, the assumption $\sin\psi_{\omega\varphi} = 0$ cannot be completely justified. The inadequacy of the peripheral-exchange model is discussed in Ref. 7 itself. In this model also, the experimental data do not agree with the calculated results. None of these difficulties are present in our quark model.

In this paper, we shall use Okubo's notation according to which Q_i stands for the quark ($i = 1,2,3$ refer to the p_0, n_0, and λ_0 quarks, respectively) and Q^i for the antiquark.[8] The pseudoscalar-meson octet P_j^i, as in the octet version, is a composite of $Q\bar{Q}$. The baryon states are contained in the direct product

$$\begin{aligned} \mathbf{3}\otimes\mathbf{3}\otimes\mathbf{3} &= (\mathbf{3}\otimes\mathbf{3}) \oplus (\mathbf{3}\otimes\mathbf{6}) \\ &= (\mathbf{8}\oplus\mathbf{1}) \oplus (\mathbf{10}\oplus\mathbf{8}'). \end{aligned} \tag{2}$$

We shall write the baryon wave functions in terms of

$$B_{ijk} \equiv Q_i Q_j Q_k, \tag{3}$$

where we suppress all the space-time dependence. Our $SU(3)$ quark wave functions for the pseudoscalar mesons and the baryons are given in Refs. 2 and 9 (Appendix).

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[9] Ramesh Chand and A. M. Gleeson (unpublished). In this paper, we give the explicit expressions for our $SU(3)$ quark wave functions for the pseudoscalar mesons and the baryons.

For the vector mesons, we take

$$[V_j{}^i]=\begin{bmatrix} \varphi^0/\sqrt{6}+\rho^0/\sqrt{2} & \rho^- & K^{*-} \\ \rho^+ & \varphi^0/\sqrt{6}-\rho^0/\sqrt{2} & \bar{K}^{*0} \\ K^{*+} & K^{*0} & -(2/\sqrt{6})\varphi^0 \end{bmatrix} \tag{4a}$$

for the octet, and

$$V_0=\omega^0 \tag{4b}$$

for the singlet. φ^0 and ω^0 are related to the physical φ and ω by the relations[8]

$$\varphi^0=\varphi\cos\psi-\omega\sin\psi, \tag{5a}$$

$$\omega^0=\varphi\sin\psi+\omega\cos\psi. \tag{5b}$$

For the mixing angle ψ, we choose the value given by the $SU(3)$ mass formula[8]

$$\cos\psi=\sqrt{\tfrac{2}{3}},\quad \sin\psi=\sqrt{\tfrac{1}{3}}. \tag{6}$$

In our $SU(3)$ quark model, there are two baryon octets **8** and **8′** present whereas, experimentally, there is only one baryon octet available. Therefore, we choose our physical baryon octet as

$$\mathbf{8}(\text{physical})\equiv\mathbf{8}'\cos\theta+\mathbf{8}\sin\theta, \tag{7}$$

where for the sake of simplicity, we choose θ to be real. In earlier work, we have found that $\theta=20°$ leads to predictions in reasonable agreement with the available data on meson-baryon scattering[2] and the photoproduction of pseudoscalar mesons[3] at high energies. Therefore, our main aim here is to determine the importance if any of $\theta=20°$ in $PN\to VB$ reactions.

In Sec. II, the t-channel matrix elements are calculated. A number of sum rules, independent of the mixing angle, are obtained in Sec. III.

II. CALCULATIONS

In calculating the matrix elements for $PN\to VB$ reactions, we shall assume (a) additivity of two-body quark amplitudes and (b) time-reversal invariance. Also, at the high energies of interest to us, it is reasonable to assume that the crossed t-channel effects dominate, with the basic interaction being governed by the exchange of $SU(3)$ singlet and octet objects only. Under these assumptions, our effective t-channel Lagrangian can be written as

$$\begin{aligned} L_{\text{eff}}=&\,6A_1{}^{(m)}B^{abc}B_{abc}P_e{}^dV_d{}^e \\ &+6[B^{abc}B_{abd}-\tfrac{1}{3}\delta_d{}^cB^{abg}B_{abg}] \\ &\times[A_s{}^{(m)}(P_e{}^dV_c{}^e+P_c{}^eV_e{}^d-\tfrac{2}{3}\delta_c{}^dP_f{}^eV_e{}^f) \\ &+A_a{}^{(m)}(P_e{}^dV_c{}^e-P_c{}^eV_e{}^d)+A_0{}^{(m)}P_c{}^dV_0]. \end{aligned} \tag{8}$$

In this expression, the numerical factors of 6 are introduced for convenience. The complex singlet amplitude $A_1{}^{(m)}$ and the octet amplitudes $A_s{}^{(m)}$, $A_a{}^{(m)}$, and $A_0{}^{(m)}$ are integrals over the space-time variables and contain all the spin and kinematic dependencies, etc. The spin coupling is taken into account by the superscript m; here, $m=8$ or 10, depending upon whether the final baryon belongs to the $SU(3)$ octet or the decuplet state. Obviously, the use of R-conjugation invariance[10] will reduce the number of allowed amplitudes $A^{(m)}$. However, since R invariance does not seem to be a good symmetry in particle physics, we shall not use it in this paper.

In order to calculate the matrix elements, we identify B^{abc} ($\equiv\bar{B}_{abc}$) with the incoming and B_{abc} with the outgoing baryon states, and drop, for brevity, the word "physical" from the baryon octet states. It is convenient to define a mixing parameter a by the relation

$$a\equiv\cos2\theta-\sqrt{3}\sin2\theta=-0.3473\quad\text{for }\theta=20°. \tag{9}$$

Then using Eqs. (4)–(7) and (9) in (8), together with the values of the $SU(3)$ quark wave functions for pseudoscalar mesons and baryons from Refs. 2 or 9, one obtains for collisions on proton p or neutron n the matrix elements given in the Appendix.

From the matrix elements in the Appendix, we first of all notice that unlike the calculations in Refs. 5 and 6, our φ-production matrix elements are not in general zero. However, to suppress considerably the φ production relative to ω production, we must require

$$\mathrm{Re}(A_a{}^{(m)*}A_0{}^{(m)})\ll\mathrm{Re}(A_s{}^{(m)*}A_0{}^{(m)})\ll0 \tag{10}$$

for both $m=8$ and $m=10$. Unfortunately, because of the inadequacy of the experimental data, this relation cannot be tested at the present time. Also, because of the lack of accurate data, it is not possible to determine the unknown amplitudes $A^{(m)}$ and hence we cannot predict the individual rates.

The most accurate determination of the mixing parameter a and hence of the mixing angle θ is provided by the ratios

$$\begin{aligned} |\langle K^{*0}\Lambda|\pi^-p\rangle/\langle K^{*0}\Sigma^0|\pi^-p\rangle|^2 &=|\langle\rho^0\Lambda|K^-p\rangle/\langle\rho^0\Sigma^0|K^-p\rangle|^2 \\ &=|\langle\varphi\Lambda|K^-p\rangle/\langle\varphi\Sigma^0|K^-p\rangle|^2 \\ &=|\langle\omega\Lambda|K^-p\rangle/\langle\omega\Sigma^0|K^-p\rangle|^2 \\ &=|\langle K^{*+}\Lambda|\pi^+n\rangle/\langle K^{*+}\Sigma^0|\pi^+n\rangle|^2 \\ &=|\langle\rho^-\Lambda|K^-n\rangle/\langle\rho^-\Sigma^0|K^-n\rangle|^2 \\ &=3|(2+a)/(2-a)|^2 \\ &=1.47\quad\text{for }\theta=20°. \end{aligned} \tag{11}$$

In order to compare these predictions with the available experimental data, we first note the relation between the measured cross section $\sigma(PN\to VB)$ and the rate $R(PN\to VB)\equiv|\langle VB|PN\rangle|^2$, given by Meshkov *et al.*[11]:

$$R=s\sigma p_{\text{in}}/p_{\text{out}}, \tag{12}$$

where s, p_{in}, and p_{out} denote in the c.m. system the total energy squared, the incident momentum, and the final momentum, respectively. However, since the matrix

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elements and hence the rates R will, in general, be energy dependent, it is essential that we compare the cross sections at the same value of s. Also, at the energies of interest to us, the Λ-Σ^0 mass difference has an effect of order less than 5%, and hence will be ignored in this paper.

The limited data available at the present time give for the above ratios[5]

$$[|\langle K^{*0}\Lambda|\pi^-p\rangle/\langle K^{*0}\Sigma^0|\pi^-p\rangle|^2]_{5\text{ GeV}/c} = (60\pm10)/(20\pm20)\,, \quad (13a)$$

$$[|\langle \rho^0\Lambda|K^-p\rangle/\langle \rho^0\Sigma^0|K^-p\rangle|^2]_{3.8\text{ GeV}/c} = (70\pm30)/(40\pm20)\,. \quad (13b)$$

These values are, within the experimental uncertainties, consistent with the predicted ratio of 1.5 for $\theta=20°$. However, in order to assess fully the importance of $\theta=20°$, it is essential to have accurate experimental data available on these reactions.

III. SUM RULES

Here we shall obtain, among the various matrix elements, several relations which are independent of the mixing parameter a and the amplitudes $A^{(m)}$. Since, at the present time, there are no experimental data available for collisions on neutrons (the data must be obtained from collisions on deuterons where the proton plays the role of the spectator), we shall confine our attention to collisions on protons only. These are

$$\langle\rho^+\Delta^+|\pi^+p\rangle=(\sqrt{\tfrac{2}{3}})\langle\rho^0\Delta^{++}|\pi^+p\rangle \quad (14a)$$

$$=\sqrt{2}\langle\rho^0\Delta^0|\pi^-p\rangle \quad (14b)$$

$$=-\langle\rho^-\Delta^+|\pi^-p\rangle\,, \quad (14c)$$

$$\langle K^{*+}\Sigma^+|\pi^+p\rangle=\sqrt{2}\langle K^{*0}\Sigma^0|\pi^-p\rangle\,, \quad (14d)$$

$$\langle K^{*0}\Delta^{++}|K^+p\rangle=-\sqrt{3}\langle K^{*+}\Delta^+|K^+p\rangle \quad (14e)$$

$$=\sqrt{3}\langle\rho^-Y_1^{*+}|K^-p\rangle\,, \quad (14f)$$

$$\langle\rho^-\Sigma^+|K^-p\rangle=2\langle\rho^0\Sigma^0|K^-p\rangle\,, \quad (14g)$$

$$\langle\rho^-Y_1^{*+}|K^-p\rangle=-2\langle\rho^0Y_1^{*0}|K^-p\rangle\,, \quad (14h)$$

$$\langle K^{*-}\Delta^+|K^-p\rangle=\langle\bar{K}^{*0}\Delta^0|K^-p\rangle \quad (14i)$$

$$=-\langle K^{*+}Y_1^{*+}|\pi^+p\rangle \quad (14j)$$

$$=\sqrt{2}\langle K^{*0}Y_1^{*0}|\pi^-p\rangle\,, \quad (14k)$$

$$\langle\varphi\Delta^{++}|\pi^+p\rangle=-\sqrt{3}\langle\varphi\Delta^0|\pi^-p\rangle\,, \quad (14l)$$

$$\langle\omega\Delta^{++}|\pi^+p\rangle=-\sqrt{3}\langle\omega\Delta^0|\pi^-p\rangle\,, \quad (14m)$$

$$\langle K^{*+}p|K^+p\rangle=\langle\rho^+p|\pi^+p\rangle+\sqrt{2}\langle K^{*0}\Sigma^0|\pi^-p\rangle\,, \quad (14n)$$

$$\langle K^{*-}p|K^-p\rangle=\langle\rho^-p|\pi^-p\rangle+\langle\rho^-\Sigma^+|K^-p\rangle\,, \quad (14o)$$

$$\sqrt{2}\langle\rho^0n|\pi^-p\rangle=\langle\rho^+p|\pi^+p\rangle-\langle\rho^-p|\pi^-p\rangle\,, \quad (14p)$$

$$\langle\rho^+\Delta^+|\pi^+p\rangle=-\langle K^{*-}\Delta^+|K^-p\rangle -\langle\rho^-Y_1^{*+}|K^-p\rangle\,, \quad (14q)$$

$$\langle\varphi\Delta^0|\pi^-p\rangle-2\langle\omega Y_1^{*0}|K^-p\rangle =\sqrt{2}[\langle\varphi Y_1^{*0}|K^-p\rangle-\langle\omega\Delta^0|\pi^-p\rangle]\,, \quad (14r)$$

$$\sqrt{2}\langle\bar{K}^{*0}n|K^-p\rangle=\langle K^{*0}\Sigma^0|\pi^-p\rangle-\sqrt{3}\langle K^{*0}\Lambda|\pi^-p\rangle\,, \quad (14s)$$

$$\langle K^{*+}\Delta^+|K^+p\rangle =\sqrt{2}[\langle K^{*0}Y_1^{*0}|\pi^-p\rangle+\langle\rho^0\Delta^0|\pi^-p\rangle]\,, \quad (14t)$$

$$\langle\rho^0n|\pi^-p\rangle+\langle\omega n|\pi^-p\rangle =\sqrt{2}[\langle\varphi n|\pi^-p\rangle-\langle\bar{K}^{*0}n|K^-p\rangle]\,, \quad (14u)$$

$$\langle\rho^0\Lambda|K^-p\rangle+\langle\omega\Lambda|K^-p\rangle =\sqrt{2}[\langle\varphi\Lambda|K^-p\rangle+\langle K^{*0}\Lambda|\pi^-p\rangle]\,, \quad (14v)$$

$$\langle\rho^0\Sigma^0|K^-p\rangle+\langle\omega\Sigma^0|K^-p\rangle =\sqrt{2}[\langle\varphi\Sigma^0|K^-p\rangle+\langle K^{*0}\Sigma^0|\pi^-p\rangle]\,. \quad (14w)$$

Relations (14a), (14e), (14f), (14i), (14l), and (14m) are trivially obtained from charge independence. Also, let $f_{2I_i}{}^{2I_{fb}}$ represent the charge-independent amplitude for isospin I_i of the incident channel and isospin I_{fb} of the final baryon. Then relation (14d) follows from charge independence if

$$f_3{}^2=-2f_1{}^2\,. \quad (15)$$

This relation at once implies that

$$\langle K^{*+}\Sigma^-|\pi^-p\rangle=0\,. \quad (16)$$

At the present time, there are no data available to test relation (16). In our simple quark model, (16) is automatically satisfied. The nonvanishing of $\langle K^{*+}\Sigma^-|\pi^-p\rangle$, which involves double charge exchange between the vector and the pseudoscalar mesons, requires contributions from higher orders. One can also find constraints imposed by charge independence on several other relations, but this is not of interest to us in this paper.

Relations (14n) and (14o) follow from the U-spin symmetry.[12] We are, of course, not interested here in determining which of these sum rules follow from the group $SU(3)/Z(3)$, etc.

Limited experimental data are available[4,5] to test relations (14e), (14g), (14n)–(14p), and (14s). Within the experimental uncertainties, these relations are satisfied with the phase angles between the production amplitudes having the values

$$\arg\langle\rho^+p|\pi^+p\rangle-\arg\langle K^{*0}\Sigma^0|\pi^-p\rangle\sim\tfrac{1}{2}\pi\,, \quad (17a)$$

$$\arg\langle\rho^-p|\pi^-p\rangle-\arg\langle\rho^-\Sigma^+|K^-p\rangle\sim\pi\,, \quad (17b)$$

$$\arg\langle\rho^+p|\pi^+p\rangle-\arg\langle\rho^-p|\pi^-p\rangle\sim\pi\,, \quad (17c)$$

$$\arg\langle K^{*0}\Sigma^0|\pi^-p\rangle-\arg\langle K^{*0}\Lambda|\pi^-p\rangle\sim\pi\,. \quad (17d)$$

Unfortunately, because of large uncertainties in the data, one can only obtain crude estimates of the phase angles. Of course, there are no data available on the values of these angles.

[12] M. Gourdin, *Unitary Symmetries* (North-Holland, Amsterdam, 1967), p. 67.

IV. CONCLUSIONS

In our naive quark model, under the assumption of additivity of the two-body quark amplitudes, we find that the Λ to Σ^0 ratio for $\theta=20°$ is consistent with the available experimental data. Also the sum rules, within the uncertainties of the data, are in agreement. However, to test (a) the universality of $\theta\simeq 20°$ and (b) the predictions of our $SU(3)$-symmetric quark model, it is desirable to have accurate experimental data available on these reactions.

Even though in our calculations we have assumed strict $SU(3)$ invariance, symmetry-breaking effects can, if necessary, be easily introduced by, e.g., treating the λ_0 quark differently from the p_0 and n_0 quarks. If we take b as the symmetry-breaking parameter, the strange-quark–to–nonstrange-quark coupling parameter, then matrix elements of the type $\langle K^{*+}\Sigma^+|\pi^+p\rangle$ will be multiplied by b relative to matrix elements of the type $\langle\rho^+p|\pi^+p\rangle$. However, because of large uncertainties in the data, it is not possible at the present time to determine the necessity of the symmetry-breaking parameter b.

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APPENDIX

Here, we give the matrix elements for physical baryons obtained using expressions (4)–(7) and (9) in (8) together with the values of the quark wave functions for pseudoscalar mesons and the baryons from Refs. 2 or 9. Then in terms of the mixing parameter a defined as

$$a\equiv\cos 2\theta-\sqrt{3}\sin 2\theta=-0.3473 \quad \text{for } \theta=20°,$$

these matrix elements are

$$\langle\rho^+p|\pi^+p\rangle=[A_1^{(8)}+(16/3)A_s^{(8)}]+2(1+a)A_a^{(8)}, \tag{A1}$$

$$\langle\rho^+\Delta^+|\pi^+p\rangle=-2[2(2-a)]^{1/2}A_a^{(10)}, \tag{A2}$$

$$\langle\rho^0\Delta^{++}|\pi^+p\rangle=-2[3(2-a)]^{1/2}A_a^{(10)}, \tag{A3}$$

$$\langle K^{*+}\Sigma^+|\pi^+p\rangle=-(2-a)(A_s^{(8)}-A_a^{(8)}), \tag{A4}$$

$$\langle K^{*+}Y_1^{*+}|\pi^+p\rangle=[2(2-a)]^{1/2}(A_s^{(10)}-A_a^{(10)}), \tag{A5}$$

$$\langle\varphi\Delta^{++}|\pi^+p\rangle=[2(2-a)]^{1/2}\times[(\sqrt{\tfrac{4}{3}})A_s^{(10)}+A_0^{(10)}], \tag{A6}$$

$$\langle\omega\Delta^{++}|\pi^+p\rangle=-2(2-a)^{1/2}\times[(\sqrt{\tfrac{1}{3}})A_s^{(10)}-A_0^{(10)}], \tag{A7}$$

$$\langle\rho^-p|\pi^-p\rangle=[A_1^{(8)}+(16/3)A_s^{(8)}]-2(1+a)A_a^{(8)}, \tag{A8}$$

$$\langle\rho^-\Delta^+|\pi^-p\rangle=2[2(2-a)]^{1/2}A_a^{(10)}, \tag{A9}$$

$$\langle\rho^0n|\pi^-p\rangle=2\sqrt{2}(1+a)A_a^{(8)}, \tag{A10}$$

$$\langle\rho^0\Delta^0|\pi^-p\rangle=-2(2-a)^{1/2}A_a^{(10)}, \tag{A11}$$

$$\langle K^{*0}\Lambda|\pi^-p\rangle=-(\sqrt{\tfrac{3}{2}})(2+a)(A_s^{(8)}-A_a^{(8)}), \tag{A12}$$

$$\langle K^{*0}\Sigma^0|\pi^-p\rangle=-(\sqrt{\tfrac{1}{2}})(2-a)(A_s^{(8)}-A_a^{(8)}), \tag{A13}$$

$$\langle K^{*0}Y_1^{*0}|\pi^-p\rangle=-(2-a)^{1/2}(A_s^{(10)}-A_a^{(10)}), \tag{A14}$$

$$\langle\varphi n|\pi^-p\rangle=(\sqrt{\tfrac{4}{3}})(1+a)\times[(\sqrt{\tfrac{4}{3}})A_s^{(8)}+A_0^{(8)}], \tag{A15}$$

$$\langle\omega n|\pi^-p\rangle=-[\sqrt{(8/3)}](1+a)\times[(\sqrt{\tfrac{1}{3}})A_s^{(8)}-A_0^{(8)}], \tag{A16}$$

$$\langle\varphi\Delta^0|\pi^-p\rangle=-[\tfrac{2}{3}(2-a)]^{1/2}\times[(\sqrt{\tfrac{4}{3}})A_s^{(10)}+A_0^{(10)}], \tag{A17}$$

$$\langle\omega\Delta^0|\pi^-p\rangle=[\tfrac{4}{3}(2-a)]^{1/2}\times[(\sqrt{\tfrac{1}{3}})A_s^{(10)}-A_0^{(10)}], \tag{A18}$$

$$\langle K^{*+}p|K^+p\rangle=(A_1^{(8)}-\tfrac{2}{3}A_s^{(8)})+(4+a)(A_s^{(8)}+A_a^{(8)}), \tag{A19}$$

$$\langle K^{*+}\Delta^+|K^+p\rangle=-[2(2-a)]^{1/2}\times(A_s^{(10)}+A_a^{(10)}), \tag{A20}$$

$$\langle K^{*0}\Delta^{++}|K^+p\rangle=[6(2-a)]^{1/2}(A_s^{(10)}+A_a^{(10)}), \tag{A21}$$

$$\langle K^{*-}p|K^-p\rangle=(A_1^{(8)}-\tfrac{2}{3}A_s^{(8)})+(4+a)(A_s^{(8)}-A_a^{(8)}), \tag{A22}$$

$$\langle K^{*-}\Delta^+|K^-p\rangle=-[2(2-a)]^{1/2}\times(A_s^{(10)}-A_a^{(10)}), \tag{A23}$$

$$\langle\bar{K}^{*0}n|K^-p\rangle=2(1+a)(A_s^{(8)}-A_a^{(8)}), \tag{A24}$$

$$\langle\bar{K}^{*0}\Delta^0|K^-p\rangle=-[2(2-a)]^{1/2}\times(A_s^{(10)}-A_a^{(10)}), \tag{A25}$$

$$\langle\rho^-\Sigma^+|K^-p\rangle=-(2-a)(A_s^{(8)}+A_a^{(8)}), \tag{A26}$$

$$\langle\rho^-Y_1^{*+}|K^-p\rangle=[2(2-a)]^{1/2}(A_s^{(10)}+A_a^{(10)}), \tag{A27}$$

$$\langle\rho^0\Lambda|K^-p\rangle=-(\sqrt{\tfrac{3}{4}})(2+a)(A_s^{(8)}+A_a^{(8)}), \tag{A28}$$

$$\langle\rho^0\Sigma^0|K^-p\rangle=-\tfrac{1}{2}(2-a)(A_s^{(8)}+A_a^{(8)}), \tag{A29}$$

$$\langle\rho^0Y_1^{*0}|K^-p\rangle=-[\tfrac{1}{2}(2-a)]^{1/2}\times(A_s^{(10)}+A_a^{(10)}), \tag{A30}$$

$$\langle\varphi\Lambda|K^-p\rangle=(\sqrt{\tfrac{1}{2}})(2+a)[(\sqrt{\tfrac{1}{3}})(A_s^{(8)}-3A_a^{(8)})-A_0^{(8)}], \tag{A31}$$

$$\langle\omega\Lambda|K^-p\rangle=-(2+a)[(\sqrt{\tfrac{1}{12}})(A_s^{(8)}-3A_a^{(8)})+A_0^{(8)}], \tag{A32}$$

$$\langle\varphi\Sigma^0|K^-p\rangle=(\sqrt{\tfrac{1}{6}})(2-a)[(\sqrt{\tfrac{1}{3}})(A_s^{(8)}-3A_a^{(8)})-A_0^{(8)}], \tag{A33}$$

$$\langle\omega\Sigma^0|K^-p\rangle=-(\sqrt{\tfrac{1}{3}})(2-a)[(\sqrt{\tfrac{1}{12}})(A_s^{(8)}-3A_a^{(8)})+A_0^{(8)}], \tag{A34}$$

$$\langle\varphi Y_1^{*0}|K^-p\rangle=[\tfrac{1}{3}(2-a)]^{1/2}[(\sqrt{\tfrac{1}{3}})(A_s^{(10)}-3A_a^{(10)})-A_0^{(10)}], \quad (A35)$$

$$\langle\omega Y_1^{*0}|K^-p\rangle=-[\tfrac{2}{3}(2-a)]^{1/2}[(\sqrt{\tfrac{1}{12}})(A_s^{(10)}-3A_a^{(10)})+A_0^{(10)}], \quad (A36)$$

$$\langle\rho^+n|\pi^+n\rangle=[A_1^{(8)}+(16/3)A_s^{(8)}]-2(1+a)A_a^{(8)}, \quad (A37)$$

$$\langle\rho^+\Delta^0|\pi^+n\rangle=-2[2(2-a)]^{1/2}A_a^{(10)}, \quad (A38)$$

$$\langle\rho^0p|\pi^+n\rangle=-2\sqrt{2}(1+a)A_a^{(8)}, \quad (A39)$$

$$\langle\rho^0\Delta^+|\pi^+n\rangle=-2[2-a]^{1/2}A_a^{(10)}, \quad (A40)$$

$$\langle K^{*+}\Lambda|\pi^+n\rangle=-(\sqrt{\tfrac{3}{2}})(2+a)(A_s^{(8)}-A_a^{(8)}), \quad (A41)$$

$$\langle K^{*+}\Sigma^0|\pi^+n\rangle=(\sqrt{\tfrac{1}{2}})(2-a)(A_s^{(8)}-A_a^{(8)}), \quad (A42)$$

$$\langle K^{*+}Y_1^{*0}|\pi^+n\rangle=(2-a)^{1/2}(A_s^{(10)}-A_a^{(10)}), \quad (A43)$$

$$\langle\varphi p|\pi^+n\rangle=(\sqrt{\tfrac{4}{3}})(1+a)\times[(\sqrt{\tfrac{4}{3}})A_s^{(8)}+A_0^{(8)}], \quad (A44)$$

$$\langle\omega p|\pi^+n\rangle=-[\sqrt{(8/3)}](1+a)\times[(\sqrt{\tfrac{1}{3}})A_s^{(8)}-A_0^{(8)}], \quad (A45)$$

$$\langle\varphi\Delta^+|\pi^+n\rangle=[\tfrac{2}{3}(2-a)]^{1/2}\times[(\sqrt{\tfrac{4}{3}})A_s^{(10)}+A_0^{(10)}], \quad (A46)$$

$$\langle\omega\Delta^+|\pi^+n\rangle=-[\tfrac{4}{3}(2-a)]^{1/2}\times[(\sqrt{\tfrac{1}{3}})A_s^{(10)}-A_0^{(10)}], \quad (A47)$$

$$\langle\rho^-n|\pi^-n\rangle=[A_1^{(8)}+(16/3)A_s^{(8)}]+2(1+a)A_a^{(8)}, \quad (A48)$$

$$\langle\rho^-\Delta^0|\pi^-n\rangle=2[2(2-a)]^{1/2}A_a^{(10)}, \quad (A49)$$

$$\langle\rho^0\Delta^-|\pi^-n\rangle=-2[3(2-a)]^{1/2}A_a^{(10)}, \quad (A50)$$

$$\langle K^{*0}\Sigma^-|\pi^-n\rangle=-(2-a)(A_s^{(8)}-A_a^{(8)}), \quad (A51)$$

$$\langle K^{*0}Y_1^{*-}|\pi^-n\rangle=-[2(2-a)]^{1/2}\times(A_s^{(10)}-A_a^{(10)}), \quad (A52)$$

$$\langle\varphi\Delta^-|\pi^-n\rangle=-[2(2-a)]^{1/2}\times[(\sqrt{\tfrac{4}{3}})A_s^{(10)}+A_0^{(10)}], \quad (A53)$$

$$\langle\omega\Delta^-|\pi^-n\rangle=[4(2-a)]^{1/2}\times[(\sqrt{\tfrac{1}{3}})A_s^{(10)}-A_0^{(10)}], \quad (A54)$$

$$\langle K^{*+}n|K^+n\rangle=(A_1^{(8)}-\tfrac{2}{3}A_s^{(8)})+(2-a)(A_s^{(8)}+A_a^{(8)}), \quad (A55)$$

$$\langle K^{*+}\Delta^0|K^+n\rangle=-[2(2-a)]^{1/2}\times(A_s^{(10)}+A_a^{(10)}), \quad (A56)$$

$$\langle K^{*0}p|K^+n\rangle=2(1+a)(A_s^{(8)}+A_a^{(8)}), \quad (A57)$$

$$\langle K^{*0}\Delta^+|K^+n\rangle=[2(2-a)]^{1/2}(A_s^{(10)}+A_a^{(10)}), \quad (A58)$$

$$\langle K^{*-}n|K^-n\rangle=(A_1^{(8)}-\tfrac{2}{3}A_s^{(8)})+(2-a)(A_s^{(8)}-A_a^{(8)}), \quad (A59)$$

$$\langle K^{*-}\Delta^0|K^-n\rangle=-[2(2-a)]^{1/2}\times(A_s^{(10)}-A_a^{(10)}), \quad (A60)$$

$$\langle\bar{K}^{*0}\Delta^-|K^-n\rangle=-[6(2-a)]^{1/2}\times(A_s^{(10)}-A_a^{(10)}), \quad (A61)$$

$$\langle\rho^-\Lambda|K^-n\rangle=-(\sqrt{\tfrac{3}{2}})(2+a)(A_s^{(8)}+A_a^{(8)}), \quad (A62)$$

$$\langle\rho^-\Sigma^0|K^-n\rangle=(\sqrt{\tfrac{1}{2}})(2-a)(A_s^{(8)}+A_a^{(8)}), \quad (A63)$$

$$\langle\rho^-Y_1^{*0}|K^-n\rangle=(2-a)^{1/2}(A_s^{(10)}+A_a^{(10)}), \quad (A64)$$

$$\langle\rho^0\Sigma^-|K^-n\rangle=-(\sqrt{\tfrac{1}{2}})(2-a)(A_s^{(8)}+A_a^{(8)}), \quad (A65)$$

$$\langle\rho^0Y_1^{*-}|K^-n\rangle=-(2-a)^{1/2}(A_s^{(10)}+A_a^{(10)}), \quad (A66)$$

$$\langle\varphi\Sigma^-|K^-n\rangle=(\sqrt{\tfrac{1}{3}})(2-a)[(\sqrt{\tfrac{1}{3}})(A_s^{(8)}-3A_a^{(8)})-A_0^{(8)}], \quad (A67)$$

$$\langle\omega\Sigma^-|K^-n\rangle=-(\sqrt{\tfrac{2}{3}})(2-a)[(\sqrt{\tfrac{1}{12}})(A_s^{(8)}-3A_a^{(8)})+A_0^{(8)}], \quad (A68)$$

$$\langle\varphi Y_1^{*-}|K^-n\rangle=[\tfrac{2}{3}(2-a)]^{1/2}[(\sqrt{\tfrac{1}{3}})(A_s^{(10)}-3A_a^{(10)})-A_0^{(10)}], \quad (A69)$$

$$\langle\omega Y_1^{*-}|K^-n\rangle=-[\tfrac{4}{3}(2-a)]^{1/2}[(\sqrt{\tfrac{1}{12}})(A_s^{(10)}-3A_a^{(10)})+A_0^{(10)}]. \quad (A70)$$