Nonmesonic Weak Decays and Roles of Strange Meson Exchanges in the Extended Model

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After our previous works [1], the modern baryon-baryon interaction models [2] are presented in which the baryon-baryon-meson coupling constants are revised new. Along with these development, we have upgraded the calculations of nonmesonic decays of light s-, p-, and medium-mass hypernuclei by incorporating new ingredients in our model so as to see whether the asymmetry parameter problem, its smallness and the sign, can still be understood in the new interaction model.

The $\Lambda N \to NN$ weak decay potential is constructed meson theoretically by extending the exchanged mesons with various quantum numbers as complete as possible. New ingredients are the followings: (1) Mesons exchanged are, (i) pseudo-scalar ($J^{PC} = 0^{-+}$); π, K (ii) vector ($J^{PC} = 1^{--}$); ρ, K^*, ω (iii) axial-vector ($J^{PC} = 1^{++}$); a_1, K_1 (iv) scalar ($J^{PC} = 0^{++}$); σ, κ. (2) The baryon-baryon-meson coupling constants of the ESC08c model by Rijken et al. [2] are adopted. Specifically the axial-vector coupling constants (a_1, K_1) changed sign from ESC04 [3]. (3) The non-local tensor operator $(\boldsymbol{\sigma_1}\cdot\boldsymbol{P})(\boldsymbol{\sigma_2}\cdot\boldsymbol{P})$ is transformed to ordinary tensor operator $3(\boldsymbol{\sigma_1}\cdot\boldsymbol{q})(\boldsymbol{\sigma_2}\cdot\boldsymbol{q})-(\boldsymbol{\sigma_1}\cdot\boldsymbol{\sigma_2})\boldsymbol{q}^2$ in the improved method developed by Th.A. Rijken [2]. (4) The "zero" form factor is introduced for the scalar meson exchanges.

Calculated potentials have following features. The central potentials in ${}^1S_0 \to {}^1S_0$ (abbreviated to (a)) and ${}^3S_1 \to {}^3S_1$ (c) channels are almost alike. The potentials of π- and K-exchanges behave oppositely in sign and tend to cancel each other. Similarly $V_{2\pi/\sigma}$ and V_κ, $V_{2\pi/\rho}$ and V_{K^*}, $V_{\rho\pi/a_1}$ and $V_{K^*\pi/K_1}$, respectively, work in opposite signs. The summed potential turns out to be negative and short range. The same features are observed for the tensor potential in ${}^3S_1 \to {}^3D_1$ (d) channel, though scalar mesons have no relevance to this channel. On the other hand, the parity-violating potentials in ${}^1S_0 \to {}^3P_0$ (b), ${}^3S_1 \to {}^1P_1$ (e), and ${}^3S_1 \to {}^3P_1$ (f) channels show quite different features from the parity-conserving potential case. Almost all mesons contribute additively in the same signs and thus enforce the summed potentials, though vector and axial-vector mesons do not contribute to the channel (f).

Nonmesonic decay rates are evaluated in the shell model with use of the $\Lambda N \to NN$ decay potential. For ${}^5_\Lambda\mathrm{He}$, the decay observables are calculated as $\Gamma_{nm}/\Gamma_\Lambda = 0.49$ (exp. 0.42 ± 0.024 [4]), $\Gamma_n/\Gamma_p = 0.46$ (exp. $0.45 \pm 0.11 \pm 0.03$ [4]), and $\alpha_\Lambda = 0.09$ (exp. $0.07 \pm 0.08 \pm 0.08$, 0.0 [5]). Agreement is satisfactory. These results comes from the special features of potentials, that is, the parity-violating force dominance of (e) and (f) channels and the relatively weak parity-conserving central and tensor forces. Calculations of the ${}^{12}_\Lambda\mathrm{C}$ decay are also done and theory-experiment comparison looks good. Concluding, our extended model works well in explaining the available exp. data, which indicates the importance of considering the strange mesons as well as the non-strange mesons on an equal footing with the new ESC08c model in the weak decay potential. This work has been done in collaboration with T. Motoba and Th.A. Rijken.

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