# Three-, Four- and Five-Body Calculations of $s$-Shell Hypernuclei with Realistic Interactions

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Few-body calculations for $A = 3-5$ $s$-shell hypernuclei are important not only to study the structure of the hypernuclei but also to pin down the reasonable hyperon-nucleon($YN$) interaction which reproduces the experimental binding energies for those systems. A particular interest is in resolving the long standing problem, that is, the anomalously small binding of ${}^5_\Lambda$He[1]. Motivated by these, we have made stochastic variational calculations for the systems, ${}^3_\Lambda$H, ${}^4_\Lambda$H, ${}^4_\Lambda$H$^*$ and ${}^5_\Lambda$He with realistic $NN$ and $YN$ interactions.

We take the G3RS potential[2] for the $NN$ interaction and the D2, NSC89(S), NSC97e(S) or NSC97f(S) potential[3] for the $YN$ interaction, where the D2 does not contain any non-central components while the others have the non-central (e.g. tensor) component. The NSC89(S), NSC97e(S) and NSC97f(S) are set to reproduce the low-energy $S$ matrix of the original Nijmegen $YN$ potentials[4]. Since all these $YN$ potentials contain $\Lambda N - \Sigma N$ coupling, and these $NN$ and $YN$ potentials(except D2) have tensor operators, the variational trial function must be flexible enough to search the accurate eigenenergies. For the spatial part, the basis function is constructed by the correlated Gaussian times the orbital angular momentum part given by the global vector representation[5]. For the spin and isospin parts, all possible configurations are taken into account.

Table 1 shows the present results for ${}^3_\Lambda$H, ${}^4_\Lambda$H, ${}^4_\Lambda$H$^*$ and ${}^5_\Lambda$He. So far as we know, this can be the first result as the bound state of ${}^5_\Lambda$He obtained by the five-body calculation with the realistic $NN$ and $YN$ interactions(the tensor force and the explicit $\Lambda - \Sigma$ coupling). No bound states have been obtained for ${}^4_\Lambda$H$^*$ and ${}^5_\Lambda$He in the case of NSC89(S) $YN$ potential.

We will discuss the several topics: i) Strong enhancement of binging energies by the central- or the tensor-type $\Lambda N - \Sigma N$ coupling potential, ii) The importance of the core excitation and distortion to produce the bound state of $A = 3, 5$ hypernuclei, iii) Searching the reasonable $YN$ interaction.

Table 1: The $\Lambda$ separation energies, in MeV, of $A = 3 - 5$ systems. The values are from $(A-1)N + \Lambda$ threshold. G3RS $NN$ potential was used.

| $YN$ | $B_\Lambda({}^3_\Lambda\mathrm{H})$ | $B_\Lambda({}^4_\Lambda\mathrm{H})$ | $B_\Lambda({}^4_\Lambda\mathrm{H}^*)$ | $B_\Lambda({}^5_\Lambda\mathrm{He})$ |
|---|---|---|---|---|
| D2 | 0.05 | 2.1 | 1.1 | 2.6 |
| NSC97e(S) | 0.20 | 2.9 | 1.6 | 3.1 |
| NSC97f(S) | 0.14 | 1.7 | 0.2 | 0.3 |
| NSC89(S) | 0.21 | 1.4 | - | - |
| Expt. | $0.13 \pm 0.05$ | $2.04 \pm 0.04$ | $1.00 \pm 0.04$ | $3.12 \pm 0.02$ |

## References

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