${}^{6}_{\Lambda}$H Modeled as ${}^{4}_{\Lambda}$H + n + n

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Evidence for the existence of a bound state of the hypernucleus ${}^{6}_{\Lambda}$H was recently reported by Agnello *et al.*[1]. The possible existence of such a neutron-rich hypernucleus was originally discussed by Dalitz and Levi-Setti [2]. The unanswered question was whether the ΛN interaction is sufficiently strong so as to bind ${}^{6}_{\Lambda}$H (^{5}H being unbound), given that the hypertriton with a deuteron core is barely bound. Dalitz and Levi-Setti suggested that ${}^{6}_{\Lambda}$H be considered as a ${}^{4}_{\Lambda}$H + n + n three-body system. Starting from the then quoted Λ-separation energy of 2.4 MeV for ${}^{4}_{\Lambda}$H, they added 2 times the estimated 0.9 MeV per p-shell neutron binding in ${}^{7}_{\Lambda}$Be to obtain a $B_\Lambda({}^{6}_{\Lambda}H)$ of ≈ 4.2 MeV. The ${}^{6}_{\Lambda}$H Λ-separation energy ($\rightarrow {}^{5}$H + Λ) estimate from Ref. [1], is 4.0 ± 1.1 MeV. This lies close to the value of the ${}^{6}_{\Lambda}$He Λ-separation energy ($\rightarrow {}^{5}$He + Λ) of $B_\Lambda({}^{6}_{\Lambda}He)$ = 4.18 ± 0.10 MeV [3], even though the isospin of the former is 3/2 and the isospin of the latter is 1/2. In fact, if one takes the ${}^{4}_{\Lambda}$H Λ-separation energy to be the 2.04 ± 0.04 MeV quoted in Ref. [3] and combines it with the two-neutron energy difference between the ${}^{7}_{\Lambda}$He and ${}^{5}_{\Lambda}$He isotopes, one obtains an estimate for the Λ-separation energy of ${}^{6}_{\Lambda}$H of ∼4.02 ± 0.4 MeV. To arrive at this result, one must note that Davis clearly states that the Λ-separation energy cannot be obtained by averaging the distinctly different observed values [4]. Pniewski and Danysz point out that one set of measurements clusters around an average of 5.1 ± 0.4 MeV corresponding to the ground state, while a second set of measurements clusters around 3.2 ± 0.4 MeV, corresponding to the first excited state of the core ^{6}He. Thus, the difference between $B_\Lambda({}^{5}_{\Lambda}He)$ = 3.12 ± 0.02 MeV and $B_\Lambda({}^{7}_{\Lambda}He)$ = 5.1 ± 0.4 MeV suggests that the contribution of the two p-shell neutrons to the ground-state and excited state Λ-separation energies of ${}^{6}_{\Lambda}$H should be about 2 MeV. Therefore, an estimate of $B_\Lambda({}^{6}_{\Lambda}H)$ = 4.04 ± 0.04 MeV is attained, which is close to the 4.2 MeV from Ref. [2] and agrees with the experimental value of 4.0 ± 1.1 MeV from Ref. [1]. A similar theoretical analysis is reported in Ref. [5]; this analysis is based on extrapolated values for $B_\Lambda({}^{7}_{\Lambda}He)$ and yields a value for $B_\Lambda({}^{6}_{\Lambda}H)$ ≈ 4.28 MeV. Nevertheless, it should be noted that a different value for $B_\Lambda({}^{7}_{\Lambda}He)$ of 5.68 ± 0.03 ± 0.25 MeV obtained from a JLab experiment has been recently published [6]. This result would suggest a larger nominal value for $B_\Lambda({}^{6}_{\Lambda}H)$, but one that is still consistent with the reported experimental value.

In addition to this interesting analysis of the possible ground state of ${}^{6}_{\Lambda}$H is the observation [1] that the mass estimates from the production and decay analysis appear to differ by about 1 MeV, which is very similar to the difference in the binding energies of the ${}^{4}_{\Lambda}$H 0^+ ground state and 1^+ excited state. That is, it is postulated [1] that the ${}^{6}_{\Lambda}$H (1^+) state is originally produced in the (K^-_{stop},π^+) reaction, and this is followed by γ decay to the ${}^{6}_{\Lambda}$H (0^+) ground state, whose weak decay is then observed.

Motivated by the recent experiments, we explore a three-body calculation for the ${}^{6}_{\Lambda}$He and ${}^{6}_{\Lambda}$H hypernuclei in which the core is ${}^{4}_{\Lambda}$H. Two of the interactions in the ${}^{6}_{\Lambda}$He system

[${}^4_\Lambda$H + p + n] are, in principle, known. That is, the np interaction is known and the ${}^4_\Lambda$H - p interaction can be fitted to the ${}^5_\Lambda$He binding energy. The ${}^4_\Lambda$H - n interaction is to be determined by fitting to the ${}^6_\Lambda$He binding energy. Given the paucity of data to constrain our ${}^4_\Lambda$H-n interaction, we choose to model it in a manner similar to that for the ^{4}He-n interaction. In the latter case the s-wave potential is modeled alternatively as a repulsive potential [7] or an attractive potential with a forbidden bound state [8]. We examine the effect of this alternative on a ^{4}He + n + Λ model of ${}^6_\Lambda$He, because it comes into play also in our ${}^4_\Lambda$H +n + n model of ${}^6_\Lambda$H where the p-shell neutrons are Pauli blocked from the s-shell of the ${}^4_\Lambda$H core.

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