Impurity effects of the Λ particle on the 2α cluster states of ^{9}Be and ^{10}Be[†]

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A unique and interesting aspect of hypernuclei is the structure change caused by the addition of a Λ particle as an impurity, which is the so-called "*impurity effect*." From this point of view, the structure of Be hyper-isotopes is of particular interest, because Be isotopes have a 2α cluster core surrounded by valence neutrons[1–3]. For example, in ^{9}Be, the first excited state $1/2^+$ is considered to have a $^{8}\mathrm{Be}(0^+) + n(s_{1/2})$ configuration, which can be regarded as a Hoyle analogue state with the replacement of an α particle by a neutron, while the ground state has a relatively compact $2\alpha + n$ structure. In the neutron-rich side, exotic structures associated with 2α clustering appear. In ^{10}Be, the coexistence of different structures has been discussed based on the concept of the molecular orbits of valence neutrons around the 2α clustering[4]. Since the two valence neutrons are considered to occupy different molecular orbits in the 0^+_1, 0^+_2, and 1^- states, the degree-of-clustering varies depending on the neutron occupation. In particular, the 0^+_2 state is considered to be largely deformed with a well-developed 2α cluster structure, whereas the ground state is rather compact. Therefore, we can expect the modification of the excitation spectra by the addition of a Λ particle. Furthermore, it is interesting to investigate the dynamical changes of these structures.

To investigate such phenomena, we applied an extended version of the antisymmetrized molecular dynamics for hypernuclei, which we call HyperAMD[5], to $^{10}_{\Lambda}$Be and $^{11}_{\Lambda}$Be in the same manner as our previous work for $^{12}_{\Lambda}$Be[6].

Figures 1(a) and (b) compare the excitation spectra of $^{10}_{\Lambda}$Be and $^{11}_{\Lambda}$Be with those of the core nuclei. It is clearly seen that the excited states of these hypernuclei are shifted up in the excitation spectra, namely the positive-parity states in $^{10}_{\Lambda}$Be and the $K^{\pi} = 0^+_2 \otimes \Lambda$ band built on the $1/2^+_2$ state in $^{11}_{\Lambda}$Be. In other words, the excitation energies of the well-pronounced 2α cluster states are increased significantly. This is because the energy gain of the Λ particle is considerably different between the ground and these excited states. To see the difference of the energy gain clearly, we calculate the binding energy of the Λ particle B_{Λ} defined as,

$$B_{\Lambda} = E(J^{\pi}; {}^{A}\mathrm{Be}) - E(J^{\pi} \otimes \Lambda; {}^{A}_{\Lambda}\mathrm{Be}), \qquad (1)$$

for each state. In Figs. 1(c) and (d), it is found that the B_{Λ} of the well-pronounced cluster states are much smaller than those of the ground states. The difference of B_{Λ} is mainly due to the difference in the deformation of each state, essentially coming from the degrees of the 2α clustering.

In this article, we also discuss the changes caused to the 2α clustering by the addition of a Λ particle. It is found that the Λ particle largely reduces the rms radii of the excited states with large nuclear quadrupole deformation β, which mainly comes from the reduction of the inter-cluster distance between 2α.

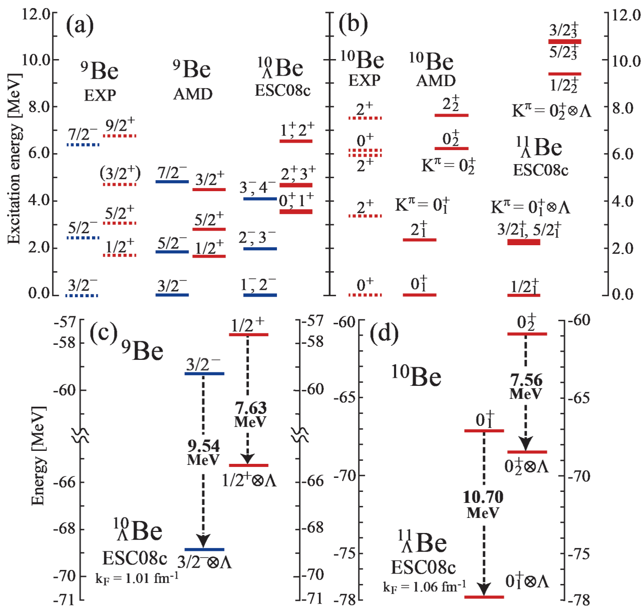

Fig. 1. (a) Calculated excitation spectra of ^{9}Be and $^{10}_{\Lambda}$Be. (b) Same as (a) but for ^{10}Be and $^{11}_{\Lambda}$Be. (c) Calculated values of B_{Λ} by using YNG-ESC08c as the ΛN interaction in $^{10}_{\Lambda}$Be (d) Same as (c) but for $^{11}_{\Lambda}$Be.

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