Unified studies of neutron-excess systems from bound to continuum

Makoto Ito
Department of Pure and Applied Physics, Kansai University,
Yamate-cho 3-3-35, Suita, Osaka 564-8680, Japan

In light neutron-excess systems, many kinds of molecular structures are discussed from the view point of the clustering phenomena. In particular, much attention has been concentrated on Be isotopes. The molecular orbital (MO) around the ^{8}Be ($=\alpha+\alpha$) core, such as π^- and σ^+ associated with the covalent binding of atomic molecules, have been shown to give a good description for the low-lying states of these isotopes [1]. In their highly-excited states, furthermore, recent experiments revealed the existence of the interesting resonant states which dominantly decay to the ^{6,8}He fragments [2]. In this report, we show the unified study of the exotic cluster structures of even Be isotopes ($=\alpha+\alpha+$XN, X=2,4,6,8) from bound states to continuum.

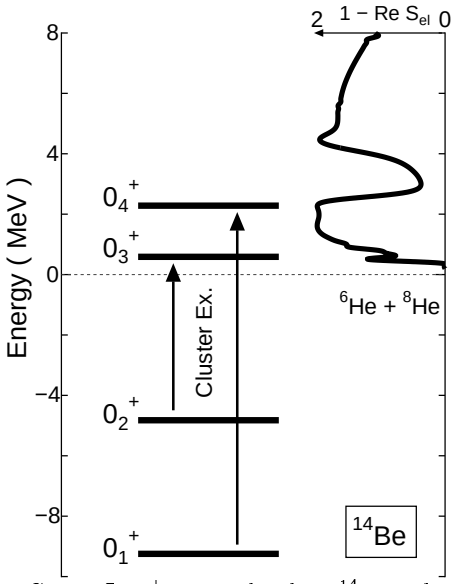

FIG. 1: $J^\pi=0^+$ energy levels in ^{14}Be. The curve above the zero energy show the total reaction cross section in the collision of ^{6}He$_{g.s.}$+^{8}He$_{g.s.}$. Two arrows represent the cluster excitations from the bound states.

We applied the generalized two-center cluster model (GTCM), in which the formations of various chemical bonding structures, such as covalent MOs and the atomic orbital (AO) configurations with ^{x}He+^{y}He, can be described in a unified manner [3,4]. Due to the consistent treatment of chemical bonding structures, this model can also describe the nuclear reactions from AOs to MOs, which are observed in continuum above particle-decay thresholds [4]. An example of the application of GTCM to ^{14}Be= $\alpha+\alpha+6N$ with the $J^\pi=0^+$ state is shown in Fig. 1.

First, we solved the bound state problem, and two energy levels are obtained (0_1^+ and 0_2^+). Next, we solved the scattering problem of ^{6}He+^{8}He and identified resonance states, which are embedded in the scattering matrix (a curve in the right side of Fig. 1). In the continuum region, we found that the 0_3^+ and 0_4^+ states correspond to the cluster excitation mode from the bound states, 0_2^+ and 0_1^+, respectively. Specifically, the two resonant states are generated by the excitation of relative motions between two α-cores in the two bound states. As a result of a cluster excitation, the AO structures, such as ^{6}He$_{g.s.}$+^{8}He$_{g.s.}$ and ^{6}He(2_1^+)+^{8}He$_{g.s.}$, are developed in the 0_3^+ and 0_4^+ states, respectively.

We performed the similar calculations for other Be isotope ($^{8\sim16}$Be) and confirmed that, in these systems, the similar ^{6,8}He clusters such as ^{10}Be=α+^{6}He, ^{12}Be=^{6}He+^{6}He (α+^{8}He), ^{16}Be=^{8}He+^{8}He are realized in the excited states embedded in continuum. Systematics of cluster structures in Be isotopes will be presented. Furthermore, feature plans on the unified studies of nuclei from bound to continuum is also discussed.

[1] N. Itagaki et al., Phys. Rev. C62, 034301 (2000), and references therein.
[2] M. Freer et al., Phys. Rev. Lett.82, 1383 (1999) ; Phys. Rev. C63, 034301 (2001).
[3] Makoto Ito, Phys. Lett. B **636**, 293(2006); *ibid*, Mod. Phys. Lett. A **21**, 2429 (2006).
[4] M. Ito, N. Itagaki, H. Sakurai, K. Ikeda, Phys. Rev. Lett. 100, 182502 (2008); M. Ito, N. Itagaki, Phy. Rev. C **78**, 011602(R) (2008);*ibid*, Phy. Rev. Focus **22**, Story 4 (2008).