Coexistence of Cluster Structure and Mean-field-type Structure in Medium-weight Nuclei

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We have studied the coexistence of cluster structure and mean-field-type structure in ^{20}Ne and ^{40}Ca using Antisymmetrized Molecular Dynamics (AMD) with a new type of constraint. We found that $K^\pi = 0_3^+$ band of ^{20}Ne,[1] and $K^\pi = 0_2^+$ and 0_3^+ bands of ^{40}Ca have non-small amount of ^{8}Be-^{12}C, α-^{36}Ar and ^{12}C-^{28}Si cluster structures, respectively.

Our interest in the coexistence of cluster structure and mean-field-type structure is especially in medium and heavy-weight nucleus. In ^{40}Ca, it was suggested that $K^\pi = 0_2^+$ band has α-^{36}Ar cluster structure theoretically,[2] and the suggestion was supported by the experiment of ^{36}Ar(^{6}Li, d)^{40}Ca reaction.[3] Furthermore, it was suggested that super deformation band of ^{40}Ca has ^{12}C-^{28}Si cluster structure theoretically[4] and experimentally.[5]

For studying coexistence of cluster structure and mean-field-type structure, we proposed a new constraint, d-constraint, for AMD.[1] The constraint is for the distance between the centers of masses of groups of nucleons corresponded to clusters. The cluster structure of a group of nucleons is determined so as to give the minimum energy of the total system by the energy variation with the constraint. Since the constraint is only for the distance between the centers of masses of clusters, the resultant wave functions of clusters are not necessarily those of ground states but are optimized due to the interaction between clusters. This point is the advantage of our method compared to traditional cluster models like Brink model.

By energy variation with d-constraint and quadrupole deformation constraint, we calculated wave functions of α-^{16}O cluster structure, ^{8}Be-^{12}C cluster structure and mean-field-type structure for ^{20}Ne, and α-^{36}Ar cluster structure, ^{8}Be-^{32}S cluster structure, α-^{32}S-α linear chain structure, ^{12}C-^{28}Si cluster structure and mean-field-type structure for ^{40}Ca. Superposing these wave functions with various types of structures, we performed GCM calculation. We found that ^{8}Be-^{12}C cluster structure was an important component of $K^\pi = 0_3^+$ band of ^{20}Ne, and α-^{36}Ar cluster structure and ^{12}C-^{28}Si cluster structure were those of $K^\pi = 0_2^+$ and 0_3^+ bands of ^{40}Ca, respectively.

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