Microscopic coupled-channels study of the α cluster structures in ^{19}Ne

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Cluster structures are well known to appear in the excited states of light nuclear systems. A typical example can be seen in ^{20}Ne. The α + ^{16}O cluster model is successful in reproducing the ground and excited rotational band structures in ^{20}Ne. In ^{19}F, which is one proton deficient system of ^{20}Ne, the formation of the α + ^{15}N cluster structures are deeply analyzed. On the contrary, the α + ^{15}O cluster structure, corresponding to the neutron deficient system of ^{20}Ne, still remains unclear although there are several pioneering works. The unbound continuum states of this cluster structure is expected to be important in the radiative capture reaction of ^{15}O(α,γ)^{19}Ne, which plays the crucial role in the advanced stage of nucleosynthesis.

In the present study, we investigate the cluster structure in ^{19}Ne by applying the microscopic cluster model, the generator coordinate method (GCM). We have solved the coupled-channels problem of (^{3}He+^{15}O) + (α+^{16}O) on the basis of GCM. In the coupled-channel GCM (CGCM), the anti-symmetrization among all nucleons in the individual cluster configurations are explicitly considered. The CGCM calculation nicely reproduce the qualitative feature of the positive and negative parity bands in the low-lying bound levels. Furthermore, the CGCM calculation predict the resonant levels above the α threshold, which are not clearly assigned in previous experiments.

In the radiative capture reaction of ^{15}O(α,γ)^{19}Ne at the astrophysical energy region, the most crucial contribution is known to arise from the $J^{\pi} = 3/2^{+}$ resonant level at 504 keV with respect to the α + ^{15}O threshold (E_x = 4.03 MeV). According to the previous studies on the mirror system of ^{19}F, any cluster model calculations cannot reproduce the respective $3/2^{+}$ resonance, which exists just below the α threshold. According to the previous experiment, the intrinsic structure of the resonance at 504 keV in ^{19}Ne is not the α + ^{15}O cluster structure, but the five particle–two hole ($5p$–$2h$) shell-model configuration with the ^{14}O$_{g.s.}$ core. The $5p$–$2h$ configuration has a large overlap with the shell model limit of the ^{5}He + ^{14}O configuration. In the present study, therefore, we have performed the extended coupled-channels calculation of (^{3}He+^{16}O) + (α+^{15}O) + (^{5}He+^{16}O). We have found that a new $3/2^{+}$ level are generated by the coupling of the (^{5}He+^{16}O) configuration. The details of the extended calculation will be reported.