Tri-nucleon cluster-states in ^{6}Li excited by (^{3}He,α) reaction at 450 MeV

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Cluster-structures are interesting phenomena in nuclear physics. Alpha-clusters have been proven to exist in light to heavy nuclei. In light nuclei, other clusters are also expected to play an important role in nuclear structure. Exotic molecular-like cluster-structures have been revealed in unstable nuclei [1]. Akimune *et al.* recently obtained evidence for a di-triton molecular resonance in ^{6}He [2]. In the A=6 isobaric system, a tri-nucleon molecular-like state is expected to exist from the isospin symmetry. Its existence was suggested experimentally as well as theoretically [3]. Such a state is described as a two-fermion (t and/or ^{3}He) system and is analogous to the two-nucleon system. However, the physics of tri-nucleon cluster-states remains unclear.

The LS-coupling t+^{3}He cluster model in ^{6}Li predicted P- and F-unbound states with respect to the t+^{3}He system. Thompson and Tang [4] predicted a P-doublet (^1P and ^3P) around E_x=22 MeV and a F-doublet (^1F and ^3F) around E_x=29 MeV by the resonating group method (RGM) calculation. Here, the symbol denotes ^{2S+1}L. Ohkura *et al.* [5], on the other hand, reported the P- and F-doublets around E_x=17 and 26 MeV, respectively, with the complex-scaled RGM calculation. In prediction of the tri-nucleon cluster-state in ^{6}Li, there is a contradiction in excitation energy for both P- and F-states.

Experimentally, the P- and F-states were reported on the basis of radiative capture reactions, and of the phase shift analysis on the ^{3}He+^{3}H elastic scattering data. Concerning the ^3P resonance, there was a serious discrepancy in excitation energy of about 3 MeV [3]. Recently, Akimune *et al.* identified the di-triton resonance at E_x=18 MeV in ^{6}He by measuring decay-tritons from states excited via the ^{6}Li(^{7}Li,^{7}Be) reaction at 65A MeV [2]. A comparison of the data with the RGM calculations for ^{6}He [4] suggests that the observed resonance is the ^3P (t+t) cluster-state whose analog cluster-state (t+^{3}He), based upon isospin symmetry, should exist around E_x = 21 MeV in ^{6}Li. Such a state was reported by the ^{6}Li(γ,t) reaction and also predicted with the RGM calculation by Thompson and Tang [4]. But these results disagree with the complex-scaled RGM calculation by Ohkura *et al.* [5] and analysis of the phase shift on the ^{3}He+^{3}H elastic scattering data [6]. Thus the tri-nucleon cluster-state in ^{6}Li is experimentally as well as theoretically unproven [3].

A 450-MeV ^{3}He^{2+} beam was provided from the Ring Cyclotron of the Research Center for Nuclear Physics, Osaka University. The target used was a self-supporting foil of a separated ^{7}Li isotope (99.9 %) with a thickness of 0.5 mg/cm^2. The target was inclined at 45° to the beam direction in order to reduce the energy loss of the decay-particle in the target.

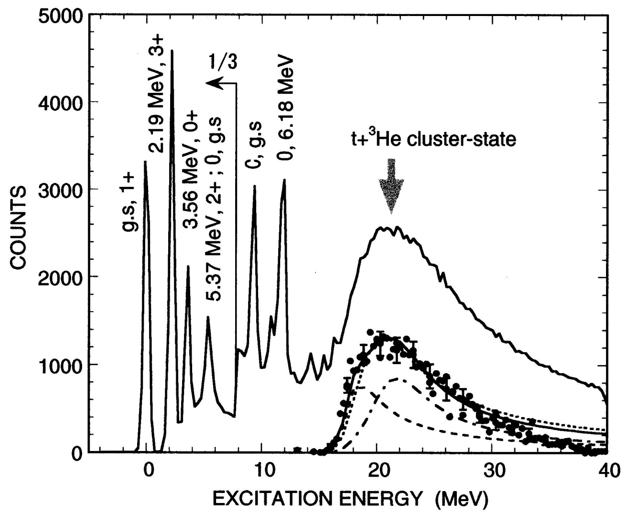

Figure 1: Singles spectrum for the ^{7}Li(^{3}He,α)^{6}Li reaction at 450 MeV and at $\theta_\alpha = 0°$. A spectrum obtained in coincidence with triton and ^{3}He decay-particles is shown by closed circles. Error bars reflect only statistcal errors. The symbols of C and O denote peaks due to carbon and oxygen contamination in the target, respectively.

The α-particles were analyzed using the magnetic spectrometer "Grand RAIDEN" [7] set at $\theta_L = -0.5°$. Charged decay-particles were detected by 8 sets of ΔE-E Si-telescope which consists of two Si-detectors with 500 μm and 300 μm thicknesses. These telescopes were located from $\theta_{\rm decay} = 90°$ to $\theta_{\rm decay} = 160°$ at 10° intervals and about 30 cm apart from the target. An identification of decay-particles was performed by a time of flight (TOF) method. Here triton and ^{3}He particles are not separable.

Figure 1 shows the singles spectrum for the ^{7}Li(^{3}He,α)^{6}Li reaction at 450 MeV and at $\theta_\alpha = 0°$. The well-known states are prominently excited in a low excitation energy region. The low-lying states in ^{6}Li are known as cluster-states of d+α [3]. In a high excitation energy region, on the other side, a broad bump was observed around E_x=21 MeV. The existence of tri-nucleon cluster-states in this excitation region has been discussed. The tri-nucleon cluster-states in ^{6}Li were investigated via the ^{7}Li(^{3}He,α) reaction by measuring triton and ^{3}He decay-particles in coincidence with α-particles. The coincidence spectrum thus obtained is shown by closed circles in figure 1. Measurements of the angular correlations of decay-particles may be used to determine angular momenta of populated states. The detailed analyses are now in progress.

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