I. 3 Three Nucleon Clustering Observed for 7− and 6− States in 16O via the 13C(α,n)16O Reaction


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The (α,n) reaction is one of the good candidate probing α-clustering in nuclei. Especially that on 4N+n nuclei such as 13C may provide straightforward information for α-clustering of low-lying states in the residual nucleus. In analog to the alpha clustering, a three-nucleon clustering may be expected to appear near the threshold for the triton or 3He-particle. The high-spin 13/2+ states known in 19F, 17N and 15N are discussed to have three nucleon clustering based on; (1) their large spectroscopic strengths for the (d5/2)3 configuration, (2) the internal wave function of the three nucleon to be s-state, and (3) location of such high-spin states near the threshold of 3-particle decay. Furthermore, some high-spin 7− and 6− states are expected to have the (d5/2)3(p1/2)−3 configuration and to be excited selectively by three nucleon transfer reaction such as 13C(α,n)16O reaction.

With motivation to identify such 7− and 6− states in 16O and to obtain spectroscopic information on these states, we have measured the 13C(α,n)16O reaction at Eα = 49 MeV. The experiment was performed using 49 MeV alpha beams and the Time of Flight facilities* at Cyclotron and Radioisotope Center, Tohoku University. The 13C target was self supporting foil of Carbon-13, the thickness of which was 0.70 mg/cm² measured by weighing. The angular distributions of the cross section were measured by using a beam swinger system.

Figure 1 shows a typical energy spectrum measured at θlab. = 20 deg. for the 13C(α,n)16O reaction. The x-axis is converted to be linear in neutron energies. In the figure, prominent peaks are seen around the 3He threshold energy of 22.8 MeV. The 20.66 and 21.67 MeV-peaks may correspond to the T = 0, 7− states which has been found in the 12C + α resonance. The peaks at Ex = 21.04, 24.08 and 24.81 MeV are found for the first time in the present work. Among them, the 24.81 and 24.08 MeV states seem to be T = 1, 7− or 6− states, analogue of the 7− or 6− states in 16N observed in the 13C(α,p)16N reaction.3)
Figure 2 shows angular distributions of neutrons leading to these states. The curves in the figure are comparison with exact finite-range distorted-wave Born-approximation calculations obtained with a $^3$He-cluster transfer, by using a code TWOFRN.\textsuperscript{6} The good fit of the calculated curves to the data may support the present assignment of the $J^\pi$ values for these states. The $\epsilon$-value in the figure denote spectroscopic strengths obtained for the pure $(d_{5/2})^3$ transfer. They are displayed in Fig. 3 together with the $\epsilon$-values for the $13/2^+$ states in $^{15}$N, $^{17}$N and $^{19}$F for comparison. It is noted that the spectroscopic strengths for the $7^-$ states in $^{16}$O are four times as large as those of the $13/2^+$ states in neighboring nuclei.

In conclusion, we found that the $^{13}$C($\alpha,n$)$^{16}$O reaction at $E_\alpha = 49$ MeV excited selectively the high-spin $7^-$ states, and that these states had quite large spectroscopic strengths for the $(d_{5/2})^3(p_{1/2})^{-3}$ configuration as a specific feature of $^3$He-clustering.

References
2) Yasue M. et al., contribution to this conference.
6) Igarashi M., Exact Finite Range DWBA code, unpublished.
Fig. 1. Typical neutron energy spectrum for the $^{13}\text{C}(\alpha,n)^{16}\text{O}$ reaction at $\theta_{\text{lab.}} = 20$ deg.
Fig. 2. Angular distributions for neutrons leading to the $E_x = 20.66, 21.62, 24.81$ and 24.08 MeV states. The curves are DWBA predictions.

Fig. 3. The spectroscopic strength comparing to the $\epsilon$-values for the $13/2^+$ states in $^{15}$N, $^{17}$N and $^{19}$F.