Excitations of the α-clusters in A=6 and 7 nuclei

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Clusters in nuclear systems are spatially localized subsystems consisting of strongly correlated nucleons. Therefore, in clustering nuclei we might expect the excitation due to an intrinsic excitation of the cluster itself. This excitation mode has not been well studied. We searched for the excitation of an α-cluster, namely, the isovector giant dipole resonance (GDR) of ^{4}He [1], in ^{6,7}Li by using the ^{6,7}Li(p,p$'$) reaction at 300 MeV, and the analogs of the GDR of the α-cluster in ^{6,7}He and ^{6,7}Be by the ^{6,7}Li(^{7}Li,^{7}Be) reaction at 455 MeV [2] and ^{6,7}Li(^{3}He,t) reaction at 450 MeV, respectively, with the beams from the ring cyclotron at the Research Center for Nuclear Physics (RCNP), Osaka University. Targets used were self-supporting metallic foils of enriched ^{6}Li (95.4%) and ^{7}Li (99.9%). Reaction particles were analyzed by using the magnetic spectrometer "Grand Raiden". The experimental details are presented elsewhere [2, 3].

Figure 1 shows typical energy spectra for the ^{6,7}Li(p,p$'$), ^{6,7}Li(^{3}He,t), and ^{6,7}Li(^{7}Li,^{7}Be) reactions. To clearly show the analog relation between the states excited in these nuclei, each spectrum in Fig. 1 is shifted such that the locations of the analog states in A=6 (3.56-MeV state in ^{6}Li, ground states in ^{6}He and ^{6}Be; 0^+, T=1) and A=7 (g.s. in ^{7}He, 11.25 and 11.01-MeV states in ^{7}Li and ^{7}Be, respectively; $3/2^-$, T=3/2) coincide horizontally. A common feature of the spectra for A=6 is the appearance of two resonances at $E_x$$\sim$27 MeV and $\sim$18 MeV, as typically seen in ^{6}Li (denoted as G1 and G2, respectively). In the spectra for A=7 nuclei, resonances similar to G1's observed in A=6 nuclei are evident. The resonances at $E_x$$\sim$27 MeV in ^{6}Li and $\sim$30 MeV in ^{7}Li were found in the present work. The resonances in A=7 nuclei were appeared to be G1 type resonances. Based on the fact that the excitation energies for the G1's measured with respect to the excitation energies of ^{6}Li and ^{7}Li are in close agreement with the excitation energy of the GDR in ^{4}He reported at $E_x$$\sim$26 MeV in the ($\gamma$,n) reaction [1], the G1's are candidates for the GDR in an α-cluster.

The excitation energies, widths and cross sections for the G1's, were deduced by decomposing the measured spectra into various peaks and underlying continuum [3]. The fitted curves are shown by the solid lines in Fig. 1. The excitation energies for the G1's are E_x=27.0, 24.0, and 23.5 MeV in ^{6}Li, ^{6}He, and ^{6}Be, respectively, and E_x=29.0, 18.0, and 28 MeV in ^{7}Li, ^{7}He and ^{7}Be, respectively. The resonance shapes were qualitatively reproduced with the GDR shape reported in the ^{4}He(γ,n) reactions. All the G1's were assigned to the dipole resonances based on the observed cross sections [2, 3]. The avaraged value for the ratios of the G1 cross sections in A=6 to that in A=7 for each element was 1.2$\pm$0.3, which as would be expected was consistent with unity. The avaraged value for the cross-section

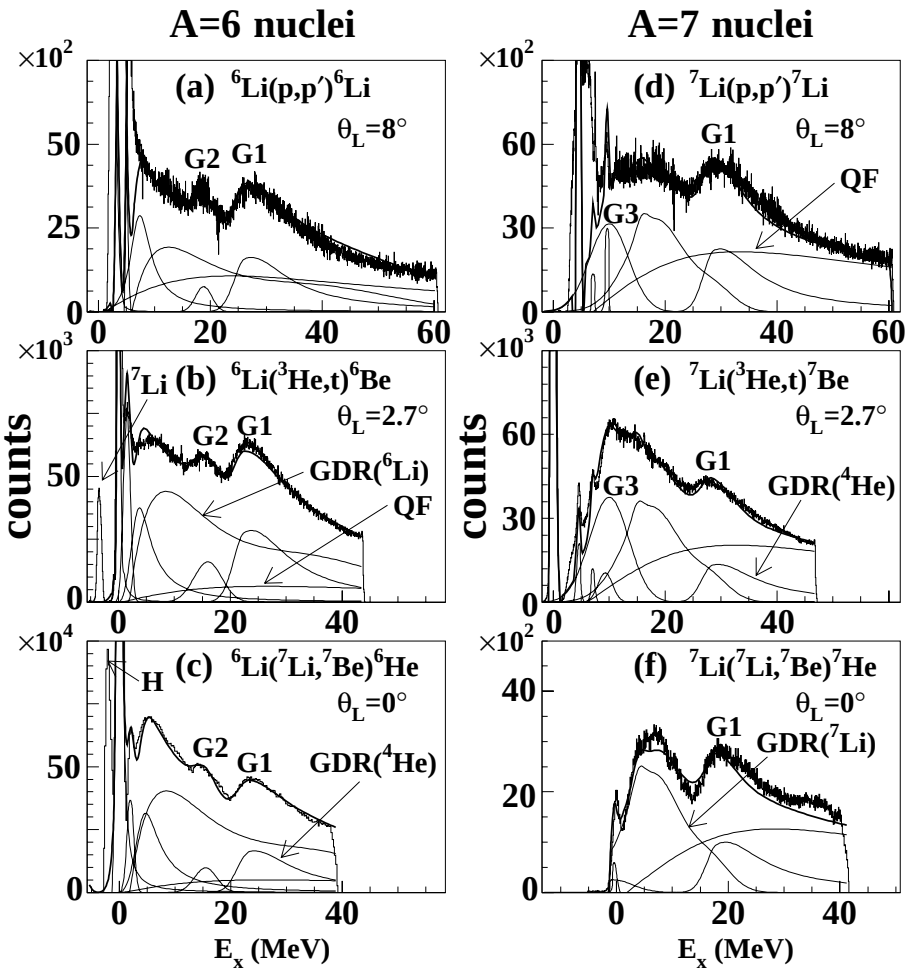

Figure 1: Spectra for the reactions of (p,p′) at θ_L=8°, (^{3}He,t) at 2.7°, and (^{7}Li,^{7}Be) at 0°. The solid lines show the peak fitting results.

ratios of the G1 to the GDR in respective target nuclei was 0.44±0.08, which was consistent with the cross-section ratios of the GDR in ^{4}He to those in ^{6,7}Li estimated from the photo-reactions [1]. The excitation energies for the dipole resonances in A=6 and 7 nuclei measured from the separation energies of α-particle in ^{6}Li and ^{7}Li, respectively, agreed well with the excitation energy for the GDR in ^{4}He, which is about 26 MeV. We concluded that the G1's observed in ^{6,7}Li are the GDR in the α-clusters, and those in ^{6,7}He and ^{6,7}Be are the analogs of the GDR in the α-cluster [3].

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