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NUCLEAR STRUCTURE IN LIGHT NUCLEI VIA THREE-NUCLEON TRANSFER REACTIONS

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A lot of data show that three-nucleon transfer reactions excite states very selectively and tend to favor the population of high-spin states of residual nuclei. Among three-nucleon transfer reactions, (^{6}Li,^{3}He) and (^{6}Li,t) reactions have been used frequently. These two reactions are in the relation of mirror ones, therefore these on a self-conjugate nuclei tend to populate mirror states in residual nuclei. In this study, we tried to measure ^{6}Li-induced three-nucleon transfer mirror reactions on self-conjugate targets; ^{12}C and ^{16}O and to identify mirror states in highly-excitated regions of A=15 and 19 nuclei. Moreover, in the residual four nuclei, three-nucleon cluster structure were explored, using information obtained about highly-excited states

The experiment was carried out using the SF cycrotron and QDD spectrograph at KEK Tanashi, and the tandem Van de Graaff accelerator and magnetic spectrograph "ENMA" at JAERI. A natural carbon foil was used for the ^{12}C target. Natural oxygen gas enclosed in a cyrindrical cell was used as a ^{16}O target. The incident energy of ^{6}Li was 40 MeV at KEK Tanashi, on the other hand, at JAERI a 60 MeV ^{6}Li beam was used in order to obtain information about higher-excited states in the residual nuclei. Data were taken from 5° to 60° in a laboratory angle.

Figure 1 shows energy spectra of emitted particles from the (^{6}Li,^{3}He) (left) and (^{6}Li,t) (right) reactions at JAERI. It is found that these energy spectra are similar to each other and many mirror states are populated up to high excitation regions of the residual nuclei.

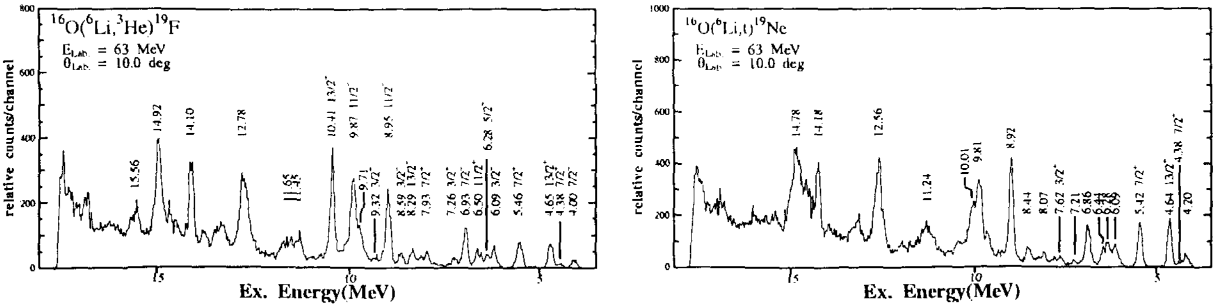

Fig. 1: Energy spactra from the reactions ^{16}O(^{6}Li,^{3}He)^{19}F (left-hand side) and ^{16}O(^{6}Li,t)^{19}Ne (right-hand side) at JAERI. Excitation energies are in MeV.

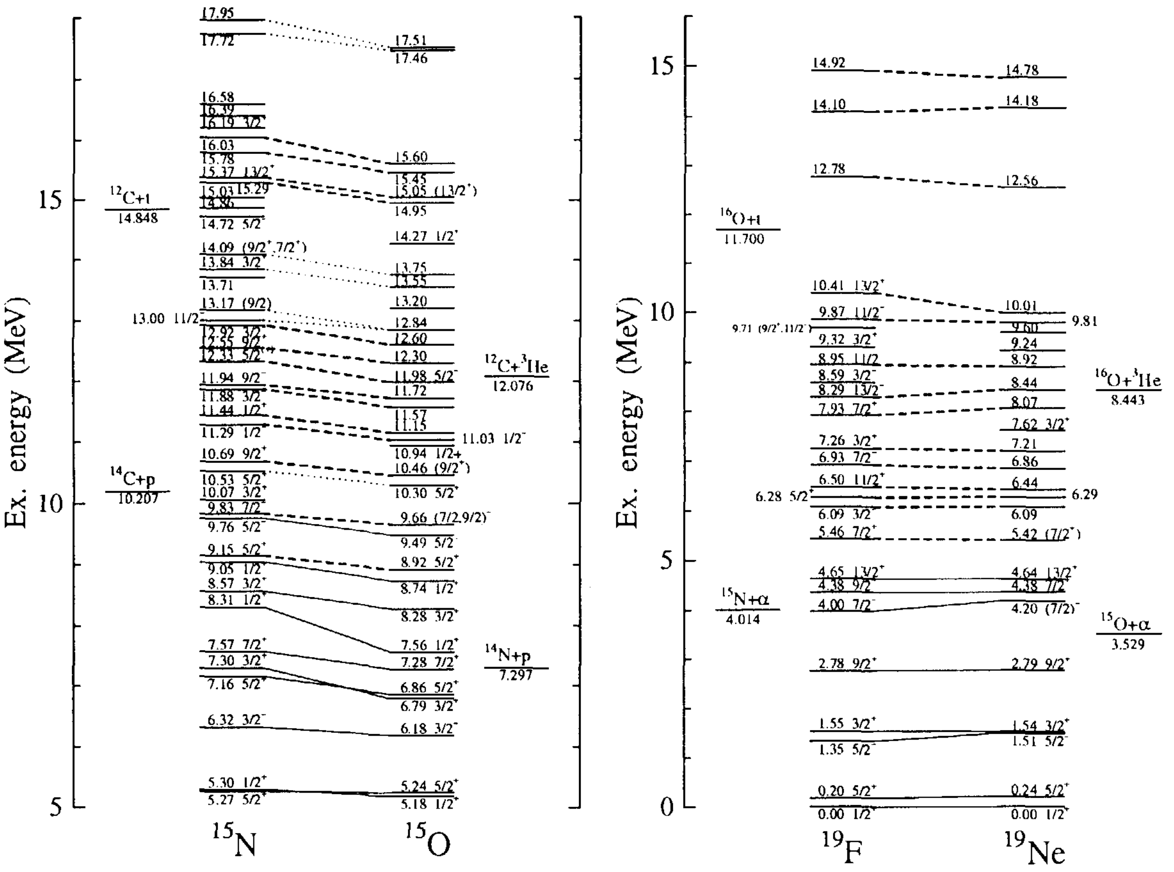

Fig. 2: Energy levels observed in the present experiment; the A=15 mirror nuclei are on left side and A=19 are on right side. The excited states connected by solid lines are known as mirror states, those by dashed lines are mirror states newly assigned in this study, and ones by dotted lines are candidates for the mirror state.

Mirror relation of states could be assigned by comparing the angular distribution of the cross section in the mirror reactions. Figure 2 shows energy levels observed in the present experiment. Many mirror states (connected by dashed lines in Fig. 2) have been newly assigned in this study. Generally, less information about the spin-parity has been obtained in a high excitation region of an unstable nucleus. From the mirror relation in the present work, we have obtained new spin-parity information about many higher-excited states in ^{15}O and ^{19}Ne.

In order to obtain spectroscopic information, angular distributions were analyzed in the framework of the finite-range DWBA. A cluster-core folded potential was used for the transfered cluster binding potential in the residual nuclei. The calculation with the folded potential well reproduces the cluster binding energies of the states belong to the $K^{\pi} = 1/2^{+}$ band in ^{19}F without varying the potential depth. According to the cluster model, negative parity $K^{\pi} = 1/2^{-}$ band which corresponds to the parity inversion band of the $1/2^{+}$ band should also exist, and the members of this band has been predicted in higher excitation energy region than about 6.5 MeV in ^{19}F by the present calculation. Differential cross sections were evaluated using the code TWOFNR under an assumption of a cluster one-step transfer mechanism. $(sd)^{3}$ for positive parity states and $(sd)^{2}(fp)^{1}$ for negative parity states were assumed as configulations of the transfered three nucleons in the residual nuclei.

Figures 3(a)~(d) compare DWBA predictions with the experimental angular distrubutions of the $1/2^+$, $5/2^+$ and $9/2^+$ members of the $K^\pi = 1/2^+$ band and of candidates for the $3/2^-$, $7/2^-$ and $11/2^-$ members of the $K^\pi = 1/2^-$ band in ^{19}F and ^{19}Ne. The calculations well reproduce the observed angular distrubutions. This result suggests that a direct reaction mechanism is dominant for the members of rotational bands. From the comparison between the experimental and theoretical results, cluster spectroscopic factors were extracted for each state.

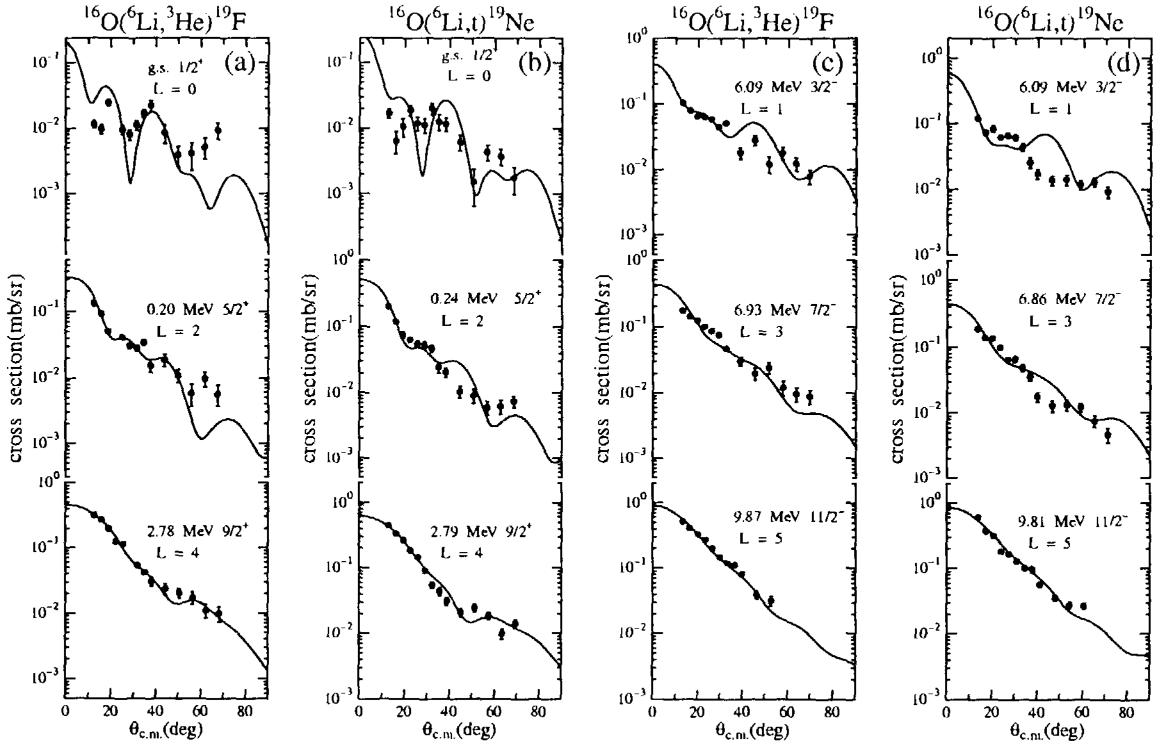

Fig. 3: Experimental (points) and theoretical (solid curves) angular distributions of the $1/2^+$, $5/2^+$ and $9/2^+$ states in the $K^\pi = 1/2^+$ band in ^{19}F (a) and ^{19}Ne (b), and the candidates for the $3/2^-$, $7/2^-$ and $11/2^-$ states in the $K^\pi = 1/2^-$ band in ^{19}F (c) and ^{19}Ne (d).

Figure 4(a) shows cluster spectroscopic factors for each state of the A=19 nuclei. In this figure, black bars represent the members of the $K^\pi = 1/2^+$ band and hatched bars candidates for the members of the $K^\pi = 1/2^-$ band. The magnitude of the spectroscopic factors for the members is almost identical except those for the $1/2^+$ and $3/2^-$ states. This similarity of the spectroscopic factor values will support that these two bands are the parity doublet bands in the three-nucleon cluster structure. There are three strong peaks in higher excitation region than 12 MeV as seen in Fig. 1. These are already assigned as the low spin states, but the spectroscopic factors are too much large . Whereas, if it is assumed that they have large spins, spectroscopic factors of these states are as much as those of low spin members of the $K^\pi = 1/2^\pm$ bands. Therefore, these three states could be candidates for the high spin members of the bands; $11/2^+$ and $15/2^-$ which have never been assigned.

Spectroscopic factors for each state of the A=15 nuclei are shown in Fig. 4(b). Black bars

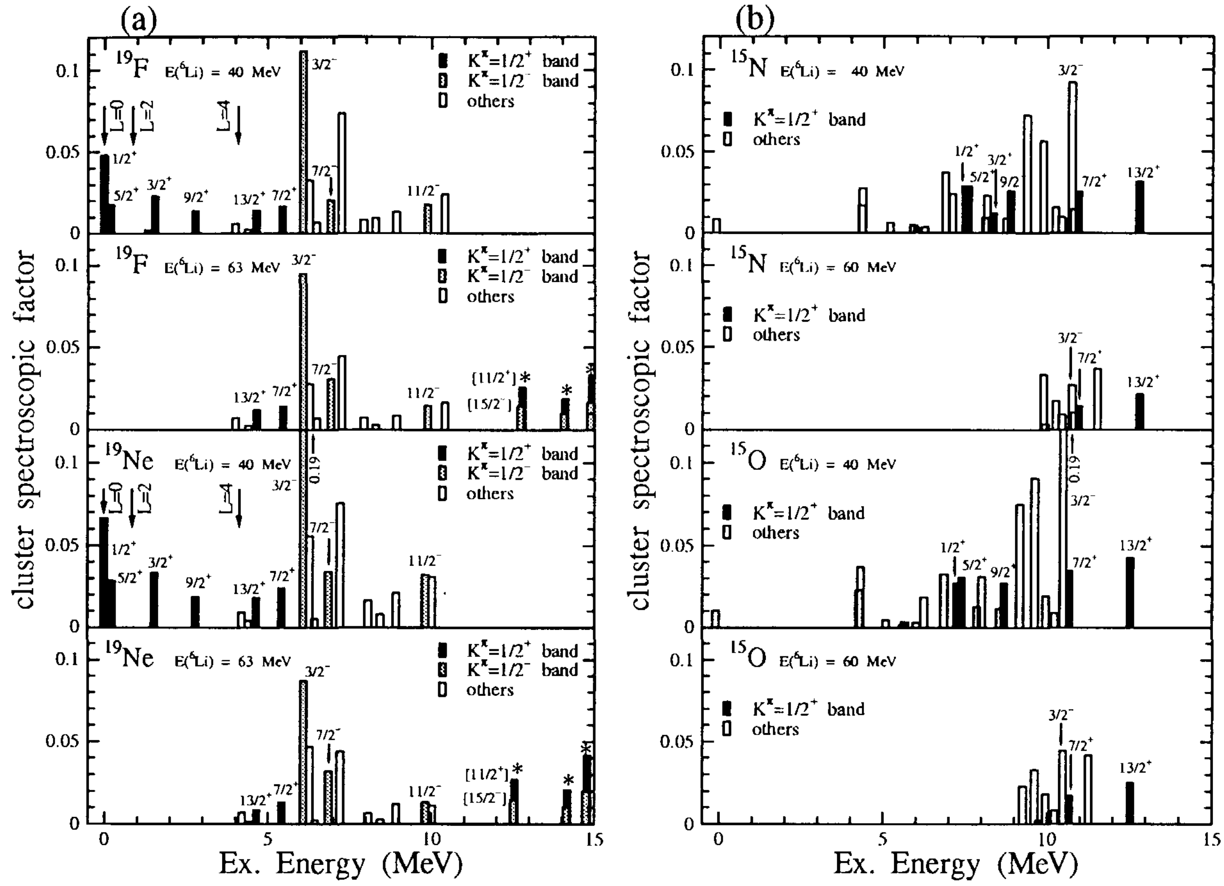

Fig. 4: Cluster spectroscopic factors for each state of the A=19 nuclei (a) and of the A=15 nuclei (b). Black bars represent the members of the $K^\pi = 1/2^+$ band (at A=15 nuclei, candidates) and hatched bars candidates for the members of the $K^\pi = 1/2^-$ band. Asterisk marks indicate the states which are assumed as high spin members of the $K^\pi = 1/2^\pm$ bands ($11/2^+$ for black bars and $15/2^-$ for hatched bars).

present candidates for the members of the $K^\pi = 1/2^+$ band. The spectroscopic factors for the members are almost uniform, but there is no candidate for the $1/2^-$ band except the $3/2^-$ state (12.92 MeV in ^{15}N and 12.60 MeV in ^{15}O). One of the causes might be a lack of the spin-parity assignment for the states in the higher (above 13 MeV) excitation energy region.

In conclusion, the existence of three-nucleon cluster structure in the A=19 nuclei is suggested, however, in the A=15 nuclei a lack of information for spin-parity in higher excitation region prevents exploring the existence of the cluster structure.