15N(p, n)15O Reaction at 35 MeV

I. 1. $^{15}N(p, n)^{15}O$ Reaction at 35 MeV

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A large number of spin-flip excitations have been extensively studied by different probes, such as (e, e'), (p, p') and (p, n) reactions, to investigate the fundamental response of spin excitation in nuclei. Especially, the (p, n) reaction has provided us many interesting information about spin-isospin excitation modes in nuclei. For example, Gamow-Teller (GT) type transitions have been studied in charge exchange reactions to examine the close relationship between the GT reduced transition probabilities B(GT), obtained from β-decay, and the cross sections for low and intermediate energy (p, n) reactions [1-2]. Also the study of stretched particle-hole states by the (p, n) reaction provides a good place to probe spin-isospin properties of nuclei, and to study the isovector part of the tensor interaction at large momentum transfer [3-5]. Moreover, the isovector $\Delta J^{\pi} = 0^{-}$ transition, studied primarily by the (p, n) reaction [6-7], gives us information of longitudinal spin response, or alternatively, that of nuclear medium effects.

Shell-model transition amplitudes for p-shell nuclei needed for microscopic DWBA calculations are available from the Cohen and Kurath wave functions [8] for the positive-parity states, and from Millener and Kurath wave functions [9] for the negative-parity states. By sampling the (p, n) reactions on ^{12}C and ^{16}O at E_p = 35 and 40 MeV, we have examined [10] the reliability of the information obtained from DWBA analyses of the low-energy (p, n) data. The tensor part of the effective nucleon-nucleon interaction, which is crucial in the DWBA prediction, has been separately tested by studying the isovector $\Delta J^{\pi} = 0^{-}$ type transitions in p-shell nuclei [6-7]. Several 1^{+} excitations with the dominant $\Delta J(\Delta L,\Delta S) = 1(2,1)$ components are observed in the $^{34}S(p, n)^{34}Cl$ reaction [2]. They are found to be quenched to less than a half of the predicted strengths. The analyses in these studies show that the effects of higher-order and exchange processes give negligibly small contributions in most cases. It has also been found [1,10] that the use of different distorting potential parameters may introduce an ambiguity of ~20 % in the absolute magnitude of predicted cross sections.

In this paper we report the experimental data of the $^{15}N(p, n)^{15}O$ reaction obtained at $E_p = 35$ MeV, and the results of their microscopic DWBA analysis.

The experiment was carried out using a 35 MeV proton beam from the AVF cyclotron at the Cyclotron and Radioisotope Center, Tohoku University. Neutron energies were measured by means of the time-of-flight (TOF) technique [11], where neutrons were detected by a detector array located at 44.3 *m* from the target. Two types of gas cell with foil-windows, e.g. calcium-, iron- and/or Havar-foil, filled with enriched (to 98.7%) ^{15}N gas were used as the target in the experiment. The target for forward-angle measurements ($\theta_{lab} < 40^o$) was a disk type having a longitudinal length of 2 *cm*. The target for backward-angle measurements ($\theta_{lab} > 30^o$) was a cylindrical type having a length of 20 *cm* and thus making it possible to shield the neutron detectors against neutrons emitted from foil-windows. In both cases, the effective target thickness were of the order of 1 mg/cm^2 and overlap region of detection angle was used for normalization of different setup measurements. Overall time resolution of the γ flash was typically 1.31 *ns* corresponding to 174 keV for the most energetic neutron.

Typical neutron spectra measured for the $^{15}N(p, n)^{15}O$ reaction at laboratory angles of 30^o is shown in Fig. 1. Except for the ground $1/2^-$ state, the (p, n) transition to which is mixture of Fermi ($\Delta J = 0$) and Gamow-Teller ($\Delta J = 1$), interesting well resolved transitions are lying in this excitation region shown in Fig. 1. Neutrons leading to the 5.183- and 5.241-MeV states are not resolved. Spin-parities for these states are, respectively, $1/2^+$ and $5/2^+$, ΔJ^π transferred to which from $1/2^-$ ^{15}N ground state are 0^-, 1^- and 2^-, 3^-. Angular distribution for these neutrons are illustrated in Fig. 2. Theoretical predictions for four transitions mentioned above are also shown, indicating that the dominant transition is $\Delta J^\pi = 2^-$. N in the figure is a normalization factor introduced to optimize fitting. It should be noted that the normalization factor of 0.8 is almost similar to the cases of the $0 \rightarrow 2$ transition in the (p, n) reactions on ^{12}C and ^{14}C [10,12], while it is 0.3 for the $^{16}O(p, n)^{16}F$ reaction[10]. Alternatively, neutrons leading to the 6.793- ($3/2^+$) and 6.859- ($5/2^+$) MeV states are unresolved. The most dominant transition for these cases is $\Delta J^\pi = 1^-$ one, N being 0.8.

The $\Delta J^\pi = 1^+$ Gamow-Teller transition is involved in the $1/2^- \rightarrow 3/2^-$ transition leading to the 6.176-MeV state, experimental and theoretical angular distributions for which are illustrated in Fig. 3. Contrary to the cases of $\Delta J^\pi = 2^-$ and 1^-, now N = 0.32 which is remarkably small factor. Angular distribution shape shows a typical L = 0 pattern, indicating that contributions from L = 2 transition in $\Delta J^\pi = 1^+$ and 2^+ are less important. The main component of the 7.276-MeV, $7/2^+$ state is $\Delta J^\pi = 3^-$, though $\Delta J^\pi = 4^-$ stretched state excitation may be observed from the view point of the particle-hole configuration. As for the last one leading to the 7.557-MeV, $1/2^+$ state is excited through the $\Delta J^\pi = 0^-$ transition, as discussed previously in ref. 7).

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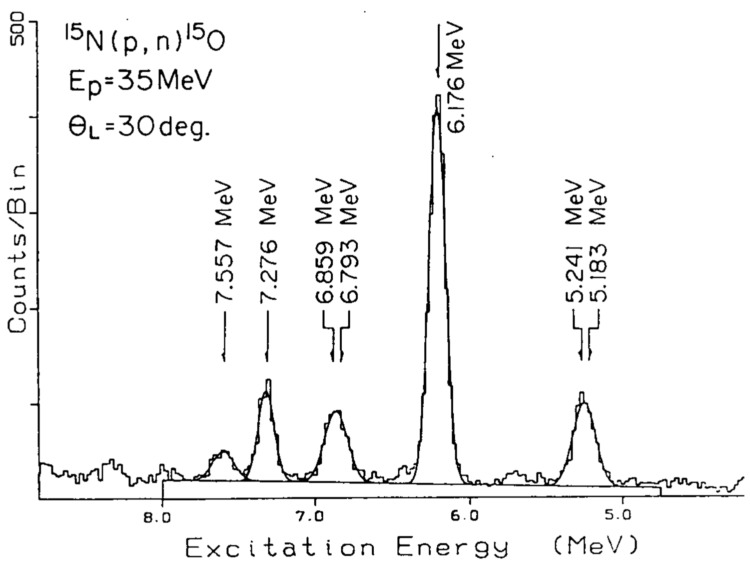

Fig. 1. Sample excitation energy spectrum for the $^{15}N(p, n)^{15}O$ reaction taken at laboratory angle of 30° with a flight path of 44.3 m. Energy per bin is 25 keV.

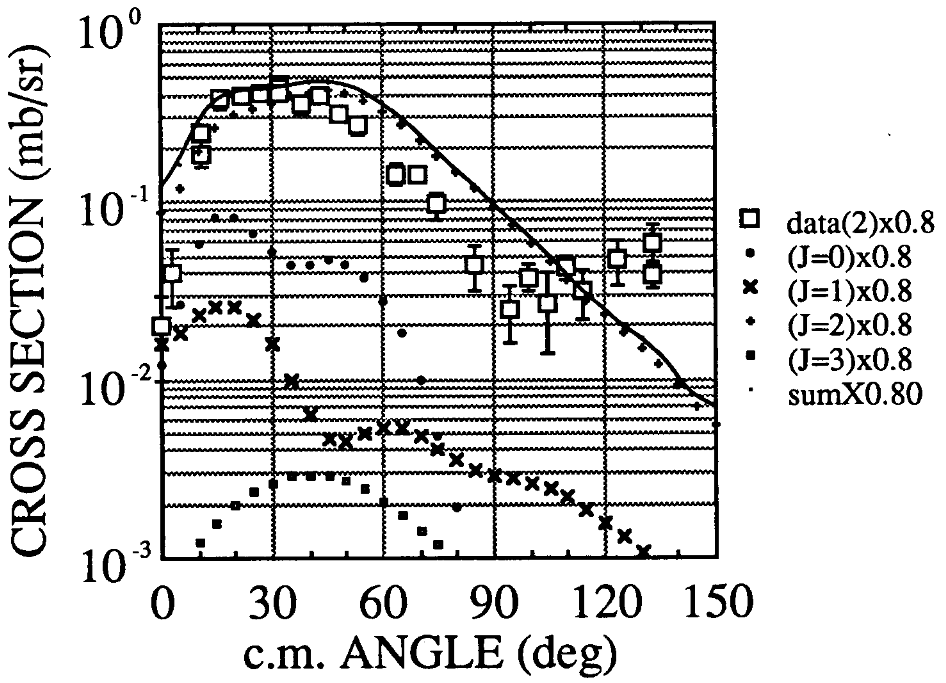

Fig. 2. Differential cross sections for neutrons from the $^{15}N(p, n)^{15}O$ reaction leading to the unresolved 5.241- and 5.183-MeV states. Curves are microscopic DWBA calculation.

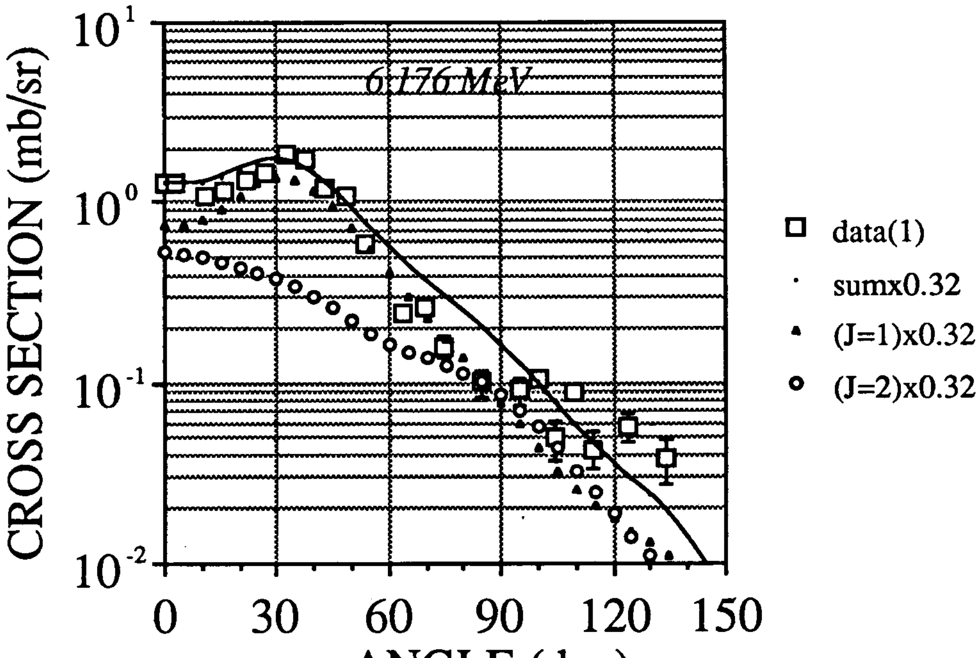

Fig. 3. Same as Fig. 2 but for the transition leading to the 6.176-MeV $3/2^-$ state.