Observation of Isovector 1hw Spin-Flip Excitation by the 18O(p, n) 18F Reaction at Ep = 35 MeV

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I. 1. Observation of Isovector 1$\hbar\omega$ Spin-Flip Excitation by the $^{18}O(p,n)^{18}F$ Reaction at E_p=35 MeV

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A large number of spin-flip excitations have been extensively studied by different probes to examine the fundamental response of spin excitation modes in nuclei. In particular, comparative studies between magnetic transitions in inelastic electron scattering and unnatural parity transitions observed in inelastic proton scattering have shown a possibility of separation of current and spin contributions to M1 excitations.1) On the other hand, Petrovich et al.2) have examined a direct extraction of the orbital current contribution to isovector M1 excitations in light nuclei by comparative study of the (e,e') and (p,n) reaction. By carrying out studies of these subjects systematically, we can get information of spin and spin-isospin excitation modes in nuclei.

We have performed systematic studies of the (p,n) reactions at E_p = 35 MeV for sd-shell nuclei.3,4) For sd-shell nuclei, the shell model wave functions by Brown-Wildenthal (BW) are extensively used and the stringent test of the BW wave functions has been achieved.5) In this report, we discuss the observation of isovector 1$\hbar\omega$ spin-flip excitation via the $^{18}O(p,n)$ reaction at E_p = 35 MeV. We have chose ^{18}O as a target since it provides a good place to test the wave functions for negative parity states. In sd-shell nuclei, spectroscopic amplitudes of unnatural parity transitions leading to the 1$\hbar\omega$ jump negative parity states are available only for A = 18 nuclei by the BW wave functions.

The experiment was carried out with a 35 MeV proton beam from the AVF-cyclotron and a beam swinger system at the Cyclotron and Radioisotope Center, Tohoku University, to measure angular distributions of emitted neutrons. The details of the experimental setup have been described previously.6) Neutron energies were measured by the time-of-flight (TOF) technique, where neutrons were detected by a detector array located at 44 m from the target. A gas cell with Havar foil windows filled with enriched (to 98.7 %) ^{18}O gas were used as the target.

Figure 1 shows the typical neutron spectrum measured for the $^{18}O(p,n)^{18}F$ reaction at a laboratory angle of 25°. The spectrum is dominated by the Gamow-Teller type transition leading to the ground-state in ^{18}F and by the ground-state analog transition leading to 0^+ state at E_x = 1.042 MeV. Several negative parity states are seen to be excited among them. Figure 2 shows the angular distribution of the differential cross sections leading to the J^π; T = 2^-; 0 state at E_x = 2.099 MeV. Figure 3 shows the angular distribution of the unresolved peak of the 1^+; 0 state at E_x = 3.724 MeV and the 3^-;0 state at Ex = 3.791 MeV. Solid curves in these figures are Distorted Wave Born Approximation (DWBA) predictions.

We have employed the computer-code DWBA74 by Schaeffer and Raynal$^{7)}$ to analyze the ^{18}O(p,n)^{18}F reaction based on direct reaction theory. Optical potential parameters of Becchetti and Greenlees$^{8)}$ were used for entrance channel, while those for exit channel were self-consistent potential parameters derived by Carlson et al.$^{9)}$ Single-particle radial wave functions were generated in a Woods-Saxon type potential with r_0 = 1.25 fm, a = 0.6 fm, V_{LS} = 6 MeV and the depth adjusted to reproduce the binding energy of a valence nucleon. Spectroscopic amplitudes namely one-body transition density (OBTD) employed in this analysis have been obtained from shell model calculation.$^{10)}$ A set of effective NN interaction by Bertsch et al. (M3Y)$^{11)}$ has been used in the calculation. Reliability of the information extracted from such DWBA analyses has been discussed by Ohnuma et al.$^{12)}$

For $\Delta J^\pi=2^-$ unnatural parity transition leading to the presently observed 2^- state (E_x = 2.099 MeV), $\Delta J(\Delta L,\Delta S)$ = 2(3,1) and 2(1,1) configurations are available in the category of direct process. The BW shell model calculation predicts that ($\nu p_{1/2},\pi d_{5/2}^{-1}$) configuration has the largest amplitude for this transition. These transitions seem to be take place through spherical tensor operator of rank 2 containing a spin-flip operator. By decomposing spectroscopic amplitude $Z_{jj'}$ into $Z_{\Delta L \Delta S}$ components, it can be confirmed that how is the spin-flip contribution. Figure 4 shows the result of DWBA calculation. This calculation clarified the spin-flip 2(1,1) component is dominant for the $\Delta J^\pi = 2^-$ transition. The spin-flip 2(2,1) component comes from exchange process.

On the other hand, for $\Delta J^\pi = 3^-$ natural parity transition leading to the 3^- state (E_x = 3.791 MeV), we can expect 3(3,0) and 3(3,1) components contributes to the transition through direct process. By checking the ΔJ ($\Delta L,\Delta S$) configuration, we can found that the spin-flip excitation dominates the spin-nonflip excitation.

In summary, it is found that the central forces, especially spin-isospin part, in the effective NN interaction play an important role in the $1\hbar\omega$ type transitions leading to the negative parity states. Also, a candidate for the $1\hbar\omega$ *p-h* stretched state leading to 6^- state located at 9.5 MeV has been discovered.

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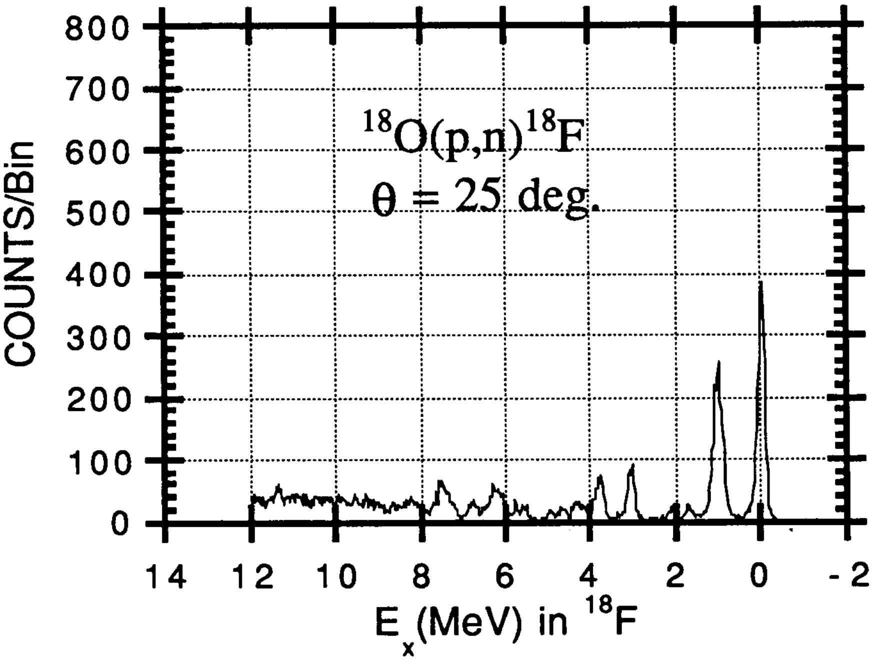

Fig. 1. Sample energy spectra for the $^{18}O(p,n)^{18}F$ reaction taken at laboratory angle 25° with a flight path of 44.3 m. Energy per bin is 25 keV.

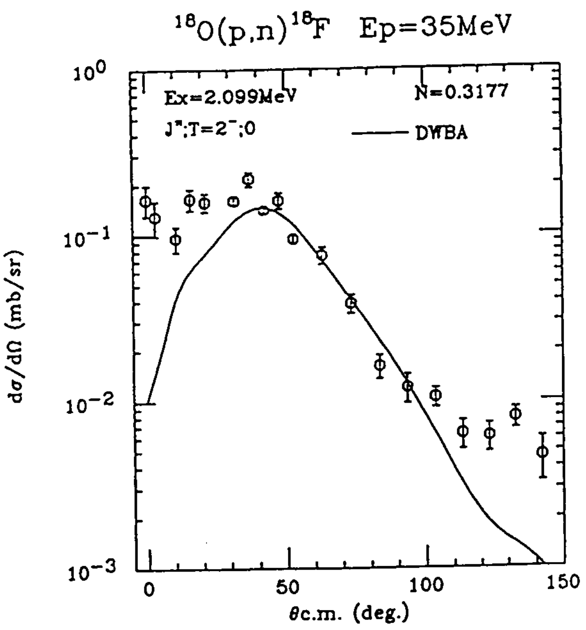

Fig. 2. Differential cross sections for neutrons from the $^{18}O(p,n)^{18}F$ reaction leading to the 2^- state at 2.099 MeV. The curves are the results of microscopic DWBA calculations.

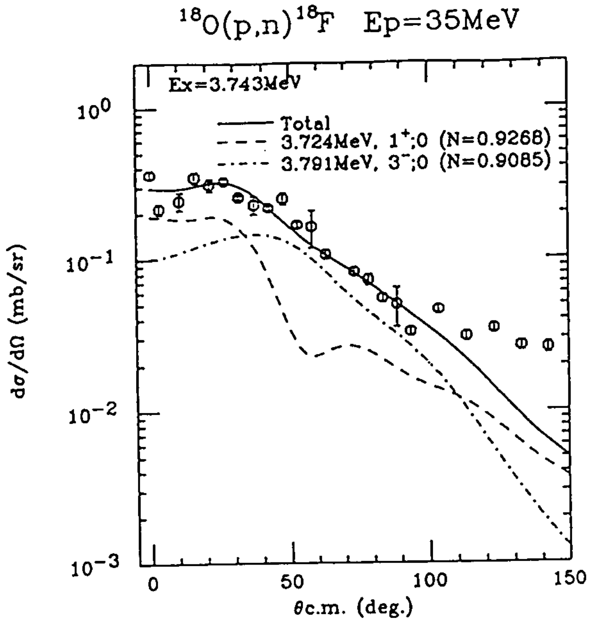

Fig. 3. Differential cross sections for neutrons from the $^{18}O(p,n)^{18}F$ reaction leading to the doublet of 1^+ state at 3.724 MeV and 3^- at 3.791 MeV. The curves are the results of macroscopic DWBA calculations.