Polarization Transfer in the ^{16}O(p,p’) Reaction at E_p = 392 MeV and tructure of the spin-dipole resonance

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Spin-isospin excitation modes in nuclei have been an important subject in nuclear physics not only because they are of the interest in nuclear structure, but also because the relevant operators mediate β-decay and neutrino capture processes. Gamow-Teller resonances (GTR; ΔT = 1, ΔS = 1, ΔL = 0) mediated by the $\vec{\sigma}\ \vec{\sigma}$ operator have been systematically studied by charge exchange reactions like (p,n) and (^{3}He,t) reactions with a selectivity for spin-flip transitions. On the other hand, spin-dipole resonance (SDR; ΔT = 1, ΔS = 1, ΔL = 1) mediated by $\vec{\sigma}\ \vec{\sigma}\, rY_1$ has not been studied in any detail although the excitations are recently received attention from the view point of detection of supernova neutrinos. The existence of three different spin states of SDR ($J^{\pi} = 2^-$, 1^-, and 0^-) makes experimental studies difficult. In addition, the 1^- states can be inherently excited by using a probe with a spin through the spin-flip and non spin-flip processes with the $\vec{\sigma}\ \vec{\sigma}\, rY_1$ and $\vec{T}\, rY_1$ operators. Thus, we have measured polarization transfer observables in ^{16}O(p,p’) eactions at extremely forward angles including 0^o aiming at studies of SDR states.

The experiment has been performed at RCNP, Osaka University using a 392 MeV polarized proton beam. Thin iced H_2O sheets with various thicknesses of 10-30 mg/cm^2 were used as oxygen targets. Self-supporting ice sheets made of pure water were mounted in the scattering chamber, which was kept under vacuum lower than 10^{-3} Pa without any window-foil. The ice targets were cooled down under 140 K by liquid nitrogen where sublimation loss of ice can be neglected. We have succeeded in obtaining significantly low background spectra by using this new ice target system.

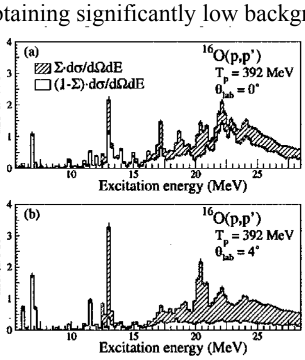

Figure 1: Spin-flip (hatched) and non spin-flip (white) spectra for ^{16}O(p,p’) at (a) 0± and (b) 4^o, respectively.

The measured spectra for the ^{16}O(p,p’) reactions at 0^o and 4^o are shown in Figure 1 (a) and (b). In order to extract spin-flip transitions, a quantity ’total spin transfer’ is introduced as $\Sigma = \{3 - (D_{SS} + D_{NN} + D_{LL})\}/4$. This quantity is unity for spin-flip transitions and zero for nonspin-flip transitions at forward angles where the spin-orbit term of effective interaction can be neglected. By using this Σ, spin-flip cross section of $\Sigma \times \frac{d\varsigma}{d\Omega}$ and non-spin-flip cross-section of $(1 - \Sigma) \times \frac{d\varsigma}{d\Omega}$ have been obtained as presented in Figure 1. Spin-flip and non-spin-flip transitions are shown as hatched and white spectra in the figures, respectively. Non-spin-flip transitions with forward peaking cross sections were observed at the excitation energies of 20.9, 22.1, 23.0, and 24.0 MeV. These transitions have been well reproduced in a simulation calculation in which the excitation strengths are converted from the photoabsorption cross sections. This result is consistent with the expectation that the isovector giant dipole resonance (IVGDR) is enhanced at 0± via Coulomb excitations in (p,p’) reaction at 392 MeV.

On the other hand, spin-flip strengths observed at the IVGDR region were found to be excited by ΔL = 1 angular momentum transfer. The resonance states observed at the same excitation energies with IVGDR carry both the IVGDR and SDR (1^-) strengths. Since the bumps at 19.0 and 20.4 MeVare not seen in the non spin-flip spectrum, they are inferred to be excited by unnatural parity transitions, and correspond to the SDR (2^-) reported in the electron scattering. We also performed the DWBA calculations using the shell model wave functions by B.A.Brown. These calculations reasonably explain our observation.