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A High-Resolution Measurement of the $^{16}O(\gamma,p)^{15}N$ Reaction Cross Section

R. P. Rassool, D. A. Sims, A. Kuzin, M. N. Thompson
School of Physics, University of Melbourne,
Parkville, 3052, Australia

T. Suda, I. Nomura, T. Ito, K. Maeda, O.Konno, and T. Terasawa

Laboratory of Nuclear Science, Tohoku University
Mikamine, Sendai 982, Japan

In the intermediate energy range, the photo-absorption process has been successfully described by microscopic model calculations of Gari and Hebach[1] and the Hartree-Fock Random Phase Approximations (HF-RPA) models of the Bologna[2] and Gent[3] groups. The importance of meson- exchange currents and long-range correlations have been emphasised. Presumably, one of the most important findings from the microscopic models has been that the reaction mechanism must include contributions from shell-model, exchange currents and nucleon-nucleon interactions. The question arises as to the relative importance of each of these different components in the photonuclear reaction mechanism.

Investigating the relative importance of the components of the reaction mechanism can be done using the reaction $^{16}O(\gamma,p)^{15}N$. The structure of the low-lying states in the residual 15N nucleus are well established. The ground and third excited (6.3 MeV) states are known to be 1-hole states, and these states can be formed by proton knock-out from the p shell. Conversely, the positive parity states, at 5.27 and at 5.30 MeV in ^{15}N, are predominantly 1p-2h states and cannot so easily be populated in such a manner.

However, it is accepted that states with this structure are likely signatures of photon absorption by two-body currents. Thus, a high resolution measurement of the $^{16}O(\gamma,p)^{15}N$ cross section to the low-lying states is a sensitive probe of the role of meson-exchange currents in photo- absorption. We have recently measured the reaction $^{16}O(\gamma,p)^{15}N$ with tagged-photons of energy $E\gamma$ = 40 and 60 MeV, at the Laboratory of Nuclear Science of Tohoku University (LNS). Experimental conditions were optimised to provide the best possible resolution. Of special note was the use of narrow 2-mm detectors on the focal-plane of the tagging spectrometer. The results are presented in Figure 1.

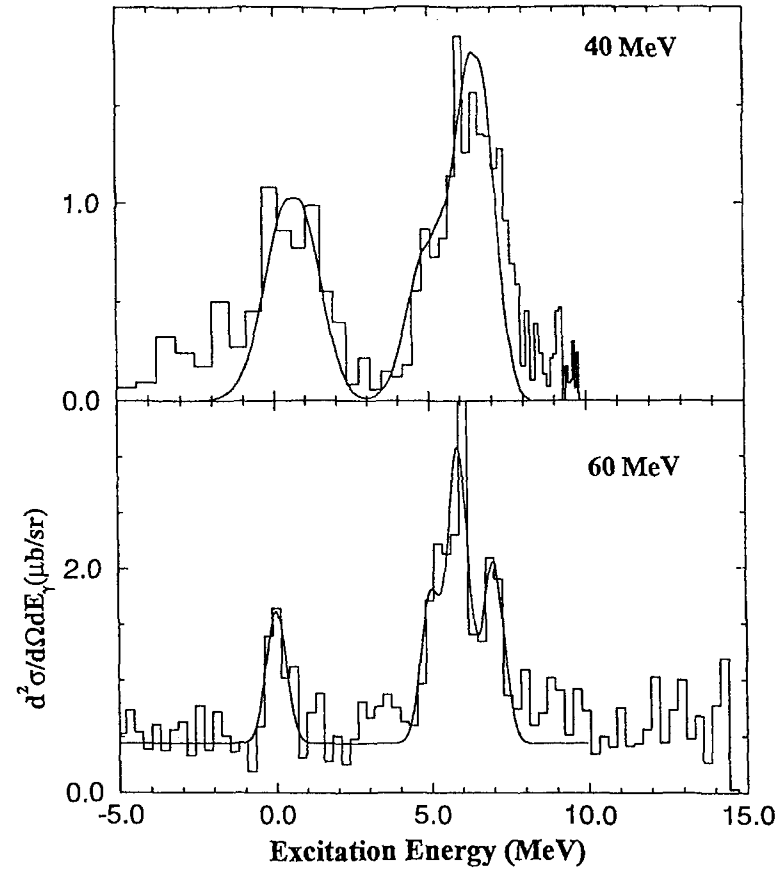

Figure 1: Fits to the excitation energy Spectra for the $^{16}O(\gamma,p)^{15}N$ reaction cross section, measured at 60 MeV.

Each of the excitation-energy spectra exhibits the hallmarks of a high resolution spectrum. The ground-state transitions are clearly resolved with a FWHM of 800 keV. Finer details are apparent in the structure near 6 MeV: in particular, the shoulder near 5 MeV, the sharp peak at approximately 6 MeV, and the valley between this peak and that near 7 MeV, are consistent with the improved resolution. The resolution of 800 keV in the 60 MeV spectrum is the best tagged-photon proton energy resolution achieved at the LNS.

To compare this data with the predictions of the theoretical models, cross sections to specific states in ^{15}N need to be extracted. Of particular relevance to the discussion is the population of the 5.3 MeV states. Given the obtained resolution, the determination of the cross section to these states was done by utilising a fitting procedure.

For some time it has been known that the ground-state wave function of oxygen is not a pure closed core. Although it consists largely of a neutron and proton configuration closed at the $p_{1/2}$ shell, there are significant admixtures with basis states involving two or four particles in the s-d shell. Agassi[4] gives a closed core configuration probability of 66.5%, with 2p-2h and 4p-4h components with probabilities of 27.1% and 5.5% respectively.

It has also been known for some time that the positive parity states, at 5.27 and 5.30 MeV in ^{15}N are essentially 1p-2h states relative to an ^{16}O core. It is also possible to consider these configurations to be based on a ^{14}N core. The dominant configuration of these states on this basis, is a particle in the s-d shell coupled to the 2-hole, 0+, T=1 state in ^{14}N. Population of the positive-parity states has been observed in earlier $^{16}O(\gamma,p)^{15}N$ measurements[5]. The present measurement confirms that their population is significant.

In the earlier HF-RPA calculations for the population of the negative-parity states, the relatively low spectroscopic factors were indicative of substantial depletion of the shell. As discussed earlier, it is well established that approximately 30% of the ^{16}O-ground-state wavefunction consists of at least 2 particles in the s-d shell. With such a configuration, it is possible to populate the positive-parity states at 5.3 MeV by direct knockout, or by a 2-nucleon absorption process where the neutron is recaptured. The most recent HF-RPA calculations[6], in which the ground-state admixtures have been included, reproduce the experimental data excellently. Consistent with the earlier observations, the major strength in the cross section is derived from photon-absorption by meson-exchange currents.

References

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Further information can be obtained from Roger Rassool by email on **roger@physics.unimelb.edu.au**