Short Communications

Aust. J. Phys., 1979, **32**, 411–14

4^- Particle–Hole States in ^{16}O†

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Abstract

4^- states of ^{16}O at excitation energies of 17·79 and 19·80 MeV ($T = 0$) and 18·98 MeV ($T = 1$) are observed to be strongly excited in inelastic scattering of 135 MeV protons at momentum transfers of 200–500 MeV/*c*. The previous ambiguity in the spin and parity assignments for the 17·79 MeV state is removed.

Excitation of stretched particle–hole 6^- states has been observed (Adams *et al.* 1977) in the inelastic scattering of intermediate energy protons on ^{24}Mg and ^{28}Si. The predominant configuration in these 6^- states was assumed to be $1f_{7/2}(1d_{5/2})^{-1}$, and the measured differential cross sections were successfully interpreted in terms of this configuration.

In 1p-shell nuclei the maximum angular momentum achievable by a single particle–hole excitation is 4^-, in a $1d_{5/2}(1p_{3/2})^{-1}$ excitation. Only two 4^- states in ^{16}O have been confirmed in transfer reactions (Mairle *et al.* 1978); a third state was observed but definite spin and parity assignments could not be made. The present work was undertaken in an attempt to observe these states in a (p, p′) reaction at 135 MeV bombarding energy and to attempt to clarify the existence of a third 4^- state.

The incident beam of 135 MeV protons, which was obtained from the Indiana University Cyclotron Facility (IUCF), bombarded a $10\,mg\,cm^{-2}$ Mylar ($C_{10}H_8O_4$) target. The carbon contribution was measured by bombardment of a polystyrene target ($(CH)_n$) of similar thickness, and the oxygen contribution was obtained by subtraction of spectra.

The inelastically scattered protons were detected with the QDDM magnetic spectrograph of the IUCF, to which the beam analysis system and beam line were dispersion matched. The excitation energy bite at the focal plane of the spectrograph was about $6\frac{1}{2}$ MeV, and the spectrograph was set to cover the excitation region from 14 to 20·5 MeV in ^{16}O. The focal plane detector system was composed of a helical delay-line gas counter for position measurement (Officer *et al.* 1975), followed by two plastic scintillators. The differential energy loss of detected particles in the two scintillators was used in particle identification; a triple coincidence from the detectors was required. Overall resolution for most of the spectra was about 80 keV FWHM.

† Work supported at Melbourne in part by the Australian Research Grants Committee and at Indiana in part by the U.S. National Science Foundation.

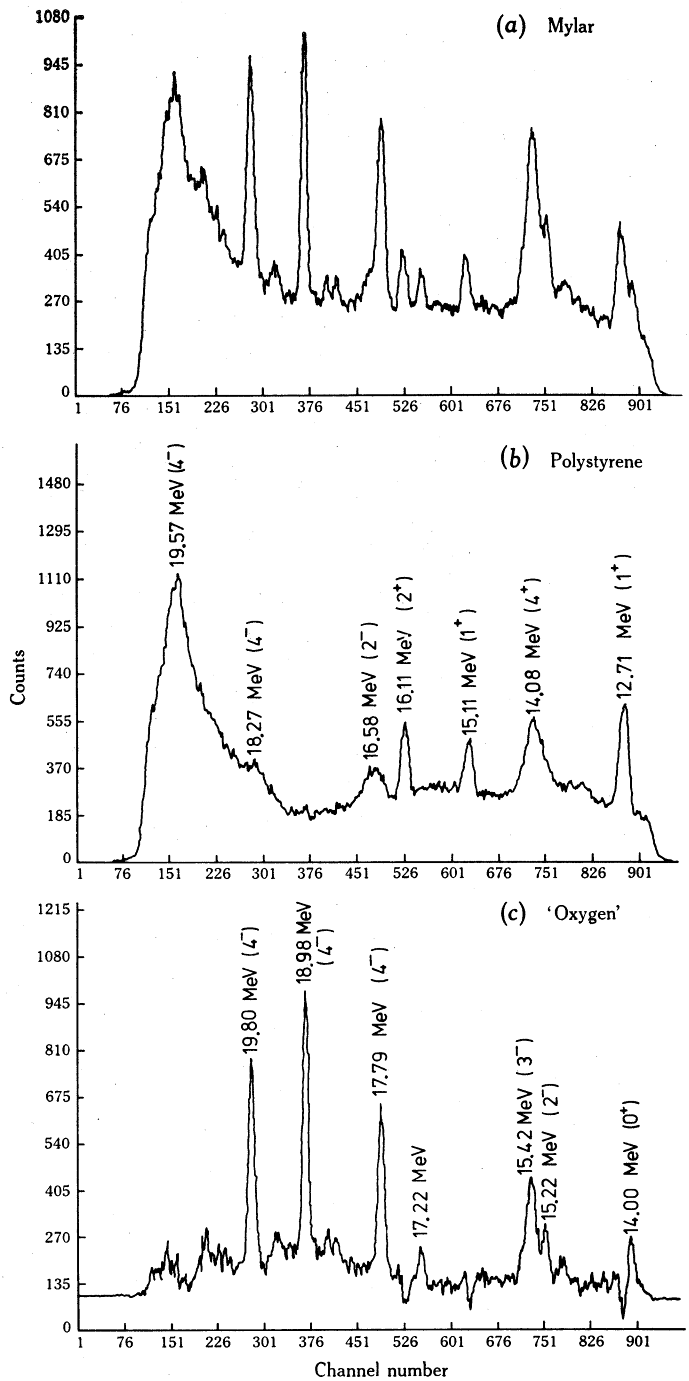

Fig. 1. Sample spectra of inelastically scattered protons, at a laboratory angle of 35°, from (*a*) Mylar, (*b*) polystyrene and (*c*) 'oxygen' as obtained by subtraction.

Typical spectra, taken at 35° laboratory scattering angle, from Mylar and polystyrene, as well as the subtracted 'oxygen' spectrum, are shown in Fig. 1. The excitation energies of the three strong ^{16}O states above 17 MeV were determined relative to the 15·11 and 16·11 MeV states of ^{12}C, and are believed to have uncertainties of less than 40 keV.

Differential cross sections for excitations of the ^{16}O states at 17·79, 18·98 and 19·80 MeV are shown in Fig. 2, along with the result of a microscopic distorted wave Born approximation calculation which assumes the simple $1d_{5/2}(1p_{3/2})^{-1}$ spectroscopy.

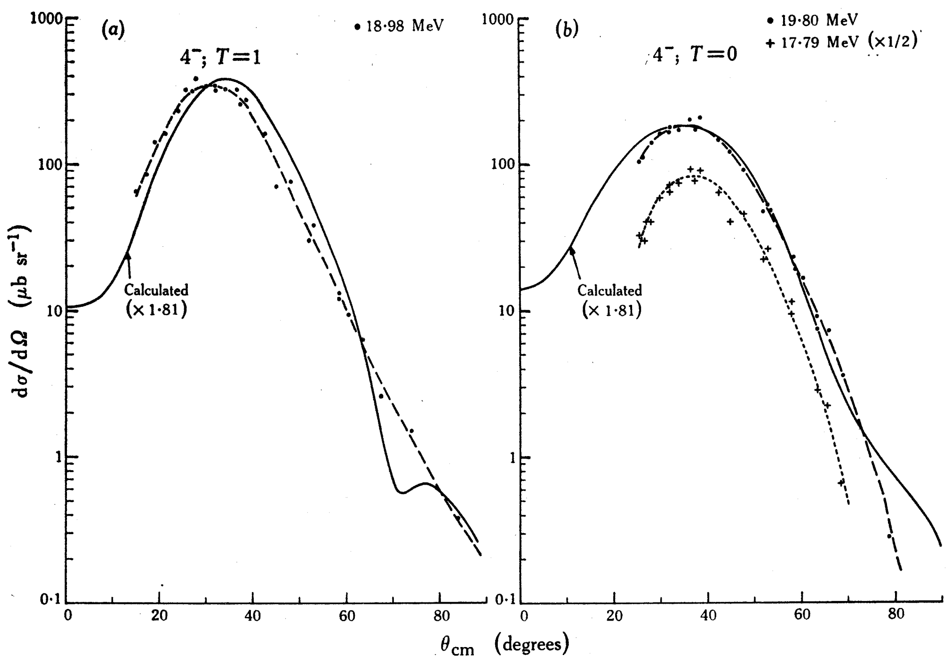

Fig. 2. Differential cross sections for the 4^- states in ^{16}O, showing the experimental results for (*a*) the $T = 1$ state at 18·98 MeV and (*b*) the $T = 0$ states at 17·79 and 19·80 MeV, together with the results of a microscopic distorted wave calculation. The dashed curves are included to show the trends of the experimental data.

The above three states of ^{16}O have also been observed in pickup reactions on ^{17}O by Mairle *et al.* (1978). They measured spectra of both tritons and ^{3}He emitted from ^{17}O when bombarded with 52 MeV deuterons. The triton groups populated both $T = 0$ and $T = 1$ states of ^{16}O, while ^{3}He groups populated only $T = 1$ states. Mairle *et al.* concluded that the 19·80 MeV state is 4^-, $T = 0$; the 18·98 MeV state is 4^-, $T = 1$; and the 17·79 MeV state is $T = 0$, with spin and parity 2^- or 4^-. The spin and parity assignment for the 17·79 MeV state was rendered uncertain by the close proximity of a peak from the contaminant $^{16}O(d, t)^{15}O$ reaction in their data.

The high momentum transfer inelastic electron scattering result reported by Sick *et al.* (1969) indicated a 4^- state at 18·7 MeV in ^{16}O; that it appears in this reaction normally requires a $T = 1$ assignment. We identify this state with the 18·98 MeV state reported in the present (p, p′) reaction.

The close similarity between the (p, p′) differential cross section shapes for the 19·80 and 17·79 MeV states leads to the conclusion that these states have the same spin and parity, and therefore that both are 4^-, $T = 0$ states. This conclusion means that the centroid of the 4^-, $T = 0$ strength is at 18·8 MeV, just 180 keV lower in energy than the one 4^-, $T = 1$ state at 18·98 MeV in which all the $T = 1$ strength appears to reside. A simple zero-range particle–hole calculation using the residual interaction strength given by Brown *et al.* (1961) gave the energy difference between the $T = 0$ and $T = 1$ centroid energies as 450 keV, in fair agreement with this experimental result. The selective splitting of the $T = 0$ strength, but not the $T = 1$ strength, is not yet explained. That the $T = 0$ strength is split implies the presence of some other (complex) configuration in the wavefunctions for the 17·79 and 19·80 MeV states, and may well account for the poor theoretical fit to the shapes of the angular distributions for these states, while that for the 18·98 MeV state is well fitted.

Acknowledgment

The Melbourne group wishes to thank Dr R. E. Pollock, the Director of the Indiana University Cyclotron Facility, for his hospitality during the visits in which these data were taken. Thanks are also due to Dr K. A. Amos for the use of his inelastic scattering DWBA program.

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Manuscript received 15 January 1979