SHORT COMMUNICATIONS

THE $^{16}O(\gamma, p_0)^{15}N$ CROSS SECTION BETWEEN 14 AND 16 MeV*†

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This paper reports an investigation of the 90° differential cross section for the $^{16}O(\gamma, p_0)^{15}N$ reaction from 14 to 16 MeV.

The work was undertaken in an attempt to resolve an apparent discrepancy between the published $^{16}O(\gamma, p_0)^{15}N$ and $^{15}N(p, \gamma_0)^{16}O$ cross sections in this energy region. The early (γ, p) work indicated a resonance at 14·7 MeV (Spicer 1955; Johansson and Forkman 1957; Shoda 1961), which was assigned a spin and parity of 2^+ and was suspected of being a collective quadrupole state predicted to be in this energy region (Barton 1959; Fallieros and Ferrell 1959; Raz 1960; Gillet and

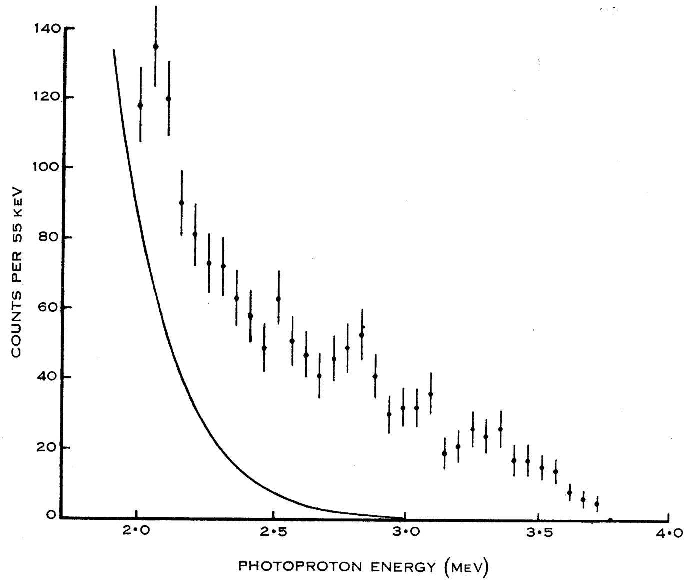

Fig. 1.—The energy spectrum of photoprotons from ^{16}O following bombardment by 16 MeV bremsstrahlung.

Vinh-Mau 1964). However, the (p, γ_0) measurements failed to confirm the existence of this state, so throwing some doubt on the existing data, or, alternatively, on the validity of the principle of detailed balance, which relates the cross sections of the two reactions.

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It was noted that in all the early (γ, p) experiments the protons were detected in nuclear emulsions, allowing the possibility of spurious counts from neutron–proton scatterings by the hydrogen of the emulsion. The present experiment repeated these measurements using a different method of detection to remove this possibility.

Experimental Details and Treatment of Data

A silicon surface barrier detector (ORTEC type SCIJ300–60) was mounted in a target chamber filled with oxygen to $\frac{1}{2}$ atm pressure. A collimated γ-ray beam of 16 MeV end point energy from the Melbourne betatron was passed axially through the chamber, the cylinder of irradiated gas seen by the detector acting as target. The detector was $3 \cdot 6$ cm from the chamber axis. The time duration of the γ-ray pulse was lengthened to about 150 μs to reduce pile-up. The background was further minimized by ensuring that the detector depletion layer was just deep enough (110 μm)

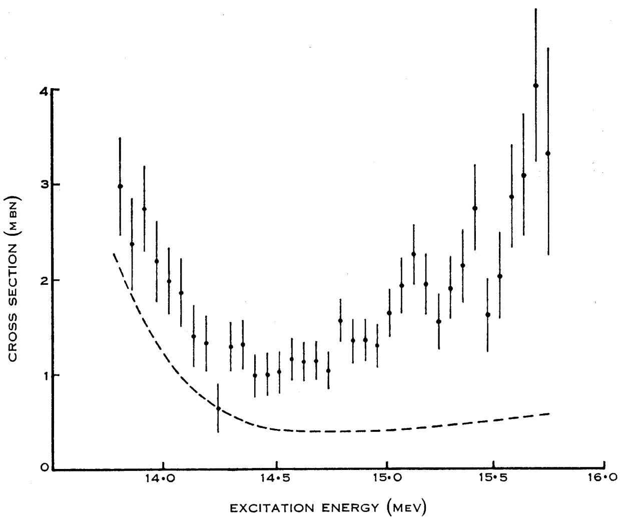

Fig. 2.—The cross section for the reaction $^{16}O(\gamma, p_0)^{15}N$, together with a cross section obtained from the inverse reaction using the principle of detailed balance.

to stop the most energetic protons produced in the reaction. The pulses were amplified, shaped, and presented to a 256 channel pulse-height analyser, which was gated on only during the betatron beam burst. Alpha particles from a ThC+C′ source were used to calibrate the system, which had a measured resolution of about 70 keV. The energy lost by a proton in traversing the gas was determined using the range–energy relations of Whaling (1957). The corrected energy spectrum is shown in Figure 1, where the indicated errors are statistical only.

The dose was monitored by placing in the beam a Victoreen thimble at the centre of a cylinder of Lucite of radius $7 \cdot 5$ cm. A dose of 2594 r was recorded in accumulating the data of Figure 1. The background was determined in a separate run performed with the chamber evacuated. In this run a dose of 1170 r was recorded.

The spectrum was converted to a cross section using a bremsstrahlung number distribution function based on the zero-degree spectrum of Schiff (1951), with $C = 111$, but modified suitably to take account of the extended duration of the γ-ray beam pulse.

The dosemeter reading was used to fit an absolute scale to the cross section, in the manner described by Johns *et al.* (1950). This cross section is presented in Figure 2, together with a cross section derived from the $^{15}N(p,\gamma_0)^{16}O$ work of Wilkinson and Bloom (1956) using the principle of detailed balance. In making this derivation, the peak cross section for the $^{15}N(p,\gamma_0)^{16}O$ reaction leading to the 13·1 MeV level of ^{16}O was taken to be 1 mbn (Schardt, Fowler, and Lauritsen 1952).

Discussion

The feature of interest in the results presented is the absence of any peak in the region of 14·7 MeV. This strongly suggests that the earlier (γ, p) work is incorrect, and that there is no real discrepancy between the (γ, p_0) and (p, γ_0) results. A possible explanation of the earlier (γ, p) results may be given in terms of neutron–proton scatterings in the detector material, the neutrons being formed in large quantities in the lead collimators used to define the γ-ray beam. However, this does not explain the angular distribution obtained by Spicer (1955), who observed appreciable numbers of protons at backward angles.

There is good agreement in shape between the cross section obtained in the present work and that derived from the (p,γ_0) cross section using the principle of detailed balance. The difference in absolute magnitudes may be ascribed to uncertainties in the assumed bremsstrahlung spectral shape, and in the determination of detector efficiency. Such uncertainties have not been included in the errors (statistical only) shown in Figure 2.

Conclusion

It is concluded that there is no essential disagreement in shape between the $^{16}O(\gamma, p_0)^{15}N$ and $^{15}N(p,\gamma_0)^{16}O$ cross sections in the region 14–16 MeV; hence the data give no cause to query the validity of the principle of detailed balance. The absence of a 2^+ state in ^{16}O at 14·7 MeV excitation is substantiated by a recent calculation of $T = 0$, 2^+ states (Eisenberg, Spicer, and Rose 1965), which shows that the inclusion of two-particle–two-hole excitations radically changes the predictions of the simpler calculations that include only one-particle–one-hole excitations (see Gillet and Vinh-Mau 1964).

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References

Barton, G. (1959).—*Nucl. Phys.* **11**: 466.
Eisenberg, J. M., Spicer, B. M., and Rose, M. E. (1965).—*Nucl. Phys.* **71**: 273.
Fallieros, S., and Ferrell, R. A. (1959).—*Phys. Rev.* **116**: 660.
Gillet, V., and Vinh-Mau, N. (1964).—*Nucl. Phys.* **54**: 321.
Johansson, S. A. E., and Forkman, B. (1957).—*Ark. Fys.* **12**: 359.
Johns, H. E., Katz, L., Douglas, R. A., and Haslam, R. N. H. (1950).—*Phys. Rev.* **80**: 1061.
Raz, B. J. (1960).—*Phys. Rev.* **120**: 169.
Schardt, A., Fowler, W. A., and Lauritsen, C. C. (1952).—*Phys. Rev.* **86**: 527.
Schiff, L. I. (1951).—*Phys. Rev.* **83**: 252.
Shoda, K. (1961).—*J. Phys. Soc. Japan* **16**: 1841.
Spicer, B. M. (1955).—*Phys. Rev.* **99**: 33.
Whaling, W. (1957).—"Handbuch der Physik." Vol. 34, p. 193. (Springer: Berlin.)
Wilkinson, D. H., and Bloom, S. D. (1956).—*Phys. Rev.* **105**: 683.