$O^{16}(\gamma,n)O^{15}$ Reaction Near 17.6 MeV*

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The photonuclear activation cross section of O^{16} near 17.6 MeV has been investigated using monochromatic gamma rays from the $Li^7(p,\gamma)$ reaction. The proton energy was set for the 441-keV resonance and the gamma-ray energy angular dependence was used to determine the relative (γ,n) cross section at the energies 17.571, 17.618, and 17.666 MeV. The absolute cross section was determined at 17.618-MeV photon energy to be 0.55 ± 0.08 mb.

INTRODUCTION

EXPERIMENTS with betatron beams[1] have suggested the existence of sharp resonances in the activation curve of $O^{16}(\gamma,n)O^{15}$ near 17.6 MeV. Doubt was cast on these results by measurements with monochromatic gamma rays.[2] In the present work, an attempt has been made to resolve the discrepancy using lithium γ rays and techniques similar to those of our previous experiment.[3]

EXPERIMENT

Protons from the University of Pennsylvania electrostatic accelerator were used to bombard a lithium fluoride target and produce monochromatic photons by the $Li^7(p,\gamma)Be^8$ reaction. At the resonance energy, $E_p=441$ keV, E_γ is equal to 17.571, 17.618, and 17.666 MeV at $\Theta=135°$, 90°, and 45°, respectively (based on a Q value of 17.253 MeV[4]). At this proton energy the intensity of the 17.6-MeV gamma ray at 45° and 135° (relative to the intensity at 90°) is 1.05 and 0.97, respectively.[5]

The lithium targets consisted of lithium fluoride evaporated on to a 10-mil tantalum backing. The target thickness was determined both by weighing and by multiple beam interferometer techniques. The two methods agreed and indicated a thickness of 20 keV using the stopping power curve of Bader *et al.*[6]

Preservation of the targets was insured by water cooling of the tantalum backing and by a liquid-nitrogen trap near the LiF target. No shift of the resonance energy greater than 2 keV was observed during the use of the target.

The O^{16} samples, consisting of distilled water in Plexiglas containers, were irradiated at 45°, 90°, and 135° as shown in Fig. 1.

At $E_p=441$ keV, and for a 10° angular width of the sample, the Doppler spread ΔE_D is equal to 12 keV at 90°, and 8 keV at both 45° and 135°. For such a sample we estimate the energy resolution to be roughly 20 keV. The target thickness, 20 keV, and the proton beam energy variations of a few keV have little effect on the resolution because the (p,γ) resonance width is 12 keV.

The sample was irradiated for a length of time equal to four half-lives. The water was then transferred to a cylindrical container which was placed within the positron detection apparatus. The resultant activity was counted in the positron detector for a preset time equal to three half-lives. The positron detector consisted of two NaI(Tl) crystals 5 in. in diameter by 2 in. thick placed $\frac{1}{2}$ in. apart described previously.[3]

RESULTS

The cross section $\sigma(\gamma,n)$ for this experimental arrangement is determined from the geometries and efficiencies as in our previous work.[3] In the evaluation of the cross section the decay scheme of O^{15} was assumed to be simple as indicated in the tables of Strominger *et al.*[7] and to occur entirely by positron emission to the ground state of N^{15}. The half-life of O^{15} was assumed to be 123.96 sec.[8]

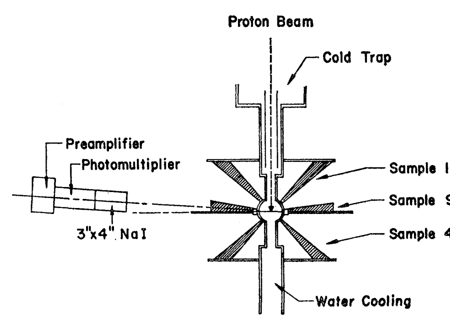

FIG. 1. Target sample and monitor geometry.

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A. Relative Cross Section

Corrections were made for differences in the geometrical shapes of the samples, for the angular distribution anisotropy of the proton capture lithium gamma rays and for the different γ-ray absorption at different angles in the container and the samples.

The effects of in-scattered γ rays from the walls of the container into the water sample and the degration of the γ-ray energy in the sample were evaluated and found to be negligible. The relative cross section is 5.62 at $\Theta=45°$, 5.13 at $\Theta=90°$, and 7.95 at $\Theta=135°$. At these angles the average γ-ray energies were 17.666, 17.618, and 17.571 MeV, respectively. The energy spread for each energy is about 20 keV and the standard error due to counting statistics amounts to about $\pm12\%$.

B. Absolute Cross Section

The absolute cross section was determined at 17.618 MeV using the data for the 90° sample.

The absolute measurement of the photon intensity was made by observing their total absorption in NaI as in our previous work.[3] The photon monitor was a 5-in.-diam by 6-in.-thick sodium iodide crystal which was collimated with a $\frac{1}{2}$-in. hole in a lead block. The shape of the response curve of this crystal was determined with the $T(p,\gamma)$ gamma rays at 20.5 MeV and its sensitivity calculated from the theoretical atomic and nuclear cross sections of NaI(Th). These cross sections had been found in our previous work[3] at 20.5 MeV to be accurate to better than 2%. The absolute value for the cross section was found to be $\sigma=(0.55\pm0.08)$ mb.

DISCUSSION

These results, shown as points in Fig. 2, agree with the previous monochromatic gamma ray measurement[2] in showing no evidence for the sharp resonances near 17.6 MeV reported by the early betatron measurements.[1] They are, also, in agreement with later betatron and positron radiation measurements. Bramblett *et al.*,[9] using positron radiation, report strong levels only at 17.1 and 19.0 MeV with a smooth dip in between.

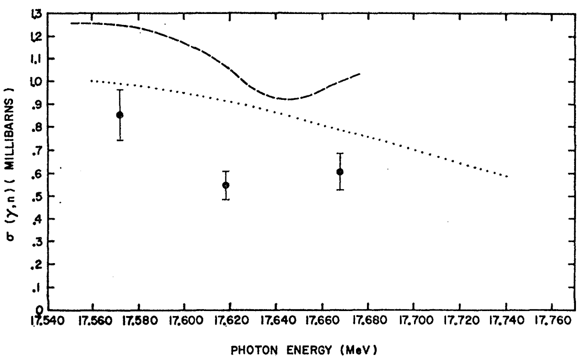

FIG. 2. Oxygen photoneutron cross section in millibarns as a function of photon energy in MeV. The points are the present results. The dashed curve represents the results of Keszthelyi *et al.* The dotted curve gives the corrected trend of Geller and Muirhead measurements.

The agreement with the present results in cross section magnitude is reasonable in view of the limited resolution (500 keV) of their measurements. Better resolution has been achieved in the neutron time-of-flight measurements of Firk and Lokan[10] and a weak resonance of about 100-keV width was indicated at 17.6 MeV. No levels at these energies were observed in O^{16} in the $N^{15}(p,\gamma)$[11] and $O^{16}(e,p)$[12] reactions.

Careful analysis of accurate betatron results has been reported by Geller and Muirhead.[13] A revised normalization[14] reduces their results to 0.6 times their published values. Their 400 keV wide, 0.7 mb peak at 17.55 MeV is then in reasonable agreement with the present results. If anything, the resonance is narrower than 400 keV as is also suggested by the data of Firk and Lokan.[10]

Our cross-section values are lower than the results of Keszthelyi *et al.*[2] but the difference is not much more than their 30% uncertainty and the energy variation is quite similar.

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