The intensity ratio is estimated using Heitler's[4] curves for the bremsstrahlung in the case of screening. The center of gravity of the C^{11} excitation curve, weighted by the Bethe-Heitler bremsstrahlung curve, is taken to be 24 Mev.[3] The corresponding point for Li^9 is estimated to be 62 Mev, making the intensity ratio 2.96:1.

It is a pleasure to give due thanks to W. K. H. Panofsky, who suggested the problem and gave invaluable encouragement and advice and identified the N^{17} decay. Thanks are also due Phyllis Hanson, George Masek, and Donald Hagerman, who provided 10^{14} electrons.

[4] W. Heitler, *Quantum Theory of Radiation* (Oxford University Press, London, 1944), p. 179.

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Total Neutron Cross Section of Phosphorus*

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The total cross section of phosphorus for neutrons has been measured in good geometry by the transmission method with a resolution of 2 kev. The energy range is from 125 kev to 850 kev, the neutrons being produced by the $Li^7(p,n)Be^7$ reaction. Red phosphorus contained in a thin steel cylinder was used as scatterer. The neutrons were detected by a hydrogen recoil counter. The neutron beam was monitored by a BF_3 long counter. The average cross section is 3 barns with an average level spacing of about 25 kev.

INTRODUCTION

SPOT measurements on the total cross section of phosphorus have been made at Argonne over an energy range of 0.024 to 0.83 Mev.[1] With a resolution of approximately 80 kev, Ricamo[2] found an average total cross section of 3 barns in an energy range from 2.0 to 3.5 Mev using a $D(d,n)$ reaction. Snowdon and Whitehead[3] have recently reported measurements from 100 to 700 kev with a resolution of 40 kev. However, this is insufficient to resolve even the major resonances.

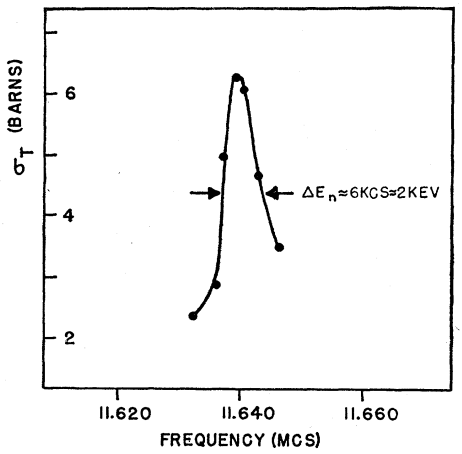

FIG. 1. Total cross section of sulfur near 588 kev. A target thickness of about 2 kev is estimated from the observed width of this resonance since the natural width $\Gamma_n \lesssim \sim 1$ kev. This target thickness agrees with that obtained from measurements of the geometric peak near the $Li(p,n)$ threshold. The scale of abscissas indicates the proton resonance frequency on the magnet control.

Preparation of Scatterer

Yellow phosphorus burns spontaneously in air and is extremely poisonous. Red phosphorus shows none of these characteristics at normal temperatures and pressures and was used throughout this experiment.

To avoid even the small corrections for scattering and absorption by containers, attempts were made to press red phosphorus into slugs of the desired size (length 2 inches, diameter 1 inch). Slugs were pressed up to 2000 psi but were found to be too soft for practical use. Rather than try higher pressures, the phosphorus was packed into a steel cylinder, 5 mils in wall thickness, and the necessary corrections made.

Neutron Source

Neutrons were obtained from the $Li^7(p,n)Be^7$ reaction using the Rockefeller electrostatic generator as the proton source.[4]

The energy resolution is primarily limited by the finite thickness of the lithium target. Measurements of this energy spread were accomplished by two methods: (a) the geometric peak of the neutron yield[5] in the

* This work was supported by the Bureau of Ships and the U. S. Office of Naval Research.

[1] Fields, Russell, Sachs, and Wattenberg, Phys. Rev. **71**, 508 (1947).

[2] R. Ricamo, Nuov cimento **8**, 383 (1951).

[3] S. C. Snowdon and W. D. Whitehead, Phys. Rev. **90**, 617 (1953).

[4] W. M. Preston and Clark Goodman, Phys. Rev. **82**, 316 (1951).

[5] Willard, Preston, and Goodman, U. S. Office of Naval Research Technical Report No. 45, Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, September 27, 1950 (unpublished).

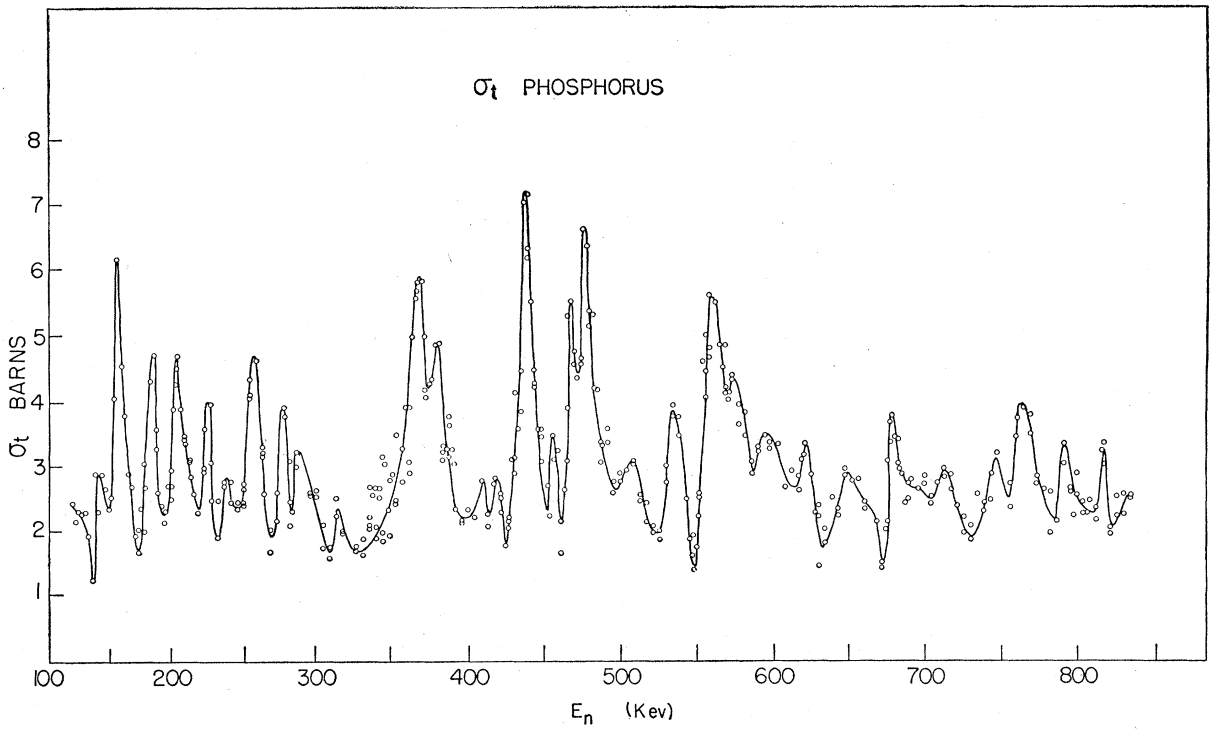

FIG. 2. Total neutron cross section of phosphorus energy resolution about 2 kev. Average total level spacing about 25 kev.

forward direction above the threshold energy (1.882 Mev), and (b) the width of the narrow resonance in sulfur at 588 kev; see Fig. 1.

EXPERIMENTAL PROCEDURE

All measurements were made in good geometry at intervals of 2.0 kev. The targets used varied from 2.0 to 5.0 kev in thickness. The detector in the forward direction was a hydrogen recoil counter of variable bias.[6] The bias was continually adjusted to eliminate background neutrons. Two BF_3 long counters were used as monitors. These were set outside the solid angle subtended by the scatterer, one at 15° from the forward direction and the other at 90°. The monitors not only serve as neutron yield integrators but give two simultaneous values of the cross section. At any point where the two values of the cross section differed by more than 10 percent the point was checked again. (Some difference is to be expected due to the anisotropy in the scattered neutron distribution.)

The container cross section was measured empty by the same method and corrections for its cross section applied. For this geometry and assuming isotropic scattering in the center-of-mass coordinates, scattering-in corrections are negligible. The background was measured by placing a paraffin shadow cone in front of the beam and measuring the counting rate. At all energies background was less than 1 percent of the total count.

RESULTS

The cross section as a function of energy is shown in Fig. 2. The average level spacing over the energy range studied was approximately 25 kev. This high level density is not unexpected for an odd-odd compound nucleus ($_{15}P^{32}$) of this mass. Several of the peaks are larger than those found in neighboring nuclei. The total cross section has an average value near 3 barns in agreement with previous investigations.

[6] F. S. Replogle, Servomechanisms Engineering Memo No. 29, Massachusetts Institute of Technology, March 18, 1952 (unpublished).