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ABSOLUTE (n,p) CROSS [redacted]TION OF SULFUR

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ABSTRACT

The absolute cross section of the (n,p) reaction in sulfur has been measured as a function of the incident neutron energy from 1.63 to 5.7 Mev.

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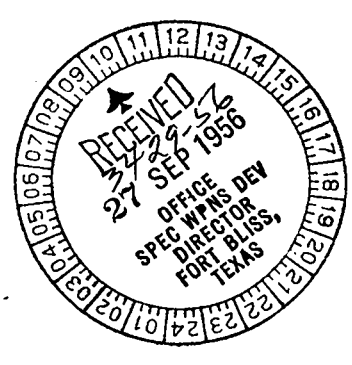

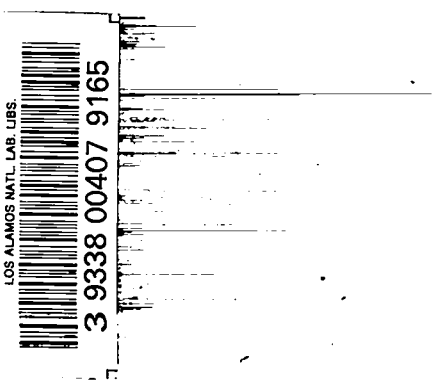

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ABSOLUTE (n,p) CROSS SECTION OF SULFUR

The measurements[1] of the relative sulfur (n,p) cross section as a function of neutron energy, described in connection with the fast-neutron measurements of the nuclear explosion, have been extended to include more neutron energies; and the absolute value of the cross section has been measured. For each calibration point, the number of neutrons passing through the sulfur was determined by counting the number of fissions occurring in a 25 foil placed between the two halves of the sulfur sample. After the irradiation, the sulfur was remelted and cast into a cylinder as described in the above report[1] and counted on a cylindrical Geiger counter with a 7-mil aluminum wall.

The measurements extended over a period of several months, and the sensitivity of the counter was checked by means of a cylinder of uranium glass fastened to an aluminum sleeve which fitted snugly over the counter so that the geometry would be kept fixed. The sensitivity of the counter remained constant to 1 per cent over the period of the measurements, even though the threshold voltage rose steadily and the length of the plateau grew shorter as the counter aged.

The calibration data were worked up as follows: We have the following relationship for the neutron monitor foil used:

$$N_f = n(\sigma_f(25)N_{25} + \sigma_f(28)N_{28}) \text{ , where}$$

N_f is the number of fissions occurring in the foil; n is the number of neutrons per cm^2 passing through the foil; $\sigma_f(25)$ and $\sigma_f(28)$ are the fission cross sections of isotopes 25 and 28, respectively, in cm^2; N_{25} and N_{28} are the numbers of 25 and 28 atoms in the foil.

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From this relationship the number of neutrons/cm^2 passing through the sulfur for each calibration energy was calculated from the observed number of fissions in the foil. The initial activity of the sulfur sample per gram of sulfur in counts per minute was calculated from the observed counting rate of the sample at a known time after the irradiation using the disintegration constant for P^{32} of 3.354×10^{-5}/mi

From these two quantities, the value of the initial activity per gram of sulfur per neutron per square cm was calculated for each calibration energy. This quantity is proportional to the (n,p) cross section of sulfur. The original calibration data have been recalculated using the values of $\sigma_f(25)$ at high energies found by Taschek and of $\sigma_f(28)/\sigma_f(25)$ measured by Hanson. Additional calibration points at neutron energies of 2.5 and 5.0 Mev have been obtained using the (d,d) source in building Z. Points at 3.4, 4.6, and 6.7 Mev were obtained using the long electrostatic generator in W with the (d,d) reaction.

The energies given for the (d,d) points obtained with the electrostatic generator refer to the average neutron energy in each case, taking into account the stopping power of the nickel foil used to contain the gas in the deuterium target, the stopping power of the gas in the target, and the angular variation of neutron energy over the sulfur disks. The stopping power of the nickel foil was calculated for each energy by R. F. Taschek, and his calculations indicate that the previous energy value given in the above report as 4.6 Mev should be 4.3 Mev.

The absolute value of the cross section was determined by counting a thin sample of sulfur and comparing its counting rate with that of two RaE standards prepared by J. H. Roberts.[2] Because of the fact that the maximum energy of the β rays from the P^{32} formed from the sulfur is 1.72 Mev, while that of the

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RaE β rays is 1.16 Mev, absorption curves were taken in each case to enable the data to be extrapolated to zero wall thickness of the Geiger counter.

Two sets of absorption measurements were made on each β spectrum. Complete absorption curves were taken in cooperation with G. A. Linenberger and Ann Kahn with a Geiger counter of the Berkeley bell-jar type with a mica window 4.28 mg/cm^2 thick by interposing aluminum sheets of known thickness between the source and the counter. The RaE source used was a thin plane one prepared by R. Prestwood, and the sulfur source used was a plane one prepared in a manner similar to the preparation of the thin cylindrical ones which will be described below.

An aluminum sleeve with a wall thickness of 8.5 mils was made which fitted snugly over the cylindrical Geiger counter used to count the sulfur samples. A hole 5/8 inch in diameter was made in the sleeve, and the two RaE standards and two small thin sulfur sources were counted in the two positions, over the hole and over the wall of the sleeve. In this manner, two points on the absorption curve for this geometry were obtained for each of the β spectra, one point corresponding to a thickness of aluminum equal to the wall thickness of the counter, and the other corresponding to the sum of the thicknesses of the counter wall and the sleeve.

The ratio of the counting rates for these two thicknesses of aluminum was compared to the ratio for the same two thicknesses as measured in the plane geometry case with the Berkeley counter. For both the RaE and the P^{32} β spectra the ratio of the ratio obtained with the Berkeley counter to that obtained with the cylindrical counter was 1.06. The absorption curve obtained using the Berkeley counter was used in each case to extrapolate the observed counting rates to zero wall thickness of the Geiger counter.

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The ratio between the counting rate per gram of sulfur for the geometry used for the calibration points to the counting rate per gram of sulfur for a thin sample was determined by irradiating a tube containing powdered sulfur in the center of the water boiler and counting parts of the sample in each of the geometries. The sulfur was irradiated in a tube 1/4 inch in diameter and 3 7/8 inches long, and it was found that the activity of the sample was not uniform after ordinary mixing.

Tests under the direction of Harold Hirsch showed that when the sulfur was ground in a mortar and pestle and sieved through a 325-mesh Tyler screen before irradiation, and then mixed with porcelain balls in a ball mill for four hours after the irradiation, the counting rates of different samples counted in the same geometry agreed within the statistical accuracy of the counting. Following this procedure, it was possible to obtain good checksamong different thin and different thick samples. The thick sampleswere made of irradiated sulfur mixed with unirradiated sulfur, and they were prepared in the manner described in the repor mentioned previously. To make sure the same activity had been excited in the water boiler as had been excited in the previous measurements, the counting rates of several samples were observed for a period of two weeks, and the same half-life as previously found was obtained.

The thin cylindrical sulfur samples were made as follows: a sheet of scotch tape was wrapped sticky side outward around a mandrel turned to be accurately the same size as the Geiger counter. The tape was lapped over about 1/8 inch in order to form a cylinder which would hold its shape and could be handled easily with tweezers. The tape cylinder was weighed on an analytical balance, placed back on the mandrel, and coated with sulfur by means of a stiff artist's brush. The sulfur layer was rubbed vigorously with the brush

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to insure that only the sulfur which the glue of the tape held remained on the cylinder. The cylinder was again removed and weighed; then it was put back on the mandrel and covered with a layer of scotch tape to protect the sulfur deposit.

The sulfur layers made in this way appeared to be quite uniform to the eye. In order to make sure the samples were thin, layers of different thickness were made by placing more or less sulfur on the brush and rubbing the deposit more or less vigorously. Samples with thicknesses between the limits of 1.24 and 1.76 milligrams/cm^2 were made. The counting rates/gram of sulfur of samples of different thickness checked quite precisely. To find out if the scotch-tape cylinders themselves experienced any change in weight during the preparation of the samples, blank cylinders were made, weighed, allowed to stand in the room in which the sulfur was put on for the length of time usually required for this process, and then reweighed. The scotch tape was kept in a room in which the humidity is controlled, and it was found that a nearly constant weight loss occurs in the above process. The effect amounts to about a one per cent correction for the average weight of sulfur used in the thin samples, and the correction was applied to all the thin samples.

The data obtained from the above measurements were worked up as follows: The quantity observed at each energy was the initial activity per gram of sulfur per neutron per square cm for the thick sulfur geometry used. For each calibration irradiation the middle of the irradiation was taken as the zero time to which the initial activities were referred. We have the following relationship for the sulfur for an irradiation short compared to the half-life of the P^{32} β's:

Initial number of active atoms/gm of sulfur = (number of sulfur atoms/gm of sulfur) (number of neutrons/cm^2) (sulfur (n,p) cross section)

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We also have

$$\text{Initial number of active atoms/gm of sulfur} = \frac{\text{Initial disintegration rate/gram of sulfur}}{\lambda}$$

where λ is the disintegration constant of the P^{32} β activity. This gives us the following expression for the sulfur (n,p) cross section, σ:

$$\sigma = \frac{\text{Initial disintegration rate per gram of sulfur per neutron per cm}^2}{\lambda(\text{number of sulfur atoms per gram of sulfur})}$$

From the measurements on the thick and thin sulfur samples, we get the ratio which converts Activity/gram of sulfur for the thick samples to Activity/gram of sulfur for the thin sulfur sample geometry. This factor is 4.67. From the absorption curves we get the ratio of the counting rate through 0 mils of aluminum to the counting rate through 7 mils of aluminum for the β spectra of RaE and P^{32}. The ratio is 2.16 for RaE and 1.26 for P^{32}.

Knowing the true disintegration rates of the RaE standards and their observed counting rates as corrected to zero wall thickness of the Geiger counter, we can find the ratio of the true number of disintegrations per minute to the observed number of counts per minute in our counter. For the two RaE standards used, the ratios found were 3.91 and 3.83. Since λ for the P^{32} β activity is 3.354×10^{-5}/min, and the number of sulfur atoms/gram of sulfur is $6.023 \times 10^{23}/32.06$, our expression for σ becomes

$$\sigma = \frac{\left[\text{Initial activity per gm of sulfur per neutron per cm}^2 \text{ (thick geometry)}\right](4.67)(1.258)(3.88)(32.06)}{(3.354 \times 10^{-5})(6.023 \times 10^{23})}$$

or

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σ = (Initial activity per gm of sulfur per neutron per cm^2) (3.62×10^{-17})

Fig. 1 gives the cross section of the (n,p) reaction in sulfur in barns as a function of the incident neutron energy in Mev.

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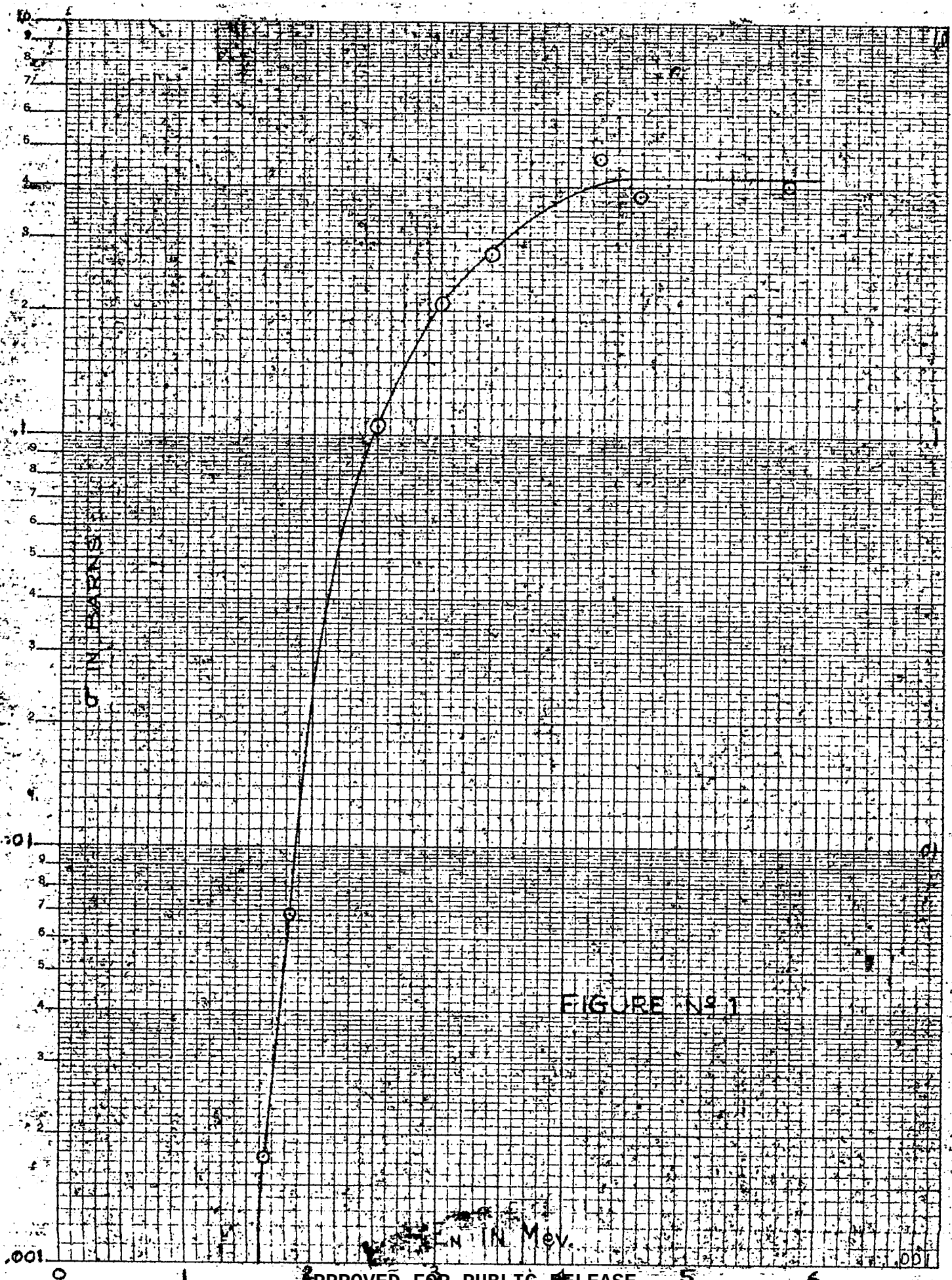

FIGURE Nº 1

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