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Neutron Total Cross Section of Arsenic at 14 Mev.

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Using the T (d,n) He' reaction as a monoergic source of neutrons of about 14 Mev the total cross section of arsenic was measured. For the production of neutrons a Zr-T target was bombarded by accelerating deuterons to 140 kev. Measurements were made with a good-geometry arrangement. The neutron detector used was a plastic scintillator of $1''\times1''\phi$. The neutron total cross section of arsenic at the neutron energy of 13.95 Mev was found to be $3.37\pm$ 0.04 barns. As a check the neutron total cross section of Oxygen was also measured and compared with earlier works.

1. INTRODUCTION

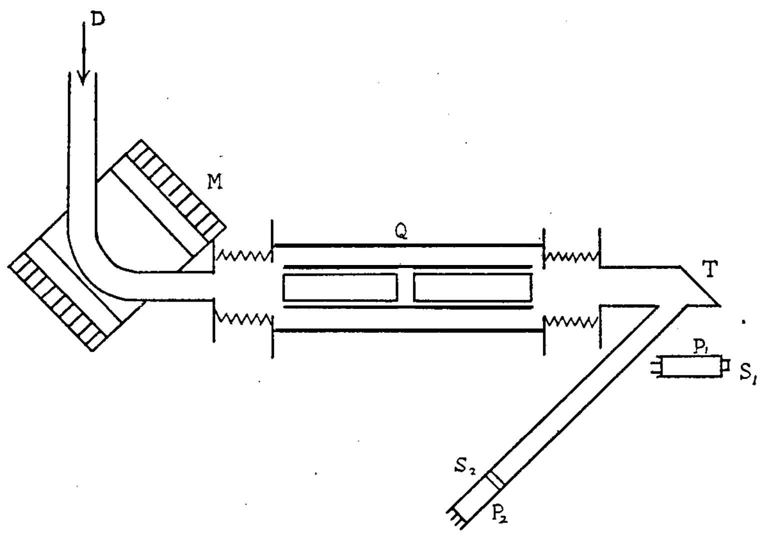
A great many measurements of the neutron total cross sections were made for various elements. The neutron total cross section of arsenic was measured by M. S. Zucker[1], Robert E. Cote[2] et al., only up to the energy of 3.2 Mev. However that at 14 Mev energy has not been found in the literatuers. We have measured it in the present work. The neutron total cross section of oxygen has also been obtained by comparing the neutron transmission of arsenic trioxide with that of arsenic in order to check the reliability throughout the course of measurements.

2. EXPERIMENTAL PROCEDURE

Neutrons were produced by using the $T(d,n)He^4$ reaction. Deuterons were accelerated by a Cockcroft-Walton accelerator to 140 kev energy. Then the deuteron beam was analyzed by a magnet and focused by a couple of electrostatic quadrupole lenses to hit on a zirconium-tritium target as shown in Fig. 1.

The arsenic 'Was purified by resublimation in vaccum several times. Then it was kept at a temperature of about 200°C until the trioxide in the sample had completely sublimated out. For the sample of arsenic trioxide the product of Merck was used. Samples were filled in lucite cylinders of diameter 3cm. The length of the cylindrical containers was determined so that the neutron transmission became about 50%. In the case of arsenic it was 8cm, while that of arsenic trioxide was 7cm. The experimental arrangement was designed for a good-geometry transmission measurement, as shown in Fig. 2.

1) M. S. Zucker, Phys. Rev. 99, 55, (1955)
2) Robert E. Cote, L. M. Bollinger, and James M. Le Blanc, Phys. Rev. 111, 288, (1958)



D: Deuteron Beam
M: Beam Analysing Magnet
Q: A Couple of Static Quadrupole Lenses
T: Zr-T Target
S_1: Plastic Scintillator 1″×1″φ
S,: ZnS
P,: DUMONT 6292
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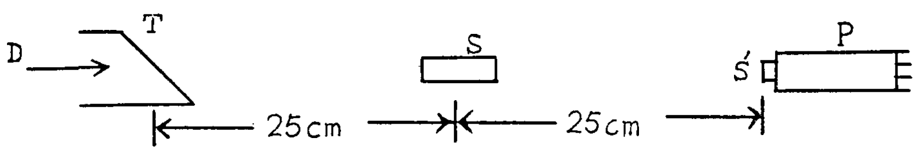
Fig. 1. **Schematic diagram of neutron source.**



T: Zr-T Target
S: Sample
S: Plastic Scintillator 1″x1″φ
P: DUMONT 6292
D: Deuteron Beam

Fig 2. **Experimental arrangement**

To measure the effect produced by neutrons scattered from the walls and floor of the room, a long copper rod (4cm φ, 30cm long) with essentially zero transmission was placed between the neutron source and the detector instead of the sample. The counting rate with the copper rod in that place was always less than 0.3% of the rate obtained from the direct neutron beam.

Because of the finite thickness of zirconium-tritium target and the fluctuation of accelerating voltage, the energy of neutrons from the $T(d,n)He^4$ reaction is expected to spread in a finite energy range. However it is possible to select an angle between the incident deuteron and the emitted neutron, so that the energy of the emitted neutron is approximately independent of the energy of the incident deuteron. It is evident from Fig. 3, the energy and angle relationahips for the $T(d,n)He^4$ reaction, that the angle at 99 ” satisfies the above condition and so it was selected as one of our measuring points. The energy spread due to the above mentioned effect and to the finite dimension of the detector was estimated as given in Table 1.

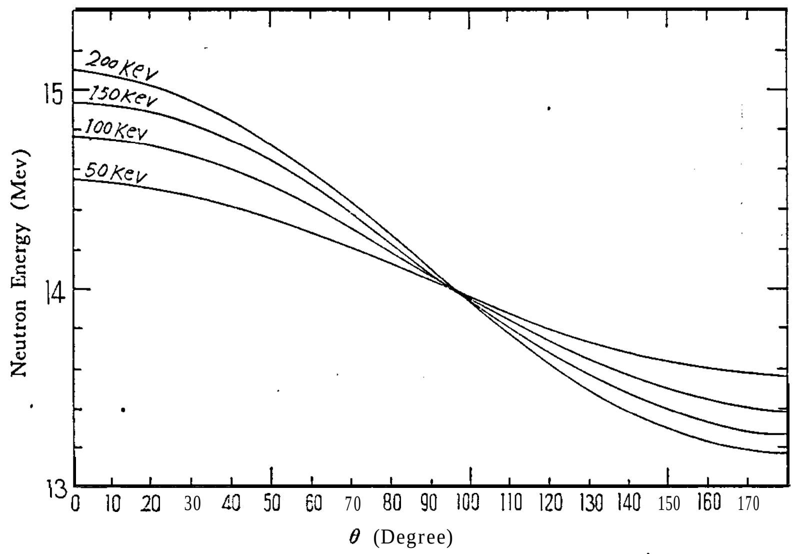


Fig. 3. Energy-and-angle relationahips for the T *(d,n)* He ’ reaction

Table 1. Energy-angle relationships and neutron-energy-spread estimated.

Angle	Energy (Mev)	Energy spread (Mev)
0°	14.75f0.15	0.03
85°	14.12±0.04	0.08
99°	13.95±0.03	0.06

The 14 Mev neutron detector consists of a plastic scintillator of 1″ x 1″ϕ and a DuMont 6292 photomultiplier. The pulse height spectrum due to 14 Mev neutron is shown in Fig 4. The pulses in the plateau at the higher pulse-height are due to the recoil protons of 14 Mev neutrons only, while pulses of the lower pulse-height are those of recoil protons due to 14 Mev neutrons and energydegraded-neutrons and also those of possible Y-rays.

The discrimination level of pulses was set sufficiently high, i. e. 60V, in order to detect only the true 14 Mev neutrons. Such high level has led to a very low background as stated previously.

The neutron yield was monitored by two detectors: one was a plastic scintillator of the same size as the main detcector of the measurement placed at a point 50 cm distant from the neutron source, and the other was a ZnS(Ag) scintillator placed at a point of

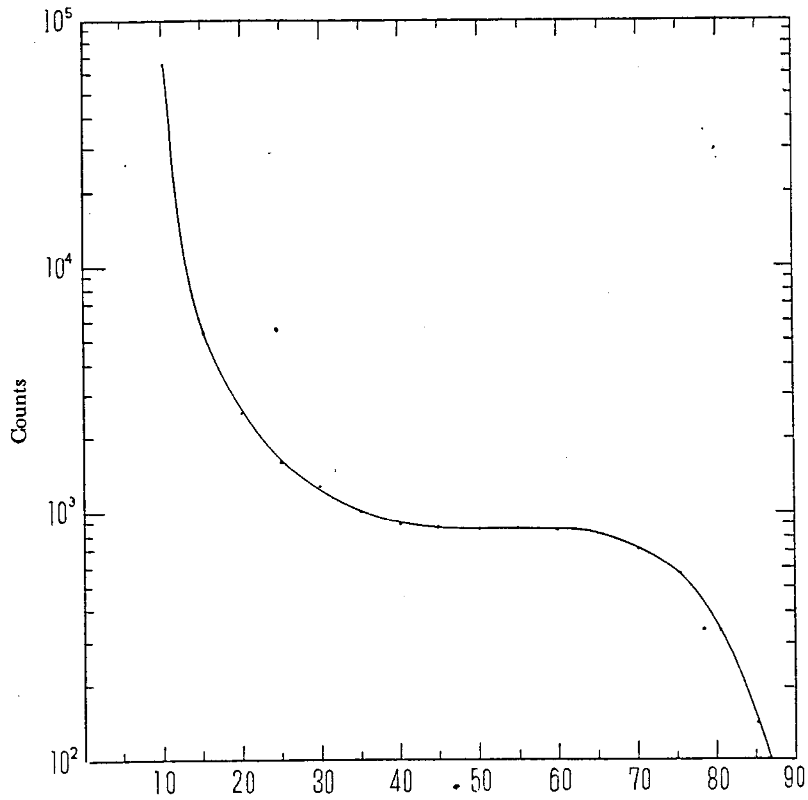


Fig. 4. Pulse height spectrum of recoil protons of 14 Mev neutrons

1 m. distant from the source to count the number of associated a-particles from the $T(d,n)He^4$ reaction. The former was mainly used throughout the measurement for the estimation of the total neutron yield.

3. RESULTS AND DISCUSSION

Counts obtained were processed by the following formula to give the total cross section, σ:

$$\exp(-N\sigma) = \frac{C_{\text{sample in}} - C_{\text{copper rod}}}{C_{\text{sample out}} - C_{\text{copper rod}}} \qquad \cdots(1)$$

where "$C_{\text{sample in}}$" represents the counts per fixed total yield of neutrons in the presence of the sample, "$C_{\text{sample out}}$" represents the counts per fixed total yield of neutrons when in the absence of the sample. "$C_{\text{copper rod}}$" represents the counts per fixed total yield of neutrons obtained with the copper rod, and N is the number of nuclei per unit area in the sample.

An in-scattering correction which should be applied to the above results was calculated from the following formula ').

4) R. B. Day and R. L. Henkel, Phys. Rev. 92, 358, (1953)

$$\frac{\Delta\sigma}{\sigma}=\frac{1}{2}\left[\frac{D}{L}(kr+1)\right]^2 \qquad (2)$$

where L is the distance between the neutron source and the detector, D the diameter of the sample, k the neutron wave number, and r the nuclear radius given by 1.4 $A^{1/3}\times 10^{-13}$cm.

The results of the neutron total cross section of arsenic together with that of neighboring elemets are summarized in Table 2. It is seen from the table that the measured value for arsenic is very close to the value expected from an interpolation between those of germanium and selenium given in the literatures.[5),6)] This agrees with a prediction of continuum theory of nuclear reactions.

Table 2. Neutron total cross section of Ge, As and Se

element	neutron energy (Mev)	neutron total cross section (barn)
Ge	14.07	3.34f0.03 [5)]
As	13.95± 0.03	3.37±0.04 present work
	14.12± 0.04	3.42±0.03 present work
	14.75± 0.15	3.32±0.04 present work
Se	14.12± 0.04	3.56±0.07 [6)]

In the Table 3, the result for the total cross sections of oxygen at 13.95 Mev is compared with that of others. They are in good agreement within the experimental errors. This fact also assures the accuracy of the present measurement of the neutron total cross section of arsenic.

Table 3. The total neutron cross section of oxygen

energy (Mev)	σ° (barn)	author
13.95±0.03	1.60±0.04	present work
14.10±0.05	1.64±0.04	Luke C. L. Yuan et al. [3)]
14	1.61±0.04	W. Nyer [7)]
14.12±0.04	1.59±0.03	H. H. Barschall *et al.* [6)]
13.95 ± *0.05*	1.55±3%	H. H. Barschall *et al.* [8)]*

*estimated from their cross section curve.

4. ACKNOWLEDGMENTS

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3) H. L. Poss, E. 0. Salant, G. A. Snow and Luke C. L. Yuan, Phys. Rev. 87, 11, (1951)
5) A. Bratenahl, J. M. Peterson and J. P. Stoering, Phys. Rev. 110, 927, (1958)
6) J. H. Coon, E. R. Graves and H. H. Barschall, Phys. Rev. 88, 562, (1952)
7) D. I. Meyer and W. Nyer, Los Alamos Report No. 1279
8) D. B. Fossan, R. L. Walter, W. E. Wilson and H. H. Barschall, Phys. Rev. 123, 209, (1961)