Total Cross Sections for High-Energy Neutrons*

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In measurements of total cross sections for high-energy neutrons, detectors accepting neutrons of relatively wide ranges of energy have been used. By utilizing the known spectrum of the neutron beam and the threshold acceptance energy values of the detectors an effective energy has been stated to about 2 percent.[1] A scintillation counter telescope allows the use of considerably narrower energy acceptance bands in the determination of total cross sections.[2] The increased resolution of such a telescope makes it a suitable instrument to analyze the variation of total cross sections as a function of energy as well as permitting a more precise determination of the effective energy.

By means of such a telescope, a good-geometry attenuation experiment has been performed with neutrons produced from a $\frac{1}{4}$-in. beryllium target bombarded by the 110-Mev internal proton beam of the Harvard 95-in. synchrocyclotron.[3] The neutron beam, collimated by pipes of rectangular cross section (so chosen to give maximum counting rate for a given energy resolution), was first monitored by a triple coincidence scintillation counter telescope of neutron threshold energy approximately 35 Mev (Fig. 1). Then the neutron beam, attenuated by samples of various elements, passed through a second rectangular collimator and its intensity was determined by another scintillation counter telescope. The second telescope (which counted exchange protons following the conventional polyethylene-carbon subtraction method) consisted of 8 plastic scintillators mounted on 1P21 photomultipliers. Five, six, seven, and eightfold coincidences were used, with the resultant energy bands determined by range differences.

The values of the cross sections are listed in Table I.[4] The cross section of hydrogen was determined from a polyethylene-carbon subtraction, of deuterium from a heavy water-ordinary water subtraction and of oxygen by an ordinary water-hydrogen subtraction. It is to be emphasized that the energies quoted and the errors given are the absolute and not the effective values. The statistics of the cross sections are counting statistics only; other sources of error are believed negligibly small.

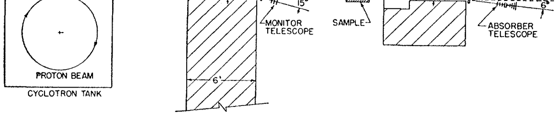

Fig. 1. Geometry of the experiment.

Table I. Total cross sections for neutrons. (10^{-27} cm^2).

Neutron energy (Mev)	94.8±1.5	98.6±2.5	102.0±0.76	107.9±5
Pb	4628±87	4595±63	4407±121	4736±209
Fe	1947±48	1874±37	1734±81	1946±184
Si	1136±52	1067±42	1041±92	925±218
Al	1067±29	1046±23	920±50	1064±126
O	721±13	675±9	649±14	668±42
C	518±6	494±4	466±7	508±18
D	110±7	108±5	81±9.9	62±21.9
H	77±5	76±3	80±7	59±16
Neutron energy (Mev)	77.7±1.3	82.2±3	86.8±1.4	100.7±12
Pb	4910±164	4957±98	4905±107	4569±46
C	614±31	585±17	602±19	518±7
Neutron energy (Mev)	61.5±1.7	66.8±3.5	72.1±1.7	93.5±19
Pb	4590±225	4551±160	4647±193	4605±121
C	674±62	671±42	601±41	521±79

In the case of lead, confirmation of the "Harwell dip"[1] is observed at the lower energy points.

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[1] A. E. Taylor and E. Wood, Phil. Mag. **44**, 95 (1953).

[2] Vaughn Culler and R. W. Waniek, Phys. Rev. **87**, 221 (1952).

[3] R. W. Waniek and Vaughn Culler, Phys. Rev. **95**, 659 (1954).

[4] Total cross sections of C and Fe far high-energy neutrons have also been obtained by B. Ragent, University of California Radiation Laboratory Report UCRL-2337, 1953 (unpublished).

Element 100 Produced by Means of Cyclotron-Accelerated Oxygen Ions

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The beam of high-energy $(O^{16})^{6+}$ ions produced by the 225-cm cyclotron of this institute[1] has been used to bombard uranium targets. An alpha activity which is ascribed to an isotope of element 100 has been found among the transmutation products formed in this way.

Uranium metal was irradiated for several hours with the internal oxygen beam, at a radius of 85 cm. At this radius the maximum attainable energy of $(O^{16})^{6+}$ ions is roughly 180 Mev. Measurements were made of the intensity of oxygen ions reaching this radius with energies greater than 60 Mev, the best beam being about 0.03 microampere. For the production of californium as a reference element the uranium target was irradiated for some hours with $(C^{12})^{6+}$ ions before the oxygen bombardment. Carbon dioxide was used as source gas for the production of both kinds of ions, and the selection of bombarding particle was made by adjusting the magnetic field to the corresponding resonance value.

The surface layer of the uranium target was dissolved and carriers were added. The separation of actinides and lanthanides was performed by lanthanum fluoride precipitation and ion exchange chromatography.[2] The identification of element 100 was established from its position relative to that of californium in the eluate.

The alpha activity was measured by means of an ionization chamber and a 16-channel pulse analyzer. The measurements were started about two hours after the end of the irradiations. In the element-100 eluate fraction, up to 20 alpha disintegrations of energy 7.7 Mev were usually found, decaying with a half-life of about half an hour. According to alpha systematics a probable mass number corresponding to these data is 250.

The first positive results were obtained on February 19. The work is still in progress.

We express our gratitude to the head of the institute, Professor Manne Siegbahn, for his continuous interest. Professor John O. Rasmussen, Jr., cooperated with us in the early development of this project during part of 1953, and his valuable advice is gratefully acknowledged. Our thanks are also due the cyclotron crew and other members of the technical staff.

[1] H. Atterling, Arkiv Fysik 7, 503 (1954). This paper is a preliminary report on the acceleration of carbon, nitrogen, and oxygen ions in the 225-cm cyclotron.

[2] E.g., Street, Thompson, and Seaborg, J. Am. Chem. Soc. 72, 4832 (1950).

Interactions of High-Energy Neutrons in Molybdenum*

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In the past, decisive evidence obtained from stars induced by neutrons in nuclear emulsions was obscured by the ambiguity in the identification of the nucleus involved in the interaction.[1,2] To obviate this difficulty we have resorted to the use of thin filaments embedded in Ilford G5 electron sensitive emulsions.[3,4] The technique required the overcoming of various problems which will be discussed in a publication to appear elsewhere. In this letter we intend to present the results obtained from emulsions with embedded molybdenum wires of 28 microns diameter. We selected this material because of its favorable position between silver and bromine and for its desirable mechanical properties. The plates were exposed in good geometry to the neutron beam obtained by internal bombardment of a $\frac{1}{8}$-in. beryllium target with the proton beam of the 95-in. synchrocyclotron. The target was located at the 70-Mev radius and the neutrons were collimated in the forward direction and then passed through a hardener (32 cm of polyethylene) before impinging into the plates. We searched for events originating in molybdenum by scanning along the wires and measured the spatial angle and the true range, discriminating between particles with single and double charge. 250 events were analyzed. Each range was corrected for self absorption in the wire as a function of the azimuth and dip angles. The shrinkage was virtually eliminated from these emulsions and the residual amount was properly taken into account in computing both the range and the spatial angle. The range spectrum presented contains only singly-charged particles (Fig. 1). Under the reasonable assumption that they are protons, the two peaks appearing in our histogram would correspond to energies of about 3 and 6 Mev, respectively. The conventionally calculated Coulomb barrier for the molybdenum nucleus is of about 9 Mev. In addition, the range spectrum of the doubly-charged particles, assumed to be predominantly alphas, showed a similar

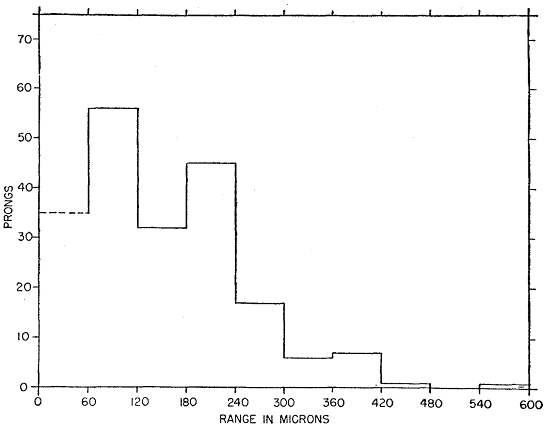

Fig. 1. Range histogram of singly-charged particles.

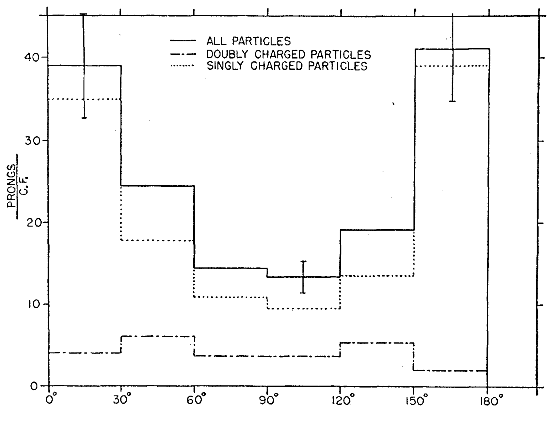

Fig. 2. Number of prongs *versus* spatial angle corrected for solid angle. (C.F. is the correction factor for the solid angle.)