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TOTAL NEUTRON CROSS SECTIONS FOR U^{235}, NORMAL URANIUM, Pu^{239}

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Distribution: DEC 2 2 1952 LA-1483

Los Alamos Report Library	1 - 20
J R. Oppenheimer	21
Argonne National Laboratory	22 - 29
Armed Forces Special Weapons Project (Sandia)	30
Armed Forces Special Weapons Project, Washington	31
Atomic Energy Commission, Washington	32 - 34
Brookhaven National Laboratory	35 - 37
Bureau of Ships	38
California Research and Development Company	39 - 40
Carbide and Carbon Chemicals Company (K-25 Plant)	41 - 42
Carbide and Carbon Chemicals Company (ORNL)	43 - 50
Carbide and Carbon Chemicals Company (Y-12 Plant)	51 - 52
Chicago Patent Group	53
Chief of Naval Research	54
Columbia University (Havens)	55
duPont Company	56 - 60
General Electric Company (ANPP)	61 - 62
General Electric Company, Richland	63 - 66
Hanford Operations Office	67
Idaho Operations Office	68 - 69
Iowa State College	70
Knolls Atomic Power Laboratory	71 - 74
Massachusetts Institute of Technology (Kaufmann)	75
Mound Laboratory	76 - 78
National Advisory Committee for Aeronautics, Cleveland	79
Naval Research Laboratory	80
New York Operations Office	81 - 82
North American Aviation, Inc.	83 - 85
Nuclear Development Associates, Inc.	86
Patent Branch Washington	87
RAND Corporation	88
Savannah River Operations Office, Augusta	89
Savannah River Operations Office, Wilmington	90
USAF-Headquarters	91
U. S. Naval Radiological Defense Laboratory	92
UCLA Medical Research Laboratory (Warren)	93
University of California Radiation Laboratory	94 - 96
University of Rochester	97 - 98
Walter Kidde Nuclear Laboratories, Inc.	99
Westinghouse Electric Corporation	100 - 103
Wright Air Development Center	104 - 107
Technical Information Service, Oak Ridge	108 - 122

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ABSTRACT

The total neutron cross sections for normal uranium, U^{235}, and Pu^{239} are reported as a continuous function of energy for neutron energies between 40 and 7500 kev. Three additional measurements were made between 17 and 20 Mev. The data were obtained from a good geometry transmission experiment in which 1 in. diameter cylindrical samples were interposed midway between a neutron source and a neutron counter spaced at about 20 in. separation. In general, the statistical errors were within ± 0.2 barn. Measurements on normal uranium were in agreement with those made at Wisconsin in 1950 (LA-1060). The total cross section curves are almost identical for the three materials and very similar to those of other heavy elements. This suggests that the total neutron cross section for other heavy elements can be predicted with some accuracy.

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INTRODUCTION

Since the total neutron cross sections for Pu^{239} and U^{235} had never been measured for fast neutrons, it was decided to measure these cross sections as a continuous function of neutron energy at the large Van de Graaff accelerator. In addition, since the five different experiments previously carried out to measure the total neutron cross section for normal uranium[1,2,3,4,5] showed such disagreement, normal uranium was again included in the present work in an attempt to verify some of the previous work. By taking advantage of the low neutron background in the accelerator building at P-9 and using improved geometry to reduce the errors due to inscattered neutrons, cross sections were obtained whose values are more reliable than those of the previous work.

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[1] J. H. Williams, CF-507 (1943).

[2] H. H. Barschall, V. F. Weisskopf, LA-169 (1944).

[3] W. H. Zinn, CP-2638 (1945).

[4] D. H. Frisch, LA-256 (1945).

[5] H. H. Barschall, LA-1060 (1950).

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PROCEDURE

Data for measuring total neutron cross sections were obtained from a good geometry transmission experiment in which samples were placed midway between a neutron source and counter 20 in. apart. The samples of material which were used in this simple transmission experiment were 1 in. diameter cylinders of different lengths. The length of sample used at a given energy was governed by the fact that the greatest accuracy in cross section value measured in a given time is obtained when the transmission is about 60%. At neutron energies between 120 and 7500 kev the geometry was such that a neutron which was scattered through an angle greater than 4° would not enter the counter. For lower energies, where closer geometry was used, neutrons scattered more than 10° would not be detected. For data taken between 17 and 20 Mev the spacing between counter and detector was 150 cm, in which geometry neutrons scattered more than 2° were not counted.

The cross sections were calculated in the usual way by assuming that the transmission varied exponentially with the thickness of the sample. A correction for the neutron background caused by neutrons scattered from the floor, etc., was obtained by placing a paraffin or polyethylene shadow cone between the source and counter. The correction was only 1 to 3% above 400 kev. When the T(d,n) reaction was used, an additional run was made with hydrogen in the target to correct for extraneous neutron background caused by deuterons striking places other than the gaseous target. This amounted to less than a 3% correction in the total cross section in

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each case. Small angle scattering from the sample into the detector was not taken into account since so little is known about this correction and since the favorable geometry used in the experiment would make the correction a small one.

Monoenergetic neutrons were produced from three sources for the present work. For the neutron energy interval between 40 and 200 kev, the $Li(p,n)Be^7$ wource was used with evaporated lithium targets of about 10 kev stopping power. Between 160 and 3500 kev, neutrons were produced by the $T(p,n)He^3$ reaction with a tritium gas target having 30 to 10 kev stopping power. The source of neutrons for the range of 4 to 7.5 Mev was the reaction $D(d,n)He^3$, which was produced by bombarding a deuterium gas target about 300 to 100 kev thick. Neutrons emitted in the forward direction were used from these reactions, except for the energy interval of 40 to 120 kev where data were obtained at 115° from the proton beam direction.

Neutron energies were calculated from the known thresholds and dynamics of the source reactions, taking into account the stopping power of the target and of the nickel or aluminum foil window used on the gas targets. They were checked occasionally by measuring the energy at which the sharp 2.080 Mev scattering resonance occurred in carbon.

Three types of neutron detectors were employed. For neutron energies above 250 kev, recoils in a gas ionization chamber were counted. The gas counter was filled with hydrogen at pressures up to 500 psi or helium at 700 psi. The helium-filled chamber proved to be more useful because it could be used from 400 to 7500 kev without changing gas pressure, while

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the hydrogen counters required pressure reduction at low neutron energies. For energies below 200 kev, a boron trifluoride proportional counter imbedded in paraffin was used. A stilbene scintillator using a 5819 photomultiplier tube served as the neutron counter above 17 Mev.

For the 400 to 3500 kev energy interval, data were taken every 30 kev with a tritium target 30 kev thick to make certain that, at least to this resolution, the cross section varied smoothly as a function of energy. With the thicker targets used at higher energies, larger steps were taken. In general, enough counts were obtained so that the statistical errors in the cross sections were less than ±0.2 barn. The low energy points below 100 kev had large mean deviations which were probably due to proton energy fluctuations while operating on a steep portion of the Li(p,n) yield curve.

RESULTS

The data are presented in curves of total cross section in barns plotted against neutron energy in Mev. Although 30 kev steps were also taken between 400 and 4 Mev, these data are not shown since within the statistical errors they were in agreement with the smooth curves shown. The statistical error for most of the points is about ±0.2 barn. The points plotted at 14 Mev were taken from the work of Coon, et al. (LA-1446). On the normal uranium curve, the triangles are averaged data taken from the Wisconsin work published in LA-1060.

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DISCUSSION

The agreement between the normal uranium curve and the data from LA-1060 is quite good. It seems to verify the Wisconsin measurements[5] instead of the earlier work.[1,2,3,4] The poorer geometry used in LA-1060 led to a 3% inscattering correction assuming isotropic scattering. The agreement with the present data indicates that this isotropic correction seems to be a reasonable correction at low energies.

The similarity of the curves for the three materials is striking. Pu^{239} is about 0.1 barn higher than normal uranium and 0.2 barn higher than U^{235} over most of the energy range.

The additional similarity with nuclei of atomic weight greater than about 180 suggests that the total neutron cross sections for other very heavy nuclei can be predicted with some accuracy on the basis of known measurements. This similarity of total neutron cross sections for neighboring nuclei has been demonstrated by Barschall[6] at the lower energies for nuclei of lower atomic weights.

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[6] H. H. Barschall, Phys. Rev. 86, 431 (1952).

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A	$A^{1/3}$	$A^{2/3}$
235.1		23.50
238.1	4.88	22.23
2[illegible].1	4.89	23.92

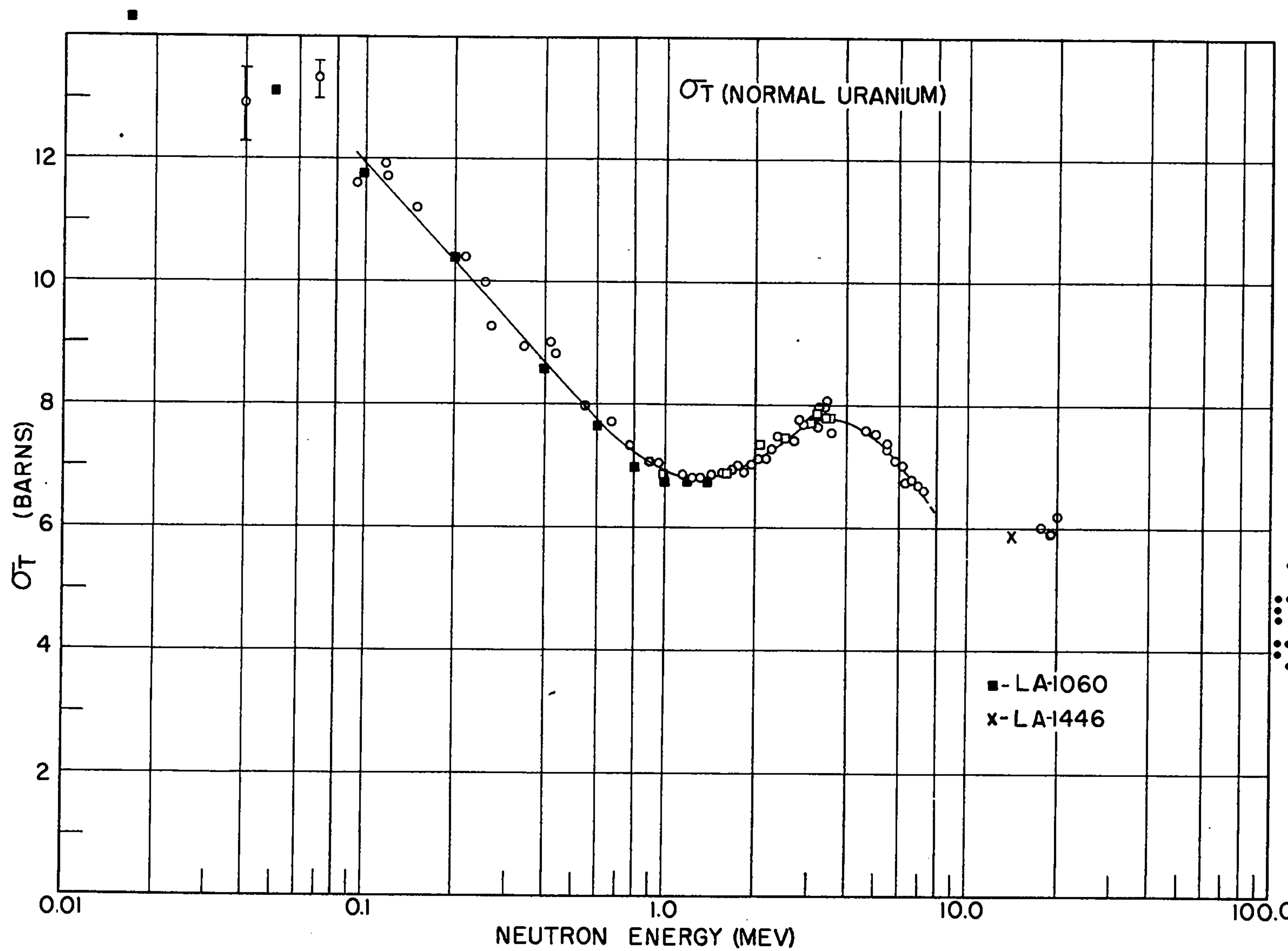

Fig. 1. Total neutron cross section for normal uranium.

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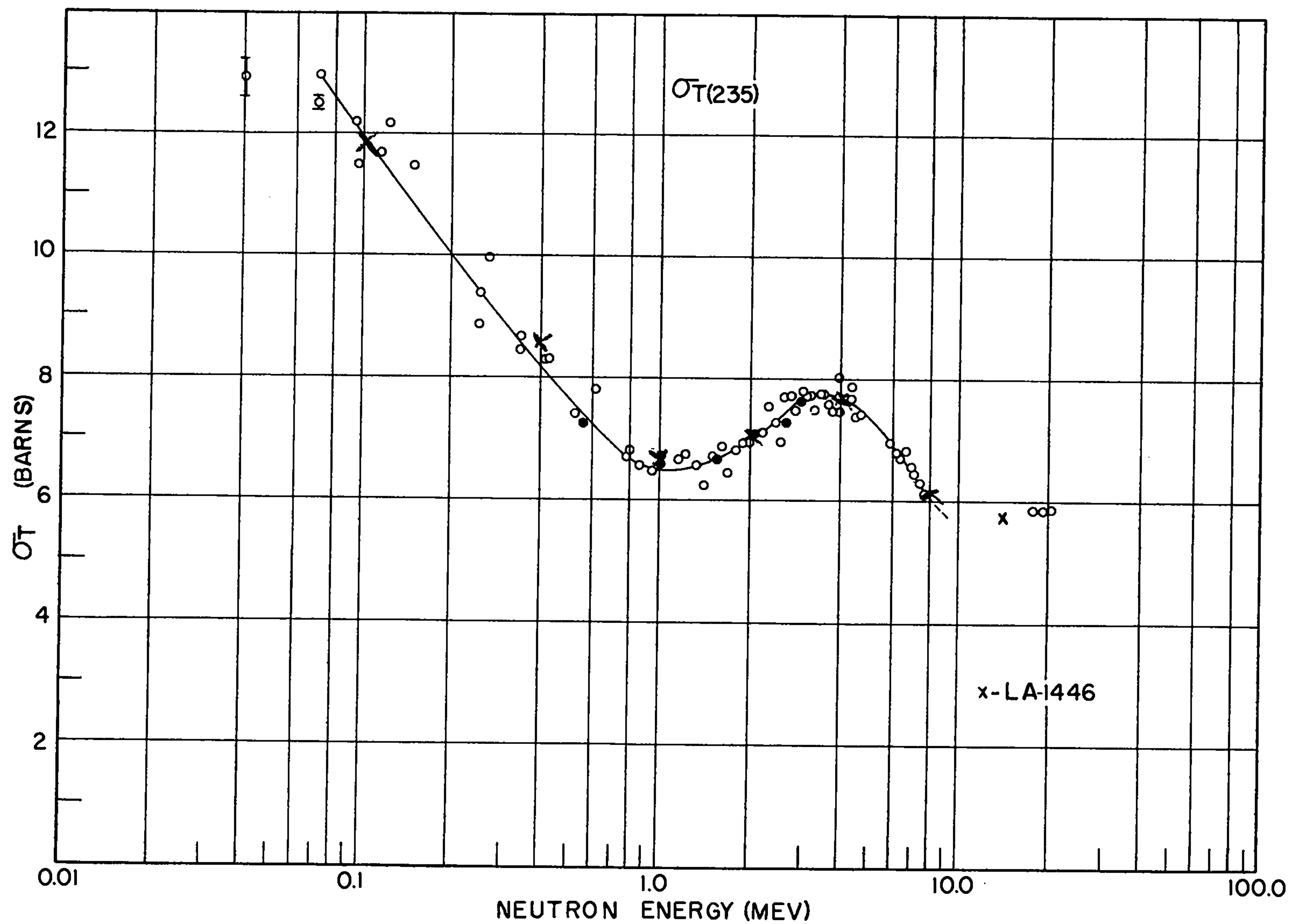

Fig. 2. Total neutron cross section for U^{235}.

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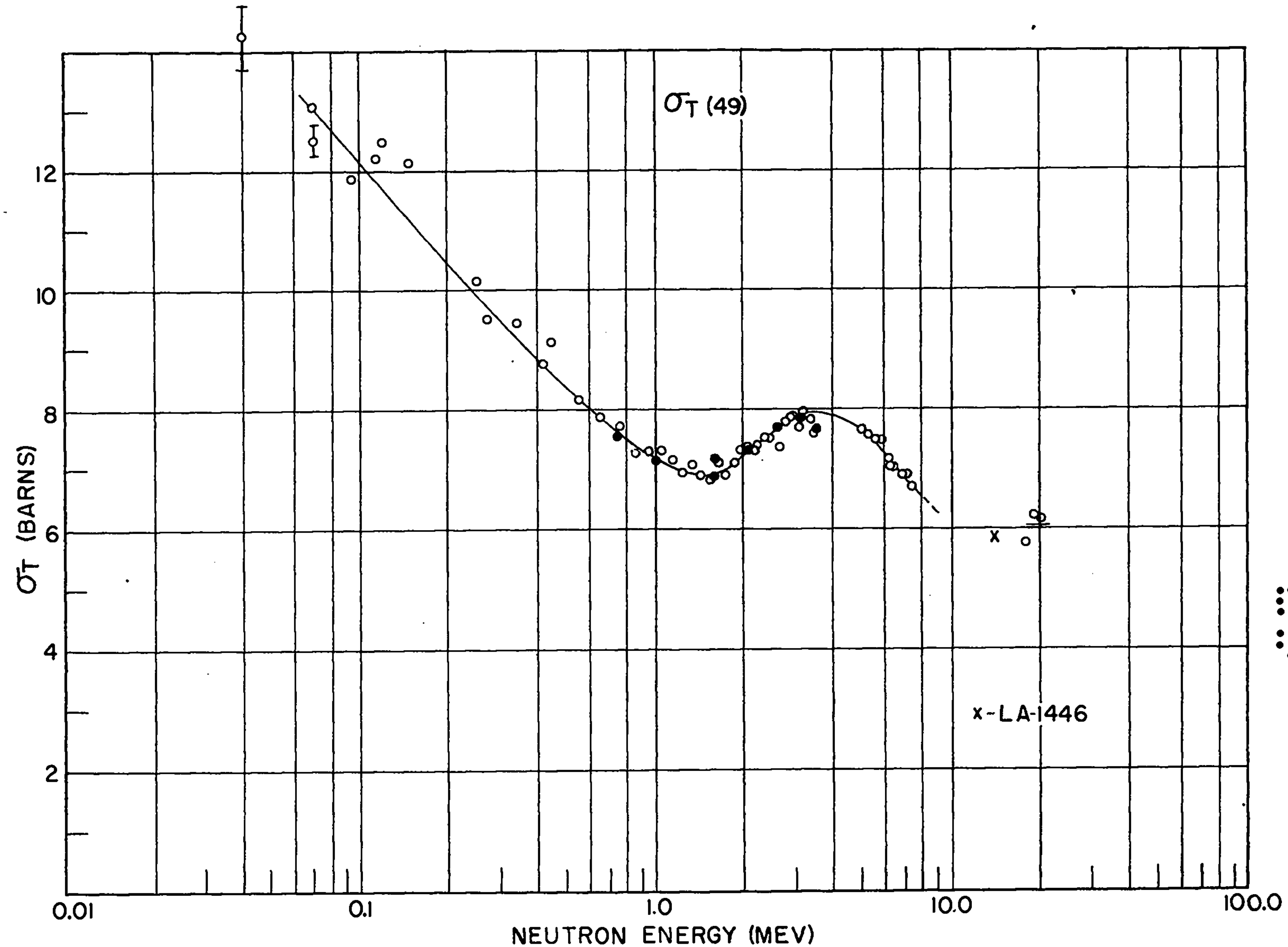

Fig. 3. Total neutron cross section for Pu^{239}.

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