NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It
has been reproduced from the best available
copy to permit the broadest possible avail-
ability.

Cross Sections for the $\text{Al}(n, xn)$ and $\text{Al}(n, x\gamma)$ Reaction Between 1 and 20 MeV

G. L. Morgan F. G. Perey

MASTER

OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION • FOR THE U.S. ATOMIC ENERGY COMMISSION

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy \$5.50; Microfiche \$2.25

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Contract No. W-7405-Eng-26

Neutron Physics Division

CROSS SECTIONS FOR THE $Al(n,xn)$ and $Al(n,x\gamma)$ REACTION
BETWEEN 1 AND 20 MeV

G. L. Morgan and F. G. Perey

JANUARY 1976

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

NOTE: This work funded by Defense Nuclear Agency under Subtask PE075

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

TABLE OF CONTENTS

	<u>Page</u>
Abstract	v
Introduction	1
Experimental Procedure	1
Data Reduction	3
Discussion	5
References	7
Appendix	8

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ABSTRACT

Differential cross sections for the production of secondary neutrons and photons from aluminum have been measured at 127° (lab) for incident neutron energies in the range 1 to 20 MeV. An electron linac was used as a neutron source with a white spectrum. Incident neutron energies were determined using time-of-flight techniques for a source-to-sample distance of 48 m. Secondary spectra were determined by unfolding the pulse-height distributions observed in a NE-213 scintillation counter. The results are compared to the current evaluated data file (ENDF/B-IV, MAT 1193).

INTRODUCTION

Differential cross sections for the $\text{Al}(n, xn)$ and $\text{Al}(n, x\gamma)$ reactions have been measured at a scattering angle of 127° (lab). The data were obtained as a function of the incident neutron energy over the range 1 to 20 MeV.

The purpose of the experiment was to provide data to test the evaluated cross section file for this nuclide over a wide range of energies. The work was performed as part of a program at ORNL to test such files for those elements which are important in applied problems involving radiation transport.

Tabulated results are provided in the Appendix along with a graphical comparison between the data and cross sections calculated from the most recent evaluation for aluminum (ENDF/B-IV, MAT 1193).¹

EXPERIMENTAL PROCEDURE

The experimental procedure used in this work has been described in detail elsewhere² and will be only briefly outlined here. The Oak Ridge Electron Linear Accelerator (ORELA) was used as a white neutron source. An electron beam pulse width of 12 ns at a repetition rate of 1000 sec^{-1} was employed. Approximately 115 hours of beam time were required to complete the experiment.

The scattering sample was located 47.7 m from the neutron source and consisted of 1132 grams of aluminum (>99% purity) formed in an annular ring about 25 cm in outer diameter, 15 cm in inner diameter, and

with a thickness of 1.3 cm ($=0.0786$ atoms/b). Details of the sample-detector geometry are shown in the first figure of the Appendix.

Secondary radiation from the sample was detected by a NE-213 scintillation counter located on the axis of the ring at a position corresponding to an average scattering angle of 127° . A shadow bar shielded the detector from the direct neutron beam.

The energy of the incident neutron was determined by the time after the electron pulse at which the neutron-induced radiation from the sample was detected. Each event in the detector was identified as either a neutron or gamma ray by pulse-shape discrimination techniques. The event was then recorded in a two-parameter array of pulse-height versus time-of-flight (one each for neutrons and gamma rays). Backgrounds were obtained by measurement with the sample removed. Overall background was about 15%.

The neutron flux incident on the sample was measured with the NE-213 detector using one parameter time-of-flight techniques. The sample and shadow bar were not in place for these measurements. A flux monitor consisting of a small plastic scintillator located in the edge of the neutron beam 30 m from the source was used to normalize the flux measurement to the actual cross-section measurement. This flux measurement had an absolute uncertainty of about 10% and is the largest source of systematic error in the cross sections reported here.

DATA REDUCTION

Two methods of data reduction were employed, each intended to make use of the available counting statistics to provide a maximum of information about a particular aspect of the cross section. In the first, the neutron or gamma-ray pulse-height spectra were integrated over intervals of neutron time-of-flight to form pulse-height spectra for specific incident neutron energy ranges. These intervals ranged in width from $\Delta E_{\text{inc}} = 0.25$ MeV at $E_{\text{inc}} = 1$ MeV to $\Delta E_{\text{inc}} = 2.5$ MeV at $E_{\text{inc}} = 20$ MeV. The pulse-height spectra so formed were then converted to neutron or gamma-ray energy distributions by unfolding with the code FERD³ using the measured neutron or gamma-ray response functions of the NE-213 detector. These distributions were then normalized to cross sections using the measured neutron flux, average sample-to-detector distance, and sample thickness.

No corrections for finite-sample effects were applied to the neutron data. The gamma-ray results were corrected for self absorption in the sample (this correction ranged from $\approx 15\%$ at $E_{\gamma} = 0.7$ MeV to $\approx 5\%$ at $E_{\gamma} = 10$ MeV). In this case neutron-multiple scattering was neglected. For the gamma-ray data extensive investigations by other workers (see, for instance, Ref. 4) have shown that the results obtained using elaborate multiple scattering corrections and those obtained by assuming uniform neutron flux throughout the sample agree to within 5% for sample thicknesses equal to or less than about $1/2$ mean free path. Since the present sample has a thickness of $\sim 1/5$ m.f.p., this assumption is clearly justified.

For the neutron case multiple scattering effects have not been as extensively investigated for this particular geometry. However, because of the poor angular resolution (approximately triangular, with a base 28° in width) and the poor energy resolution of the detector (varying from $\approx 30\%$ at 1 MeV to $\approx 15\%$ at 20 MeV) the effects of multiple scattering are expected to approximately cancel out those introduced by neutron attenuation in the sample.

As a test of this assumption the effects of multiple scattering on the neutron data were investigated for the elastically scattered neutrons using a one-velocity Monte Carlo code⁵ adapted to the present geometry. Over the range of energies in this work the results indicate that the assumption stated in the previous paragraph is valid to within 10% or better at all incident energies. Since this uncertainty is less than or equal to the uncertainty introduced by the measurement of the incident flux, finite-sample effects were neglected.

Numerical results are tabulated in Tables 1 and 2 of the Appendix. The measured cross sections are compared to cross sections calculated from the evaluation in the figures contained in the Appendix. The curves generated from the evaluation have been averaged over each incident neutron energy range and over the angular spread of the sample-detector system. The evaluated curves have been smeared to the experimental energy resolution.

The unfolded data described above provide detailed information about the secondary neutron and gamma-ray spectra, but because the unfolding technique requires good statistical accuracy the data must be binned over rather large incident energy intervals. Therefore a second

type of data reduction, pulse-height weighting,^{2,6} was also used. This technique provided only integral information about the secondary spectra (i.e. total yield and average energy), but because the demands on statistical accuracy are less severe it allowed better resolution in the incident neutron energy. For the work reported here the pulse-height weighting analysis was applied to spectra formed by integration over time-of-flight intervals corresponding to $\Delta E_{inc} = 0.05$ MeV at $E_{inc} = 1$ MeV and increasing to $\Delta E_{inc} = 0.5$ MeV at $E_{inc} = 20$ MeV. The results of this analysis for the total yield of secondary neutrons and secondary gamma rays and their average energies are tabulated as a function of the incident energy in Table 3. Comparisons to the evaluation are shown in the last four figures of the Appendix.

DISCUSSION

The measurements presented in this report provide data to test the evaluated secondary cross sections over a wide range of energies. The experimental resolution in the incident energy (≈ 0.4 ns/m contributed by electron pulse width and sample-to-detector transport time) is very good thus causing the resolution of the final data to be limited only by the bin widths necessary for adequate statistical accuracy. Energy resolution for the secondary spectra is due to the NE-213 detector and is rather poor. The secondary spectra do not allow full separation of the various reactions contributing to the secondary spectra. Because of this inability to resolve the secondary spectra completely, results have been tabulated only as laboratory cross sections.

The evaluation can be tested only to within this resolution. For example, at the higher incident energies the secondary neutron spectra contain a high energy peak which is the sum of the elastic neutron group and the inelastic groups to the first few excited states in ^{27}Al . Therefore care should be exercised in deciding which cross sections are contributing to any discrepancy between experiment and evaluation.

Reference to the figures in the Appendix indicates generally very good agreement between the measurement and evaluation for the gamma-ray production cross sections. Discrepancies in the neutron data are larger, the worst cases being the elastic cross section at the lower incident energies and the hard nonelastic processes [Q-values for $(n,2n)$, (n,pn) , and $(n,\alpha n)$ are -13.1, -8.3, and -10.1 MeV, respectively] at the higher incident energies.

ACKNOWLEDGEMENTS

The authors wish to thank J. W. McConnell and J. G. Craven for their assistance with the electronics and computers and H. A. Todd and the ORELA staff for operation of the accelerator. Special thanks are due W. E. Kinney for help with the multiple scattering calculations.

REFERENCES

1. P. G. Young and D. G. Foster, Jr., A Preliminary Evaluation of the Neutron and Photon-Production Cross Sections for Aluminum, LA-4726 (ENDF-175), December 1972.
2. G. L. Morgan, T. A. Love, and F. G. Perey, Nucl. Instr. Methods 128, 125 (1975).
3. W. R. Burrus and V. V. Verbinski, Nucl. Instr. Methods 67, 181 (1969).
4. Robert B. Day, Phys. Rev. 102, 767 (1956).
5. W. E. Kinney, private communication.
6. Frances Pleasonton, Robert L. Ferguson, and H. W. Schmitt, Phys. Rev. C 6, 1023 (1972).

APPENDIX

This Appendix contains tabular and graphical presentations of the data described in the text. The uncertainties quoted in the tables and shown in the figures do not include an estimated error in overall normalization of 10%.

ORNL-DWG 75-5686

TABLE 1. AL(M,IN) LABORATORY CROSS SECTION: AT 127 DEGREES. THE NUMBERS IN PARENTHESIS ARE STATISTICAL UNCERTAINTIES (IN THE SAME UNITS AS THE DATA). THE OVERALL UNCERTAINTY IN NORMALIZATION IS ABOUT 10%.

INCIDENT ENERGY-	17.42-20.09	14.98-17.42	12.49-14.98	10.03-12.49	9.00-10.03	8.02- 9.00	7.01- 8.02
SECONDARY ENERGY (KEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)
0.811	13.73 (2.35)	13.03 (1.97)	7.56 (1.61)	9.95 (1.17)	13.31 (1.40)	11.61 (1.38)	14.97 (1.33)
0.937	17.46 (1.41)	13.74 (1.23)	10.80 (1.13)	12.33 (1.00)	13.14 (0.85)	12.54 (0.83)	15.47 (0.73)
1.007	16.87 (1.19)	13.32 (1.06)	10.42 (0.89)	12.07 (0.66)	12.86 (0.74)	13.80 (0.73)	15.27 (0.69)
1.107	14.74 (1.50)	12.68 (1.14)	8.82 (1.22)	11.18 (1.06)	13.21 (0.77)	15.41 (0.73)	15.69 (0.69)
1.235	12.81 (1.36)	12.33 (1.21)	9.41 (1.10)	10.49 (0.70)	13.25 (0.72)	15.95 (0.67)	17.70 (0.64)
1.310	11.84 (1.31)	11.52 (1.19)	10.59 (0.97)	10.86 (0.57)	13.10 (0.67)	15.70 (0.64)	19.50 (0.60)
1.412	12.67 (1.32)	10.92 (1.22)	10.89 (1.06)	11.87 (0.57)	13.24 (0.68)	15.14 (0.67)	19.03 (0.63)
1.511	13.69 (1.24)	10.83 (1.10)	10.87 (0.99)	12.26 (0.62)	13.22 (0.68)	14.91 (0.67)	17.34 (0.63)
1.610	13.31 (1.23)	10.93 (1.07)	10.62 (0.90)	11.66 (0.51)	12.69 (0.64)	14.78 (0.63)	15.76 (0.58)
1.709	12.41 (1.21)	10.79 (0.95)	9.79 (0.74)	10.69 (0.46)	11.92 (0.63)	14.04 (0.62)	14.83 (0.57)
1.813	12.20 (1.14)	10.76 (0.92)	8.93 (0.64)	10.24 (0.50)	11.32 (0.67)	13.05 (0.66)	14.56 (0.61)
1.932	12.64 (1.10)	10.22 (0.83)	8.70 (0.64)	10.39 (0.48)	11.10 (0.66)	12.56 (0.66)	14.65 (0.62)
2.100	11.98 (1.12)	8.76 (0.75)	9.26 (0.62)	10.32 (0.50)	11.01 (0.64)	12.66 (0.64)	14.04 (0.60)
2.296	9.99 (1.04)	7.74 (0.75)	9.53 (0.62)	9.67 (0.49)	11.19 (0.65)	13.40 (0.65)	11.61 (0.63)
2.499	9.39 (0.90)	7.19 (0.66)	9.23 (0.53)	9.64 (0.41)	11.49 (0.56)	13.24 (0.54)	9.52 (0.52)
2.703	8.41 (0.85)	6.51 (0.66)	8.21 (0.53)	9.53 (0.47)	10.46 (0.63)	11.80 (0.61)	8.32 (0.57)
2.898	7.25 (0.87)	6.40 (0.68)	7.21 (0.55)	8.94 (0.49)	9.22 (0.65)	10.83 (0.65)	6.99 (0.59)
3.097	7.01 (0.85)	6.74 (0.67)	6.73 (0.58)	8.36 (0.51)	8.63 (0.67)	9.44 (0.65)	6.13 (0.65)
3.236	6.81 (0.81)	6.28 (0.59)	6.25 (0.48)	7.68 (0.42)	8.20 (0.57)	7.78 (0.58)	7.14 (0.56)
3.501	6.44 (0.81)	5.43 (0.68)	6.06 (0.59)	7.23 (0.50)	7.52 (0.65)	6.39 (0.66)	9.50 (0.64)
3.737	5.60 (0.72)	4.91 (0.57)	6.23 (0.49)	6.90 (0.42)	6.89 (0.57)	5.18 (0.58)	12.04 (0.57)
3.926	4.43 (0.68)	4.95 (0.50)	6.14 (0.43)	6.35 (0.37)	6.47 (0.49)	4.53 (0.51)	13.44 (0.51)
4.153	3.81 (0.66)	5.05 (0.52)	5.44 (0.45)	5.59 (0.39)	5.51 (0.53)	4.99 (0.53)	12.41 (0.53)
4.454	4.30 (0.56)	4.57 (0.45)	4.92 (0.39)	5.06 (0.34)	4.00 (0.48)	6.56 (0.48)	9.14 (0.44)
4.752	4.18 (0.53)	4.45 (0.43)	5.08 (0.39)	5.11 (0.34)	3.94 (0.49)	8.09 (0.49)	6.50 (0.43)
5.042	3.54 (0.51)	4.35 (0.44)	4.75 (0.39)	4.95 (0.34)	4.69 (0.45)	7.91 (0.46)	5.45 (0.44)
5.346	3.45 (0.48)	3.72 (0.41)	4.03 (0.36)	4.22 (0.32)	5.40 (0.46)	6.20 (0.45)	5.79 (0.44)
5.645	3.86 (0.52)	3.05 (0.45)	3.52 (0.39)	3.47 (0.36)	5.74 (0.51)	4.66 (0.50)	7.49 (0.43)
5.938	3.81 (0.54)	2.68 (0.47)	3.13 (0.40)	3.34 (0.36)	5.69 (0.48)	3.85 (0.45)	10.23 (0.38)
6.254	2.99 (0.53)	2.55 (0.48)	2.85 (0.43)	3.48 (0.41)	5.01 (0.56)	3.96 (0.54)	12.41 (0.46)
6.556	2.23 (0.47)	2.44 (0.43)	2.76 (0.39)	3.45 (0.36)	4.01 (0.49)	5.52 (0.47)	11.88 (0.39)
6.839	2.00 (0.44)	2.31 (0.39)	2.70 (0.36)	3.49 (0.32)	3.60 (0.41)	8.01 (0.38)	9.27 (0.25)
7.235	2.07 (0.52)	2.45 (0.46)	2.50 (0.38)	3.59 (0.33)	4.81 (0.45)	10.35 (0.35)	4.74 (0.19)
7.736	2.39 (0.50)	2.68 (0.45)	1.91 (0.41)	3.52 (0.37)	7.97 (0.47)	8.16 (0.27)	1.15 (0.14)
8.236	2.42 (0.48)	2.09 (0.45)	1.66 (0.43)	3.70 (0.37)	9.03 (0.37)	3.80 (0.22)	0.10 (0.09)
8.758	1.85 (0.45)	1.35 (0.40)	2.04 (0.37)	5.00 (0.29)	6.33 (0.26)	1.00 (0.14)	0.08 (0.06)
9.261	1.41 (0.43)	1.09 (0.38)	1.93 (0.35)	6.64 (0.28)	2.84 (0.21)	0.14 (0.09)	
9.741	1.25 (0.45)	1.34 (0.43)	1.81 (0.39)	6.71 (0.25)	0.83 (0.16)	0.03 (0.06)	
10.259	1.20 (0.44)	1.52 (0.41)	2.54 (0.36)	5.14 (0.21)	0.12 (0.11)		
10.777	1.03 (0.45)	1.26 (0.41)	4.10 (0.35)	3.19 (0.17)	0.05 (0.07)		
11.247	0.74 (0.46)	1.10 (0.43)	5.20 (0.34)	1.78 (0.14)			
11.751	0.58 (0.45)	1.44 (0.43)	5.24 (0.30)	0.80 (0.11)			
12.393	0.69 (0.47)	2.15 (0.42)	3.85 (0.27)	0.19 (0.07)			
13.201	0.60 (0.47)	2.62 (0.39)	1.72 (0.18)				
14.021	0.68 (0.47)	2.70 (0.40)	0.52 (0.13)				
14.792	1.51 (0.47)	2.06 (0.32)	0.12 (0.11)				
15.629	2.28 (0.50)	0.98 (0.24)					
16.539	2.08 (0.43)	0.19 (0.21)					
17.533	1.14 (0.32)						
18.521	0.39 (0.29)						
19.498	0.04 (0.21)						

INCIDENT ENERGY-	6.01 7.01	4.93- 6.01	4.43- 4.93	4.00- 4.43	3.50- 4.00	3.00- 3.50	2.49- 3.00
SECONDARY ENERGY (KEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)
0.811	14.95 (1.31)	16.03 (1.22)	4.64 (1.78)	29.12 (1.89)	23.08 (1.69)	30.96 (1.75)	3.38 (1.75)
0.937	20.47 (0.73)	18.88 (0.59)	6.40 (1.04)	39.13 (1.02)	24.15 (0.94)	32.06 (0.98)	3.65 (1.04)
1.007	21.78 (0.65)	18.09 (0.63)	8.05 (0.96)	43.67 (0.89)	24.62 (0.82)	22.63 (0.87)	3.28 (0.96)
1.107	19.04 (0.68)	13.90 (0.66)	13.65 (1.02)	40.86 (0.91)	27.36 (0.85)	11.09 (0.93)	8.85 (1.01)
1.235	17.81 (0.62)	10.09 (0.62)	25.49 (0.94)	32.14 (0.82)	28.39 (0.77)	4.58 (0.87)	20.06 (0.96)
1.310	16.88 (0.58)	8.07 (0.59)	38.06 (0.88)	23.52 (0.81)	24.51 (0.78)	2.50 (0.91)	29.30 (1.00)
1.412	16.67 (0.61)	8.10 (0.64)	42.63 (0.93)	21.16 (0.80)	17.97 (0.79)	4.03 (0.93)	34.21 (1.00)
1.511	16.72 (0.63)	9.73 (0.67)	39.69 (0.94)	22.49 (0.80)	11.68 (0.79)	8.55 (0.92)	34.08 (0.98)
1.610	16.49 (0.58)	12.32 (0.62)	33.34 (0.85)	23.17 (0.80)	6.89 (0.82)	15.82 (0.95)	28.54 (1.00)
1.709	15.47 (0.58)	15.37 (0.63)	27.72 (0.84)	21.08 (0.80)	4.61 (0.83)	24.54 (0.95)	21.87 (1.00)
1.813	13.44 (0.62)	18.40 (0.67)	25.23 (0.90)	16.20 (0.88)	4.46 (0.88)	31.52 (0.99)	21.31 (1.01)
1.932	10.86 (0.64)	20.87 (0.67)	25.91 (0.91)	9.74 (0.86)	6.03 (0.92)	33.05 (1.01)	38.97 (1.00)
2.100	8.87 (0.63)	22.80 (0.66)	25.46 (0.87)	4.48 (0.91)	12.88 (0.95)	25.61 (1.01)	89.24 (1.01)
2.296	9.25 (0.68)	24.17 (0.69)	16.89 (0.93)	5.76 (0.86)	23.76 (0.86)	23.30 (0.88)	125.46 (0.70)
2.499	12.80 (0.55)	22.62 (0.57)	6.65 (0.80)	12.66 (0.86)	23.89 (0.86)	44.89 (0.84)	102.01 (0.56)
2.733	16.26 (0.63)	17.90 (0.62)	4.77 (0.88)	20.11 (0.83)	21.24 (0.77)	69.27 (0.67)	52.23 (0.38)
2.898	17.65 (0.63)	13.52 (0.63)	11.44 (0.91)	21.98 (0.85)	34.01 (0.74)	66.45 (0.58)	19.05 (0.25)
3.097	17.79 (0.71)	10.97 (0.73)	18.20 (1.05)	21.74 (0.88)	52.41 (0.60)	42.32 (0.44)	5.05 (0.17)
3.236	16.50 (0.77)	10.07 (0.63)	18.96 (0.85)	28.05 (0.75)	53.86 (0.52)	18.91 (0.31)	1.08 (0.12)
3.501	13.64 (0.68)	10.12 (0.73)	19.17 (0.98)	38.22 (0.73)	37.52 (0.43)	5.97 (0.23)	
3.737	10.14 (0.58)	11.10 (0.60)	25.76 (0.75)	39.82 (0.57)	18.74 (0.32)	1.23 (0.16)	
3.926	8.31 (0.52)	13.53 (0.55)	34.94 (0.64)	30.44 (0.47)	7.28 (0.23)		
4.153	7.78 (0.53)	18.91 (0.53)	37.68 (0.59)	14.92 (0.34)	1.51 (0.14)		
4.454	8.51 (0.46)	25.50 (0.43)	24.87 (0.41)	3.76 (0.24)			
4.752	10.57 (0.43)	26.51 (0.35)	10.48 (0.28)	0.58 (0.15)			
5.042	14.12 (0.42)	20.90 (0.30)	3.23 (0.19)				
5.346	17.02 (0.38)	12.02 (0.23)	0.78 (0.13)				
5.645	16.31 (0.34)	5.18 (0.18)					
5.938	12.41 (0.29)	1.73 (0.14)					
6.254	7.35 (0.26)	0.43 (0.10)					
6.556	3.65 (0.22)	0.16 (0.07)					
6.839	1.58 (0.16)						
7.235	0.37 (0.10)						

INCIDENT ENERGY-	2.00- 2.49	1.75- 2.00	1.50- 1.75	1.25- 1.50	1.00- 1.25
SECONDARY ENERGY (KEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)
0.811	26.42 (1.45)	39.19 (1.84)	2.84 (1.97)	7.64 (2.32)	199.62 (2.50)
0.937	39.75 (0.81)	27.28 (1.02)	2.62 (1.07)	43.16 (1.15)	353.25 (1.11)
1.007	44.19 (0.75)	12.61 (0.99)	9.29 (1.02)	140.37 (0.98)	351.79 (0.71)
1.107	39.40 (0.77)	5.83 (1.01)	46.64 (0.97)	247.36 (0.83)	223.68 (0.52)
1.235	29.43 (0.75)	11.58 (0.96)	129.22 (0.86)	266.63 (0.66)	103.19 (0.34)
1.310	18.90 (0.77)	42.21 (0.95)	219.11 (0.77)	191.87 (0.51)	34.05 (0.21)
1.412	17.33 (0.75)	103.96 (0.85)	237.68 (0.63)	101.38 (0.38)	9.31 (0.13)
1.511	13.82 (0.72)	169.74 (0.74)	187.00 (0.50)	42.95 (0.25)	
1.610	70.62 (0.67)	197.59 (0.62)	114.36 (0.38)	14.87 (0.16)	
1.709	116.28 (0.62)	173.16 (0.51)	56.95 (0.26)	4.13 (0.11)	
1.813	152.58 (0.56)	117.90 (0.41)	22.95 (0.18)		
1.932	160.82 (0.50)	58.19 (0.30)	6.35 (0.12)		
2.100	116.17 (0.37)	14.71 (0.17)	0.48 (0.08)		
2.296	86.22 (0.24)	1.52 (0.10)			
2.499	12.47 (0.14)				
2.703	2.52 (0.09)				
2.898	0.66 (0.06)				

TABLE 2. $AL(N, X)$ DIFFERENTIAL CROSS SECTIONS AT 127 DEGREES. THE NUMBERS IN PARENTHESIS ARE STATISTICAL UNCERTAINTIES (IN THE SAME UNITS AS THE DATA). THE OVERALL UNCERTAINTY IN NORMALIZATION IS ABOUT 10%.

INCIDENT ENERGY	17.42-20.09	14.98-17.42	12.49-14.98	10.03-12.49	9.00-10.03	8.02- 9.00	7.01- 8.02
DATA RAY ENERGY (MEV)	CROSS SECTION (MB/SR/MEV)	CROSS SECTION (MB/SR/MEV)	CROSS SECTION (MB/SR/MEV)	CROSS SECTION (MB/SR/MEV)	CROSS SECTION (MB/SR/MEV)	CROSS SECTION (MB/SR/MEV)	CROSS SECTION (MB/SR/MEV)
0.760	26.91 (8.96)	19.95 (7.92)	31.96 (8.10)	29.97 (7.88)	31.56 (8.72)	33.59 (8.74)	30.02 (8.09)
0.800	25.75 (3.60)	26.76 (3.09)	35.69 (2.96)	40.84 (2.75)	42.67 (3.21)	46.14 (3.18)	43.60 (2.92)
0.930	27.18 (2.51)	31.12 (2.09)	39.34 (1.81)	49.61 (1.56)	50.50 (1.99)	54.44 (1.94)	53.52 (1.74)
0.880	31.69 (2.37)	35.28 (1.96)	44.88 (1.66)	58.08 (1.41)	58.54 (1.84)	62.35 (1.77)	63.50 (1.58)
0.920	38.45 (2.40)	41.60 (1.99)	51.63 (1.69)	66.94 (1.44)	68.14 (1.86)	72.95 (1.79)	76.77 (1.61)
0.950	45.13 (2.39)	47.25 (1.97)	55.62 (1.66)	72.99 (1.39)	75.96 (1.81)	82.86 (1.75)	88.44 (1.56)
1.000	48.81 (2.40)	48.24 (1.96)	53.93 (1.64)	71.84 (1.37)	76.93 (1.79)	84.37 (1.73)	89.76 (1.54)
1.080	48.78 (2.36)	48.55 (1.92)	47.46 (1.61)	62.67 (1.33)	68.86 (1.74)	74.20 (1.66)	78.29 (1.48)
1.080	46.15 (2.38)	39.24 (1.93)	39.44 (1.62)	49.30 (1.31)	54.53 (1.70)	57.18 (1.62)	60.02 (1.43)
1.125	41.26 (2.31)	33.44 (1.86)	31.62 (1.56)	35.33 (1.31)	37.23 (1.63)	38.42 (1.54)	40.24 (1.36)
1.175	34.21 (2.27)	26.92 (1.86)	25.61 (1.57)	24.82 (1.28)	22.92 (1.60)	23.51 (1.52)	24.20 (1.32)
1.225	26.51 (2.31)	20.48 (1.92)	21.43 (1.65)	18.88 (1.35)	15.34 (1.67)	14.88 (1.58)	14.14 (1.38)
1.275	19.71 (2.30)	15.80 (1.93)	17.98 (1.69)	15.77 (1.41)	12.22 (1.71)	11.16 (1.61)	9.35 (1.40)
1.325	15.63 (2.21)	14.05 (1.83)	15.68 (1.58)	14.76 (1.28)	11.54 (1.60)	10.71 (1.51)	8.79 (1.31)
1.375	14.15 (2.18)	13.79 (1.80)	15.32 (1.51)	15.09 (1.22)	12.01 (1.56)	10.71 (1.47)	9.45 (1.28)
1.425	14.80 (2.26)	14.01 (1.88)	17.12 (1.60)	16.09 (1.30)	13.22 (1.65)	10.21 (1.56)	9.53 (1.36)
1.475	16.96 (2.34)	15.27 (1.91)	19.94 (1.64)	17.73 (1.30)	15.08 (1.68)	10.65 (1.59)	10.03 (1.39)
1.525	21.43 (2.27)	19.12 (1.86)	22.93 (1.57)	20.28 (1.26)	17.71 (1.61)	13.47 (1.51)	12.36 (1.33)
1.575	30.02 (2.23)	26.65 (1.84)	27.10 (1.55)	23.67 (1.24)	20.81 (1.59)	18.11 (1.50)	16.12 (1.31)
1.680	48.40 (2.26)	41.40 (1.86)	35.94 (1.55)	27.15 (1.25)	23.86 (1.60)	23.23 (1.52)	20.42 (1.33)
1.720	71.89 (2.31)	59.88 (1.89)	47.75 (1.55)	26.70 (1.24)	23.92 (1.60)	23.96 (1.51)	21.79 (1.32)
1.800	77.80 (2.31)	65.18 (1.91)	50.47 (1.57)	24.45 (1.26)	22.01 (1.63)	20.87 (1.53)	19.72 (1.35)
1.880	63.43 (2.17)	56.14 (1.82)	43.21 (1.53)	25.08 (1.24)	21.42 (1.61)	18.92 (1.53)	18.65 (1.33)
1.960	44.33 (2.10)	42.42 (1.81)	36.18 (1.57)	29.00 (1.33)	25.06 (1.72)	21.92 (1.63)	22.96 (1.42)
2.080	34.38 (1.93)	34.25 (1.67)	37.34 (1.47)	37.38 (1.26)	35.66 (1.65)	32.34 (1.55)	32.75 (1.36)
2.120	33.48 (1.91)	33.10 (1.63)	43.91 (1.47)	48.95 (1.26)	49.10 (1.65)	46.83 (1.57)	44.29 (1.37)
2.200	34.61 (1.84)	33.80 (1.59)	47.93 (1.43)	56.27 (1.24)	54.98 (1.61)	56.46 (1.59)	51.95 (1.34)
2.280	33.29 (1.78)	31.80 (1.54)	45.10 (1.40)	53.20 (1.21)	49.02 (1.56)	55.06 (1.51)	50.80 (1.30)
2.360	29.49 (1.74)	27.35 (1.50)	37.22 (1.35)	42.35 (1.17)	37.43 (1.51)	44.85 (1.46)	41.50 (1.25)
2.450	24.21 (1.66)	22.32 (1.43)	27.57 (1.30)	29.71 (1.11)	27.02 (1.44)	31.03 (1.39)	28.80 (1.19)
2.550	19.63 (1.55)	18.16 (1.35)	20.33 (1.22)	21.89 (1.03)	21.83 (1.36)	20.87 (1.29)	20.39 (1.10)
2.650	17.59 (1.54)	15.68 (1.34)	17.61 (1.21)	20.61 (1.03)	21.50 (1.36)	18.95 (1.28)	19.01 (1.09)
2.750	17.65 (1.48)	16.29 (1.32)	18.95 (1.20)	23.97 (1.03)	24.85 (1.34)	23.92 (1.26)	22.54 (1.07)
2.850	18.57 (1.43)	19.47 (1.29)	23.05 (1.16)	29.55 (1.01)	29.82 (1.31)	31.03 (1.23)	29.19 (1.05)
2.950	18.45 (1.42)	21.17 (1.30)	26.51 (1.18)	33.24 (1.02)	32.62 (1.32)	34.25 (1.24)	34.40 (1.06)
3.050	16.19 (1.41)	19.07 (1.28)	26.03 (1.18)	31.93 (1.02)	31.03 (1.30)	31.43 (1.22)	33.56 (1.05)
3.150	12.48 (1.40)	15.07 (1.25)	21.64 (1.17)	26.28 (1.01)	25.81 (1.30)	25.46 (1.20)	27.24 (1.00)
3.250	9.35 (1.38)	12.00 (1.25)	16.26 (1.16)	19.43 (1.01)	19.59 (1.28)	20.15 (1.19)	20.19 (0.99)
3.350	7.69 (1.36)	10.24 (1.24)	12.17 (1.16)	13.94 (1.00)	14.66 (1.27)	16.40 (1.17)	15.39 (0.96)
3.450	7.00 (1.33)	8.75 (1.23)	9.92 (1.14)	10.81 (0.98)	12.09 (1.24)	13.34 (1.14)	12.54 (0.93)
3.550	6.46 (1.34)	7.14 (1.23)	9.03 (1.17)	9.70 (1.01)	11.47 (1.28)	10.49 (1.18)	10.37 (0.94)
3.650	6.06 (1.37)	5.73 (1.27)	8.94 (1.18)	9.70 (1.04)	11.72 (1.30)	7.95 (1.18)	8.54 (0.94)
3.750	6.40 (1.37)	5.36 (1.30)	9.27 (1.21)	10.12 (1.06)	11.61 (1.30)	6.83 (1.19)	8.16 (0.95)
3.925	6.95 (1.44)	5.59 (1.38)	9.36 (1.30)	10.49 (1.11)	10.57 (1.36)	7.55 (1.21)	9.05 (0.96)
4.055	6.34 (1.49)	5.70 (1.44)	8.86 (1.38)	10.41 (1.17)	8.67 (1.44)	9.52 (1.27)	9.42 (0.99)
4.185	4.23 (1.57)	5.62 (1.53)	7.85 (1.44)	9.72 (1.24)	6.33 (1.54)	11.63 (1.39)	8.59 (1.02)
4.315	2.29 (1.62)	5.59 (1.63)	7.06 (1.57)	8.93 (1.37)	4.43 (1.65)	12.62 (1.46)	7.49 (1.09)
4.445	1.84 (1.74)	5.81 (1.77)	7.15 (1.70)	8.74 (1.51)	4.18 (1.77)	11.96 (1.54)	7.08 (1.14)
4.575	2.92 (1.82)	6.61 (1.85)	8.00 (1.86)	9.14 (1.63)	6.34 (1.95)	10.43 (1.61)	7.42 (1.20)
4.705	4.22 (1.86)	7.54 (1.89)	8.80 (1.88)	9.46 (1.68)	10.09 (1.96)	9.43 (1.64)	8.16 (1.18)
4.835	5.12 (1.89)	7.89 (1.95)	8.77 (2.00)	9.25 (1.76)	13.30 (2.06)	9.48 (1.70)	8.80 (1.17)
4.985	5.59 (1.96)	6.98 (2.11)	7.82 (2.16)	8.77 (1.96)	14.13 (2.20)	9.99 (1.78)	8.98 (1.21)
5.155	5.50 (1.99)	4.92 (2.15)	6.56 (2.34)	8.48 (2.06)	11.29 (2.35)	9.51 (1.86)	8.43 (1.23)
5.325	4.86 (2.04)	3.70 (2.22)	5.78 (2.41)	8.50 (2.16)	7.63 (2.41)	7.78 (1.87)	7.30 (1.13)
5.495	3.62 (2.02)	3.87 (2.27)	5.39 (2.51)	8.56 (2.28)	6.28 (2.38)	6.40 (1.84)	6.15 (1.13)
5.665	2.28 (2.04)	4.40 (2.30)	5.17 (2.54)	8.37 (2.28)	6.92 (2.40)	6.31 (1.83)	5.18 (1.06)
5.835	1.44 (1.91)	4.28 (2.18)	5.29 (2.46)	8.10 (2.19)	7.74 (2.29)	6.90 (1.74)	4.68 (0.91)
6.005	1.28 (1.74)	3.26 (2.07)	5.73 (2.27)	7.67 (2.03)	7.21 (2.12)	6.95 (1.53)	4.49 (0.75)
6.175	1.58 (1.66)	2.27 (1.96)	6.13 (2.17)	7.23 (1.94)	5.87 (1.91)	6.22 (1.38)	4.33 (0.64)
6.345	2.22 (1.52)	2.03 (1.76)	6.06 (1.96)	6.58 (1.74)	4.88 (1.76)	5.12 (1.17)	3.92 (0.55)
6.515	2.81 (1.37)	2.64 (1.59)	5.50 (1.73)	5.76 (1.57)	4.88 (1.51)	4.17 (1.01)	3.19 (0.40)
6.700	3.15 (1.10)	3.64 (1.32)	4.69 (1.44)	4.99 (1.28)	5.30 (1.21)	3.64 (0.75)	2.24 (0.26)
6.900	2.78 (0.95)	4.07 (1.13)	4.13 (1.27)	4.70 (1.11)	5.37 (0.97)	3.44 (0.57)	1.32 (0.18)
7.100	2.05 (0.87)	3.62 (1.02)	3.95 (1.15)	4.85 (0.99)	4.71 (0.85)	3.18 (0.46)	0.70 (0.12)
7.300	1.38 (0.77)	2.67 (0.88)	3.80 (0.97)	4.88 (0.87)	3.77 (0.65)	2.68 (0.32)	0.32 (0.07)
7.500	1.05 (0.64)	1.78 (0.76)	3.49 (0.88)	4.52 (0.78)	3.06 (0.54)	2.01 (0.22)	0.14 (0.04)
7.700	1.08 (0.54)	1.15 (0.67)	3.04 (0.78)	3.84 (0.63)	2.58 (0.47)	1.33 (0.17)	0.05 (0.02)
7.900	1.18 (0.46)	0.88 (0.58)	2.59 (0.64)	3.12 (0.54)	2.21 (0.33)	0.78 (0.14)	0.02 (0.01)
8.100	1.23 (0.36)	0.90 (0.49)	2.27 (0.53)	2.49 (0.45)	1.80 (0.22)	0.42 (0.09)	0.01 (0.00)
8.300	1.11 (0.26)	0.98 (0.44)	2.06 (0.47)	1.97 (0.39)	1.32 (0.16)	0.20 (0.06)	0.00 (0.00)
8.500	0.87 (0.22)	1.13 (0.37)	1.91 (0.38)	1.53 (0.31)	0.88 (0.14)	0.09 (0.03)	0.00 (0.00)
8.725	0.58 (0.18)	1.14 (0.27)	1.70 (0.26)	1.18 (0.25)	0.49 (0.10)	0.03 (0.01)	0.00 (0.00)
8.975	0.32 (0.13)	0.99 (0.22)	1.35 (0.18)	0.88 (0.18)	0.23 (0.06)	0.01 (0.00)	0.00 (0.00)
9.225	0.15 (0.08)	0.74 (0.17)	0.94 (0.15)	0.66 (0.12)	0.09 (0.03)	0.00 (0.00)	0.00 (0.00)
9.475	0.07 (0.04)	0.48 (0.13)	0.57 (0.12)	0.48 (0.09)	0.03 (0.01)	0.00 (0.00)	0.00 (0.00)
9.725	0.03 (0.02)	0.27 (0.09)	0.31 (0.07)	0.31 (0.07)	0.01 (0.00)	0.00 (0.00)	0.00 (0.00)
9.975	0.01 (0.01)	0.15 (0.06)	0.15 (0.04)	0.19 (0.05)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

TABLE 2. AL (M, 16) DIFFERENTIAL CROSS SECTIONS AT 127 DEGREES. THE NUMBERS IN PARENTHESIS ARE STATISTICAL UNCERTAINTIES (IN THE SAME UNITS AS THE DATA). THE OVERALL UNCERTAINTY IN NORMALIZATION IS ABOUT 10%.

INCIDENT ENERGY=	6.01- 7.01	4.99- 6.01	4.49- 4.99	4.00- 4.49	3.50- 4.00	3.00- 3.50	2.49- 3.00
GASNA RAY ENERGY (MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)
0.750	32.43 (7.96)	32.70 (7.15)	33.71 (7.48)	42.48 (7.07)	34.73 (6.31)	29.70 (6.38)	27.26 (4.83)
0.800	47.71 (2.83)	47.03 (2.52)	49.95 (2.80)	49.86 (2.63)	44.31 (2.34)	43.90 (2.37)	38.09 (1.82)
0.880	57.55 (1.65)	56.15 (1.45)	58.61 (1.78)	54.66 (1.65)	49.42 (1.47)	53.12 (1.49)	45.63 (1.16)
0.880	67.37 (1.49)	65.17 (1.30)	65.19 (1.62)	60.20 (1.49)	53.88 (1.33)	61.70 (1.35)	52.39 (1.05)
0.920	81.59 (1.51)	78.26 (1.32)	75.98 (1.62)	71.62 (1.50)	62.45 (1.33)	73.76 (1.35)	61.20 (1.05)
0.960	94.86 (1.47)	90.23 (1.28)	87.30 (1.60)	84.23 (1.48)	71.99 (1.31)	85.51 (1.33)	69.80 (1.01)
1.000	97.49 (1.45)	92.16 (1.26)	89.66 (1.54)	87.69 (1.42)	74.75 (1.27)	88.56 (1.28)	72.01 (0.97)
1.040	86.21 (1.38)	80.50 (1.19)	78.92 (1.46)	77.85 (1.35)	67.16 (1.21)	79.01 (1.20)	64.35 (0.90)
1.080	66.53 (1.32)	60.73 (1.12)	60.28 (1.39)	59.86 (1.28)	52.65 (1.14)	61.04 (1.12)	49.52 (0.81)
1.125	83.81 (1.26)	38.88 (1.06)	39.52 (1.27)	38.90 (1.16)	34.91 (1.05)	39.65 (1.00)	31.39 (0.69)
1.175	24.84 (1.21)	21.63 (1.01)	23.02 (1.19)	21.09 (1.06)	19.12 (0.97)	21.59 (0.89)	15.99 (0.58)
1.225	13.49 (1.25)	11.20 (1.04)	12.67 (1.20)	9.86 (1.08)	9.23 (0.97)	10.57 (0.89)	6.95 (0.55)
1.275	8.06 (1.28)	5.73 (1.07)	6.30 (1.19)	4.11 (1.06)	4.54 (0.97)	4.90 (0.88)	2.69 (0.51)
1.325	6.43 (1.20)	4.58 (0.99)	3.75 (1.14)	2.82 (1.02)	3.41 (0.93)	3.15 (0.85)	1.61 (0.50)
1.375	6.55 (1.16)	6.21 (0.97)	3.95 (1.14)	3.91 (1.02)	3.80 (0.93)	3.34 (0.84)	2.02 (0.51)
1.425	7.83 (1.24)	8.59 (1.03)	5.12 (1.19)	5.39 (1.06)	4.85 (0.96)	4.11 (0.88)	2.48 (0.52)
1.475	10.56 (1.26)	10.70 (1.05)	6.22 (1.22)	6.38 (1.09)	6.47 (0.99)	5.36 (0.90)	2.37 (0.54)
1.525	14.52 (1.21)	12.99 (1.01)	7.95 (1.18)	7.65 (1.06)	8.94 (0.96)	7.85 (0.87)	2.08 (0.52)
1.575	18.80 (1.19)	16.42 (0.98)	11.03 (1.15)	10.17 (1.03)	12.34 (0.94)	11.40 (0.85)	1.99 (0.51)
1.640	22.90 (1.19)	22.21 (1.00)	16.43 (1.16)	15.37 (1.05)	17.20 (0.95)	15.45 (0.86)	2.13 (0.51)
1.720	23.37 (1.19)	26.02 (1.00)	20.46 (1.19)	20.32 (1.07)	19.56 (0.96)	16.04 (0.87)	1.75 (0.53)
1.800	19.80 (1.21)	22.49 (1.02)	18.10 (1.20)	18.25 (1.09)	15.91 (0.96)	13.10 (0.87)	1.15 (0.53)
1.880	17.13 (1.18)	17.22 (0.98)	13.19 (1.18)	11.93 (1.06)	11.69 (0.94)	11.44 (0.86)	2.26 (0.55)
1.960	20.35 (1.27)	17.94 (1.05)	14.00 (1.23)	11.26 (1.09)	13.09 (1.00)	15.00 (0.90)	6.87 (0.60)
2.040	30.57 (1.21)	26.98 (0.99)	24.31 (1.20)	20.67 (1.07)	21.71 (0.96)	25.16 (0.88)	14.74 (0.58)
2.120	43.35 (1.23)	40.08 (1.00)	37.83 (1.21)	33.27 (1.08)	33.41 (0.97)	37.47 (0.89)	22.55 (0.59)
2.200	51.04 (1.21)	48.53 (1.00)	43.82 (1.19)	39.15 (1.07)	39.84 (0.95)	43.20 (0.87)	25.79 (0.53)
2.280	48.81 (1.18)	46.00 (0.95)	38.56 (1.15)	35.17 (1.02)	35.88 (0.92)	38.06 (0.80)	22.89 (0.46)
2.360	39.12 (1.13)	34.89 (0.89)	27.42 (1.07)	25.28 (0.96)	25.07 (0.84)	26.24 (0.70)	16.23 (0.39)
2.450	27.59 (1.06)	21.74 (0.82)	16.38 (0.98)	14.34 (0.88)	13.89 (0.75)	13.89 (0.57)	8.73 (0.27)
2.550	21.00 (0.98)	14.49 (0.75)	10.41 (0.90)	8.68 (0.79)	8.67 (0.67)	6.79 (0.48)	3.50 (0.18)
2.650	20.84 (0.97)	14.80 (0.74)	11.23 (0.89)	11.15 (0.79)	9.92 (0.65)	5.10 (0.43)	1.30 (0.11)
2.750	24.99 (0.94)	19.43 (0.73)	18.20 (0.89)	18.74 (0.77)	14.85 (0.60)	5.91 (0.38)	0.60 (0.08)
2.850	31.60 (0.92)	25.48 (0.71)	27.80 (0.87)	26.45 (0.76)	20.52 (0.58)	7.45 (0.35)	0.36 (0.06)
2.950	36.54 (0.92)	29.02 (0.71)	33.15 (0.87)	29.63 (0.75)	23.28 (0.54)	8.24 (0.31)	0.23 (0.04)
3.050	35.67 (0.91)	27.34 (0.69)	30.47 (0.80)	26.69 (0.65)	21.27 (0.46)	7.49 (0.27)	0.12 (0.04)
3.150	29.10 (0.86)	21.44 (0.64)	22.30 (0.71)	19.87 (0.55)	15.92 (0.38)	5.56 (0.21)	0.04 (0.03)
3.250	20.96 (0.83)	14.86 (0.60)	13.89 (0.61)	12.61 (0.46)	9.95 (0.30)	3.46 (0.16)	0.00 (0.02)
3.350	14.66 (0.79)	9.97 (0.57)	8.13 (0.52)	7.12 (0.36)	5.33 (0.21)	1.83 (0.12)	
3.450	10.80 (0.75)	7.05 (0.53)	4.90 (0.45)	3.74 (0.29)	2.49 (0.16)	0.85 (0.09)	
3.550	8.50 (0.76)	5.30 (0.51)	3.09 (0.40)	1.94 (0.24)	1.05 (0.12)	0.37 (0.06)	
3.655	7.25 (0.74)	4.16 (0.51)	1.97 (0.37)	1.03 (0.20)	0.36 (0.09)	0.16 (0.05)	
3.795	7.51 (0.73)	4.03 (0.48)	1.67 (0.35)	0.73 (0.17)	0.12 (0.07)	0.10 (0.04)	
3.925	8.40 (0.75)	5.00 (0.49)	2.08 (0.33)	0.66 (0.15)	0.05 (0.05)		
4.055	8.41 (0.76)	6.26 (0.50)	2.53 (0.30)	0.56 (0.12)	0.03 (0.04)		
4.185	7.61 (0.77)	7.00 (0.50)	2.54 (0.25)	0.40 (0.10)	0.00 (0.03)		
4.315	7.12 (0.79)	7.08 (0.49)	2.12 (0.22)	0.22 (0.09)	-0.01 (0.03)		
4.445	7.34 (0.83)	6.65 (0.48)	1.51 (0.20)	0.09 (0.07)			
4.575	7.63 (0.83)	5.84 (0.43)	0.95 (0.16)	0.01 (0.05)			
4.705	7.25 (0.80)	4.75 (0.39)	0.53 (0.11)	-0.01 (0.05)			
4.835	6.31 (0.75)	3.50 (0.34)	0.26 (0.08)	-0.01 (0.08)			
4.985	5.42 (0.71)	2.20 (0.30)	0.11 (0.06)				
5.155	5.50 (0.67)	1.22 (0.24)	0.02 (0.05)				
5.325	5.96 (0.57)	0.78 (0.20)	-0.00 (0.04)				
5.495	5.59 (0.50)	0.65 (0.17)					
5.665	4.27 (0.44)	0.55 (0.15)					
5.835	2.70 (0.35)	0.43 (0.12)					
6.005	1.46 (0.27)	0.29 (0.10)					
6.175	0.70 (0.22)	0.15 (0.07)					
6.345	0.32 (0.17)	0.05 (0.06)					
6.515	0.16 (0.13)	-0.00 (0.05)					
6.700	0.08 (0.09)						
6.900	0.06 (0.05)						
7.100	0.05 (0.04)						
7.300	0.04 (0.03)						
7.500	0.03 (0.02)						
7.700	0.02 (0.02)						

INCIDENT ENERGY=	2.00- 2.49	1.75- 2.00	1.50- 1.75	1.25- 1.50	1.00- 1.25
GASNA RAY ENERGY (MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)	CROSS SECTION (NB/SR/MEV)
0.760	23.22 (3.60)	19.79 (3.28)	29.53 (3.56)	23.05 (2.73)	14.42 (1.91)
0.800	36.06 (1.29)	29.77 (1.24)	42.13 (1.29)	32.19 (1.02)	21.88 (0.74)
0.880	44.26 (0.76)	36.19 (0.79)	48.90 (0.78)	36.85 (0.65)	25.56 (0.51)
0.880	50.66 (0.67)	42.18 (0.71)	51.88 (0.68)	38.15 (0.57)	26.05 (0.45)
0.920	59.31 (0.66)	50.88 (0.70)	55.88 (0.66)	39.41 (0.53)	25.86 (0.41)
0.960	67.77 (0.63)	58.95 (0.67)	60.11 (0.62)	40.60 (0.49)	25.55 (0.38)
1.000	69.47 (0.60)	60.34 (0.62)	59.50 (0.57)	39.08 (0.44)	23.81 (0.34)
1.040	61.55 (0.54)	53.05 (0.55)	51.69 (0.51)	33.50 (0.40)	19.94 (0.29)
1.080	47.18 (0.44)	40.34 (0.47)	39.08 (0.42)	25.21 (0.32)	14.73 (0.24)
1.125	30.14 (0.35)	25.48 (0.35)	24.44 (0.32)	15.83 (0.24)	9.10 (0.19)
1.175	15.84 (0.26)	13.16 (0.25)	12.26 (0.22)	8.05 (0.17)	4.56 (0.12)
1.225	7.38 (0.21)	6.05 (0.17)	5.30 (0.15)	3.54 (0.12)	2.00 (0.09)
1.275	3.13 (0.17)	2.56 (0.13)	2.09 (0.11)	1.37 (0.08)	0.78 (0.07)
1.325	1.35 (0.16)	1.03 (0.10)	0.87 (0.09)	0.46 (0.06)	0.27 (0.05)
1.375	0.78 (0.16)	0.39 (0.09)	0.46 (0.07)	0.13 (0.06)	
1.425	0.64 (0.16)	0.14 (0.08)	0.31 (0.06)	0.02 (0.05)	
1.475	0.53 (0.16)	0.05 (0.07)	0.22 (0.06)	-0.01 (0.05)	
1.525	0.34 (0.15)	0.03 (0.06)	0.13 (0.05)	-0.03 (0.04)	
1.575	0.13 (0.15)	0.03 (0.06)	0.07 (0.05)	-0.04 (0.04)	
1.640	-0.03 (0.14)	0.03 (0.05)	0.02 (0.04)	-0.04 (0.03)	
1.720	0.00 (0.15)	0.00 (0.04)	0.00 (0.03)		
1.800	0.13 (0.15)	-0.01 (0.03)	-0.00 (0.03)		
1.880	0.31 (0.15)	-0.01 (0.03)	-0.02 (0.03)		
1.960	0.87 (0.16)	0.00 (0.03)			
2.040	1.96 (0.16)	0.02 (0.03)			
2.120	3.11 (0.15)	0.04 (0.03)			
2.200	3.60 (0.15)				
2.280	3.21 (0.12)				
2.360	2.29 (0.10)				
2.450	1.26 (0.07)				
2.550	0.53 (0.05)				
2.650	0.21 (0.04)				

TABLE 3. TOTAL SECONDARY YIELDS AND AVERAGE SECONDARY ENERGIES FOR NEUTRONS AND GAMMA RAYS DUE TO NEUTRON INTERACTIONS WITH ALUMINUM. THESE RESULTS ARE FOR SECONDARY NEUTRONS WITH ENERGIES GREATER THAN 0.764 MEV AND GAMMA RAYS WITH ENERGIES GREATER THAN 0.700 MEV. UNCERTAINTIES ARE GIVEN IN PARENTHESES IN THE SAME UNITS AS THE DATA. UNCERTAINTIES IN TOTAL YIELDS DO NOT INCLUDE A 10% ERROR IN ABSOLUTE NORMALIZATION. THE ANGLE IS 127 DEGREES.

INCIDENT NEUTRON ENERGY (MEV)	ENERGY SPREAD	SECONDARY NEUTRON YIELD (NB/SR)	AVERAGE NEUTRON ENERGY (MEV)	SECONDARY PHOTON YIELD (NB/SR)	AVERAGE PHOTON ENERGY (MEV)
1.023	0.048	132.34 (1.60)	0.915 (.013)	0.27 (0.06)	1.185 (.421)
1.073	0.052	125.32 (1.47)	0.928 (.013)	3.66 (0.11)	0.860 (.044)
1.124	0.050	142.26 (1.63)	0.936 (.013)	9.66 (0.18)	0.929 (.025)
1.175	0.053	132.27 (1.46)	0.982 (.013)	15.82 (0.22)	0.938 (.018)
1.227	0.050	113.77 (1.39)	1.072 (.015)	17.60 (0.23)	0.917 (.017)
1.276	0.047	106.94 (1.41)	1.119 (.017)	13.70 (0.21)	0.966 (.021)
1.324	0.049	103.12 (1.38)	1.128 (.018)	9.05 (0.17)	0.935 (.026)
1.375	0.052	112.71 (1.30)	1.146 (.015)	16.84 (0.23)	0.898 (.017)
1.425	0.047	99.94 (1.27)	1.195 (.018)	17.39 (0.25)	0.904 (.018)
1.474	0.050	103.25 (1.17)	1.258 (.016)	17.39 (0.23)	0.929 (.017)
1.525	0.052	117.65 (1.14)	1.331 (.015)	18.27 (0.23)	0.924 (.017)
1.574	0.046	94.21 (1.13)	1.385 (.019)	24.14 (0.29)	0.928 (.015)
1.626	0.058	91.53 (0.97)	1.427 (.017)	20.06 (0.24)	0.924 (.015)
1.680	0.051	108.87 (1.05)	1.452 (.016)	24.75 (0.28)	0.944 (.015)
1.726	0.042	103.91 (1.15)	1.469 (.018)	20.28 (0.28)	0.964 (.019)
1.774	0.055	87.39 (0.96)	1.469 (.018)	15.84 (0.23)	0.958 (.019)
1.825	0.046	90.33 (1.03)	1.477 (.019)	17.47 (0.27)	0.924 (.020)
1.871	0.048	98.45 (0.99)	1.519 (.017)	20.37 (0.28)	0.944 (.018)
1.920	0.049	122.27 (1.07)	1.578 (.016)	21.86 (0.29)	0.974 (.017)
1.970	0.051	120.63 (1.05)	1.554 (.015)	21.59 (0.29)	0.962 (.017)
2.051	0.109	123.86 (0.75)	1.627 (.011)	24.33 (0.22)	0.955 (.012)
2.149	0.088	115.30 (0.86)	1.676 (.014)	22.19 (0.25)	0.949 (.015)
2.248	0.110	119.17 (0.80)	1.772 (.013)	25.53 (0.25)	0.960 (.013)
2.353	0.101	107.01 (0.81)	1.881 (.016)	23.41 (0.26)	1.142 (.017)
2.447	0.089	107.39 (0.89)	1.917 (.018)	27.31 (0.31)	1.212 (.018)
2.549	0.113	114.40 (0.84)	2.052 (.017)	32.15 (0.31)	1.307 (.017)
2.656	0.101	92.86 (0.91)	2.102 (.023)	34.83 (0.39)	1.335 (.020)
2.748	0.085	105.08 (1.20)	2.221 (.028)	37.19 (0.52)	1.278 (.024)
2.846	0.112	94.20 (1.00)	2.344 (.027)	32.60 (0.43)	1.335 (.023)
2.949	0.094	105.22 (1.10)	2.318 (.027)	43.72 (0.51)	1.475 (.023)
3.046	0.099	87.83 (0.98)	2.389 (.030)	47.06 (0.50)	1.502 (.021)
3.147	0.104	85.97 (0.96)	2.275 (.029)	59.46 (0.55)	1.462 (.018)
3.246	0.095	83.84 (1.08)	2.145 (.032)	62.60 (0.58)	1.546 (.019)
3.344	0.099	90.51 (1.07)	2.317 (.031)	64.82 (0.57)	1.663 (.019)
3.445	0.104	69.98 (0.96)	2.422 (.038)	52.28 (0.50)	1.674 (.021)
3.552	0.109	76.79 (0.93)	2.574 (.036)	56.51 (0.50)	1.765 (.021)
3.655	0.097	87.89 (1.03)	2.504 (.034)	62.99 (0.57)	1.761 (.021)
3.755	0.101	73.83 (0.98)	2.463 (.038)	68.15 (0.58)	1.755 (.020)
3.849	0.088	76.36 (1.03)	2.544 (.040)	56.75 (0.57)	1.807 (.024)
3.948	0.109	81.08 (0.98)	2.439 (.034)	63.59 (0.54)	1.812 (.021)
4.050	0.095	86.62 (1.11)	2.400 (.035)	68.92 (0.60)	1.823 (.021)
4.147	0.098	86.79 (1.09)	2.528 (.037)	65.30 (0.58)	1.795 (.022)
4.247	0.102	80.90 (1.07)	2.496 (.039)	67.20 (0.60)	1.810 (.022)
4.350	0.106	82.66 (1.08)	2.600 (.040)	71.69 (0.63)	1.809 (.021)
4.447	0.087	79.79 (1.18)	2.544 (.044)	70.54 (0.69)	1.805 (.024)
4.547	0.113	85.31 (1.00)	2.679 (.037)	72.20 (0.61)	1.857 (.021)
4.650	0.093	91.83 (1.09)	2.807 (.039)	74.15 (0.69)	1.900 (.024)
4.744	0.096	92.08 (1.03)	2.881 (.038)	73.67 (0.67)	1.883 (.023)
4.842	0.099	81.18 (0.98)	2.834 (.041)	79.61 (0.70)	1.884 (.022)
4.943	0.102	92.58 (0.96)	3.169 (.039)	78.64 (0.69)	1.911 (.023)
5.101	0.215	80.51 (0.66)	3.190 (.031)	84.48 (0.50)	1.968 (.016)
5.308	0.199	81.65 (0.70)	3.257 (.034)	84.21 (0.53)	2.048 (.018)
5.498	0.180	75.49 (0.73)	3.212 (.038)	83.50 (0.56)	2.046 (.019)
5.699	0.222	84.47 (0.72)	3.268 (.034)	86.83 (0.52)	2.133 (.018)
5.910	0.201	86.34 (0.79)	3.329 (.037)	101.67 (0.60)	2.163 (.018)
6.098	0.175	73.01 (0.78)	3.400 (.045)	100.01 (0.64)	2.226 (.020)
6.296	0.221	73.43 (0.69)	3.473 (.041)	99.05 (0.57)	2.260 (.018)
6.503	0.193	79.49 (0.79)	3.350 (.043)	107.13 (0.64)	2.326 (.020)
6.701	0.202	77.65 (0.81)	3.323 (.044)	108.87 (0.64)	2.346 (.020)
6.908	0.212	78.20 (0.81)	3.446 (.045)	114.57 (0.65)	2.400 (.019)
7.102	0.176	73.44 (0.86)	3.478 (.053)	114.75 (0.73)	2.420 (.022)
7.305	0.230	69.13 (0.74)	3.660 (.052)	111.65 (0.64)	2.486 (.021)
7.517	0.192	73.44 (0.81)	3.864 (.056)	107.71 (0.69)	2.555 (.024)
7.713	0.200	67.64 (0.77)	3.761 (.057)	107.03 (0.67)	2.590 (.023)
7.916	0.208	66.71 (0.77)	3.759 (.058)	107.84 (0.67)	2.609 (.024)
8.101	0.161	62.26 (0.88)	3.748 (.071)	112.01 (0.79)	2.641 (.027)
8.293	0.223	66.19 (0.77)	3.964 (.062)	114.37 (0.71)	2.682 (.024)
8.491	0.173	68.38 (0.89)	3.925 (.069)	122.94 (0.84)	2.731 (.027)
8.698	0.240	65.79 (0.76)	4.051 (.064)	124.91 (0.73)	2.761 (.023)
8.911	0.186	63.78 (0.86)	3.962 (.074)	118.41 (0.80)	2.814 (.028)
9.100	0.192	61.74 (0.83)	3.964 (.075)	116.67 (0.79)	2.807 (.028)
9.295	0.199	62.93 (0.82)	4.138 (.075)	114.81 (0.77)	2.862 (.028)
9.497	0.205	63.61 (0.82)	4.357 (.080)	119.38 (0.80)	2.865 (.028)
9.706	0.212	65.93 (0.84)	4.355 (.080)	123.22 (0.82)	2.899 (.029)
9.921	0.219	65.78 (0.85)	4.519 (.084)	126.93 (0.84)	2.887 (.028)
10.261	0.461	64.75 (0.61)	4.671 (.064)	127.09 (0.60)	2.918 (.020)
10.738	0.494	63.70 (0.59)	4.910 (.067)	126.55 (0.59)	2.943 (.020)
11.250	0.529	63.25 (0.60)	5.032 (.072)	127.80 (0.59)	2.995 (.020)
11.750	0.471	63.55 (0.68)	5.093 (.084)	125.54 (0.66)	2.991 (.023)
12.236	0.501	59.39 (0.67)	5.388 (.094)	121.19 (0.64)	2.984 (.023)
12.753	0.533	59.31 (0.70)	5.438 (.102)	121.76 (0.67)	2.937 (.024)
13.246	0.452	58.00 (0.79)	5.446 (.124)	119.34 (0.75)	2.926 (.027)
13.709	0.476	57.05 (0.79)	5.573 (.131)	117.19 (0.76)	2.886 (.028)
14.198	0.502	54.98 (0.79)	5.704 (.139)	113.05 (0.75)	2.792 (.028)
14.714	0.529	54.80 (0.80)	5.642 (.146)	104.44 (0.75)	2.791 (.028)
15.258	0.559	53.39 (0.84)	5.465 (.158)	104.24 (0.76)	2.738 (.030)
15.758	0.441	54.48 (0.99)	5.391 (.190)	100.11 (0.88)	2.686 (.035)
16.208	0.460	55.78 (1.03)	5.419 (.194)	95.92 (0.88)	2.665 (.036)
16.678	0.480	55.92 (1.05)	5.216 (.204)	97.23 (0.90)	2.562 (.035)
17.169	0.502	54.49 (1.11)	5.211 (.225)	95.86 (0.92)	2.537 (.036)
17.682	0.524	56.40 (1.14)	5.385 (.230)	95.90 (0.94)	2.517 (.037)
18.218	0.549	57.47 (1.18)	5.127 (.236)	94.95 (0.95)	2.471 (.037)
18.780	0.574	57.23 (1.24)	5.250 (.257)	98.70 (1.02)	2.367 (.036)
19.266	0.398	57.10 (1.52)	4.844 (.322)	101.91 (1.28)	2.349 (.044)
19.776	0.621	59.62 (1.29)	5.290 (.276)	103.24 (1.08)	2.330 (.036)

**THIS PAGE
WAS INTENTIONALLY
LEFT BLANK**

INTERNAL DISTRIBUTION

1-3. L. S. Abbott	16. F. R. Mynatt
4. R. G. Alsmiller, Jr.	17. E. M. Oblow
5. G. T. Chapman	18. R. W. Peelle
6. C. E. Clifford	19-33. F. G. Perey
7. S. N. Cramer	34-43. RSIC
8. J. K. Dickens	44. A. Zucker
9. C. Y. Fu	45. P. F. Fox (Consultant)
10. H. Goldstein (Consultant)	46. W. W. Havens, Jr. (Consultant)
11. W. E. Kinney	47. A. F. Henry (Consultant)
12. D. C. Larson	48-49. Central Research Library
13. T. A. Love	50. ORNL - Y-12 Technical Library,
Document Reference Section
14. F. C. Maienschein	51. ORNL Patent Office
15. G. L. Morgan	52-53. Laboratory Records

EXTERNAL DISTRIBUTION

- 54. H. Feshbach, Theoretical Physics, Massachusetts Institute of Technology, Cambridge, MA 02139
- 55. Norman Francis, Knolls Atomic Power Laboratory, General Electric, Schenectady, NY 12309
- 56. P. B. Hemmig, Division of Reactor Research and Development, ERDA, Washington, DC 20545
- 57. C. E. Hollandsworth, USA Nuclear Effects Laboratory, Aberdeen Proving Ground, MD 21005
- 58. Director, Reactor Division, ERDA-oro
- 59. A. B. Smith, Argonne National Laboratory, Argonne, IL 60439
- 60. Leona Stewart, Los Alamos Scientific Laboratory, Los Alamos, NM 87544
- 61. Mendel Beer, MAGI, 3 Westchester Plaza, Elmsford, NY 10523
- 62. P. G. Young, Los Alamos Scientific Laboratory, Los Alamos, NM 87544
- 63. Research and Technical Support Division, ERDA, ORO
- 64-90. Technical Information Center, Oak Ridge
- 91-224. DNA Radiation Transport Distribution