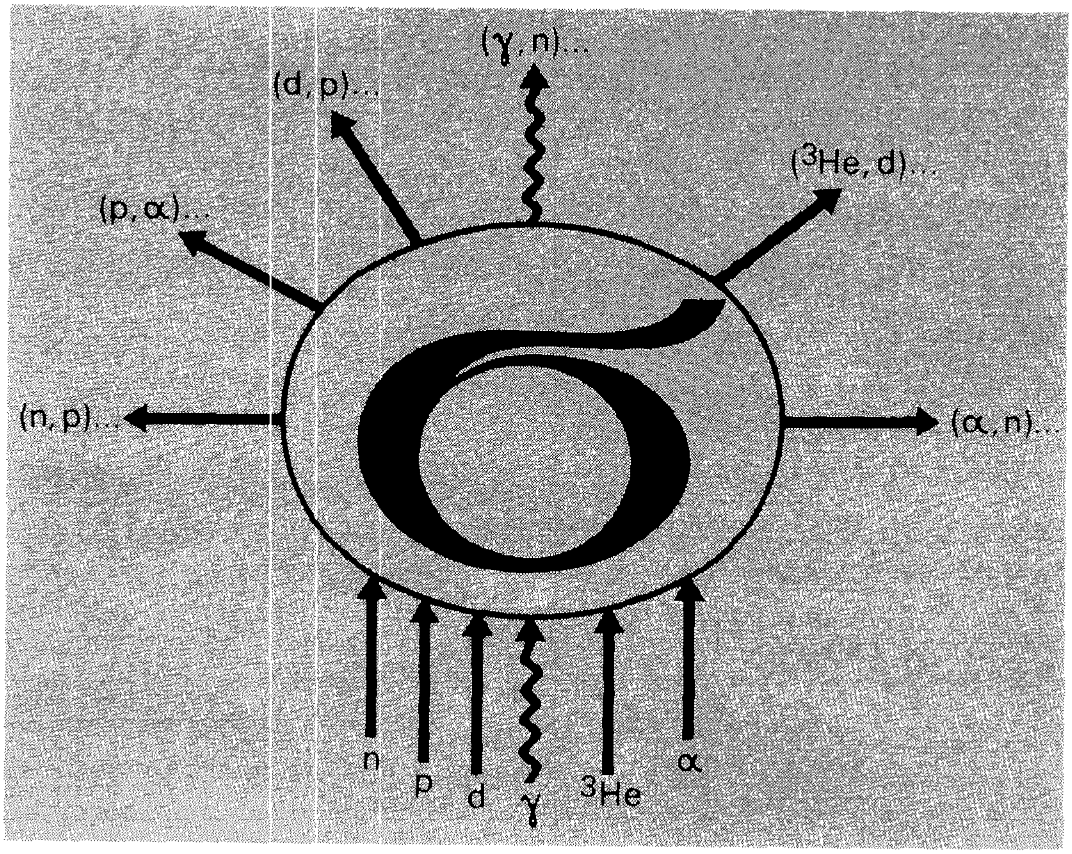

TECHNICAL REPORTS SERIES No. 156

Handbook on Nuclear Activation Cross-Sections

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1974

HANDBOOK ON NUCLEAR ACTIVATION CROSS-SECTIONS

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June 1974

TECHNICAL REPORTS SERIES No. 156

HANDBOOK ON NUCLEAR ACTIVATION CROSS-SECTIONS

Neutron, Photon and Charged-Particle
Nuclear Reaction Cross-Section Data

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1974

HANDBOOK ON NUCLEAR ACTIVATION CROSS-SECTIONS
IAEA, VIENNA, 1974
STI/DOC/10/156

FOREWORD

This Handbook contains data on cross-sections for thermal, epithermal and fast neutron induced nuclear reactions as well as for those induced by charged particles and photons. It is issued for users in various nuclear application fields, with the main emphasis on activation analysis, but also with an eye to radioisotope production and radiobiological protection. To some extent the compilations are also useful in reactor technology.

Activation analysis, which has made rapid progress during the last decade, is widely used in such spheres as medicine and biology, environmental control, industry, agriculture and forensic investigations. Thus the main part of this collection consists of cross-section data needed for these purposes.

In the early days of activation analysis the thermal neutron played the most predominant role as the bombarding particle responsible for inducing radioactivity. Today the thermal neutron is probably still the particle most used for such purposes. However, epithermal and fast neutrons are becoming increasingly important as projectiles in nuclear analytical chemistry.

Thermal and epithermal neutrons are usually produced in reactors, whereas fast neutrons are emitted from isotopic sources (e.g. ^{252}Cf-sources) or generated in 14-MeV neutron generators of the Cockcroft-Walton or neutron generators of the Van de Graaff type.

For photon activation analysis, various electron accelerators producing bremsstrahlung in heavy materials are used. In some instances a hospital betatron can be used for such studies.

Neutron and photon activation analysis is mainly used for bulk analysis inasmuch as the intensity or energy of the bombarding particles or radiations is usually not changed in any essential way when passing the sample. On the other hand, charged particles at low or intermediate energies are stopped in a metal surface. For this reason charged particles are mainly used for surface analysis, i.e. the determination of an element in a surface or of its concentration profile just below a surface. In charged particle activation analysis, accelerators of various types are used, the Van de Graaff type being perhaps the most common.

As a rule of thumb, reactions induced with photons, charged particles or 14-MeV neutrons are mainly used for the analysis of light elements, whereas thermal and epithermal neutrons are applied in the analysis of intermediate or heavier elements.

With a specific analytical problem in mind, the analytical chemist has to select the most suitable nuclear reaction for solving his problem, and a knowledge of cross-section values or excitation functions is essential. A handbook containing the various types of cross-section values is thought to be valuable for a first survey, particularly for scientists and technicians in developing countries who may not always have easy access to the desired information.

Many scientists have contributed to the preparation of this Handbook. The editors, Mr. D. Brune of Aktiebolaget Atomenergi, Studsvik, Sweden, and Mr. J.J. Schmidt of the IAEA Nuclear Data Section, Vienna, wish to express their sincere gratitude to these scientists for their valuable contributions and co-operation.

CONTENTS

2200 m/s NEUTRON ACTIVATION CROSS-SECTIONS

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ABSTRACT. 2200 m/s neutron activation cross-sections for a large number of isotopes of interest to neutron activation analysis are presented. In addition to the cross-sections, values are given for the half-lives of the activities formed and the cross-sections for activation of isomeric and ground-states, if these are both of interest.

INTRODUCTION

The following table of thermal cross-section values is based primarily on recent compilations by N. Holden [1] and D. T. Goldman et al. [2]. Only isotopes of potential interest in thermal neutron activation analysis are included, but these fall into two classes: those of intrinsic interest because they are likely to be the materials being analysed, and those whose activation is likely to be an important source of background. Of course, many elements can fall into either class.

All entries are cross-sections at a neutron energy of 0.0253 eV (neutron velocity of 2200 m/s). In most cases, the values are based on measurements of the activation cross-section, but occasionally values inferred from absorption cross-sections are used.

In many cases, Holden's values differ somewhat from those of Goldman et al., partly because of the inclusion of later data, and partly because of differing judgements as to best values of the mean and error spread of several measurements. As a general rule, when later data made the values of Goldman et al. obsolete, Holden's values were given greater weight; when differences between the two sets were due to different evaluations of the same data, those of Goldman et al. were used for the most part. This simply reflects the present author's greater familiarity with the latter. In some cases the data were re-evaluated.

The error limits should not be taken too literally in most cases. Often a set of several measured values falling far outside their individually quoted limits of error had to be reconciled, and in the spirit of Goldman et al. many of the quoted error limits simply represent a rough indication of the spread of the individual measurements. Because of this, they are often considerably larger than the uncertainties claimed by individual experimenters.

To include a complete bibliography of the original cross-section measurements would have encumbered an already lengthy table. Measurements up to about 1966 are referenced in BNL-325 [3]; references to more recent results can be found in bibliography and data compilations such as CINDA [4] and the NEA Neutron Data Compilation Centre Newsletter [5], or can be obtained from the various neutron data centres[1].

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[1] National Neutron Cross-Section Center, Brookhaven National Laboratory, Upton, L.I., N.Y. 11973, USA.
NEA Neutron Data Compilation Centre, F-91190 Gif-sur-Yvette, B.P. No 9, France.
Centr po Jadernym Dannym, Fiziko-Energeticheskij Institut, Obninsk, Kaluga oblast, USSR.
Nuclear Data Section, IAEA, 1010 Vienna, Austria.

Table I lists, in addition to the cross-sections, the half-lives of the activities formed and the cross-sections for activation of isomeric and ground-states, if these are both of interest.

Unless otherwise noted, cross-section values refer to the effective activation of the state, not its direct formation. Thus, for example, in ^{164}Dy, where the 1.25-min isomer decays to the 2.3-hour ground-state, the cross-section value for the ground-state listed is the sum of the formation cross-sections to the two levels. In a few cases, the isomeric state has other modes of decay besides the transition to the ground-state; for those the contribution to the ground-state activation cross-section is corrected by the branching ratio. The principal cases for which the ground-state activation cross-section is not given by the sum of its direct-formation cross-section plus the isomeric-state cross-section are those in which the half-life of the isomeric state is comparable to or longer than that of the ground-state, and those in which the isomeric state does not decay to the ground-state. These instances carry the notation "direct formation", if there is possible ambiguity.

Not all of the entries in the table are of equal importance, of course. However, the increasing use in neutron-activation analysis of high-resolution detectors and the increasing sophistication of sample preparation and separation techniques make it desirable to include many isotopes whose activities admittedly will be seldom seen.

No attempt has been made to list the radioactive properties of the activation products other than half-lives, since these are easily available in sources such as Lederer et al. [6].

ACKNOWLEDGEMENTS

I am greatly indebted to N. Holden and to D.T. Goldman, J.R. Stehn, and P. Aline for permission to use their compilations. They should not be blamed for any errors in the table, for which I take full responsibility.

REFERENCES TO INTRODUCTION

[1] HOLDEN, N., "Recommended values of thermal-neutron cross sections and resonance integrals for the 1972 chart of the nuclides", March 1973 version (unpublished).

[2] GOLDMAN, D.T., ALINE, P., SHER, R., STEHN, J., "2200 m/sec absorption cross sections" (unpublished).

[3] BROOKHAVEN NATIONAL LABORATORY, Neutron Cross Sections, 2nd Edn, Brookhaven National Lab. Rep. BNL-325 (1958), with Supplements 1960 and 1966.

[4] CINDA 71, An Index to the Literature on Microscopic Neutron Data, published by IAEA on behalf of the four CINDA centres, IAEA, Vienna (1971).

[5] NEA Neutron Data Compilation Centre Newsletter, NEA, Saclay.

[6] LEDERER, C.M., HOLLANDER, J.M., PERLMAN, I., Table of Isotopes, 6th Edn, Wiley, New York (1968).

TABLE I. THERMAL CROSS-SECTION VALUES

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Carbon	^{13}C	1.11	5730 years	$(0.9 \pm 0.2) \times 10^{-3}$
Nitrogen	^{14}N	99.63	5730 years (^{14}C)	($\sigma_{n,p}$ = 1.82 ± 0.03)
	^{15}N	0.37	7.2 sec	$(24 \pm 8) \times 10^{-6}$
Oxygen	^{18}O	0.204	26.8 sec	$(0.16 \pm 0.01) \times 10^{-3}$
Fluorine	^{19}F	100	11.2 sec	$(9.8 \pm 0.7) \times 10^{-3}$
Sodium	^{23}Na	100	15 hours	0.528 ± 0.005
Magnesium	^{26}Mg	11.17	9.5 min	$(38 \pm 3) \times 10^{-3}$
Aluminum	^{27}Al	100	2.3 min	0.232 ± 0.003
Silicon	^{30}Si	3.09	2.62 hours	0.105 ± 0.005
Phosphorus	^{31}P	100	14.3 days	0.190 ± 0.010
Sulfur	^{34}S	4.22	88 days	0.034 ± 0.005
	^{36}S	0.014	5.06 min	0.15 ± 0.03
Chlorine	^{37}Cl	24.47	0.7 sec $^{38}Cl^m$	$(5 \pm 3) \times 10^{-3}$
			37 min $^{38}Cl^g$	0.43 ± 0.01
Argon	^{36}Ar	0.337	34 days	6 ± 2
	^{38}Ar	0.063	269 years	0.8 ± 0.2
	^{40}Ar	99.6	1.83 hours	0.65 ± 0.03
Potassium	^{41}K	6.88	12.4 hours	1.48 ± 0.03

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Calcium	^{44}Ca	2.06	165 days	1.1 ± 0.3
	^{46}Ca	0.0033	4.53 days	0.7 ± 0.2
	^{48}Ca	0.18	8.8 minutes	1.1 ± 0.1
Scandium	^{45}Sc	100	20 sec $^{46}Sc^m$	10 ± 4
			83.8 days $^{46}Sc^g$	25 ± 2
Titanium	^{50}Ti	5.34	5.8 minutes	0.179 ± .003
Vanadium	^{51}V	99.76	3.76 minutes	4.90 ± 0.05
Chromium	^{50}Cr	4.31	27.8 days	16.0 ± 0.5
	^{54}Cr	2.38	3.5 minutes	0.38 ± 0.04
Manganese	^{55}Mn	100	2.58 hours	13.3 ± 0.1
Iron	^{54}Fe	5.82	2.6 years	2.5 ± 0.4
	^{58}Fe	0.33	45 days	1.14 ± 0.05
Cobalt	^{59}Co	100	10.5 min $^{60}Co^m$	19.9 ± 0.91
			5.26 yrs $^{60}Co^g$	37.5 ± 0.2
	($^{60}Co^m$	10.5 min	99 minutes	58 ± 8)
	($^{60}Co^g$	5.26 yrs	99 minutes	2.0 ± 0.2)
Nickel	^{64}Ni	1.16	2.56 hours	1.50 ± 0.05
Copper	^{63}Cu	69.09	12.8 hours	4.4 ± 0.2
	^{65}Cu	30.91	5.1 minutes	2.20 ± 0.05

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Zinc	^{64}Zn	48.89	245 days	0.82 ± 0.01
	^{68}Zn	18.57	13.8 hrs $^{69}Zn^m$	0.07 ± 0.01
			57 min $^{69}Zn^g$	1.0 ± 0.2 (dir. formation)
	^{70}Zn	0.62	3.97 hrs $^{71}Zn^m$	$(9 \pm 1) \times 10^{-3}$
			2.4 min $^{71}Zn^g$	$(90 \pm 10) \times 10^{-3}$ (dir. form.)
Gallium	^{69}Ga	60.4	21.1 minutes	1.7 ± 0.2
	^{71}Ga	39.6	36 μsec $^{72}Ga^m$	0.15 ± 0.05
			14 hrs $^{72}Ga^g$	4.7 ± 0.3
Germanium	^{70}Ge	20.52	20 msec $^{71}Ge^m$	0.28 ± 0.07
			11.4 days $^{71}Ge^g$	3.5 ± 0.13
	^{74}Ge	36.54	48 sec $^{75}Ge^m$	0.16 ± 0.03
			82 min $^{75}Ge^g$	0.52 ± 0.06
	^{76}Ge	7.76	54 sec $^{77}Ge^m$	0.09 ± 0.02
			11 hrs $^{77}Ge^g$	0.07 ± 0.02 (dir. formation)
Arsenic	^{75}As	100	26.5 hours	4.4 ± 0.2
Selenium	^{74}Se	0.87	120.4 days	55 ± 5
	^{76}Se	9.02	17.5 sec $^{77}Se^m$	21 ± 2
	^{78}Se	23.52	3.9 min $^{79}Se^m$	0.33 ± 0.04
	^{80}Se	49.82	57 min $^{81}Se^m$	0.08 ± 0.01
			18.6 min $^{81}Se^g$	0.54 ± 0.04 (dir. formation)
	^{82}Se	9.19	70 sec $^{83}Se^m$	$(6 \pm 1) \times 10^{-3}$
			25 min $^{83}Se^g$	$(39 \pm 3) \times 10^{-3}$ (dir. form.)

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Bromine	^{79}Br	50.54	4.38 hrs $^{80}Br^m$	2.6 ± 0.2
			17.6 min $^{80}Br^g$	8.4 ± 0.3 (direct formation)
	^{81}Br	49.46	6.1 min $^{82}Br^m$	2.7 ± 0.3
			35.34 hrs $^{82}Br^g$	3.0 ± 0.3
Krypton	^{78}Kr	0.35	55 sec $^{78}Kr^m$	0.2 ± 0.05
			34.9 hrs $^{78}Kr^g$	4.7 ± 0.7
	^{80}Kr	2.27	13 sec $^{81}Kr^m$	4.6 ± 0.7
	^{82}Kr	11.56	1.86 hrs $^{83}Kr^m$	20 ± 4
	^{84}Kr	56.90	4.4 hrs $^{85}Kr^m$	0.10 ± 0.03
			10.76 yrs $^{85}Kr^g$	(42 ± 4) x 10^{-3} (dir. form.)
	^{86}Kr	17.37	76 minutes	(60 ± 20) x 10^{-3}
Rubidium	^{85}Rb	72.15	1.05 min $^{86}Rb^m$	(50 ± 5) x 10^{-3}
			18.65 days $^{86}Rb^g$	0.45 ± 0.02
	^{87}Rb (5 x 10^{10} yrs)	27.85	17.8 minutes	0.12 ± 0.03
Strontium	^{84}Sr	0.56	70 min $^{85}Sr^m$	0.57 ± 0.05
			64 days $^{85}Sr^g$	0.3 ± 0.1 (direct formation)
	^{86}Sr	9.86	2.83 hrs $^{87}Sr^m$	0.8 ± 0.1
	^{88}Sr	82.56	52 days	(5 ± 1) x 10^{-3}
Yttrium	^{89}Y	100	3.1 hrs $^{90}Y^m$	(1.0 ± 0.2) x 10^{-3}
			64 hours $^{90}Y^g$	1.2 ± 0.1
Zirconium	^{94}Zr	17.40	65 days	(75 ± 8) x 10^{-3}
	^{96}Zr	2.80	17 hours	0.05 ± 0.01

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Niobium	^{93}Nb	100	6.3 min $^{94}Nb^m$	0.15 ± 0.10
Molybdenum	^{98}Mo	23.78	67 hours	0.14 ± 0.02
	^{100}Mo	9.63	14.6 minutes	0.20 ± 0.05
Ruthenium	^{96}Ru	5.51	2.9 days	0.21 ± 0.02
	^{102}Ru	31.61	39.6 days	1.3 ± 0.1
	^{104}Ru	18.58	4.44 hours	0.47 ± 0.20
Rhodium	^{103}Rh	100	4.41 min $^{104}Rh^m$	11 ± 1
			43 sec $^{104}Rh^g$	139 ± 5 (direct formation)
Palladium	^{106}Pd	27.33	22 sec $^{107}Pd^m$	$(13 \pm 2) \times 10^{-3}$
	^{108}Pd	26.71	4.7 min $^{109}Pd^m$	0.17 ± 0.02
			13.47hrs $^{109}Pd^g$	12 ± 2
	^{110}Pd	11.81	5.5 hrs $^{111}Pd^m$	$(20 \pm 15) \times 10^{-3}$
			22 min $^{111}Pd^g$	0.36 ± 0.05 (dir. form.)
Silver	^{107}Ag	51.82	2.42 min $^{108}Ag^g$	37 ± 2
	^{109}Ag	48.18	253 days $^{110}Ag^m$	4.7 ± 0.4
			24.2 sec $^{110}Ag^g$	89 ± 4
Cadmium	^{106}Cd	1.22	6.5 hours	1.0 ± 0.5
	^{114}Cd	28.86	43 days $^{115}Cd^m$	$(36 \pm 7) \times 10^{-3}$
			53.5 hrs $^{115}Cd^g$	0.300 ± 0.015
	^{116}Cd	7.58	3.4 hrs $^{117}Cd^m$	$(27 \pm 5) \times 10^{-3}$
			2.4 hrs $^{117}Cd^g$	$(50 \pm 8) \times 10^{-3}$

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Indium	^{113}In	4.28	50 day $^{114}In^m$	7.8 ± 2.0
			72 sec $^{114}In^g$	3.0 ± 1.0
	^{115}In	95.72	2.2 sec $^{116}In^m$	91 ± 10
			54 min $^{116}In^m$	161 ± 5
			14 sec $^{116}In^g$	42 ± 4
Tin	^{112}Sn	0.96	20 min $^{113}Sn^m$	0.35 ± 0.08
			115 day $^{113}Sn^g$	0.71 ± 0.10
	^{116}Sn	14.30	14 day $^{117}Sn^m$	(6 ± 2) x 10^{-3}
	^{118}Sn	24.03	250 day $^{119}Sn^m$	(8 ± 2) x 10^{-3}
	^{120}Sn	32.85	27 hours	0.14 ± 0.03
	^{122}Sn	4.72	40 min $^{123}Sn^m$	0.15 ± 0.02
	^{124}Sn	5.94	9.7 min $^{125}Sn^m$	0.14 ± 0.02
			9.4 day $^{125}Sn^g$	4 ± 2
Antimony	^{121}Sb	57.25	4.2 min $^{122}Sb^m$	(55 ± 10) x 10^{-3}
			2.8 days $^{122}Sb^g$	6.2 ± 0.2
	^{123}Sb	42.75	21 min $^{124}Sb^{m_2}$	(15 ± 4) x 10^{-3}
			93 sec $^{124}Sb^{m_1}$	(30 ± 8) x 10^{-3}
			60 day $^{124}Sb^g$	4.0 ± 0.2
Tellurium	^{120}Te	0.089	154 day $^{121}Te^m$	0.34 ± 0.06
			17 day $^{121}Te^g$	2.0 ± 0.3
	^{122}Te	2.46	117 day $^{123}Te^m$	1.1 ± 0.5
	^{124}Te	4.61	58 day $^{125}Te^m$	(40 ± 25) x 10^{-3}
	^{126}Te	18.71	109 day $^{127}Te^m$	0.125 ± 0.023
			9.4 hour $^{127}Te^g$	0.9 ± 0.15
	^{128}Te	31.79	34 day $^{129}Te^m$	(15 ± 2) x 10^{-3}
			69 min $^{129}Te^g$	0.155 ± 0.040

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Tellurium (cont.)	^{130}Te	34.48	30 hour $^{131}Te^m$	0.02 ± 0.01
			25 min $^{131}Te^g$	0.2 ± 0.1
Iodine	^{127}I	100	25 minutes	6.2 ± 0.2
Xenon	^{124}Xe	0.096	17 hours	100 ± 20
	^{128}Xe	1.92	8 day $^{129}Xe^m$	0.43 ± 0.10
	^{130}Xe	4.08	11.8 day $^{131}Xe^m$	0.34 ± 0.08
	^{132}Xe	26.89	2.26 day $^{133}Xe^m$	0.53 ± 0.10
			5.27 day $^{133}Xe^g$	0.05 ± 0.02 (dir. form.)
	^{134}Xe	10.44	9.2 hours	0.23 ± 0.02
	^{136}Xe	8.87	3.9 minutes	0.16 ± 0.05
Cesium	^{133}Cs	100	2.9 hour $^{134}Cs^m$	2.6 ± 0.2
			2.05 year $^{134}Cs^g$	30.0 ± 1.5
Barium	^{130}Ba	0.101	15 min $^{131}Ba^m$	2.5 ± 0.3
			12 day $^{131}Ba^g$	11 ± 3
	^{132}Ba	0.097	7.2 year $^{133}Ba^g$	8.5 ± 1.0
	^{134}Ba	2.42	29 hour $^{135}Ba^m$	0.16 ± 0.02
	^{136}Ba	7.81	2.55 min $^{137}Ba^m$	$(10 \pm 1) \times 10^{-3}$
	^{138}Ba	71.66	82.9 minutes	0.35 ± 0.15
Lanthanum	^{139}La	99.911	40.2 hours	9.0 ± 0.3
Cerium	^{136}Ce	0.193	34.4 hour $^{137}Ce^m$	0.95 ± 0.25
			9.0 hour $^{137}Ce^g$	6.3 ± 1.5 (dir. formation)
	^{138}Ce	0.250	55 sec $^{139}Ce^m$	$(15 \pm 5) \times 10^{-3}$
			140 day $^{139}Ce^g$	1.1 ± 0.3

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Cerium (cont.)	^{140}Ce	88.48	33 days	0.58 ± 0.06
	^{142}Ce	11.07	33.7 hours	1.1 ± 0.3
Praseodymium	^{141}Pr	100	14.6 min $^{142}Pr^m$	3.9 ± 0.5
			19.2 hour $^{142}Pr^g$	11.5 ± 1.0
Neodymium	^{146}Nd	17.22	11.1 days	1.4 ± 0.2
	^{148}Nd	5.73	1.8 hours	2.5 ± 0.2
	^{150}Nd	5.62	12 minutes	1.3 ± 0.3
Samarium	^{144}Sm	3.09	340 days	0.7 ± 0.3
	^{150}Sm	7.44	87 years	102 ± 5
	^{152}Sm	26.72	47 hours	210 ± 10
	^{154}Sm	22.71	23 minutes	5.5 ± 1.1
Europium	^{151}Eu	47.82	96 min $^{152}Eu^{m_2}$	3.8 ± 1.9
			9 hour $^{152}Eu^{m_1}$	2800 ± 300
			12 year $^{152}Eu^g$	5300 ± 300
	^{153}Eu	52.18	16 years	400 ± 100
Gadolinium	^{152}Gd	0.20	242 days	1100 ± 100
	^{158}Gd	24.87	18 hours	3.5 ± 1.0
	^{160}Gd	21.90	3.7 minutes	0.77 ± 0.04
Terbium	^{159}Tb	100	72.1 days	25 ± 5
Dysprosium	^{158}Dy	0.090	144 days	96 ± 20
	^{164}Dy	28.18	1.26 min $^{165}Dy^m$	2100 ± 400
			139 min $^{165}Dy^g$	2600 ± 200
Holmium	^{165}Ho	100	26.9 hr $^{166}Ho^g$	61.5 ± 2.0

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Erbium	^{162}Er	0.136	75 minutes	160 ± 30
	^{164}Er	1.56	10.3 hours	13 ± 5
	^{168}Er	27.07	9.4 days	1.9 ± 0.2
	^{170}Er	14.88	7.52 hours	6 ± 1
Thulium	^{169}Tm	100	130 days	106 ± 5
Ytterbium	^{168}Yb	0.135	32 days	3200 ± 400
	^{174}Yb	31.84	101 hr $^{175}Yb^{g}$	65 ± 5
	^{176}Yb	12.73	1.9 hr $^{177}Yb^{g}$	5.5 ± 1.0
Lutetium	^{175}Lu	97.41	3.69 hr $^{176}Lu^{m}$	18 ± 3
	^{176}Lu	2.59	155 day $^{177}Lu^{m}$	7 ± 2
			6.7 day $^{177}Lu^{g}$	2050 ± 50
Hafnium	^{174}Hf	0.18	70 days	390 ± 55
	^{177}Hf	18.50	4.3 sec $^{178}Hf^{m}$	1.1 ± 0.1
	^{178}Hf	27.14	18.6 sec $^{179}Hf^{m}$	52 ± 6
	^{179}Hf	13.75	5.5 hour $^{180}Hf^{m}$	0.34 ± 0.03
	^{180}Hf	35.24	42.3 days	12.6 ± 0.7
Tantalum	^{181}Ta	100	16.5 min $^{182}Ta^{m}$	$(10 \pm 2) \times 10^{-3}$
			115 day $^{182}Ta^{g}$	22 ± 1
Tungsten	^{184}W	30.64	1.6 min $^{185}W^{m}$	$(2.4 \pm 0.4) \times 10^{-3}$
			75 day $^{185}W^{g}$	1.8 ± 0.2
	^{186}W	38.41	23.9 hours	37 ± 2

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Rhenium	^{185}Re	37.07	90 hours	110 ± 5
	^{187}Re	62.93	18.7 min $^{188}Re^m$	2.0 ± 1.0
			16.7 hour $^{188}Re^g$	75 ± 4
Osmium	^{184}Os	0.02	94 days	3000 ± 600
	^{189}Os	16.1	9.9 min $^{190}Os^m$	(0.26 ± 0.03) x 10^{-3}
	^{190}Os	26.4	13 hour $^{191}Os^m$	12 ± 6
			15 day $^{191}Os^g$	16 ± 6
	^{192}Os	41.0	31 hours	1.6 ± 0.4
Iridium	^{191}Ir	37.3	75 year $^{192}Ir^{m_2}$	0.4 ± 0.2
			1.4 min $^{192}Ir^{m_1}$	610 ± 60
			74 day $^{192}Ir^g$	925 ± 50
	^{193}Ir	62.7	17.4 hours	110 ± 15
Platinum	^{192}Pt	0.78	4.3 day $^{193}Pt^m$	2 ± 1
	^{194}Pt	32.9	4.1 day $^{195}Pt^m$	(87 ± 13) x 10^{-3}
	^{196}Pt	25.3	80 min $^{197}Pt^m$	(60 ± 20) x 10^{-3}
			18 hour $^{197}Pt^g$	0.8 ± 0.1
	^{198}Pt	7.21	30 minutes	3.7 ± 0.2
Gold	^{197}Au	100	2.7 days	98.8 ± 0.3
Mercury	^{196}Hg	0.146	24 hour $^{197}Hg^m$	120 ± 15
			65 hour $^{197}Hg^g$	3000 ± 100 (dir. form.)
	^{198}Hg	10.02	43 min $^{199}Hg^m$	0.02 ± 0.01
	^{202}Hg	29.80	46.9 days	4.9 ± 0.2
	^{204}Hg	6.85	5.5 minutes	0.43 ± 0.10

TABLE I (cont.)

Element	Isotope	Abundance (Percent)	Product Half-Life	$\sigma_{n,\gamma}$ (barns)
Thallium	^{203}Tl	29.50	3.8 years	10 ± 1
	^{205}Tl	70.50	4.19 minutes	0.5 ± 0.2
Lead	^{208}Pb	52.3	3.30 hours	$(20 \pm 10) \times 10^{-3}$
Bismuth	^{209}Bi	100	5.0 days	$(19 \pm 2) \times 10^{-3}$
Thorium	^{232}Th	100	22.2 minutes	7.4 ± 0.1
Uranium	^{235}U	0.72		(σ_f = 580 ± 2)
	^{238}U	99.27	23.5 minutes	2.720 ± 0.025
Plutonium	^{239}Pu			(σ_f = 742 ± 3)

INFINITE-DILUTION RESONANCE INTEGRALS

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ABSTRACT. A compilation is given of infinite-dilution resonance integrals (1/v contribution included). Most results have been obtained from experiments, although in some cases evaluated data have also been included. The resonance-integral values have been normalized to conform to various standards, mainly those from ^{197}Au and ^{59}Co.

INTRODUCTION

The present compilation of values of infinite-dilution resonance integrals is based on two sources: (1) a print-out of resonance-integral references from the NEA Neutron Data Compilation Centre, and (2) a listing of IAEA references. For most nuclei new results have been added to those presented earlier by Drake [1]. References to some older papers have not been included, however, if newer and more precise data were available. Generally, progress reports or laboratory reports have not been considered, unless they were presented by Drake or as references in journals. Some earlier resonance-integral values given in journals have also been omitted if they were superseded by more recent data in laboratory reports. If these were not of official character, however, such information has not been used in the present compilation.

Readers interested in a full coverage are, of course, referred to CINDA 73 and its supplement [2].

Presentation of data in the table

The compilation is presented in the form of a table, which is arranged as follows:

Column 1 (Isotope): The relevant target nucleus is presented in a standard manner, such as ^{52}Cr, which stands for the element chromium of mass 52. If the mass number is not given, the notation stands for natural chromium. m and g attached to an element symbol indicate a metastable state and the ground-state of the nucleus, respectively. As far as a metastable state is concerned it is further specified in the last column (Comments) if necessary.

Column 2 (Ref.): The resonance integrals are taken from bibliographical references, a list of which follows the table.

Column 3 (Symbol): Symbol refers to the resonance integral quantity, the value of which is given in column 4. The following notations have been used:

- I = Reduced resonance integral, i. e. with the 1/v component subtracted, taken over the whole epi-Maxwellian spectrum
- RI = Resonance integral above the cadmium cutoff, i. e. normally above 0.5 eV.

Column 4 (Value): Here are given the values of I or RI, depending on the notation in column 3, expressed in units of barns.

Column 5 (Method): The following notations are used to indicate the method for obtaining the resonance integral:

act	= activation, with or without the cadmium method, absolute activation, or cadmium ratio relative to thermal activation
abs	= absorption
react	= from reactivity measurements
pile osc	= comparison of pile-oscillator reactivity to a standard
mass spec	= comparison of irradiated and non-irradiated material using the mass-spectrometer method
calc	= calculated from measured capture cross-sections
t of f	= from time-of-flight measurements using a fast chopper
rec	= recommended in the reference
eval	= evaluated in the reference

Column 6 (Comments): As the standards for the resonance integrals may vary from one experiment to another, most of them are presented. This is done in a way similar to that used by Drake [1], i.e. Au (1558) means that in the particular experiment presented in the reference the standard for RI was gold with the value of 1558 barns (see also below). If the RI or I values in the literature are not given in a direct form, as presented in column 4, but for example as the ratio of RI/σ_0, this is mentioned here. For simplicity, σ_0 stands for the absorption cross-section at the energy of 0.0253 eV. The RI (or I) value given in column 4 is then the one obtained by multiplying the RI/σ_0 (or I/σ_0) ratio by the relevant cross-section value found in Sher's article [3] in this Handbook. In a few cases the results of the experiments are expressed as Westcott S_0 values [4], i.e. $S_0 = 2/\sqrt{\pi} \cdot I/\sigma_0$, where I is the reduced resonance integral and σ_0 is the absorption cross-section at the energy of 0.0253 eV. The RI and I values are also obtained here by using the pertinent value of σ_0 given by Sher [3].

Standards used in the table

Unless otherwise stated in column 6, the resonance-integral values are given so as to conform to the conventions used by Drake [1], namely:

(1) The resonance integral is defined by

$$RI = \int_{E_c}^{\infty} \sigma(E) \frac{dE}{E}$$

(2) The cadmium cutoff energy, E_c, is set at 0.5 eV.

(3) The 1/v contribution is taken from Macklin and Pomerance [5] as $0.44\ \sigma_0$.

(4) Normalization standards for the resonance integrals of ^{197}Au and ^{59}Co are respectively:

$$RI\ (^{197}Au) = 1550\ b$$

$$RI\ (^{59}Co) = 75.0\ b$$

The corresponding 2200-m/s cross-sections have been chosen from Sher [3] as:

$$\sigma_0\ (^{197}Au) = 98.8\ b$$

$$\sigma_0\ (^{59}Co) = 37.5\ b$$

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REFERENCES TO INTRODUCTION

[1] DRAKE, M.K., Nucleonics 24 8 (1966) 108.

[2] CINDA 73 and SUPPLEMENT, An Index to the Literature on Microscopic Neutron Data, IAEA, Vienna (1973).

[3] SHER, R., "2200 metre/sec neutron activation cross-sections", this Handbook.

[4] WESTCOTT, C.H., WALKER, W.H., ALEXANDER, T.K., "Effective cross sections and cadmium ratios for the neutron spectra of thermal reactors", 2nd Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1958) 16, UN, New York (1958) 70.

[5] MACKLIN, R.L., POMERANCE, H.S., "Resonance capture integrals", 1st Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1955) 5, UN, New York (1956) 96.

TABLE OF INFINITE-DILUTION RESONANCE INTEGRALS

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Li	1	RI	28	pile osc	Au (1558)
	2	RI	32.2	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E
B	2	RI	280 ± 40	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E
^{14}N	2	RI	4.8 ± 2.4	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E
^{18}O	3	RI	$(8.5 \pm 0.4) \times 10^{-4}$	calc	Calculated from measured cross-section relative to σ_o (^{23}Na)
^{19}F	2	RI	2.3 ± 0.5	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E
	4	RI	0.041 ± 0.001	act	Au (1551). RI/σ_o measured
		RI	0.023 ± 0.005	act	Resonance parameters 2.7 to 1 500 keV
^{22}Na	5	RI	203 000 ± 27 000	act	Co (69.9). Cd thickness coefficient 2.293
^{23}Na	1	RI	0.251	pile osc	Au (1588)
	4	RI	0.37 ± 0.01	act	Au (1551). RI/σ_o measured
	6	RI	0.291 ± 0.012	act	Au (1550)
	7, 11	I	0.07 ± 0.01	act	Au (1490). RI = 0.312
	8	I	0.07 ± 0.01	act	Au (1490). RI = 0.311
	9	RI	0.514	act	Au (1607)
	10	I	0.080 ± 0.012	act	Au (1514). RI = 0.317

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{23}Na (cont.)	40	RI	0.32 ± 0.03	act	Au (1551). E_c = 0.2 eV
RECOMMENDED VALUE RI = 0.31 FOR ^{23}Na					
Mg	1	RI	0.92	pile osc	Au (1558)
	12	I	0.045 ± 0.020	pile osc	Au (1513). RI = 0.07
^{26}Mg	4	RI	0.036 ± 0.002	act	Au (1551). RI/σ_o measured
	10	I	0.008 ± 0.012	pile osc	Au (1513). RI = 0.025
RECOMMENDED VALUE RI = 0.030 FOR ^{26}Mg					
^{27}Al	1	RI	0.19	pile osc	Au (1558)
	1	RI	0.17	act	Au (1558)
	12	I	<0.08	pile osc	Au (1513)
	4	RI	0.25	act	Au (1551). RI/σ_o measured
	10	I	0.066 ± 0.009	act	Au (1514). RI = 0.17
	13	RI	0.159	act	Cd-ratio and σ_o used to calculate RI
RECOMMENDED VALUE RI = 0.17					
Si	1	RI	0.58	pile osc	Au (1558)
	4, 7	RI	0.69	act	Au (1551). RI/σ_o measured
RECOMMENDED VALUE RI = 0.6					
^{31}P	1	RI	<2	pile osc	Au (1558)
	1	RI	0.092	act	Au (1558)
S	1	RI	0.64	pile osc	Au (1558)
Cl	1	RI	12.1	pile osc	Au (1558)
	2	RI	12.8 ± 1.7	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Cl (cont.)	14	RI	14.0 ± 0.7	calc	Calculated from measured capture cross-section
^{35}Cl	15	RI	<20	act	Co (69.9)
^{37}Cl	4	RI	0.213 ± 0.009	act	Au (1551). RI/σ_o measured
	79	I	0.35 ± 0.10	act	Au (1510). RI = 0.37
	10	I	0.12 ± 0.06	act	Au (1514). RI = 0.31
RECOMMENDED VALUES: RI = 0.17 FOR ^{37}Cl AND 0.12 FOR Cl					
^{40}Ar	16	RI	0.42	act	Au (1534)
K	1	RI	1.13	pile osc	Au (1558)
	2	RI	3.5 ± 1.1	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
^{41}K	4	RI	1.37 ± 0.06	act	Au (1551). RI/σ_o measured
	17	RI	1.35 ± 0.06	calc	
	18	RI	1.09	act	E_c = 0.68 eV σ_o = 1.2 ± 0.1
	10	I	0.77 ± 0.15	act	Au (1514). RI = 1.40
RECOMMENDED VALUE RI = 1.28 FOR ^{41}K					
Ca	1	RI	1.87	pile osc	Au (1558)
^{44}Ca	19	RI	0.56 ± 0.01	act	Co (69.9)
^{46}Ca	6	RI	0.32 ± 0.12	act	Au (1550)
^{48}Ca	4	RI	0.90 ± 0.01	act	Au (1551). RI/σ_o measured

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{45}Sc	1	RI	10.2	act	Au (1558). Cd ratio relative to thermal activation
	4	RI	13 ± 1	act	Au (1551). RI/σ_o measured
	6	RI	10.7 ± 0.9	act	Au (1550)
RECOMMENDED VALUE RI = 11					
Ti	1	RI	3.2	pile osc	Au (1558)
	2	RI	3.8 ± 0.9	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
^{50}Ti	4	RI	5.5 ± 0.4	act	Au (1551). RI/σ_o measured
	10	I	0.038 ± 0.011	act	Au (1514). RI = 0.12
^{51}V	2	RI	3.3 ± 0.8	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	12	I	<1.6	pile osc	Au (1513). RI < 2.1
	1	RI	2.15	act	Au (1558)
	4	RI	3.0 ± 0.1	act	Au (1551). RI/σ_o measured
	50	RI	2.45 ± 0.03	act	Neutron energy range 1 - 50 000 eV
	20	I	0.36 ± 0.10	act	E_c = 0.68 eV. RI = 2.52
	10, 7	I	0.48 ± 0.09	act	Au (1514). RI = 2.64
	23	RI	4.10 ± 0.40	act	
	18	RI	2.62	act	E_c = 0.68 eV σ_o = 4.5 ± 0.5
RECOMMENDED VALUE RI = 2.7					

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Cr	1	RI	2.04	pile osc	Au (1558)
	2	RI	2.6 ± 1.1	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E.
	21	RI	1.5 ± 0.1	calc	
	23	RI	1.58 ± 0.16		Calculated from data from pure isotopes
^{50}Cr	21	RI	7.4 ± 0.4	calc	
	22	RI	10.4 ± 0.4	act	Co (69.9)
	4	RI	7.8 ± 0.4	act	Au (1551). RI/σ_o measured
	23	RI	8.58 ± 0.86	act	
^{52}Cr	21	RI	0.43 ± 0.04	calc	
	23	RI	0.22 ± 0.03	act	
^{53}Cr	21	RI	8.4 ± 0.7	calc	
	23	RI	10.75 ± 1.00	act	
^{54}Cr	23	RI	0.03 ± 0.01	act	

RECOMMENDED VALUES RI = 2.0 FOR Cr
RI = 8.5 FOR ^{50}Cr

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{55}Mn	24	RI	14	abs	Au (1558)
	25	I	10.3	pile osc	Au (1540). RI = 16
	1	RI	10.7	pile osc	Au (1558)
	2	RI	11.7 ± 1.5	react	Li (32.2)
	12	I	4.5 ± 2.5	pile osc	Au (1513). RI = 10.5

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{55}Mn (cont.)	4	RI	13.8 ± 0.8	act	Au (1551). RI/σ_o measured
	74	I	7.8	abs	Au (1525). RI = 13.7
	28, 7	RI	14.2		E_c = 0.55 eV
	26	RI	15.0 ± 1.4	act	
	8	RI	14.1	act	Au (1490)
	27	RI	14.6	act	Au (1500)
	147	RI	18.1 ± 1.2	act	Au (1530)
	13	RI	15.6	act	Cd-ratio and σ_o used to calculate RI
	9	RI	17.6	act	Au (1607)
	29	RI	13.9 ± 0.7	act	Au
	40	RI	12.8 ± 1.1	act	Au (1551) E_c = 0.2 eV
	18	RI	13.4 ± 0.5	act	E_c = 0.68 eV
	148	I	5.7 ± 1.7		RI = 11.6. Mn bath method

RECOMMENDED VALUE RI = 14

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Fe	1	RI	2.17	pile osc	Au (1558)
	2	RI	2.3 ± 0.4	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E
	12	RI	1.86	pile osc	Au (1513)
	25	I	1.0	pile osc	Au (1540). RI = 2.14
^{58}Fe	4, 7	RI	1.7 ± 0.1	act	Au (1551). RI/σ_o measured
	6	RI	1.18 ± 0.07	act	Au (1550). σ_o = 1.23

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{58}Fe (cont.)	30	I	0.58 ± 0.16	act	Au (1490). RI = 1.15
RECOMMENDED VALUE RI = 1.2 FOR ^{58}Fe					
^{58}Co	31	RI	2.5×10^5	act	Co (75). Measured 9.0 h isomer only
	150	RI	$(5.5 \pm 2.2) \times 10^5$	act	9.1 h isomer
	149	I	$(7.6 \pm 1.6) \times 10^5$	act	τ = 13.3 h for the decay curve ($T_{1/2}$ = 9.4 h)
^{59}Co	4	RI	76.1	act	Au (1551). RI/σ_o measured
	6	RI	77 ± 4	act	Au (1550)
	7	RI	70 ± 6	rec	
	67	I	50 ± 5	pile osc	Au (1540). RI = 66.7
	24	RI	74.6	abs	Au (1558)
	32	RI	72.1	act	Au (1535)
	33	RI	73.2	act	Au (1565)
RECOMMENDED VALUE RI = 75.0 FOR ^{59}Co					
Ni	1	RI	4.03	pile osc	Au (1558)
	2	RI	3.2 ± 0.5	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	25	I	1.0	pile osc	Au (1540). RI = 1.04
^{60}Ni	23	RI	2.10 ± 0.21	act	
^{62}Ni	19	RI	9.6 ± 3.5	act	Co (69.9)
^{64}Ni	4	RI	0.77 ± 0.03	act	Au (1551). RI/σ_o measured

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{64}Ni (cont.)	10, 7	I	0.44 ± 0.14	act	Au (1514). RI = 1.1
RECOMMENDED VALUE RI = 0.9 FOR ^{64}Ni					
Cu	1	RI	4.15	pile osc	Au (1558)
	2	RI	3.7 ± 0.8	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	25	I	2.2	pile osc	Au (1540). RI = 3.85
	12	I	1.2 ± 0.5	pile osc	Au (1510). RI = 3.07
	35	I	2.6 ± 0.3	calc	RI = 4.31
	112	RI	3.3 ± 0.3	react	B std
	1	RI	3.82	act	Au (1558)
^{63}Cu	1	RI	4.68	act	Au (1558)
	8	I	3.09 ± 0.15	act	Au (1490). RI = 5.12
	11	I	3.17 ± 0.18	act	Au (1490). RI = 5.42
	4	RI	5.7 ± 0.3	act	Au (1551). RI/σ_o measured
	10, 7	I	2.5 ± 0.2	act	Au (1514). RI = 4.4
	40	RI	5.6 ± 0.5	act	Au (1551). E_c = 0.2 eV
	151	RI	4.2	act	Au (1555)
^{65}Cu	1	RI	2.42	act	Au (1558)
	8	I	1.38 ± 0.40	act	Au (1490). RI = 2.64
	11	I	1.39 ± 0.22	act	Au (1490). RI = 2.63
	4	RI	2.6 ± 0.2	act	Au (1551). RI/σ_o measured
	10	I	1.17 ± 0.12	act	Au (1514). RI = 2.2

Isotope	Ref.	Symbol	Value (b)	Method	Comments
RECOMMENDED VALUES RI = 3.8 FOR Cu RI = 5.0 FOR ^{63}Cu RI = 2.5 FOR ^{65}Cu					
Zn	1	RI	2	pile osc	Au (1558)
	2	RI	3.4 ± 0.8	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E
	36	I	1.6 ± 0.2	pile osc	Au (1510). RI = 2.2
^{64}Zn	4	RI	1.8 ± 0.1	act	Au (1551). RI/σ_o measured
	6	RI	1.43 ± 0.10	act	Au (1550)
	30	I	0.67 ± 0.14	act	Au (1490). RI = 0.91
	37	I	1.50	act	Measured S_o = 2.06 ± 0.03. S_o (Au) = 17.7. RI = 1.8
	42	RI	1.34 ± 0.06	act	Co (37.5)
$^{68}Zn^m$	4	RI	0.22 ± 0.02	act	Au (1551). RI/σ_o measured
	6	RI	0.25 ± 0.03	act	Au (1550)
	30	I	0.17 ± 0.03	act	Au (1490). RI = 0.24
$^{68}Zn^g$	37	I	3.30	act	Measured S_o = 3.72 ± 0.14 S_o (Au) = 17.7. RI = 3.74
^{72}Zn	38	RI	0.07	eval	
RECOMMENDED VALUES RI = 2.8 FOR Zn RI = 1.6 FOR ^{64}Zn RI = 0.24 FOR $^{68}Zn^m$					
Ga	2	RI	11.7 ± 2.7	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E

Isotope	Ref.	Symbol	Value (b)			Method	Comments
^{69}Ga	1	RI	12.3			act	Au (1558)
	4	RI	10.5	±	1.9	act	Au (1551). RI/σ_o measured
	45	I	14.8	±	1.5	act	Au (1514). RI = 15.5
^{71}Ga	1	RI	21.6			act	Au (1558)
	4	RI	12.7	±	0.3	act	Au (1551). RI/σ_o measured
	45	I	29.1	±	2.9	act	Au (1514). RI = 31.2
^{72}Ga	38	RI	25.7			eval	

RECOMMENDED VALUES RI = 13 FOR ^{69}Ga
RI = 25 FOR ^{71}Ga

Isotope	Ref.	Symbol	Value (b)			Method	Comments
Ge	2	RI	3.5	±	2.9	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E
^{72}Ge	38	RI	0.55			eval	
^{73}Ge	38	RI	34.1			eval	
^{74}Ge	38	RI	0.36			eval	
	4	RI	0.83	±	0.03	act	Au (1551). RI/σ_o measured
	39	I	0.79			act	Measured I/σ_o RI= 1.02
^{76}Ge	38	RI	0.18			eval	
$^{76}Ge^g$	4	RI	0.8	±	0.1	act	Au (1551). RI/σ_o measured
$^{76}Ge^m$	39	I	1.99	±	0.36	act	Measured I/σ_o. RI = 2.1
^{77}Ge	38	RI	7.01			eval	

RECOMMENDED VALUE RI = 0.9 FOR ^{74}Ge

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{75}As	41	I	63 ± 7	pile osc	RI = 65 ± 7
	108	RI	61.5	act	Au (1558)
	38	RI	60.53	eval	
	4	RI	42 ± 1	act	Au (1551). RI/σ_o measured
	40	RI	68 ± 15	act	Au (1551). E_c = 0.2 eV
	45	I	59 ± 6	act	Au (1514). RI = 61
^{76}As	38	RI	216.1	eval	
^{77}As	38	RI	68.25	eval	

RECOMMENDED VALUE RI = 63 FOR ^{75}As

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Se	2	RI	9.6 ± 1.2	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E
^{74}Se	42	RI	589 ± 12	act	Co (37.5)
	43	I	504	act	Measured S_o = 10.3 ± 0.1 RI = 528
	4	RI	451	act	Au (1551). RI/σ_o measured
^{76}Se	38	RI	42.08	eval	
^{77}Se	38	RI	28.89	eval	
	46	I	14	eval	
^{78}Se	38	RI	7.09	eval	
	43	I	3.6 ± 0.1	act	3.9 min $^{79}Se^m$. Measured S_o^m = 12.3 ± 0.3. RI = 3.7

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{79}Se	38	RI	55.48	eval	
^{80}Se	38	RI	1.000	eval	
	43	I	1.30 ± 0.02	act	Measured S_o = 2.65 ± 0.02 RI = 1.31
	46	I	1.3	rec	
	4	RI	0.50 ± 0.02	act	Au (1551). RI/σ_o measured. 57 min $^{81}Se^m$

RECOMMENDED VALUES RI = 500 FOR ^{74}Se
RI = 1.30 FOR ^{80}Se

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Br	2	RI	118 ± 14	react	Li (32.2). Reactor measurements, not corrected for deviation from 1/E
^{79}Br	1	RI	153	act	Au (1558)
	4	RI	155 ± 4	act	Au (1551). RI/σ_o measured
	10	I	92 ± 10	act	Au (1514). RI = 96
	108	RI	98.8	act	Au (1558)
^{81}Br	38	RI	59.61	eval	
	43	I	65 ± 10	act	Measured S_o = 24.3 ± 0.4 RI = 66
	4	RI	45 ± 1	act	Au (1551). RI/σ_o measured
	44	RI	56 ± 5	eval	
	10	I	50 ± 5	act	Au (1514). RI = 51
	108	RI	50.6	act	Au (1558)
	34	RI	41.3 ± 1.0	act	Au (1558)

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{82}Br	38	RI	90.46	eval	
RECOMMENDED VALUES RI = 125 FOR ^{79}Br RI = 50 FOR ^{81}Br					
^{80}Kr	47	RI	58.8 ± 2.8	mass spec	E_c = 0.4 eV
^{82}Kr	38	RI	191.5	eval	
	46	I	190	eval	Absorption. RI = 200
^{83}Kr	38	RI	217.3	eval	
	46	I	150	eval	Absorption. RI = 240
^{84}Kr	38	RI	3.60	eval	
	46	I	6	eval	4.4 hrs $^{83}Kr^m$
	46	I	2	eval	10.76 yrs $^{83}Kr^g$
^{85}Kr	38	RI	8.16	eval	
	48	RI	1.8 ± 1.0	mass spec	E_c = 0.54 eV
^{86}Kr	38	RI	0.48	eval	
	46	I	0	eval	
Rb	2	RI	9.0 ± 2.3	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
^{85}Rb	38	RI	7.00	eval	
	37	I	7.34 ± 0.68	act	Measured S_o = 18.4 ± 0.6. S_o (Au) = 17.7. RI = 7.5
	4	RI	3.56 ± 0.20	act	Au (1551). RI/σ_o measured. $^{86}Rb^g$

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{85}Rb (cont.)	4	RI	0.97 ± 0.03	act	Au (1551). RI/σ_o measured. $^{86}Rb^m$
	6	RI	8.0 ± 0.9	act	Au (1550)
	42	RI	24.7 ± 1.7	act	Co (37.5)
^{86}Rb	38	RI	43.6	eval	
^{87}Rb	38	RI	2.47	eval	
	4	RI	1.9 ± 0.1	act	Au (1551). RI/σ_o measured
	46	I	2.3	rec	

RECOMMENDED VALUES RI = 7 FOR ^{85}Rb
RI = 2.3 FOR ^{87}Rb

Sr	1	RI	17.1	pile osc	Au (1558)
	2	RI	10.0 ± 2.6	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
^{84}Sr	49	I	6.7 ± 1.3	act	RI = 7.0
	4	RI	7.8 ± 0.8	act	Au (1551). RI/σ_o measured
	6	RI	7.6 ± 1.0	act	Au (1550). σ_o = 0.80
^{86}Sr	38	RI	3.35	eval	
	4	RI	4.56 ± 0.24	act	Au (1551). RI/σ_o measured
	46	I	3.0	rec	
^{87}Sr	46	I	100	rec	
^{88}Sr	38	RI	0.05	eval	
	46	I	0.06	rec	

Isotope	Ref.	Symbol	Value (b)			Method	Comments
^{89}Sr	38	RI	0.36			eval	
^{90}Sr	38	RI	0.41			eval	
^{91}Sr	38	RI	0.62			eval	
RECOMMENDED VALUE RI = 7.5 FOR ^{84}Sr							
^{89}Y	1	RI	0.84			act	Au (1558)
	38	RI	0.68			eval	
	4	RI	0.89			act	Au (1551). RI/σ_o measured. 3.1 hrs $^{90}Y^m$
	46	I	0.3			rec	
	45	I	0.44	±	0.06	act	Au (1514). RI = 0.97. 64 hrs $^{90}Y^g$
^{91}Y	38	RI	2.61			eval	
	38	RI	1.94			eval	
	38	RI	0.99			eval	
RECOMMENDED VALUE RI = 0.9 FOR ^{89}Y (3.1 hrs $^{90}Y^m$)							
Zr	1	RI	2.9			pile osc	Au (1558)
	2	RI	3.7	±	0.5	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	36	I	0.60	±	0.06	pile osc	Au (1510). RI = 0.65
	25	I	1.06			pile osc	Au (1540). RI = 1.08
	50	RI	1.1	±	0.2	act	Neutron energy range 1 - 50 000 eV

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Zr (cont.)	152	RI	0.92 ± 0.10	pile osc	Au (1540)
^{90}Zr	38	RI	0.085	eval	
	50	RI	0.20 ± 0.03	act	Neutron energy range 1 - 50 000 eV
	46	I	0.15	eval	
^{91}Zr	38	RI	7.81	eval	
	51	RI	5.0 ± 1.5	react	
	50	RI	7.3 ± 0.8	act	Neutron energy range 1 - 50 000 eV
	46	I	6.5	eval	
^{92}Zr	38	RI	0.297	eval	
	46	I	0.5	eval	
^{93}Zr	38	RI	26.0	eval	
	46	I	22	eval	
^{94}Zr	38	RI	0.21	eval	
	4	RI	0.57 ± 0.03	act	Au (1551). RI/σ_o measured
	50	RI	0.23 ± 0.03	act	Neutron energy range 1 - 50 000 eV
	52	RI	0.30 ± 0.03	act	
	53	RI	0.398	act	Measured s_o = 6.62 ± 0.06. I = 0.369 ± 0.037
	44	I	0.37 ± 0.04	eval	
	46	I	0.26	eval	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{95}Zr	38	RI	5.42	eval	
^{96}Zr	38	RI	5.30	eval	
	52	RI	5.0 ± 0.4	act	
	53	I	4.97 ± 0.05	act	Measured S_o = 945 ± 40. RI = 4.97
	46	I	6.0	eval	
	44	I	5.0 ± 0.5	eval	
^{97}Zr	38	RI	1.55	eval	

RECOMMENDED VALUES RI = 0.95 FOR Zr
RI = 0.38 FOR ^{94}Zr
RI = 5.0 FOR ^{96}Zr

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{93}Nb	1	RI	8.5	pile osc	Au (1558)
	12	I	13 ± 5	pile osc	Au (1513). RI = 12.7 Au (1558)
	54	I	8.15 ± 0.65	pile osc	Au (1500). RI = 8.73
	108	RI	5.8	act	
	1	RI	4	act	Au (1558)
	4	RI	8.4 ± 2.6	act	Au (1551). RI/σ_o measured. σ_o = 1.15
	45	I	6.2 ± 1.4	act	Au (1514). RI = 6.7
^{95}Nb	38	RI	25.1	eval	

RECOMMENDED VALUE RI = 8.0 FOR ^{93}Nb

Isotope	Ref.	Symbol	Value (b)			Method	Comments
Mo	2	RI	13.8	±	1.7	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	12	I	19.0	±	2.5	pile osc	Au (1513). RI = 19.5
	35	I	25	±	1	calc	RI = 26.2
	55	RI	32.1	±	3.1	pile osc	Au (1558)
	25	I	22.5			pile osc	Au (1540). RI = 23.1
	56	RI	27	±	2	t of f	Calculated from resonance parameters
	57	RI_{eff}	29.23			react	RI calculated as a function of plate thickness
^{95}Mo	38	RI	106.3			eval	
	12	I	100	±	20	pile osc	Au (1513). RI = 101
	46	I	100			eval	
^{96}Mo	38	RI	26.11			eval	
	46	I	25			eval	
^{97}Mo	38	RI	15.05			eval	
	46	I	15			eval	
^{98}Mo	38	RI	6.698			eval	
	35	I	6.3			calc	RI = 6.37
	58	RI	6.69	±	0.13	react	Au (1558)
	8	I	10.7	±	2.3	act	Au (1490). RI = 9.1
	11, 3	I	9.9	±	1.1	act	Au (1490). RI = 8.9

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{98}Mo (cont.)	4	RI	1.3 ± 0.1	act	Au (1551). RI/σ_o measured
	6	RI	7.1 ± 1.0	act	Au (1550)
	44	I	7 ± 1	eval	
	46	I	8.0	eval	
	42	RI	6.79 ± 0.42	act	Co (37.5)
	59	I	6.38 ± 0.15		RI = 6.4
	108	RI	21.0	act	Au (1558)
^{99}Mo	38	RI	24.8	eval	
^{100}Mo	38	RI	4.00	eval	
	35	I	1.1 ± 0.2	cal	RI = 1.19
	60	RI	3.73 ± 0.20	act	Au (1558)
	11	I	4.06 ± 0.23	act	Au (1490). RI = 4.15
	108	RI	3.29	act	Au (1558)
	37	I	3.8 ± 0.2	act	Measured S_o = 21.7 ± 0.8 S_o (Au) = 17.7. RI = 3.9
	4	RI	4.2 ± 0.2	act	Au (1551). RI/σ_o measured
	46	I	3.9	rec	

RECOMMENDED VALUES RI = 25 FOR Mo
RI = 7.5 FOR ^{98}Mo
RI = 3.9 FOR ^{100}Mo

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{99}Tc	38	RI	197.9	eval	
	12	I	60 ± 20	pile osc	Au (1513). RI = 92

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{99}Tc (cont.)	46	I	200	rec	
RECOMMENDED VALUE RI = 200					
^{96}Ru	61	RI	5.51 ± 0.40	act	Mn (13.1)
	4	RI	4.6 ± 0.2	act	Au (1551). RI/σ_o measured
	49	I	6.67 ± 0.11	act	RI = 6.7
^{99}Ru	61	RI	195 ± 20	mass spec	Co (75)
^{100}Ru	38	RI	11.57	eval	
	61	RI	11.3 ± 2.6	act	Co (75)
^{101}Ru	61	RI	79.2 ± 8.0	act	Co (75)
	38	RI	79.6	eval	
	46	I	76	eval	
^{102}Ru	38	RI	4.266	eval	
	37	I	4.19 ± 0.04	act	Measured S_o = 3.76 ± 0.03 S_o (Au) = 17.7. RI = 4.8
	4	RI	4.3 ± 0.4	act	Au (1551). RI/σ_o measured
	46	I	4.2	rec	
	61	RI	4.16 ± 0.41	act	Co (75)
^{103}Ru	38	RI	66.0	eval	
^{104}Ru	38	RI	5.43	eval	
	49	I	4.36	act	RI = 4.6
	4	RI	6.1 ± 0.3	act	Au (1551). RI/σ_o measured
	62	RI	4.6 ± 0.4	act	Co (75)

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{104}Ru (cont.)	46	I	4.4	rec	
^{105}Ru	38	RI	5.10	eval	
^{106}Ru	38	RI	1.28	eval	
	63	RI	0.6	act	Co (75)
	64	RI	2.0 ± 0.6	act	Co (72.7)

RECOMMENDED VALUES RI = 5.5 FOR ^{96}Ru
RI = 11 FOR ^{100}Ru
RI = 4.2 FOR ^{102}Ru
RI = 5.2 FOR ^{103}Ru
RI = 1.0 FOR ^{106}Ru

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{103}Rh	1	RI	592	pile osc	Au (1558)
	65	RI	1 200 ± 100	react	Au (1558)
	1	RI	675	act	Au (1558)
	66	I	1 080 ± 40	act	In std
	4	RI	610 ± 24	act	Au (1551). RI/σ_o measured. 4.4 min $^{104}Rh^m$
	59	I	78 ± 7	act	4.4 min $^{104}Rh^m$. RI = 85
	59	I	1 054 ± 74	act	$^{104}Rh^g$. RI = 1 120
	38	RI	1 013.7		eval
	46	I	1 100	rec	
^{105}Rh	38	RI	1.7×10^4	eval	
	62	RI	1.65×10^4	act	

RECOMMENDED VALUES RI = 1 100 FOR ^{103}Rh
RI = 17 000 FOR ^{105}Rh

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Pd	1	RI	22.3	pile osc	Au (1558)
^{104}Pd	38	RI	22.9	eval	
^{105}Pd	38	RI	74.8	eval	
	46	I	85	rec	
^{106}Pd	38	RI	5.601	eval	
	62	RI	5.96 ± 0.57	act	
	46	I	5.6	rec	
^{107}Pd	38	RI	80.4	eval	
^{108}Pd	38	RI	215.2	eval	
	4	RI	186 ± 9	act	Au (1551). RI/σ_o measured. 13.47 hrs $^{109}Pd^g$
	46	I	240	rec	
^{109}Pd	38	RI	60.9	eval	
^{110}Pd	38	RI	7.10	eval	
	4	RI	4.6 ± 0.6	act	Au (1551). RI/σ_o measured. 22 min $^{111}Pd^g$
	46	I	6.0	rec	
^{112}Pd	38	RI	1.99	eval	

RECOMMENDED VALUE RI = 5.8 FOR ^{106}Pd

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Ag	1	RI	>650	pile osc	Au (1558)
	2	RI	466 ± 70	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E

Isotope	Ref.	Symbol	Value (b)		Method	Comments
Ag (cont.)	12	I	810	± 50	pile osc	Au (1513). RI = 835
	67	I	670	± 20	pile osc	Au (1540). RI = 698
	68	RI	780	± 20	pile osc	Au (1540)
	115	I	715	± 30	pile osc	Au (1550). RI = 740
	71	RI	755		rec	
	116	RI	750	± 40	act	Au (1565)
^{107}Ag	1	RI	87.2		act	Au (1558)
	4	RI	144	± 6	act	Au (1551). RI/σ_o measured
	45	I	77	± 5	act	Au (1514). RI = 90
^{109}Ag	12	I	1 870	± 200	pile osc	Au (1513). RI = 1 910
	1	RI	1 240		act	Au (1558)
	69	RI	47.5	± 6.6	act	Au (1549). 253 days $^{110}Ag^m$
	38	RI	1 444.2		eval	
	4	RI	1 118	± 68	act	Au (1551). RI/σ_o measured
	4	RI	57	± 1	act	Au (1551). RI/σ_o measured. 253 days $^{110}Ag^m$
	22, 7	RI	81.1	± 2.2	act	Co (69.9). 253 days $^{110}Ag^m$
	44	I	1 500	± 200	eval	
	110	RI	38	± 8	act	249 days $^{110}Ag^m$
	70	RI	57.0	± 16.4	act	S_o (Au) = 17.88 ± 0.50. I/σ_o = 16.28 ± 0.45
	46	I	1 450		rec	
	46	I^m	50		rec	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{111}Ag	38	RI	105.8	eval	
	46	I	100	rec	
RECOMMENDED VALUES RI = 755 FOR Ag RI = 1 400 FOR ^{109}Ag					
Cd	71	RI	102.2	rec	Absorption
^{110}Cd	38	RI	51.11	eval	
	4	RI/σ_o	19.7 ± 0.9	act	$^{111}Cd^m$
	46	I	37	rec	
^{111}Cd	38	RI	45.88	eval	
	46	I	47	rec	
^{112}Cd	38	RI	14.18	eval	
	46	I	17	rec	
^{113}Cd	38	RI	365.6	eval	
^{114}Cd	38	RI	16.45	eval	
	72	RI	23.3 ± 2.0	act	
	4	RI/σ_o	11.4 ± 0.6	act	Au (1551). RI/σ_o measured 53.5 hrs $^{115}Cd^g$. RI = 3.4
	46	I^m	3	rec	43 days $^{115}Cd^m$
	46	I^g	20	rec	53.5 hrs $^{115}Cd^g$
^{115}Cd	38	RI	79.9	eval	
^{116}Cd	38	RI	1.29	eval	
RECOMMENDED VALUES RI = 3 FOR ^{114}Cd ($^{115}Cd^m$) RI = 20 FOR ^{114}Cd ($^{115}Cd^g$)					

Isotope	Ref.	Symbol	Value (b)	Method	Comments
In	2	RI	2 220 ± 300	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	12	I	3 600 ± 350	pile osc	Au (1513). RI = 3 740
	67	I	3 140 ± 70	pile osc	Au (1540). RI = 3 290
^{113}In	37	I	158 ± 4	act	Measured S_o = 24.7 ± 0.5 S_o (Au) = 17.7. RI = 160 50 days $^{114}In^m$
	4	RI	213 ± 10	act	Au (1551). RI/σ_o measured 50 days $^{114}In^m$
^{115}In	38	RI	3 221.1	eval	
	1	RI	2 640	act	Au (1558)
	9	I	2 886	act	Au (1490). RI = 3 440
	11	I	3 200 ± 100	act	Au (1530). RI = 3 280
	73	RI	2 500 ± 85	act	Au. RI/σ_0 = 15.37 ± 0.47 54 min $^{116}In^m$
	74	I	3 530 ± 100	act	Au (1525). RI = 3 620 I/σ_o = 17.3
	4	RI	2 190 ± 30	act	Au (1551). RI/σ_o measured 54 min $^{116}In^m$
	10, 7	I	2 710 ± 200	act	Au (1514). RI = 2 800
	29	RI	3 350 ± 150	act	Au
RECOMMENDED VALUE RI = 2 600 FOR ^{115}In					
Sn	1	RI	4.56	pile osc	Au (1558)
	2	RI	5.7 ± 0.7	react	Li (32.2). Reactor measurement, not corrected for deviation for 1/E

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Sn (cont.)	12	I	8.5 ± 2.0	pile osc	Au (1513). RI = 8.7
^{112}Sn	4	RI	27.4 ± 2.1	act	Au (1551). RI/σ_o = 13.6
^{115}Sn	38	RI	27.16	eval	
^{116}Sn	38	RI	17.5	eval	
	4	RI	0.49 ± 0.02	act	Au (1551). RI/σ_o measured
	46	I	15	rec	
^{117}Sn	38	RI	16.57	eval	
	46	I	12	rec	
^{118}Sn	38	RI	7.41	eval	
	46	I	8	rec	
^{119}Sn	38	RI	5.32	eval	
	46	I	3.5	rec	
^{120}Sn	38	RI	1.31	eval	
	46	I	1.5	rec	
^{121}Sn	38	RI	26.29	eval	
^{122}Sn	38	RI	0.893	eval	
	4	RI	0.83 ± 0.02	act	Au (1551). RI/σ_o measured
	46	I	0.6	rec	
^{123}Sn	38	RI	2.39	eval	
^{124}Sn	38	RI	11.34	eval	

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{124}Sn (cont.)	49	I	7.5		act	RI = 7.6
	4	RI	8.7	± 0.4	act	Au (1551). RI/σ_o measured
	46	I	9		rec	
^{125}Sn	38	RI	13.89		eval	
^{126}Sn	38	RI	0.232		eval	
RECOMMENDED VALUE RI = 9 FOR ^{124}Sn (9.7 min $^{125}Sn^m$)						
Sb	2	RI	106	± 13	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	112	RI	115	± 12	react	B std
^{121}Sb	38	RI	205.5		eval	
	49	I	168	± 26	act	RI = 170
	4	RI	129	± 5	act	Au (1551). RI/σ_o measured
	6	RI	169	± 9	act	Au (1550)
	108	RI	134		act	Au (1558)
	1	RI	143		act	Au (1558)
	10	I	206	± 15	act	Au (1514). RI = 210
	29	RI	200	± 17	act	Au
	46	I	200		rec	
^{122}Sb	38	RI	159.0		eval	
^{123}Sb	38	RI	125.6		eval	
	37	I	97	± 8	act	Measured S_o = 28.3 ± 2.1 S_o (Au) = 17.7. RI = 100

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{123}Sb (cont.)	4	RI	219 ± 11	act	Au (1551). RI/σ_o measured
	44	I	120 ± 10	eval	
	22	RI	140 ± 4	act	Co (69.9)
	46	I	130	rec	
	108	RI	58.2	act	Au (1558)
	29	RI	116 ± 10	act	Au
	10	I	120 ± 12	act	Au (1514). RI = 122
^{124}Sb	38	RI	19.25	eval	
^{125}Sb	38	RI	19.05	eval	
^{126}Sb	38	RI	64.5	eval	
^{127}Sb	38	RI	14.7	eval	
^{128}Sb	38	RI	15.9	eval	

RECOMMENDED VALUES RI = 180 FOR ^{121}Sb
RI = 120 FOR ^{123}Sb

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Te	1	RI	37	pile osc	Au (1558)
	2	RI	50 ± 6	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	12	I	72	pile osc	Au (1513). RI = 74
^{122}Te	38	RI	46.87	eval	
	46	I	66	rec	
^{123}Te	38	RI	5 661	eval	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{123}Te (cont.)	46	I	5 400	rec	
^{124}Te	38	RI	7.94	eval	
^{125}Te	38	RI	17.53	eval	
	46	I	18	rec	
^{126}Te	38	RI	8.18	eval	
	4	RI	8.0 ± 0.7	act	Au (1551). RI/σ_o measured
	46	I	9	rec	
^{127}Te	38	RI	48.7	eval	
^{128}Te	38	RI	1.558	eval	
	4	RI	1.2 ± 0.1	act	Au (1551). RI/σ_o measured 69 min $^{129}Te^g$
	75	RI	1.55 ± 0.13	act	Au (1543). σ_o (Te) = 0.20 69 min $^{129}Te^g$
	75	RI	0.077 ± 0.006	act	Au (1543). 34 days $^{129}Te^m$
	46	I	1.5	rec	69 min $^{129}Te^g$
	46	I	0.08	rec	34 days $^{129}Te^m$
^{129}Te	38	RI	7.41	eval	
^{130}Te	38	RI	0.184	eval	
	43	I	0.47 ± 0.14	act	Measured S_o = 2.10 ± 0.17 S_o (Au) = 17.7. RI = 0.48
	4	RI	0.34 ± 0.04	act	Au (1551). RI/σ_o measured
	46	I	0.36	rec	
^{131}Te	38	RI	0.05	eval	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{132}Te	38	RI	0.007	eval	

RECOMMENDED VALUES RI = 1.5 FOR ^{128}Te (69 min $^{129}Te^{g}$)
RI = 0.08 FOR ^{128}Te (34 days $^{129}Te^{m}$)
RI = 0.4 FOR ^{130}Te

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{125}I	76	RI	13 730	act	Co (75)
^{127}I	38	RI	151.8	eval	
	112	RI	130 ± 18	react	B std
	108	RI	132	act	Au (1558)
	2	RI	106 ± 12	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	12	I	180 ± 30	pile osc	Au (1513). RI = 177
	43	I	145 ± 6	act	Measured S_o = 27.8 ± 0.5 S_o (Au) = 17.7. RI = 150
	4	RI	95 ± 5	act	Au (1551). RI/σ_o measured
	10	I	145 ± 9	act	Au (1514). RI = 150
	13	RI	146 ± 7	act	Cd-ratio and σ_o used to calculate RI
	79	I	227 ± 45	act	Au (1510). RI = 230
	46	I	150	rec	
	111	RI	140 ± 20	t of f	
^{129}I	38	RI	25.97	eval	
	77	RI	50	act	Co std
	111	RI	22 ± 7	t of f	
	46	I	23	rec	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{130}I	38	RI	173.3	eval	
^{131}I	38	RI	10.0	eval	
	78	RI	8	act	
	46	I	8	rec	
^{133}I	38	RI	0.005	eval	
^{135}I	38	RI	0.03	eval	
RECOMMENDED VALUE RI = 150 FOR ^{127}I					
^{126}Xe	153	RI	38.0 ± 3.8	act	Co (75)
^{128}Xe	38	RI	110.0	eval	
	46	I	100	rec	
^{129}Xe	46	I	220	rec	
^{130}Xe	38	RI	17.29	eval	
	46	I	12	rec	
^{131}Xe	38	RI	789.9	eval	
	46	I	830	rec	
^{132}Xe	38	RI	2.46	eval	
	46	I	2.4	rec	
^{133}Xe	38	RI	52.25	eval	
^{134}Xe	38	RI	4.604	eval	
	46	I	6	rec	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{135}Xe	38	RI	7 262	eval	
^{136}Xe	38	RI	0.120	eval	
^{133}Cs	12	I	490 ± 80	pile osc	Au (1513). RI = 550
	67	I	450 ± 15	pile osc	Au (1540). RI = 465
	80	RI	370 ± 50	act	Co (74)
	38	RI	460.3	eval	
	22	RI	495 ± 17	act	Co (69.9)
	6	RI	437 ± 26	act	Au (1550)
	10	I	30 ± 6	act	Au (1514). RI = 30 29 h $^{134}Cs^m$
	4	RI	360 ± 90	act	Au (1551). RI/σ_o measured
	81	RI	461 ± 25	act	Co (75)
	46	I	450	rec	
^{134}Cs	38	RI	87.97	eval	
^{135}Cs	38	RI	61.99	eval	
	82	RI	80	act	Co std
	46	I	58	rec	
^{136}Cs	38	RI	15.55	eval	
^{137}Cs	38	RI	0.414	eval	

RECOMMENDED VALUE RI = 465 FOR ^{133}Cs

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Ba	1	RI	7.4	pile osc	Au (1558)
	2	RI	12.6 ± 1.7	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{130}Ba	6	RI	270 ± 70	act	Au (1550)
	4	RI	276 ± 10	act	Au (1551). RI/σ_o measured
^{134}Ba	4	RI	24 ± 2	act	Au (1551). RI/σ_o measured
	38	RI	37.80	eval	
	46	I	10	rec	
^{135}Ba	46	I	100	rec	
^{136}Ba	38	RI	17.07	eval	
	46	I	17	rec	
	4	RI	0.7	act	Au (1551). RI/σ_o measured 2.5 min $^{137}Ba^m$
^{137}Ba	38	RI	4.916	eval	
	46	I	2	rec	
^{138}Ba	38	RI	0.219	eval	
	4	RI	0.31 ± 0.02	act	Au (1551). RI/σ_o measured
	43	I	0.20 ± 0.09	act	Measured S_o = 0.649 ± 0.04 S_o (Au) = 17.7. RI = 0.35
	46	I	0.2	rec	
^{140}Ba	38	RI	13.59	eval	
	46	I	13	rec	

RECOMMENDED VALUE RI = 0.3 FOR ^{138}Ba

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{139}La	38	RI	15.63	eval	
	6	RI	11.8 ± 1.2	act	Au (1550)

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{139}La (cont.)	45	I	7.5 ± 0.8	act	Au (1514). RI = 12
	1	RI	10.7	pile osc	Au (1558)
	83	RI	14.1 ± 0.9	calc	
	4	RI	11.5 ± 0.8	act	Au (1551). RI/σ_o measured
	29	RI	10.8 ± 1.1	act	Au
	154	RI	11.2 ± 0.6	act	
	84	RI	12.1 ± 1.0	abs	
	46	I	11	rec	
^{140}La	38	RI	70.68	eval	
	154	RI	69 ± 4	act	
	46	I	70	rec	

RECOMMENDED VALUES RI = 11 FOR ^{139}La
RI = 70 FOR ^{140}La

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Ce	2	RI	3.7 ± 1.7	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
^{140}Ce	38	RI	0.507	eval	
	85	RI	0.49 ± 0.05	act	Au (1558)
	6	RI	0.48 ± 0.05	act	Au (1550)
	86	RI	0.49 ± 0.05	act	Au (1558)
	43	I	0.23 ± 0.01	act	Measured S_o = 0.476 ± 0.003 S_o (Au) = 17.7. RI = 0.48
	4	RI	0.44 ± 0.03	act	Au (1551). RI/σ_o measured
	46	I	0.24	rec	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{141}Ce	38	RI	28.73	eval	
^{142}Ce	38	RI	1.514	eval	
	85	RI	1.6 ± 0.2	act	Au (1558)
	43	I	0.81 ± 0.10	act	Measured S_o = 0.865 ± 0.005 S_o (Au) = 17.7. RI = 1.3
	4	RI	1.20	act	Au (1551). RI/σ_o measured
	46	I	1.0	rec	
^{143}Ce	38	RI	42.66	eval	
^{144}Ce	38	RI	2.602	eval	
	87	RI	2.62 ± 0.26	act	Co (75)
	46	I	2.2	rec	

RECOMMENDED VALUES RI = 0.49 FOR ^{140}Ce
RI = 1.40 FOR ^{142}Ce

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{141}Pr	38	RI	17.52	eval	
	6	RI	14.1 ± 0.2	act	Au (1550)
	4	RI	20.7 ± 3.0	act	Au (1551). RI/σ_o measured
	1	RI	12.1	act	Au (1558)
	83	RI	18	calc	
	46	RI	13	rec	
^{142}Pr	38	RI	143.8	eval	
^{143}Pr	38	RI	190.0	eval	
	88	RI	190 ± 25		Co std
	46	I	150	rec	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{145}Pr	38	RI	445.1	eval	
RECOMMENDED VALUE RI = 14 FOR ^{141}Pr					
Nd	89	RI	43 ± 4	react	Au (1558)
	112	RI	40 ± 6	react	B std
^{142}Nd	38	RI	8.84	eval	
	46	I	0.2	rec	
^{143}Nd	38	RI	64.47	eval	
	10	I	<50	pile osc	Au (1513)
	46	I	60	rec	
^{144}Nd	38	RI	7.64	eval	
	46	I	3.6	rec	
^{145}Nd	38	RI	271.3	eval	
	10	I	130 ± 15	pile osc	Au (1513). RI = 154
	46	I	250	rec	
^{146}Nd	38	RI	2.36	eval	
	6	RI	3.2 ± 0.5	act	Au (1550)
	85	RI	3.0 ± 0.3	act	Au (1558)
	17	RI	2.60 ± 0.18	calc	
	4	RI	2.85 ± 0.18	act	Au (1551). RI/σ_o measured
	46	I	2.0	rec	
^{147}Nd	38	RI	649.8	eval	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{148}Nd	38	RI	14.01	eval	
	85	RI	14 ± 2	act	Au (1558)
	17	RI	13.8 ± 1.0	calc	
	4	RI	14.0 ± 0.7	act	Au (1551). RI/σ_o measured
	90	RI	18.7 ± 0.5	act	Au (1558)
	46	I	20	rec	
^{150}Nd	38	RI	2.59	eval	
	85	RI	14 ± 4	act	Au (1558)
	17	RI	12.6 ± 0.2	calc	
	4	RI	20.5 ± 0.7	act	Au (1551). RI/σ_o measured
	46	I	14	rec	
RECOMMENDED VALUES RI = 2.8 FOR ^{146}Nd					
RI = 17 FOR ^{148}Nd					
RI = 14 FOR ^{150}Nd					
^{147}Pm	38	RI	2 178	eval	
	44	I	2 400 ± 300	eval	
	91	I	1 274 ± 66	act	RI = 1 320. 5.4 day ^{148}Pm
	92	RI	1 700 ± 250	act	5.39 day $^{148}Pm^m$
	92	RI	1 520 ± 230	act	40.6 day $^{148}Pm^m$
	92	RI	3 220	act	Total activation RI
	93	I	2 280 ± 200	t of f	σ_o = 198 ± 8. RI = 2 400
	94	I	2 192 ± 100	t of f	σ_o = 200 ± 7. RI = 2 300

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{147}Pm (cont.)	95	RI	720 ± 200	mass spec	40.6 day $^{148}Pm^m$
	95	RI	800 ± 250	mass spec	5.39 day $^{148}Pm^m$
	46	I	1 050	rec	40.6 day $^{148}Pm^m$
	46	I	1 150	rec	5.39 day $^{148}Pm^m$
^{148}Pm	38	RI	43 980	eval	5.39 day ^{148}Pm
	93	I	3 600 ± 2 400	t of f	σ_o = 10 600
	38	RI	31 990	eval	40.6 day $^{148}Pm^m$
^{149}Pm	38	RI	927.7	eval	
^{151}Pm	38	RI	1 210	eval	

RECOMMENDED VALUES RI = 1 300 FOR ^{147}Pm (5.39 day $^{148}Pm^m$)
RI = 1 200 FOR ^{147}Pm (40.6 day $^{148}Pm^m$)

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Sm	2	RI	1 790 ± 270	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
^{147}Sm	38	RI	566.2	eval	
	44	I	646 ± 60	eval	
	95	RI	640 ± 200	mass spec	Co std
	107	RI	646 ± 60	mass spec	
	103	RI	714 ± 50	t of f	
	46	I	600	rec	
^{148}Sm	38	RI	18.51	eval	
	103 44	RI	27 ± 14	mass spec	
^{149}Sm	38	RI	3 705	eval	

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{149}Sm (cont.)	96	RI	4 400		mass spec	Co (72.3)
^{150}Sm	38	RI	257.1		eval	
	97	RI	227	± 23	act	Co (75)
	103	RI	310	± 15	t of f	
	46	I	240		rec	
^{151}Sm	38	RI	2 178		eval	
	111	RI	3 300	± 700	t of f	
	46	I	3 100		rec	
^{152}Sm	38	RI	3 240		eval	
	98	RI	2 644	± 604	t of f	
	99	I	3 050	± 200	act	Au std. RI = 3 150
	100	RI	3 200	± 100	act	Au (1540)
	12	I	2 850	± 300	pile osc	Au (1510). RI = 2 950
	6	RI	2 530	± 150	act	Au (1550)
	4	RI	3 270	± 170	act	Au (1551). RI/σ_o measured
	46	I	3 000		rec	
	108	RI	2 920		act	Au (1558)
^{153}Sm	38	RI	1 137		eval	
^{154}Sm	38	RI	38.21		eval	
	98	RI	31	± 6	t of f	
	4	RI	23.0	± 1.0	act	Au (1551). RI/σ_o measured

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{156}Sm	38	RI	331.9		eval	

RECOMMENDED VALUES: RI = 660 FOR ^{147}Sm
RI = 270 FOR ^{150}Sm
RI = 2 900 FOR ^{152}Sm
RI = 27 FOR ^{154}Sm

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{151}Eu	98	RI	3 265	± 310	t of f	
	108	RI	3 420		act	Au (1558)
	101 7	RI	1 400	± 40		9.3 hrs $^{152}Eu^m$
	4	RI	3 550	± 160	act	Au (1551). RI/σ_o measured 12 year $^{152}Eu^g$
	4	RI	2 580	± 130	act	Au (1551). RI/σ_o measured 9.3 hour $^{152}Eu^m$
	102	RI	11 410	± 450	act	12 year $^{152}Eu^g$
	102	RI	3 847	± 270	act	9.3 h $^{152}Eu^m$
^{153}Eu	98	RI	1 632	± 195	t of f	
	12	I	1 280	± 100	pile osc	Au (1513). RI = 1 430
	4	RI	1 520	± 80	act	Au (1551). RI/σ_o measured
	102	RI	3 887	± 62	act	
^{154}Eu	38	RI	1 240		eval	
^{155}Eu	38	RI	1 223		eval	
^{156}Eu	38	RI	1 258		eval	
^{157}Eu	38	RI	826.4		eval	

RECOMMENDED VALUES RI = 2 600 FOR ^{151}Eu (9.3 hour $^{152}Eu^m$)
RI = 7 000 FOR ^{151}Eu (12 year $^{152}Eu^g$)
RI = 1 500 FOR ^{153}Eu

Isotope	Ref.	Symbol	Value (b)	Method	Comments
Gd	2	RI	67 ± 8	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	104	RI	393	calc	
^{152}Gd	6	RI	3 000 ± 300	act	Au (1550)
^{154}Gd	98	RI	177 ± 17	t of f	
	107	RI	335 ± 50	mass spec	
	105	RI	530	mass spec	
	46	I	250	rec	
^{155}Gd	38	RI	1 563	eval	
	104	RI	1 720	calc	
^{156}Gd	38	RI	90.0	eval	
	107	RI	100 ± 30	mass spec	
	104	RI	95	calc	
	46	I	90	rec	
	105	RI	23	mass spec	
^{157}Gd	38	RI	3 410	eval	
	104	RI	711	calc	
^{158}Gd	38	RI	97.9	eval	
	98	RI	60.5 ± 6.0	t of f	
	104	RI	72	calc	
	6	RI	84 ± 20	act	Au (1550)

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{158}Gd (cont.)	4	RI	116 ± 6	act	Au (1551). RI/σ_o measured
^{159}Gd	38	RI	186.7	eval	
^{160}Gd	38	RI	1.445	eval	
	98	RI	6.9 ± 1.0	t of f	
	104	RI	4.8	calc	
	46	I	7.0	rec	
RECOMMENDED VALUES RI = 300 FOR ^{154}Gd RI = 80 FOR ^{158}Gd					
^{159}Tb	38	RI	376.4	eval	
	49	I	343 ± 35	act	I/σ_o = 15.6 ± 0.8 S_o (Au) = 17.7. RI = 365
	6	RI	365 ± 40	act	Au (1550)
	85	RI	450 ± 50	act	Au (1558)
	4	RI	403 ± 20	act	Au (1551). RI/σ_o measured
	108	RI	780	act	Au (1558)
	46	I	420	rec	
^{160}Tb	38	RI	1 140	eval	
^{161}Tb	38	RI	655.9	eval	
RECOMMENDED VALUE RI = 400 FOR ^{159}Tb					
Dy	106	RI	1 840 ± 180	react	
^{160}Dy	106	RI	1 160 ± 130	react	
	38	RI	1 160	eval	
	46	I	1 200	rec	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{160}Dy (cont.)	107	RI	915 ± 90	mass spec	
^{161}Dy	38	RI	1 670	eval	
	107	RI	1 060 ± 80	mass spec	
	46	I	1 200	rec	
	106	RI	1 670 ± 167	react	
^{162}Dy	38	RI	2 550	eval	
	46	I	2 800	rec	
	106	RI	3 324 ± 400	react	
	107	RI	1 170 ± 80	mass spec	
^{163}Dy	38	RI	1 650	eval	
	106	RI	1 962 ± 176	react	
	107	RI	1 380 ± 100	mass spec	
	46	I	1 900	rec	
^{164}Dy	38	RI	795	eval	
	106	RI	377 ± 34	react	
	7	RI	332 ± 10	rec	
	4	RI	780 ± 60	act	Au (1551). RI/σ_o measured

RECOMMENDED VALUES RI = 1 200 FOR ^{160}Dy
RI = 1 300 FOR ^{161}Dy
RI = 2 600 FOR ^{162}Dy
RI = 1 900 FOR ^{163}Dy
RI = 800 FOR ^{164}Dy

Isotope	Ref.	Symbol	Value (b)			Method	Comments
^{165}Ho	38	RI	678			eval	
	108	RI	628			act	Au (1558)
	4	RI	620	±	90	act	Au (1551). RI/σ_o measured
	6	RI	710	±	30	act	Au (1550)
	46	I	700			rec	
RECOMMENDED VALUE RI = 660							
^{166}Er	98	RI	122	±	13	t of f	
	107	RI	57	±	16	mass spec	
^{167}Er	98	RI	3 177	±	325	t of f	
^{168}Er	98	RI	35.5	±	7.0	t of f	
^{170}Er	98	RI	44	±	7	t of f	
	108	RI	32.2			act	Au (1558)
	4	RI	25.2	±	3.0	act	Au (1551). RI/σ_o measured
RECOMMENDED VALUE RI = 35 FOR ^{170}Er							
^{169}Tm	6	RI	1 550	±	200	act	Au (1550)
	4	RI	1 450	±	65	act	Au (1551). RI/σ_o measured
	19	RI	2 240	±	130	act	Co (69.9)
RECOMMENDED VALUE RI = 1 700							
Yb	109	RI	177	±	24	calc	
^{168}Yb	109	RI	30 950			calc	
	19	RI	21 000	±	4 200	act	Co (69.9)
	98	RI	31 900	±	4 500	t of f	

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{168}Yb (cont.)	6	RI	14 700	± 1 900	act	Au (1550)
	4	RI	23 000	± 5 000	act	Au (1551). RI/σ_o measured
	49	I	35 706	± 17 139	act	I/σ_o = 6.49 ± 0.13 S_o (Au) = 17.7. RI = 37 000
^{170}Yb	109	RI	326		calc	
	98	RI	211	± 20	t of f	
	107	RI	270	± 30	mass spec	
^{171}Yb	109	RI	313		calc	
	98	RI	344	± 39	t of f	
	107	RI	332	± 30	mass spec	
^{172}Yb	109	RI	23.5		calc	
	98	RI	26.2	± 6.0	t of f	
	107	RI	25	± 7	mass spec	
^{173}Yb	109	RI	394		calc	
	107	RI	410	± 40	mass spec	
^{174}Yb	109	RI	33.8		calc	
	19	RI	68.6	± 7.2	act	Co (69.9)
	98	RI	26	± 6	t of f	
	6	RI	30	± 3	act	Au (1550)
	4	RI	37.6	± 1.5	act	Au (1551). RI/σ_o measured
^{176}Yb	109	RI	7.6		calc	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{176}Yb (cont.)	98	RI	8 ± 2	t of f	
	4	RI/σ_o	2.4 ± 0.2	act	Au (1551)
RECOMMENDED VALUES RI = 25 000 FOR ^{168}Yb; RI = 270 FOR ^{170}Yb; RI = 330 FOR ^{171}Yb; RI = 25 FOR ^{172}Yb; RI = 31 FOR ^{174}Yb; RI = 7 FOR ^{176}Yb					
Lu	112	RI	720 ± 70	react	B std
^{175}Lu	101, 7	RI	405 ± 15		
	98	RI	1 158 ± 280	t of f	
	4	RI	550 ± 75	act	Au (1551). RI/σ_o measured
^{176}Lu	4	RI	1 060 ± 45	act	Au (1551). RI/σ_o measured
	7	RI	2 400 ± 250	rec	
RECOMMENDED VALUE RI = 600 FOR ^{175}Lu					
Hf	1	RI	1 160	pile osc	Au (1558)
	2	RI	1 470 ± 200	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	36	I	2 850 ± 350	pile osc	Au (1510). RI = 2 280
	112	RI	2 800 ± 600	react	B std
	67	I	2 080 ± 50	pile osc	Au (1540). RI = 2 130
	65	RI	2 130 ± 60	react	Au (1558)
	1	RI	1 750	act	Au (1558)
	113	RI	2 300 ± 60	react	

Isotope	Ref.	Symbol	Value (b)		Method	Comments
Hf (cont.)	114	RI	2 280	± 180	abs	
^{174}Hf	4	RI	300	± 200	act	Au (1551). RI/σ_o measured
^{176}Hf	113	RI	880	± 40	react	
	65	RI	400	± 20	react	Au (1558)
^{177}Hf	113	RI	7 000	± 240	react	
^{178}Hf	113	RI	1 710	± 50	react	
^{179}Hf	113	RI	595	± 55	react	
	4	RI	3.9	± 0.2	act	Au (1551). RI/σ_o measured 5.5 hr ^{180}Hf^m
^{180}Hf	113	RI	52	± 7	react	
	1	RI	21.6		act	Au (1558)
	6	RI	32	± 3	act	Au (1550)
	4	RI	32.5	± 1.5	act	Au (1551). RI/σ_o measured
	37	I	24.3	± 1.6	act	Measured S_o = 2.17 ± 0.09 S_o (Au) = 17.7. RI = 30

RECOMMENDED VALUES RI = 2 100 FOR Hf
RI = 28 FOR ^{180}Hf

^{181}Ta	2	RI	474	± 62	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	12	I	1 100	± 400	pile osc	Au (1513). RI =1 220
	1	RI	578		pile osc	Au (1558)
	6	RI	750	± 50	act	Au (1550)
	115	I	690	± 25	pile osc	Au (1550). RI = 700

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{181}Ta (cont.)	116	RI	690	± 40	act	Au (1565)
	108	RI	800		act	Au (1558)
	4	RI	715	± 70	act	Au (1551). RI/σ_o measured
	71	RI	660		rec	
^{182}Ta	155	RI	943	± 50	t of f	
RECOMMENDED VALUE RI = 700 FOR ^{181}Ta						
W	2	RI	290	± 35	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
	12	I	330	± 60	pile osc	Au (1513). RI = 340
	112	RI	170	± 20	react	B std
	119	RI	372		eval	
	35	I	325	± 20	calc	RI = 335
	117	RI	367	± 33	react	Au (1558)
	118	RI	360	± 70	react	Au (1558)
	71	RI	373		rec	
	57	RI	338		react	RI calculated as a function of plate thickness
^{182}W	98	RI	592	± 60	t of f	
	119	RI	591		eval	
^{183}W	98	RI	371	± 42	t of f	
	119	RI	387		eval	
^{184}W	98	RI	14.1	± 1.5	t of f	

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{184}W (cont.)	119	RI	13.5	eval	
	118	RI	8.4 ± 2.0	react	Au (1558)
	120	RI	14.9 ± 1.6	act	
	4	RI	22.0 ± 1.0	act	Au (1551). RI/σ_o measured
^{186}W	98	RI	486 ± 50	t of f	
	119	RI	551	eval	
	108	RI	345	act	Au (1558)
	120 7	RI	441 ± 22	act	
	118	RI	490 ± 100	react	Au (1558)
	11	I	476 ± 50	act	Au (1490). RI = 560
	1	RI	390	act	Au (1558)
	121	RI	450 ± 36	act	
	122	RI	318	act	
	4	RI	420 ± 45	act	Au (1551). RI/σ_o measured
	40	RI	380 ± 84	act	Au (1551). E_c = 0.2 eV
^{187}W	122	RI	2 760	act	

RECOMMENDED VALUES RI = 370 FOR W
RI = 15 FOR ^{184}W
RI = 420 FOR ^{186}W

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{185}Re	1	RI	1 100	act	Au(1558)
	123	RI	1 726 ± 68	calc	Calculated from resonance parameters
	124	RI	1 650 ± 90	capt	Moxon-Rae detector
	124	RI	1 753 ± 90	act	

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{185}Re (cont.)	125	RI	1 828	± 120	act	
	4	RI	1 250		act	Au(1551). RI/σ_o measured
^{187}Re	123	RI	308	± 20	calc	Calculated from resonance parameters
	125	RI	312	± 22	act	
	1	RI	288		act	
	4	RI	315	± 35	act	Au(1551). RI/σ_o measured

RECOMMENDED VALUES RI = 1700 FOR ^{185}Re
RI = 310 FOR ^{187}Re

Isotope	Ref.	Symbol	Value (b)		Method	Comments
Os	2	RI	180	± 20	react	Li(32.2). Reactor measurement, not corrected for deviation from 1/E.
^{184}Os	4	RI	600	± 120	act	Au(1551). RI/σ_o measured
^{189}Os	4	RI	0.013		act	Au(1551). RI/σ_o measured
^{190}Os	4	RI	39	± 18	act	Au(1551). RI/σ_o measured 15 day $^{191}Os^g$
	4	RI	29	± 15	act	Au(1551). RI/σ_o measured 13 hour $^{191}Os^m$
^{192}Os	4	RI	3.6	± 1.0	act	Au(1551). RI/σ_o measured
Ir	2	RI	2 000	± 490	react	Li(32.2). Reactor measurement, not corrected for deviation from 1/E.
^{191}Ir	1	RI	3 500		act	Au(1558)
	22	RI	4 800	± 240	act	Co(69.9)
	59	I	4 074	± 28		RI = 4500. 74 day $^{192}Ir^g$
	59	I	940	± 160		RI = 1200. 1.4 min $^{192}Ir^m$

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{191}Ir (cont.)	4	RI	3 400	± 400	act	Au(1551). RI/σ_o measured 74 day $^{192}Ir^g$
^{193}Ir	1	RI	1 370		act	Au(1558)
	4	RI	1 390	± 200	act	Au(1551). RI/σ_o measured
RECOMMENDED VALUE RI = 4000 FOR ^{191}Ir						
Pt	1	RI	81.5		pile osc	Au(1558)
	12	I	185		pile osc	Au(1513). RI = 200
^{196}Pt	45	I	8	± 2	act	Au(1514). RI = 12
	4	RI	5.6	± 0.6	act	Au(1551). RI/σ_o measured
^{198}Pt	108	RI	55.3		act	Au(1558)
	45	I	54	± 6	act	Au(1514). RI = 55
	4	RI	48	± 4	act	Au(1551). RI/σ_o measured
RECOMMENDED VALUE RI = 53 FOR ^{198}Pt						
^{197}Au	1	RI	1 558		act	
	71	RI	1 550		rec	Absorption. Cd cutoff = 0.5 eV
	40	RI	1 551	± 20	act	
	156	I	1 510	± 40	act	RI = 1 553
RECOMMENDED VALUE RI = 1 550						
Hg	1	RI	31		pile osc	Au(1558)
	2	RI	72.4	± 8.0	react	Li(32.2). Reactor measurement, not corrected for deviation from 1/E.
	112	RI	73	± 5	react	B std
^{196}Hg	4	RI	1 230	± 130	act	Au(1551). RI/σ_o measured 65 hour $^{197}Hg^g$

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{196}Hg (cont.)	126	RI	413 ± 15	act	Au(1550). Co(75) 65 hour $^{197}Hg^{g}$
	4	RI	47 ± 5	act	Au(1551). RI/σ_o measured 24 hour $^{197}Hg^{m}$
	126	RI	58.9 ± 2.4	act	Au(1550). Co(75) 24 hour $^{197}Hg^{m}$
^{198}Hg	4	RI	2.00 ± 0.15	act	Au(1551). RI/σ_o measured
^{202}Hg	30	I	2.1 ± 0.5	act	Au(1490). RI = 4.1
	126	RI	4.99 ± 0.19	act	Au(1550). Co(75)
	22	RI	3.94 ± 0.08	act	Co(69.9)
	4	RI	3.98 ± 0.25	act	Au(1551). RI/σ_o measured
^{204}Hg	4	RI	0.85 ± 0.06	act	Au(1551). RI/σ_o measured
RECOMMENDED VALUES RI = 73 FOR Hg					
RI = 4.3 FOR ^{202}Hg					
Tl	157	RI	12 ± 2	abs	Neutron slowing-down technique
^{203}Tl	19	RI	349 ± 17	act	Co(69.9)
	1	RI	129	act	Au(1558)
	157	RI	40 ± 5	abs	Neutron slowing-down technique
^{205}Tl	1	RI	0.5	act	Au(1558)
	157	RI	0.7 ± 0.1	abs	Neutron slowing-down technique
Pb	1	RI	0.094	pile osc	Au(1558)
	12	I	0.05 ± 0.03	pile osc	Au(1513). RI = 0.12

Isotope	Ref.	Symbol	Value (b)			Method	Comments
^{209}Bi	1	RI	0.53			pile osc	Au(1558)
	36	I	0.050	±	0.012	pile osc	Au(1510). RI = 0.062
^{210}Bi	127	RI	0.20	±	0.02	act	Mn(13.1)
^{230}Th	128	RI	996	±	40	act	Co(74)
	129	RI	1 020	±	30	act	
	158	RI	1 035	±	85	t of f	
^{232}Th	6	RI	88	±	3	act	Au(1550)
	4	RI	72.6	±	5.0	act	Au(1551). RI/σ_o measured
	13	RI	89.8	±	4.0	act	
	13	RI	93	±	6	abs	
	2	RI	61.8	±	12.0	react	Li(32.2). Reactor measurement, not corrected for deviation from 1/E
	67	I	84	±	4	pile osc	Au(1540). RI = 85
	130	RI	81.2	±	3.4	react	Au(1579)
	1	RI	71.4			pile osc	Au(1558)
	131	RI	83.3	±	3.0	act	Au(1555)
	132	RI	86	±	6	calc	
	44	I	82			eval	RI = 85
	133	RI	82.7	±	1.8	act	Au(1561)

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{232}Th (cont.)	134	RI	79 ± 4	calc	RI calculated from resonance parameters
	135	RI	84 ± 1	act	Au (1565)
	136	I	83 ± 6	act	Au (1510). RI = 84.4
	142	RI	82.5 ± 3.0	act	Au (1555)
	71	RI	84	rec	
^{233}Th	135	RI	386 ± 100	act	Au (1565)
RECOMMENDED VALUE RI = 82 FOR ^{232}Th					
^{231}Pa	71	RI	480	rec	
	174	RI	11. 820	abs	$^{237}N_p$ (945) for capture
^{233}Pa	137	RI	470 ± 90	act	Co (75). 1.2 min $^{234}Pa^m$
	137	RI	460 ± 100	act	Co (75). 6.7 hrs $^{234}Pm^m$
	137	RI	930 ± 135	act	Co (75)
	138	RI	920 ± 90	act	Co (75)
	71	RI	820	rec	
	159	RI	842 ± 35	act	Co (72.0)
	44	I	860	eval	RI = 875
	160		901 ± 45	t of f	RI = 920
RECOMMENDED VALUE RI = 880 FOR ^{233}Pa					
U	2	RI	224 ± 40	react	Li (32.2). Reactor measurement, not corrected for deviation from 1/E
^{232}U	139	RI	280	mass spec	Capture. Co (75)

Isotope	Ref.	Symbol		Value (b)	Method	Comments
^{232}U (cont.)	71	RI	540		rec	Absorption
	71	RI	320		rec	Fission
	71	RI	220		rec	Capture
^{233}U	44	RI	750	± 20	eval	Fission
	140	RI	837	± 40	act	Fission. Co (75)
	141	RI	743	± 36		Fission. In std Cd ratio, *fiss prod gammas.*
	141	RI	743	± 24		Fission. Au (1535). Cd ratio, fiss counter detect
	142	RI	792	± 27		Fission. Au (1555). Cd ratio, fiss counter detect
	161	RI	771	± 49		Fission. Co std
	143	RI	821	± 59	act	Fission. Au (1555)
	144	RI	838	± 40		Fission
	145	RI	830	± 60		Fission. Analysis of ^{137}Cs
	162	RI	765			Fission. Pulsed n source
	163	RI	780	± 40	eval	Fission
	164	RI	850	± 90		Fission
	71	RI	780		rec	Fission
	140	RI	981	± 45		Absorption
	146	RI	899	± 50		Absorption
	143	RI	965	± 65		Absorption
	71	RI	917		rec	Absorption

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{233}U (cont.)	161	RI	135 ± 8	act	Capture. Co std
	163	RI	137 ± 7	eval	Capture
	71	RI	137	rec	Capture
	145	RI	146 ± 8	mass spec	Capture
	140	RI	144 ± 7	mass spec	Capture
^{234}U	71	RI	665	rec	Absorption
	44	I	600	rec	Capture. RI = 645
	166	RI	700	rec	Capture
^{235}U	1	RI	271	act	Fission
	161	RI	275 ± 16		Fission. Co std
	167	RI	278 ± 9		Fission. Cd and B filters
	164	RI	274 ± 11		Fission
	145	RI	292 ± 14		Fission. Analysis of ^{137}Cs
	163	RI	280 ± 11	eval	Fission
	168	RI	275 ± 4		Fission. Pulsed n source
	44	RI	270 ± 10	rec	Fission
	11	RI	263 ± 12		Fission. Cd ratio, tot fiss prod gammas
	141	RI	265 ± 8		Fission. Au (1535). Cd ratio, fiss counter detect
	141	RI	269 ± 8		Fission. Au (1535). Cd ratio, tot fiss prod gammas
	141	RI	291 ± 14		Fission. In std Cd ratio, tot fiss prod gammas

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{235}U (cont.)	71	RI	280		rec	Fission
	175	RI	300	± 50	rec	Fission
	175	RI	450	± 100	rec	Absorption
	71	RI	420		rec	Absorption
	161	RI	136	± 8	act	Capture. Co std
	169	RI	143	± 7	mass spec	Capture
	163	RI	140	± 8	eval	Capture
	145	RI	150	± 6	mass spec	Capture
	168	RI	140	± 5		Capture. Pulsed n source
	71	RI	140		rec	Capture
	175	RI	150	± 50	rec	Capture
^{236}U	170	RI	417	± 25	act	Capture
	171	RI	350	± 25	calc	Capture
	172	RI	397	± 34	act	Capture
	71	RI	320		rec	
	44	RI	415		eval	
	173	RI	419	± 25		Capture. Au (1550)
^{238}U	36	I	285	± 25	pile osc	Absorption. RI = 286
	6	RI	267	± 5	act	Absorption
	44	I	269		rec	Absorption. RI = 270
	11	I	280	± 10	act	Absorption. RI = 281

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{238}U (cont.)	1	RI	281		act	Absorption
	71	RI	278		rec	
	175	RI	280	± 15	rec	Capture
	176	RI	279	± 20	t of f	Capture

RECOMMENDED VALUES RI = 320 FOR ^{232}U FISSION
RI = 220 FOR ^{232}U CAPTURE
RI = 540 FOR ^{232}U ABSORPTION

RI = 790 FOR ^{233}U FISSION
RI = 140 FOR ^{233}U CAPTURE
RI = 930 FOR ^{233}U ABSORPTION

RI = 675 FOR ^{234}U ABSORPTION

RI = 275 FOR ^{235}U FISSION
RI = 140 FOR ^{235}U CAPTURE
RI = 415 FOR ^{235}U ABSORPTION

RI = 410 FOR ^{236}U CAPTURE

RI = 280 FOR ^{238}U ABSORPTION

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{237}Np	173	RI	850			Capture
	44	I	870		rec	Capture. RI = 950
	36	I	870	± 130	pile osc	Capture. Au (1510). RI = 950
	44	I	6		rec	Fission. RI = 6
^{238}Np	44	I	510		rec	Fission. RI = 1 500
	173	RI	1 500	± 500		Fission
	44	I	10		rec	Capture. RI = 12

RECOMMENDED VALUES RI = 920 FOR ^{237}Np CAPTURE
RI = 1 500 FOR ^{238}Np FISSION

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{238}Pu	166	RI	25	rec	Fission. Measured
	44	I	16.7	eval	Fission. RI = 23.9
	189	RI	26 ± 5	act	Fission
	177	RI	164 ± 15	t of f	Absorption
	44	RI	164	eval	Absorption
	173	RI	169	eval	Absorption
	166	RL	150	rec	Capture
	178	RI	3420	act	Absorption
^{239}Pu	167	RI	301 ± 10		Fission. Cd and B filters
	179	RI	327 ± 22		fission, Cd ratio, tot fiss prod gammas
	141	RI	289 ± 9		Fission. Au (1535). Cd ratio, fiss count detect
	164	RI	330 ± 30		Fission
	146	RI	310 ± 20	rec	Fission
	163	RI	301	eval	Fission
	44	RI	300 ± 10	eval	Fission
	180	RI	366 ± 26		Fission
	181 7	RI	300 ± 10		Fission
	141	RI	360 ± 18		Fission. In std Cd ratio, tot fiss prod gammas
	71	RI	288	rec	Fission
	190	RI	230 ± 5	t of f	Fission. E_c = 1 eV. Not evaluated for lower cutoff

Isotope	Ref.	Symbol	Value (b)		Method	Comments
^{239}Pu (cont.)	71	RI	472		rec	Absorption
	71	RI	134		rec	Capture
	190	RI	188	± 17	t of f	Capture. E_c = 1 eV
^{240}Pu	44	RI	8220		rec	Absorption
	36	I	11 300	± 1 000	pile osc	Absorption. RI = 11 500
	182	RI	10 000	± 2 800	pile osc	Absorption
	74	I	8 780	± 550	act	Absorption. RI = 8850
	183	RI	8 607	± 700	react	Absorption
	184	RI	11 000	± 4 000	react	Absorption
	185	I	8 270	± 500	react	Absorption. Au (1513) RI = 8420
	186	RI	9 000	± 3 000	act	Absorption
	187	RI	8 850	± 800	act	Activation
	71	RI	8 280		rec	Absorption
	175	RI	9 000	± 1 500	rec	Capture
	166	RI	8 000		rec	Capture
	192	RI	8 650		abs	Absorption
^{241}Pu	179	RI	581	± 33		Fission. Au (1555). Cd ratio, tot fiss prod gammas
	141	RI	532	± 16		Fission. Au (1535). Cd ratio, tot fiss prod gammas
	71	RI	573		rec	Fission
	164	RI	550	± 40		Fission
	166	RI	545		rec	Fission

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{241}Pu (cont.)	145	RI	569 ± 37		Fission. E_c = 3.0 eV
	44	RI	580 ± 40	eval	Fission
	163	RI	617		Fission
	71	RI	712	rec	Absorption
	71	RI	139	rec	Capture
	145	RI	162 ± 8	rec	Capture. E_c = 0.2 eV
	166	RI	260	rec	Capture
^{242}Pu	178	RI	1 310	act	Absorption. Co (48.6) U-238 (282)
	188	RI	1 280 ± 60	act	Absorption. Co (75)
	71	RI	1 100	rec	Absorption
	166	RI	1 150	rec	Capture
	175	RI	1 300 ± 200	rec	Capture
	191	RI	1 055 ± 170	t *of f*	Capture
	193	RI	1 110 ± 60	t of f	Absorption

RECOMMENDED VALUES RI = 25 FOR ^{238}Pu FISSION
RI = 160 FOR ^{238}Pu ABSORPTION

RI = 310 FOR ^{239}Pu FISSION
RI = 140 FOR ^{239}Pu CAPTURE
RI = 450 FOR ^{239}Pu ABSORPTION

RI = 9 000 FOR ^{240}Pu ABSORPTION

RI = 570 FOR ^{241}Pu FISSION
RI = 140 FOR ^{241}Pu CAPTURE
RI = 710 FOR ^{241}Pu ABSORPTION

RI = 1 200 FOR ^{242}Pu ABSORPTION

Isotope	Ref.	Symbol	Value (b)			Method	Comments
^{241}Am	166	RI	8.5			rec	Fission
	194	RI	21	±	2	act	Fission
	164	RI	21	±	2	act	Fission
	65	RI	900			act	Activation. (16 hour ^{242}Am)
	166	RI	1 600			rec	Capture
	194	RI	2 100	±	200	act	Capture. ($^{242}Am^{g}$)
	194	RI	300	±	30	act	Capture. ($^{242}Am^{m}$)
^{242}Am	194	RI	<300			act	Fission
	195	RI	1 570			t of f	Fission
	196	RI	1 570	±	10	t of f	Fission
^{243}Am	178	RI	2 340	±	50	act	Absorption. Co (48.6) U-238 (282)
	166	RI	1 400			rec	Capture
	191	RI	1 480	±	135	t of f	Capture
	194	RI	2 300	±	200	act	Absorption

RECOMMENDED VALUE RI = 20 FOR ^{241}Am FISSION

Isotope	Ref.	Symbol	Value (b)			Method	Comments
^{243}Cm	199	RI	1 860	±	400	act	Fission
	197	RI	2 345	±	470	t of f	Absorption
^{244}Cm	198	RI	19	±	1	act	Fission
	199	RI	13.0	±	2.5	act	Fission
	166	RI	650			rec	Capture
	199	RI	650	±	50	act	Capture
	197	RI	550	±	40	t of f	Absorption

Isotope	Ref.	Symbol	Value (b)	Method	Comments
^{245}Cm	198	RI	900 ± 50	act	Fission
	199	RI	770 ± 150	act	Fission
	200	RI	1 140 ± 100		Fission
	201	RI	105		Capture
	199	RI	100 ± 20		Capture
	197	RI	810 ± 180	t of f	Absorption
^{246}Cm	198	RI	11.0 ± 0.5	act	Fission
	199	RI	(low)	act	Fission
	199	RI	120 ± 25	act	Capture
	201	RI	120		Capture
	204	RI	260		Absorption
^{247}Cm	198	RI	800 ± 50	act	Fission
	199	RI	950 ± 190	act	Fission
	200	RI	1 060 ± 110		Fission
	199	RI	810 ± 400	act	Capture
^{248}Cm	198	RI	13.5 ± 0.8	act	Fission
	199	RI	275 ± 75	act	Capture
	202	RI	350 ± 40	act	Capture. Mn (13.1)
^{249}Bk	204	RI	1 240		Absorption. Co (75)
^{249}Cf	198	RI	2 200 ± 70	act	Fission
	200	RI	2 940 ± 280		Fission
	204	RI	2 750		Absorption

Isotope	Ref.	Symbol	Value (b)			Method	Comments
^{250}Cf	204	RI	5 300				Capture
	205	RI	4 975				Absorption
^{251}Cf	205	RI	1 370				Fission
	204	RI	980				Capture
	205	RI	2 100				Absorption
^{252}Cf	205	RI	12				Fission
	203	RI	43.5	±	2.0		Capture
	204	RI	42				Capture
	205	RI	58				Absorption
^{253}Cf	205	RI	2 235				Fission
	205	RI	2 250				Absorption
^{254}Cf	205	RI	100				Absorption
^{254}Es	206	RI	2 300	±	90		Fission. Cf std

REFERENCES TO TABLE

[1] MACKLIN, R.L., POMERANCE, H.S., "Resonance capture integrals", 1st Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1955) 5, UN, New York (1956) 96.
[2] KLIMENTOV, V.B., GRIAZEV, V.M., J. Nucl. Energy 9 (1957) 507.
[3] BLASER, W., WYTTENBACH, A., BAERTSCHI, P., J. Inorg. Nucl. Chem. 33 (1971) 1221.
[4] VAN DER LINDEN, R., DE CORTE, F., HOSTE, J., "Resonance integrals applied to the multiple-comparator method in reactor neutron activation analysis", Nuclear Data in Science and Technology (Proc. Symp. Paris, 1973) 2, IAEA, Vienna (1973) 241;
VAN DER LINDEN, R., DE CORTE, F., VAN DEN WINKEL, P., HOSTE, J., J. Radioanal. Chem. 11 (1972) 133.
[5] SIMS, G.H.E., JUHNKE, D.G., J. Inorg. Nucl. Chem. 29 (1967) 593.
[6] STEINNESS, E., J. Inorg. Nucl. Chem. 34 (1972) 2699.
[7] ZIJP, W.L., "Nuclear data for neutron metrology", Nuclear Data in Science and Technology (Proc. Symp. Paris, 1973) 2, IAEA, Vienna (1973) 271.
[8] DAHLBERG, R., JIRLOW, K., JOHANSSON, E., J. Nucl. Energy 14 A/B (1961) 53.
[9] BEN-DAVID, G., HUEBSCHMANN, B., J. Nucl. Energy 16 A/B (1962) 291.
[10] RYVES, T.B., J. Nucl. Energy 24 (1970) 35.
[11] BAUMANN, N.P., Resonance Integrals and Self-shielding Factors for Detector Foils, Rep. DP-817 (1965).

[12] TATTERSALL, R.B., et al., J. Nucl. Energy 12 A (1960) 32.
[13] BREITENHUBER, L., HEIMEL, H., PINTER, M., Atomkernenergie 15 (1970) 83.
[14] KASHUKEEV, N.T., et al., J. Nucl. Energy 14 A/B (1961) 76.
[15] SIMS, G.H.E., JUHNKE, D.G., J. Inorg. Nucl. Chem. 31 (1969) 3721.
[16] FRENCH, R.L.D., BRADLEY, B., Nucl. Phys. 65 (1965) 225.
[17] KIM, J.I., GRYNTAKIS, E., Radiochim. Acta 17 (1972) 191.
[18] KÖHLER, W., SCHMELZ, H., Nukleonik 9 (1967) 270.
[19] SIMS, G.H.E., JUHNKE, D.G., J. Inorg. Nucl. Chem. 32 (1970) 2839.
[20] GEIGER, K.W., VAN DER ZWAN, L., Nukleonik 10 (1967) 277.
[21] KAPCHIGASHEV, S.P., POPOV, Yu.P., At. Ehnerg. 16 (1964) 256.
[22] SIMS, G.H.E., JUHNKE, D.G., J. Inorg. Nucl. Chem. 30 (1968) 349.
[23] STIEGLITZ, R.G., HOCKENBURY, R.W., BLOCK, R.C., Nucl. Phys. A163 (1970) 592.
[24] SCOVILLE, J.J., et al., Reports to the AEC Nuclear Cross-Section Advisory Group, WASH-1041 (1962) 37.
[25] CARRE, J.C., VIDAL, R., "Mesures des sections efficaces et des intégrales de résonance par la méthode d'oscillation", Nuclear Data for Reactors (Proc. Int. Conf. Paris, 1966) 1, IAEA, Vienna (1967) 479.
[26] LOUWRIER, P.W.F., ATEN, A.H.W., Jr., J. Nucl. Energy 19 A/B (1965) 267.
[27] AXTON, E.J., J. Nucl. Energy 17 A/B (1963) 125.
[28] STORY, J.S., "The resonance capture integral of manganese", Note in JAMES, M.F., STORY, J.S., *Winfrith Nuclear Data Group Notes on Topics in Nuclear Data Evaluation*, 1964-1968, AEEW-M-790 (1968).
[29] ORVINI, E., GAGGERO, G., LESCA, L., BRESESTI, A.M., BRESESTI, M., J. Inorg. Nucl. Chem. 30 (1968) 1353.
[30] BRUNE, D., JIRLOW, K., J. Nucl. Energy 17 A/B (1963) 350.
[31] HALPERIN, J., et al., Chem. Div. Ann. Prog. Rep. for Period ending June 20, 1964, ORNL-3676 (1964) 16.
[32] EASTWOOD, T.A., WERNER, R.D., Can. J. Phys. 41 (1963) 1263.
[33] JOHNSTON, F.J., HALPERIN, J., STOUGHTON, R.W., J. Nucl. Energy 11 A (1960) 95.
[34] EMERY, J.F., J. Inorg. Nucl. Chem. 27 (1965) 903.
[35] KAPCHIGASHEV, S.P., POPOV, Yu.P., At. Ehnerg. 15 (1963) 120.
[36] ROSE, H., COOPER, W.A., TATTERSALL, R.B., "The use of the pile oscillator in thermal reactor problems", 2nd Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1958) 1, UN, New York (1958) 16.
[37] RICABARRA, M.D., TURJANSKI, R., RICABARRA, G.H., Can. J. Phys. 47 (1969) 2031.
[38] CLAYTON, E., Australian AEC, Rep. AAEC/TM619 (1972).
[39] RICABARRA, M.D., TURJANSKI, R., RICABARRA, G.H., Can. J. Phys. 50 (1972) 1978.
[40] BORCHARDT, G., Rep. Jül-503-RX (1967).
[41] SOKOLOWSKI, E.K., BLADH, R., Rep. AE-351 (1969).
[42] SIMS, G.H.E., JUHNKE, D.G., J. Inorg. Nucl. Chem. 29 (1967) 2853.
[43] RICABARRA, M.D., TURJANSKI, R., RICABARRA, G.H., BIGHAM, C.B., Can. J. Phys. 46 (1968) 2473.
[44] EDER, O.J., LAMMER, M., "Influence of uncertainties in fission-product nuclear data on the interpretation of gamma-spectrometric measurements on burnt fuel elements", Nuclear Data in Science and Technology (Proc. Symp. Paris, 1973) 1, IAEA, Vienna (1973) 233.
[45] RYVES, T.B., J. Nucl. Energy 25 (1971) 129.
[46] WALKER, W.H., Rep. AECL-3037 (1969).
[47] BRADLEY, J.G., JOHNSON, W.H., Nucl. Sci. Eng. 47 (1972) 151.
[48] BEMIS, C.E., Jr., DRUSCHEL, R.E., HALPERIN, J., WOLTON, J.R., Nucl. Sci. Eng. 47 (1972) 371.
[49] RICABARRA, G.H., TURJANSKI, R., RICABARRA, M.D., "Medidas de integrales de resonancia de activación a dilución infinita con un espectrometro de rayos gamma de Ge-Li y comparación con los valores calculados", Nuclear Data for Reactors (Proc. Conf. Helsinki, 1970) 2, IAEA, Vienna (1970) 589.
[50] KAPCHIGASHEV, S.P., At. Ehnerg. 19 (1965) 294.
[51] SKOLNIK, W., FRANCIS, N.C., Trans. Am. Nucl. Soc. 2 (1959) 121.
[52] FULMER, R.H., STRICOS, D.P., RUANE, T.F., Nucl. Sci. Eng. 46 (1971) 314.
[53] RICABARRA, M.D., TURJANSKI, R., RICABARRA, G.H., Can. J. Phys. 48 (1970) 2362.
[54] HELLSTRAND, E., LUNDGREN, G., Nukleonik 4 (1962) 323.
[55] ARGONNE NATIONAL LAB., Ill., Reactor Development Program, Prog. Rep. June 1962, ANL-6580 (1962) 32.
[56] SCHWE, H., COTE, R.E., Phys. Rev. 179 (1969) 1148.
[57] HEIMEL, H., HEINDLER, M., Atomkernenergie 20 (1972) 135.
[58] CABELL, M.J., J. Inorg. Nucl. Chem. 21 (1961) 1.
[59] KÖHLER, W., SCHNEIDER, E., Nukleonik 12 (1969) 197.
[60] CABELL, M.J., J. Nucl. Energy 12 A (1960) 172.

[61] HALPERIN, J., et al., Chem. Div. Ann. Prog. Rep. for Period ending May 20, 1965, ORNL-3822 (1965) 4.
[62] LANTZ, P.M., Chem. Div. Ann. Prog. Rep. for Period ending June 20, 1964, ORNL-3679 (1964) 10.
[63] HALPERIN, J., DRUSCHEL, R.E., Chem. Div. Ann. Prog. Rep. for Period ending June 20, 1964, ORNL-3679 (1964) 15.
[64] WERNER, R.D., EASTWOOD, T.A., Nucl. Sci. Eng. 21 (1965) 20.
[65] SCOVILLE, J.J., FAST, E., Reports to the AEC Nuclear Cross-Section Advisory Group, WASH-1053 (1964) 78.
[66] WALKER, W.H., COPLEY, L.A., Can. J. Phys. 44 (1966) 1985.
[67] VIDAL, R., Mesure des intégrales de résonance d'absorption, Rep. CEA-R-2486 (1964).
[68] MARKOVIC, V., KOCIC, A., Bull. Boris Kidric Inst. Nucl. Sci. 18 (1967) 11.
[69] LUX, F., KÖHLER, W., Prog. Rep. Nucl. Data Res., Euratom, July 1, 1963 - Dec. 31, 1964, EANDC(E) 57 "V" (1965) 28.
[70] BRESESTI, A.M., BRESESTI, M., NEUMANN, H., J. Inorg. Nucl. Chem. 29 (1967) 2477.
[71] DRAKE, M. K., Nucleonics 24 8 (1966) 108.
[72] PEARLSTEIN, S., Nucl. Sci. Eng. 26 (1966) 281.
[73] BECKURTS, K.H., BROSE, M., KNOCHE, M., KRÜGER, G., PÖNITZ, W., SCHMIDT, H., Nucl. Sci. Eng. 17 (1963) 329.
[74] WALKER, W.H., WESTCOTT, C.H., ALEXANDER, T.K., Can. J. Phys. 38 (1960) 57.
[75] MAXIA, V., ORVINI, E., ROLLIER, M., Nucl. Sci. Eng. 35 (1969) 88.
[76] BRESESTI, M., BRESESTI, A.M., NEUMANN, H., ORVINI, E., J. Inorg. Nucl. Chem. 26 (1964) 1625.
[77] ROY, J.C., WUSCHKE, D., Can. J. Chem. 36 (1958) 1424.
[78] HALPERIN, J., DRUSCHEL, R.E., Chem. Div. Ann. Prog. Rep. for Period ending June 20, 1963, ORNL-3488 (1963) 15.
[79] BRUNE, D., Radiochim. Acta 12 (1969) 119.
[80] BROWN, F., CAMPION, P.J., OLIVER, B.H., J. Nucl. Energy 13 A (1961) 141.
[81] BAERG, A.P., BARTHOLOMEW, R.M., Can. J. Chem. 38 (1960) 2528.
[82] BAERG, A.P., BROWN, F., LOUNSBURY, M., Can. J. Phys. 36 (1958) 863.
[83] KONKS, V.A., POPOV, Yu.P., SHAPIRO, F.L., J. Exp. Theor. Phys. 46 (1964) 80.
[84] SCHWE, H., COTE, R.E., PRESTWICH, W.V., Phys. Rev. 159 (1967) 1050.
[85] ALSTAD, J., JAHNSEN, T., PAPPAS, A.C., J. Inorg. Nucl. Chem. 29 (1967) 2155.
[86] LANTZ, P.M., BALDOCK, C.R., IDON, L.E., Nucl. Sci. Eng. 20 (1964) 302.
[87] LANTZ, P., Nucl. Sci. Eng. 13 (1962) 289.
[88] ROY, J.C., ROY, L.P., Can. J. Phys. 37 (1959) 907.
[89] SCOVILLE, J.J., ROGER, J.R., Trans. Am. Nucl. Soc. 8 (1965) 290.
[90] RUIZ, C.P., PETERSON, S.P., Jr., RIDER, B.F., Trans. Am. Nucl. Soc. 7 (1964) 270.
[91] CABELL, M.J., J. Inorg. Nucl. Chem. 32 (1970) 3433.
[92] SCHUMAN, R.P., BERRETH, J.R., Nucl. Sci. Eng. 12 (1962) 519.
[93] KIRUAC, G.J., EILAND, H.M., CONRAD, C.A., SLOVACEK, R.E., SEEMANN, K.W., Nucl. Sci. Eng. 52 (1973) 310.
[94] CODDING, J.E., Jr., TROMP, R.L., SIMPSON, F.B., Nucl. Sci. Eng. 43 (1971) 58.
[95] FENNER, N.C., LARGE, R.S., J. Inorg. Nucl. Chem. 29 (1967) 2147.
[96] AITKIN, K.L., CORNISH, F.W., J. Inorg. Nucl. Chem. 17 (1961) 6.
[97] HALPERIN, J., DRUSCHEL, R.E., BALDOCK, C.R., Trans. Am. Nucl. Soc. 5 (1962) 376.
[98] RAHN, F., et al., Nucl. Sci. Eng. 48 (1972) 219.
[99] WALKER, W.H., GREEN, R.E., Can. J. Phys. 39 (1961) 1184.
[100] CABELL, M., J. Inorg. Nucl. Chem. 24 (1962) 749.
[101] GIBELLO, A., ORESTANO, F.V., PISTELLA, F., SANTANDREA, E., Nucl. Sci. Eng. 40 (1970) 51.
[102] SIMS, G.H.E., JUHNKE, D.G., J. Inorg. Nucl. Chem. 29 (1967) 2671.
[103] EILAND, H.M., WEINSTEIN, S., SEEMANN, K.W., "Neutron cross sections and strength functions of Sm-147 and Sm-150", Neutron Cross Sections and Technology (Proc. 3rd Conf. Knoxville, 1971) 2, CONF-710301 (1971) 673.
[104] MUGHABGHAB, S.F., CHRIEN, R.E., Phys. Rev. 180 (1969) 1131.
[105] LANTZ, P.M., BALDOCK, C.R., IDOM, L.E., Chem. Div. Ann. Prog. Rep. for Period ending May 20, 1965, ORNL-3832 (1965) 7.
[106] SCOVILLE, J.J., FAST, E., ROGERS, J.W., Nucl. Sci. Eng. 25 (1966) 12.
[107] DOBROZEMSKY, R., PICHLMAYER, F., VIEHBÖCK, F.P., Massenspektrometrische Bestimmung der Neutroneneinfangsquerschnitte von Isotopen der seltenen Erden, Rep. SGAE-PH-104/1971, Reaktorzentrum Seibersdorf, Austria (1971).
[108] OFFICE OF ATOMIC ENERGY FOR PEACE, Bangkok, Certain Accounts on the Utilization of the THAI Research Reactor, Bangkok Conf. Rep. THAI-AEC-10 (1967).

[109] MUGHABGHAB, S.F., CHRIEN, R.E., Phys. Rev. 174 (1968) 1400.
[110] NILSSON, R., Nucl. Phys. 29 (1962) 66.
[111] PATTENDEN, N.J., Nucl. Sci. Eng. 17 (1963) 371.
[112] SPIVAK, P.E., et al., "Measurements of the resonance absorption integrals for various materials and ν_{eff} – the multiplication coefficient of resonance neutrons for fissionable isotopes", 1st Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1955) 5, UN, New York (1956) 91.
[113] ROGERS, J.W., SCOVILLE, J.J., Nucl. Sci. Eng. 33 (1968) 350.
[114] DEMMELER, M., et al., Atomwirtsch. 16 (1971) 532.
[115] LATEK, S., TOPA, J., Nukleonika 13 (1968) 881.
[116] LESAGE, L., SHER, R., "Measurement of infinite dilution capture resonance integrals with a Moxon-Rae detector", Reactor Physics in the Resonance and Thermal Regions (Proc. ANS Natl. Top. Meet. San Diego, Calif., 1966) 2, MIT Press, Cambridge, Mass., and London (1966) 175.
[117] ARGONNE NATIONAL LAB., Ill., Reactor Development Program, Prog. Rep. June 1962, ANL-6580 (1962) 32.
[118] FAST, E., SCOVILLE, J.J., MTR-ETR Technical Branches Quarterly Rep., Jan. 1 - Mar. 31, 1962, IDO-16781 (1962) 2.
[119] JOANOU, G., STEVENS, C., Neutron Cross Section for the W Isotopes, General Atomic Rep. GA-5885 (1964).
[120] PIERCE, C.R., SHOOK, D.F., Nucl. Sci. Eng. 31 (1968) 431.
[121] BELLER, L., LATHAM, D., OTTER, J., Measurements of the Resonance Integral in ^{186}W, North American Aviation, Inc., Rep. NAA-SR-12500 (1967).
[122] GILETTE, J., Review of the Radioisotope Program, Rep. ORNL-4013 (1965).
[123] FRIESENHAHN, S.J., GIBBS, D.A., HADDAD, E., FRÖHNER, F.H., LOPEZ, W.M., J. Nucl. Energy 22 (1968) 191.
[124] SHER, R., LESAGE, L., CONNOLLY, T.J., BROWN, H.L., Proc. Am. Nucl. Soc. 9 (1966) 248.
[125] SHOOK, D.F., PIERCE, C.R., Proc. Am. Nucl. Soc. 10 (1967) 261.
[126] KIM, J.I., ADAMS, F., Radiochim. Acta 8 (1967) 165.
[127] HALPERIN, J., OLIVER, J.H., Chem. Div. Ann. Prog. Rep. for Period ending June 20, 1962, ORNL-3320 (1962) 2.
[128] ATTREE, R.W., et al., Can. J. Phys. 40 (1962) 194.
[129] COTE, R.E., DIAMOND, H., GINDLER, J.E., SCHWE, H., Phys. Rev. 176 (1968) 1421.
[130] FOELL, W.K., CONOLLY, J., Nucl. Sci. Eng. 21 (1965) 406.
[131] HARDY, J., Nucl. Sci. Eng. 22 (1965) 121.
[132] BHAT, M.R., CHRIEN, R.E., Phys. Rev. 155 (1967) 1362.
[133] BROSE, M., Nucl. Sci. Eng. 19 (1964) 244.
[134] ASGHAR, M., et al., Nucl. Phys. 76 (1966) 196.
[135] JOHNSTON, F.J., HALPERIN, J., STOUGHTON, R.W., J. Nucl. Energy 11 A (1960) 95.
[136] TIREN, L.I., JENKINS, J.M., Resonance Shielding in Thorium-Graphite Mixtures, Rep. AEEW-R-163 (1962).
[137] EASTWOOD, T.A., WERNER, R.D., Can. J. Phys. 38 (1960) 751.
[138] HALPERIN, J., et al., Chem. Div. Ann. Prog. Rep. for Period ending June 20, 1962, ORNL-3320 (1962) 1.
[139] HALPERIN, J., BALDOCK, C.R., OLIVER, J.H., Nucl. Sci. Eng. 21 (1965) 257.
[140] HALPERIN, J., et al., Nucl. Sci. Eng. 16 (1963) 245.
[141] BIGHAM, C.B., Fission Resonance Integrals of U-233, U-235, Pu-239, and Pu-241, Chalk River Rep. AECL-1910 (1964).
[142] HARDY, J., Nucl. Sci. Eng. 22 (1965) 121.
[143] ESCH, L.J., FEINER, F., Trans. Am. Nucl. Soc. 7 (1964) 272.
[144] YASUNO, T., J. Nucl. Sci. Technol. 2 (1965) 532.
[145] EILAND, H.M., ESCH, L.J., FEINER, F., MEWHERTER, J.L., Nucl. Sci. Eng. 44 (1971) 180.
[146] FEINER, F., ESCH, L.J., "Survey of capture and fission integrals of fissile materials", Reactor Physics in the Resonance and Thermal Regions (Proc. ANS Natl. Top. Meet. San Diego, Calif., 1966) 2, MIT Press, Cambridge, Mass., and London (1966) 299.
[147] BAUMANN, N.P., Reports to the AEC Nuclear Cross-Section Advisory Group, WASH-1046 (1964) 49.
[148] RYVES, T.B., HUNT, J.B., GOODIER, I.W., J. Nucl. Energy 22 (1968) 465.
[149] KONDUROV, I.A., EGOROV, A.I., KAMINKER, M., KOROTKIKH, E.M., NIKITIN, A.M., At. Ehnerg. 24 (1968) 533.
[150] HOGG, C., WEBER, L., YATES, E., Phillips Petr., USA, Rep. IDO-16744 (1962).
[151] ANDERSSON, L.L., Health Phys. 10 (1964) 315.
[152] KOCIC, A., MARKOVIC, V., Bull. Boris Kidric Inst. Nucl. Sci. 19 (1968) 13.

[153] BRESESTI, M., CAPPELLANI, F., DEL TURCO, A.M., NEUMANN, H., J. Inorg. Nucl. Chem. 27 (1965) 1175.
[154] O'BRIEN, H.A., Jr., ELDRIDGE, J.S., DRUSCHEL, R.E., HALPERIN, J., J. Inorg. Nucl. Chem. 29 (1967) 584.
[155] STOKES, G.E., SCHUMAN, R.P., SIMPSON, O.D., Nucl. Sci. Eng. 33 (1968) 16.
[156] JOHANSSON, E., Diss. Chalmers Tekn. Högskola, Göteborg (1966).
[157] KONKS, V.A., SHAPIRO, F.L., Sov. Phys. – JETP 20 (1965) 531.
[158] KALEBIN, S.M., et al., Sov. J. At. Energy 26 (1969) 588.
[159] CONNOR, J.C., BAYARD, R.T., MACDONALD, D., GUNST, S.B., Nucl. Sci. Eng. 29 (1967) 408.
[160] SIMPSON, F.B., CODDING, J.W., Jr., Nucl. Sci. Eng. 28 (1967) 133.
[161] CONWAY, D.E., GUNST, S.B., Nucl. Sci. Eng. 29 (1967) 1.
[162] CAO, M.G., MIGNECO, E., THEOBALD, J.P., MERLA, M., "Fission-cross-section measurement of ^{233}U", Nuclear Data for Reactors (Proc. Conf. Helsinki, 1970) 1, IAEA, Vienna (1970) 419.
[163] HENNIES, H.H., "Cross-sections and resonance parameters for ^{235}U, ^{233}U, ^{239}Pu and ^{241}Pu between cadmium cutoff and 10 keV", Nuclear Data for Reactors (Proc. Conf. Paris, 1966) 2, IAEA, Vienna (1967) 333.
[164] BAK, M.A., et al., Sov. J. At. Energy 28 (1970) 460.
[165] KONAKHOVICH, Yu. Ya., PEVZNER, M.I., Sov. J. At. Energy 8 (1961) 39.
[166] PEARLSTEIN, S., Cross Sections for Transuranium Element Production, Rep. BNL-982 (1966) 22.
[167] HELLSTRAND, E., Studies of the Fission Integrals of U235 and Pu239 with Cadmium and Boron Filters, Rep. AE-181 (1965).
[168] DE SAUSSURE, G., et al., "Measurement of the neutron capture and fission cross-sections and of their ratio alpha for ^{233}U, ^{235}U and ^{239}Pu", Nuclear Data for Reactors (Proc. Conf. Paris, 1966) 2, IAEA, Vienna (1967) 233.
[169] DURHAM, R.W., et al., "Ratio of capture to fission in ^{235}U and ^{239}Pu", Nuclear Data for Reactors (Proc. Conf. Paris, 1966) 2, IAEA, Vienna (1967) 17.
[170] BAUMANN, N.P., HALFORD, J.D., PELLARIN, D.J., Nucl. Sci. Eng. 32 (1969) 265.
[171] CARLSON, A.D., FRIESENHAHN, S.J., LOPEZ, W.M., FRICKE, M.P., Nucl. Phys. A141 (1970) 577.
[172] CABELL, M.J., EASTWOOD, T.A., CAMPION, P.J., J. Nucl. Energy 7 (1958) 81.
[173] HENELLY, E.J., CORNMAN, W.R., BAUMANN, N.P., "Pu238 production predictions from available neutron cross sections", Neutron Cross Section and Technology (Proc. Conf. Washington, 1968) 2 (GOLDBERG, D.T., Ed.) (1968) 1271.
[174] ALEKSANDROV, B.M., BAK, M.A., KRIVOKHATSKIJ, A.S., SHIYAMIN, E.A., Sov. J. At. Energy 32 (1972) 203.
[175] STOUGHTON, R.W., HALPERIN, J., Nucl. Sci. Eng. 6 (1959) 100.
[176] BOLLINGER, L.M., COTE, R.E., DAHLBERG, D.A., THOMAS, G.E., Phys. Rev. 105 (1957) 661.
[177] YOUNG, T.E., SIMPSON, F.B., BERRETH, J.R., Nucl. Sci. Eng. 30 (1967) 355.
[178] BUTLER, J.P., LOUNSBURY, M., MERRITT, J.J., Can. J. Phys. 35 (1957) 147.
[179] HARDY, J., Jr., KLEIN, D., SMITH, G.G., Nucl. Sci. Eng. 9 (1961) 341.
[180] YASUNO, T.J., Nucl. Sci. Technol. 4 (1967) 43.
[181] HANNA, G.C., WESTCOTT, C.H., LEMMEL, H.D., LEONARD, B.R., Jr., STORY, J.S., ATTREE, P.M., At. Energy Rev. 7 (1969) 3.
[182] KRUPCHINSKY, P.A., J. Nucl. Energy 6 (1957) 155.
[183] NICHOLS, W.H., Nucl. Sci. Eng. 17 (1963) 144.
[184] SPIVAK, P.E., et al., in Record of Proceedings of Session 20A, 1st Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1955) 5, UN, New York (1956) 172.
[185] TATTERSALL, R.B., Thermal Cross-section and Resonance Absorption Integral of Pu^{240}, Rep. AEEW-R115 (1962).
[186] EROZOLYMSKY, B.G., et al., J. Nucl. Energy 4 (1957) 86.
[187] CORNISH, F.W., LOUNSBURY, M., Cross Section of Pu^{239} and Pu^{240} in the Thermal and Epicadmium Region, Rep. CRC-633 (1956).
[188] HALPERIN, J., OLIVER, J.H., Chem. Div. Ann. Prog. Rep. for Period ending June 20, 1964, ORNL-3679 (1964) 13.
[189] EASTWOOD, T.A., et al., "Radiochemical methods applied to the determination of cross sections of reactor interest", 2nd Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1958) 16, UN, Geneva (1958) 54.
[190] BOLLINGER, L.M., COTE, R.E., THOMAS, G.E., "The slow neutron cross sections of plutonium-239", 2nd Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1958) 15, UN, Geneva (1958) 127.

[191] COTE, R.E., BOLLINGER, L.M., BARNES, R.F., DIAMOND, H., "Slow neutron cross sections of Pu^{240}, Pu^{242} and Am^{243}", 2nd Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1958) 16, UN, Geneva (1958) 77.
[192] LEONARD, B.R., Jr., SEPPI, E.J., FRIESEN, W.J., Nucl. Sci. Eng. 5 (1959) 32.
[193] YOUNG, T.E., REEDER, S.D., Nucl. Sci. Eng. 40 (1970) 389.
[194] BAK, M.A., et al., Sov. J. At. Energy 23 (1967) 1059.
[195] BOWMAN, C.D., AUCHAMPAUGH, G.F., FULTZ, S.C., HOFF, R.W., Phys. Rev. 166 (1968) 1219.
[196] PERKINS, S.T., AUCHAMPAUGH, G.F., HOFF, R.W., BOWMAN, C.D., Nucl. Sci. Eng. 32 (1968) 131.
[197] BERRETH, J.R., SIMPSON, F.B., RUSCHKE, B.C., Nucl. Sci. Eng. 49 (1972) 203.
[198] BENJAMIN, R.W., MACMURDO, K.W., SPENCER, J.D., Nucl. Sci. Eng. 47 (1972) 203.
[199] THOMPSON, M.C., HYDER, M.L., REULAND, R.J., J. Inorg. Nucl. Chem. 33 (1971) 1553.
[200] HALPERIN, J., OLIVER, J.H., STOUGHTON, R.W., Chem. Div. Ann. Prog. Rep. 1970, ORNL-4581 (1971) 28.
[201] HALPERIN, J., DRUSCHEL, R.E., EBY, R.E., USAEC Rep. ORNL-4437 (1969).
[202] CHETHAM-STRODE, A., Chem. Div. Ann. Prog. Rep. for Period ending May 20, 1965, ORNL-3832 (1965) 1.
[203] HALPERIN, J., BEMIS, C.E., DRUSCHEL, R.E., STOKELY, J.R., Nucl. Sci. Eng. 37 (1969) 228.
[204] FOLGER, R.L., SMITH, J.A., BROWN, L.C., OVERMAN, R.F., HOLCOMB, H.P., Foil Measurements of Integral Cross Sections of Higher Mass Actinides, Rep. DP-MS-67-112 (1968).
[205] RUSCHE, B.C., Trans. Am. Nucl. Soc. 14 (1971) 344.
[206] MACMURDO, K.W., HARBOUR, R.M., J. Inorg. Nucl. Chem. 34 (1972) 449.

TABLES AND GRAPHS OF CROSS-SECTIONS FOR (n, p), (n,α) and (n, 2n) REACTIONS IN THE NEUTRON ENERGY REGION 1 - 37 MeV

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Part 1

TABLES OF CROSS-SECTIONS

(Range: 13.9 - 15.1 MeV)

ABSTRACT. The tables of recommended cross-sections are intended mainly to be of practical use in activation analysis and also in nuclear chemical research or systematic nuclear physical analysis. Therefore the compilation is not extended to the reaction types (n, d), (n, γ), (n, τ) and (n, t), which are usually of minor practical interest. The literature before 1 March 1972 has been considered. The recommended values were deduced from the data by preferentially using series of newer publications. The mean values are characterized by typical errors; it was not possible to calculate weighted mean values because the information given in the literature is sometimes too incomplete to be treated consistently. Occasionally the well-known semiempirical formulae were applied. In some cases no recommendation could be given because of lack of a sufficient number of reliable measurements. The interval of the excitation functions is divided into three groups: 13.9 - 14.29 MeV, 14.3 - 14.69 MeV and 14.7 - 15.09 MeV neutron energy. Usually one recommended value for each interval is given. Special attention should be paid to the original literature because in several cases the main sources of errors are the use of different standard values of cross-sections and the incomplete knowledge of the decay scheme of the radioactive isotope considered.

INTRODUCTION

The following tables are the result of a compilation of all data on cross-sections of neutron-induced reactions of the types (n, p), (n,α) and (n, 2n) in the neutron energy range from 13.9 to 15.1 MeV that were available to us in the literature. The tables are restricted to reactions leading to α-, β- or γ-active residual nuclei with experimentally manageable half-lives so that activation techniques can be used.

From this pool of data, mean values were deduced for each reaction as far as possible, taking into account considerations as mentioned below. These mean values are recommended for further applications, e.g. in nuclear chemical research or in systematic nuclear physical analyses, as they were calculated repeatedly for all three reaction types [1-6]. However, these recommended data are intended mainly to be of practical use in activation analysis. Therefore, this compilation was not extended to the reaction types (n, d), (n, γ), (n, τ) and (n, t)[1] that are usually of minor practical interest. As regards (n, t) reactions, the reader is referred to an article by Qaim et al. [7].

[1] (n, τ) = (n, ^{3}He); (n, t) = (n, ^{3}H).

Procedure of recommendation

This compilation includes experimental cross-section data available in the literature up to 1 March 1972. Of great help for the preparation of it was an older compilation [8] and the CINDA report of literature on neutron data [9].

The original papers often contain no complete information on the details of the experiments and the evaluation of the measured quantities. Especially the comments on the half-lives or the nuclear level schemes and branching ratios or the isotopic abundances used, on the method of neutron flux measurement and the behaviour of the neutron flux as a function of time, and on the determination of the counting efficiencies are sometimes incomplete. Therefore the available data cannot be treated consistently and also cannot be brought to a comparable state, so that a part of them may contain systematic errors.

Furthermore the errors, if there are any given, often are not specified as to their meaning (statistical or maximum error, standard deviation, etc.). Thus it is not possible to perform the calculation of a weighted mean value in a clear-cut way using, e.g., the reciprocal square of the errors, as has been done for (n, 2n) reactions only [10, 11].

Therefore we have tried to deduce recommended values from the available data by preferentially using series of newer publications, especially those which contain a greater number of cross-sections that were measured for different target nuclei with similar methods, and other publications that present extraordinarily thorough measurements. The accuracy of these mean values is characterized by typical errors (standard deviations). Measured cross-sections showing large deviations from the majority of the other results on the same reaction were not taken into consideration. Occasionally the well-known semiempirical formulae [1, 2, 12] were applied so as to get information on the general trend of the cross-section values.

In some cases no value could be recommended, either because of lack of reliable measurements or because only a very small number of contradicting results was available. These cases are marked in the tables with a dagger (†).

The recommendations are given for neutron energies from 13.9 to 15.1 MeV. In this interval the excitation functions of some of the reactions change rapidly. The typical neutron energy spread is about ± 200 keV. Therefore it seemed to be reasonable to divide the published data into three groups according to the incident neutron energy. These groups correspond to the energy intervals 13.9 - 14.29 MeV, 14.3 - 14.69 MeV and 14.7 - 15.09 MeV, respectively. For many reactions recommended values are given only for two or one of these intervals. If an excitation function of the reaction is available (see Part 2), the missing value should be interpolated.

Structure and notation of the tables

For each type of reaction – (n, p), (n, α) and (n, 2n) – a table is given (Tables I, II and III). The reactions are arranged according to increasing atomic number Z of the target and, within one element, according to increasing mass number A. The following items are given:

Column 1: Nuclear reaction. If not otherwise specified, the total cross-section of the reaction (σ^{tot}) is presented. The additional symbol m in the nuclear reaction scheme indicates that the cross-section σ^m for that part of the reaction leading to the residual nucleus in a metastable state is given. The symbol g instead of m in the reaction scheme characterizes the part of the reaction leading to the formation of the residual nucleus in the ground-state prior to further decay (σ^g). In this case the metastable state is not involved.

If the metastable state of a residual nucleus decays totally, with an isomeric transition to the ground-state and if, furthermore, for the half-lives the relation $T^g_{\frac{1}{2}} \gg T^m_{\frac{1}{2}}$ is valid, the total cross-section σ^{tot} can be measured by observing the cumulative decay of the ground-state (σ^{g*}) occurring with the half-life $T^g_{\frac{1}{2}}$. This case is characterized by the symbols $^gR^*$ at the residual nucleus named R. Figure 1 illustrates the symbolism.

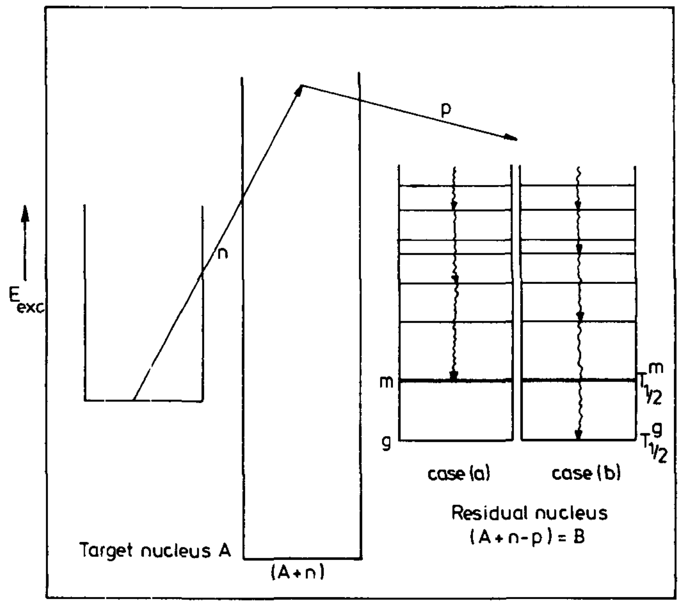


FIG. 1. Reaction A(n, p)B with metastable state in the residual nucleus. The event in case (a) contributes to the cross-section σ^m, in case (b) to σ^g. $\sigma^{tot} = \sigma^m + \sigma^g$. If $T^g_{1/2} \gg T^m_{1/2}$ and if the metastable state m decays in an isomeric transition with 100% to the ground-state, then σ^{g*}, the cross-section corresponding to the cumulative decay with half-life $T^g_{1/2}$, is equal to $\sigma^m + \sigma^g$.

In those cases where no value could be recommended the symbol † is added. The symbol ⊕ indicates that there are, according to the tables of Lederer et al. [13] that have been used here, uncertainties in the decay scheme of the reaction or that special attention should be paid to the scheme.

Column 2: Isotopic abundance (in per cent) of the target nucleus in atomic abundance. The values listed are taken from Ref. [14]. Uncertainties are characterized by the symbol #.

Column 3: Half-life ($T_{\frac{1}{2}}$) of the residual nucleus. These data are taken from Ref. [14] if not otherwise indicated.

Columns 4-6: Cross-sections (in mb) for the energy intervals 14.1 ± 0.2 MeV, 14.5 ± 0.2 MeV, 14.9 ± 0.2 MeV, respectively. Usually one recommended value is given. Further values listed in square brackets [ ] are experimental results that show unexplainable deviations from the recommendation. If only values in square brackets are given, a recommendation is not possible and no experimental result can be preferred.

Column 7: List of reference numbers. References in square brackets [ ] are those for the corresponding values given in columns 4 - 6. References in round brackets ( ) were excluded from consideration because they show strong deviations or are improbable for physical reasons.

Table III is followed by a list of comments. The handwritten numbers throughout the table refer to this list.

REFERENCES TO INTRODUCTION

[1] PEARLSTEIN, S., Nucl. Data 3A (1967) 327.
[2] PAI, H.L., CLARKE, R.L., CROSS, W.G., Nucl. Phys. A164 (1971) 526.
[3] QAIM, S.M., Z. Naturforsch. 25a (1970) 1977.
[4] BORMANN, M., LAMMERS, B., Nucl. Phys. A130 (1969) 195.
[5] QAIM, S.M., Nucl. Phys. A185 (1972) 614.
[6] GARDNER, D.G., ROSENBAUM, S., Nucl. Phys. A96 (1967) 121.
[7] QAIM, S.M., WÖLFLE, R., STÖCKLIN, G., Chemical Nuclear Data, Measurements and Applications (Proc. Conf. Canterbury, 1971), Inst. of Civil Engineers, London (1971) 121.
[8] BROOKHAVEN NATIONAL LABORATORY, Neutron Cross Sections, Rep. BNL-325, 2nd Edn (1966).
[9] CINDA 71, An Index to the Literature on Microscopic Neutron Data, published by the IAEA on behalf of the four CINDA centres, IAEA, Vienna (1971).
[10] BÖDY, Z.T., Thesis, Kossuth University, Debrecen (1972).
[11] BÖDY, Z.T., CSIKAI, J., At. Energy Rev. 11 (1973) 153; see also BÖDY, Z.T., INDC (HUN)-10 (1973), report available from Nuclear Data Section, IAEA, Vienna.
[12] GARDNER, D.G., YU-WEN-YU, Nucl. Phys. 60 (1964) 49.
[13] LEDERER, C.M., HOLLANDER, J.M., PERLMAN, I., Table of Isotopes (6th Edn), Wiley, New York (1967).
[14] SEELMANN-EGGEBERT, W., PFENNIG, G., MÜNZEL, H., Nuklidkarte (3rd Edn), edited by Bundesministerium für Wissenschaftliche Forschung, Bonn (1968).

TABLE I. 14-MeV (n, p) CROSS-SECTIONS

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{6}Li(n,p)^{6}He$	7.42	0.8 s	8 ± 2			390; 399
					8.5 ± 2	21; 401
$^{9}Be(n,p)^{9}Li$	100	0.17 s			< 4	402; (10); (403)
$^{11}B(n,p)^{11}Be$	80.39	13.65 s	[5]			[404]
					25 ± 4	401; (159)
$^{12}C(n,p)^{12}B$	98.893	0.0203 s			1.93 ± 0.25	177
					[19 ± 4]	[405]
$^{14}N(n,p)^{14}C$	99.6337	5730 yr	77 ± 14			400; 406
$^{15}N(n,p)^{15}C$	0.3663	2.25 s			16 ± 4	351; 401
$^{16}O(n,p)^{16}N$	99.759	7.1 s	41 ± 4			41; 63; 158; 279; 409; (193)
				39 ± 4		41; 63; 279; 407; (221)
					34 ± 4	41; 63; 158; 159; 279; 351; 401; 408; 410; (193)
$^{19}F(n,p)^{19}O$	100	27 s	20 ± 2			37; 236; 406
				19 ± 6		411; (221)
					18 ± 5	159; 225; 401; 408; (236); (351)
$^{23}Na(n,p)^{23}Ne$	100	38 s	43 ± 8			236; 406; 412
				[34 ± 15]		[221]
					43 ± 5	225; 227; 236; 338; 351; 401; 408
$^{24}Mg(n,p)^{24g}Na$*	78.70	15.05 h	200 ± 20			56; 74; 105; 114; 151; 223; (293; 412)
				190 ± 19		56; 74; 114; 221; 223; (116)
					180 ± 18	56; 74; 114; 151; 223; 225; 287; 307; 413; (401)
^{24m}Na		0.020 s			138 ± 14	384
$^{25}Mg(n,p)^{25}Na$	10.13	59.6 s	49 ± 5 [63 ± 10]			41; [412]
				44 ± 5		41; 221
					40 ± 4 [59 ± 6]	41; [225; 247; 385; 401]
$^{26}Mg(n,p)^{26}Na$	11.17	1.0 s	27 ± 7			412
					[50 ± 5]	[385]

* m decays with 100% to g ($T^{g}_{1/2} \gg T^{m}_{1/2}$).

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{½}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{27}Al(n,p)^{27}Mg$	100	9.46 min	78 ± 7			9; 93; 110; 147; 196; 228; 241; 270; 295; 323; 327; 367; 412; 416; 418; (105); (164); (196)
				75 ± 8		67; 84; 93; 147; 159; 261; 388; (114); (221)
					75 ± 7	36; 147; 149; 159; 196; 214; 287; (238); (401); (408); (417)
$^{28}Si(n,p)^{28}Al$	92.21	2.3 min	250 ± 30			74; 412; (155); (163); (405)
				230 ± 30		74; 221; 261; (163)
					210 ± 20	74; 155; 225; 287; 338; 401; 408; (82); (163)
$^{29}Si(n,p)^{29}Al$	4.70	6.6 min		120 ± 20		221; 261
					147 ± 18	401; (225)
$^{30}Si(n,p)^{30m}Al$	3.09	72 s	0.18 ± 0.06			419
				< 7		261
$^{31}P(n,p)^{31}Si$	100	2.62 h	88 ± 8			110, 124; (412) (221); (414)
					83 ± 5 [52 ± 10]	128; 159; [225; 401]
$^{32}S(n,p)^{32}P$	95.0	14.3 d	225 ± 25			8; 271; 348; 412; 421; (420)
				225 ± 12 [380 ± 30]		8; [221; 422]
					212 ± 15	8; 26; 225; 271; 340; (338)
$^{34}S(n,p)^{34}P$	4.22	12.4 s	78 ± 7.5			41
				[85 ± 39]		[221]
					73 ± 7 [32 ± 8]	41; [247; 401]
$^{35}Cl(n,p)^{35}S$	75.529	88 d	107 ± 38			412
				120 ± 20		216; 423
$^{37}Cl(n,p)^{37}S$	24.471	5.1 min	25 ± 5			74, 201
				33 ± 6		74; 221
					41 ± 4	74; 338; 401; (225); (275); (408)
$^{38}Ar(n,p)^{38}Cl$	0.063	37.3 min		75 ± 20		377
					110 ± 22	148
$^{40}Ar(n,p)^{40}Cl$	99.600	1.4 min		15.7 ± 2		377
					20 ± 5	148; 379
$^{39}K(n,p)^{39}Ar$	93.10	269 yr	354 ± 45			180; 387

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{41}K(n,p)^{41}Ar$	6.88	1.83 h	50 ± 5			44; 295
				[81 ± 33]		[221]
					48 ± 10	44; 49; 401; (225); (338); (340)
$^{42}Ca(n,p)^{42}K$	0.64	12.36 h	175 ± 10			216; 295; 348
				182 ± 22		216
					180 ± 10	207; 340; (145)
$^{43}Ca(n,p)^{43}K$	0.145	22 h	97 ± 10			295; 406
				110 ± 13		216
					[501 ± 24]	[207]
$^{44}Ca(n,p)^{44}K$	2.06	22.0 min	35 ± 7			295; 348; 406
					36 ± 7	53; 145; 207; 340; (338)
$^{45}Sc(n,p)^{45}Ca$	100	165 d	55 ± 5			18; 406
				56 ± 4		18
					53 ± 6	18; 340
$^{46}Ti(n,p)^{46}Sc$	7.93	84 d	290 ± 20			38; 185; (348); (412)
				280 ± 20		81; 185
					270 ± 25	38; 185; 224; 345; 426; (238)
$^{47}Ti(n,p)^{47}Sc$	7.28	3.35 d	120 ± 20			412; (348)
				120 ± 20		81; 139
					120 ± 20	224; (238); (345)
$^{48}Ti(n,p)^{48}Sc$	73.94	44.1 h	61 ± 6			38; 114; 348; (412)
				61 ± 6		81; 114; 139; (221)
					61 ± 6	38; 114; 224; 238; 345; 401; 426; (82)
$^{49}Ti(n,p)^{49}Sc$	5.51	57.5 min	30 ± 2			348 (164)
				35 ± 4		81
					39 ± 6	224; 345; 401; (238)
$^{50}Ti(n,p)^{50}Sc$	5.34	1.7 min	[147 ± 13]			[164]
				17 ± 3		81
					24 ± 5	49; 224; 238; 345; 401; (426)
$^{51}V(n,p)^{51}Ti$	99.76	5.8 min	35 ± 5			35; 348; 412
				[27 ± 4.5]		[221]
					36 ± 3	35; 82; 345; 401; (49); (239); (338); (408)

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{52}Cr(n,p)^{52}V$	83.76	3.75 min	90 ± 13			163; 348; 412
				94 ± 10		163; 221
					96 ± 10	66; 163; 214; 338; 405; 408; (401)
$^{53}Cr(n,p)^{53}V$	9.55	2.0 min	45 ± 6			348; 412
					36 ± 6	66; 401
$^{55}Mn(n,p)^{55}Cr$	100	3.6 min	45 ± 7			348; 412; (179)
					37 ± 7	370; 401
$^{54}Fe(n,p)^{54}Mn$	5.82	303 d	350 ± 30			80; 273; 348; 417; (9); (241); (412); (428)
				310 ± 25		79; (363)
					315 ± 25	26; 254
$^{56}Fe(n,p)^{56}Mn$	91.66	2.57 h	112 ± 6			80; 110; 184; 241; 272; 291; 323; 348; 429; 430; (9); (412); (417); (431)
				103 ± 6		79; 184; 221; 272; 383
					103 ± 6	26; 36; 80; 184; 254; 272; 291; 340; 383; 432; (65); (95); (163); (405)
$^{57}Fe(n,p)^{57}Mn$	2.19	1.7 min	[55 ± 6]			[241; 348]
				75 ± 8		81
					71 ± 7	65
$^{58}Fe(n,p)^{58}Mn$	0.33	1.1 min	23 ± 4			348
					23 ± 3.5	65
$^{59}Co(n,p)^{59}Fe$	100	45 d	78 ± 10			412; 417
				80 ± 23		311
					82 ± 8	367; (340); (434)
$^{58}Ni(n,p)^{58g}Co$*	67.88	71 d	410 ± 30			41; 68; 80; 119; 348; 417; (9); (97); (251); (417)
				370 ± 40		41; 79; 119; (414)
					330 ± 30	20; 26; 41; 49; 68; 80; 119; 287; 345; 367; 433; (97)
^{58m}Co		9.15 h	218 ± 20			219
				190 ± 18		219
					160 ± 15	219; 345; (367)
$^{60}Ni(n,p)^{60g}Co$*	26.23	5.26 yr	138 ± 10			227; 348; 412; 417; (9)
				118 ± 8		227; (79)
					109 ± 8	227; 345
^{60m}Co		10.5 min			25 ± 6	401; (367)

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References	
$^{61}Ni(n,p)^{61g}Co$*	1.19	1.6 h	88 ± 3			348; 435	
				103 ± 10		79; (221)	
					98 ± 10	345; (367)	
$^{62}Ni(n,p)^{62g}Co$	3.66	13.9 min	19 ± 4			101; 435	1)
				24 ± 6		79	
					21 ± 3	345; (240)	
^{62m}Co		1.5 min	34 ± 2			435	
				[15 ± 3]		[79]	
					23 ± 4	345; (240)	
$^{64}Ni(n,p)^{64g}Co$	1.08	7.8 min	5 ± 1			435	1)
					4.1 ± 0.05	240	
^{64m}Co		2 min	2 ± 1			435	
					[0.43 ± 0.02]	[240]	
$^{63}Cu(n,p)^{63}Ni$	69.09	92 yr	118 ± 20			348; 412; 417	
$^{65}Cu(n,p)^{65}Ni$	30.91	2.56 h	24 ± 4			35; 110; 241; 274; 348; 368; 417; 437	
				21 ± 5		35; 274	
					23 ± 3	36; 49; 95; 214; 238; 274; 275; 365; 368	
$^{64}Zn(n,p)^{64}Cu$	48.89	12.8 h	200 ± 15			35; 44; 114; 312; 348; 412; 436; 437	
				185 ± 20		312; 438; (221)	
					170 ± 15	44; 114; 312; 362; 365; 401; (49); (245)	
$^{66}Zn(n,p)^{66}Cu$	27.81	5.1 min	75 ± 20			348; (412)	
				65 ± 6		261; (221)	
					70 ± 7	37; 365; 367; 401	
$^{67}Zn(n,p)^{67}Cu$	4.11	61.9 h	39 ± 6			348; 412	
				43 ± 10		365	
$^{68}Zn(n,p)^{68}Cu$	18.57	30 m	25			348	
				[8 ± 1]		[261]	
					19 ± 4	240; 401	
$^{69}Ga(n,p)^{69g}Zn$	60.4	57 min		17 ± 4		97	
					10 ± 1.5	365	
^{69m}Zn		13.9 h		21 ± 3		97	
					23.6 ± 3.0	365; (33)	

1) Association of decay to ground-state or metastable state not accurately known.

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{71}Ga(n,p)^{71g}Zn$	39.6	2.4 min		<4		440
					5.4 ± 1.2	365
^{71m}Zn		3.9 h		12 ± 4		440
					11 ± 1.5	365
$^{70}Ge(n,p)^{70}Ga$	20.52	21.1 min	110 ± 20			348
				[129 ± 65]		[221]
					[70 ± 10]	[338; 365]
$^{72}Ge(n,p)^{72}Ga$	27.43	14.10 h	32			348
				[47 ± 5]		[221; 321]
					31 ± 4	365
$^{73}Ge(n,p)^{73}Ga$	7.76	4.8 h	21			348
				26 ± 3		321; (221)
					20 ± 4	365
$^{74}Ge(n,p)^{74}Ga$	36.54	7.9 min		13.2 ± 1.3		321
					10 ± 3	365
$^{75}As(n,p)^{75g}Ge$ *	100	83 min	21 ± 3			18; 41;101; 111; 183; 219; 445
				20 ± 3		18; 219; 512; (221)
					19 ± 3	18; 41; 219; 303; (401)
^{75m}Ge		48 s	18 ± 2			1; 101; 111; 445
				16 ± 1.5		1
					14.5 ± 1.3	1
$^{74}Se(n,p)^{74}As$	0.87	17.7 d	135 ± 20			41; 145
				[108 ± 20]		[41; 363]
					134 ± 20	41; 145; 154; (303)
$^{76}Se(n,p)^{76}As$	9.02	26.4 h		56 ± 5.6		363
					56 ± 5	153; 154; 303; 364
$^{77}Se(n,p)^{77}As$	7.58	38.8 h	45			348
				35 ± 10		221; 363
					36 ± 10	303
$^{78}Se(n,p)^{78g}As$ *	23.52	1.5 h		24 ± 2.4		363
					22 ± 3	154; 364; (303)
^{78m}As		6 min		0.93 ± 0.09		364
$^{80}Se(n,p)^{80}As$	49.82	15 s			16 ± 2	208

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{79}Br(n,p)^{79m}Se$	50.537	3.9 min			10 ± 3	362
$^{81}Br(n,p)^{81g}Se$	49.463	18 min		[25 ± 6]		[286]
					7 ± 1.5	303; 362
^{81m}Se		57 min		22 ± 7		286; 512
					20 ± 5	128; 209; 303; 362
$^{80}Kr(n,p)^{80m}Br$	2.27	4.4 h		55 ± 9		175
$^{82}Kr(n,p)^{82}Br$	11.56	35.4 h		23 ± 4		175
$^{84}Kr(n,p)^{84g}Br$	56.90	32 min		8.5 ± 1.5		175
$^{85}Rb(n,p)^{85m}Kr$	72.15	4.4 h	4.3 ± 0.3			41
				4.1 ± 0.4		512
					4.7 ± 0.5	41; 149
$^{87}Rb(n,p)^{87}Kr$ †	27.85	76 min		[4.9 ± 0.5]		[512]
					[10 ± 2]	[149; 401]
$^{86}Sr(n,p)^{86g}Rb$ *	9.86	18.7 d	41 ± 4			18; 348
				42 ± 4		18; (286)
					45 ± 4	18; 340
^{86m}Rb		1.0 min			9 ± 1	149
$^{88}Sr(n,p)^{88}Rb$	82.56	17.8 min	17 ± 1.5			74; 348
				17 ± 2		74; 221; 512; (286)
					17 ± 2	74; 149; 340; (354); (401)
$^{89}Y(n,p)^{89}Sr$	100	50.5 d	23 ± 1.5			18; (293); (406)
				24 ± 1.6		18
					24 ± 2	18; 340
$^{90}Zr(n,p)^{90g}Y$ *	51.46	64.1 h	44 ± 4			18; 262; 348
				45 ± 4		18; 221; 286; 333
					46 ± 4	18; 61; (345)
^{90m}Y		3.18 h		12.9 ± 1.0		189
					11 ± 2	149; 345; 352

† No value recommended.

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{91}Zr(n,p)^{91g}Y$*	11.23	58.8 d	32 ± 2			262
				40 ± 8		348; (286)
					34 ± 7	345; (354)
^{91m}Y		50 min	17.5 ± 0.8			262
				18.6 ± 1.9		189
$^{92}Zr(n,p)^{92}Y$	17.11	3.5 h	21 ± 1			262; 348
				19 ± 2		189; 333; (286)
					21 ± 2	49; 345; 354; 401
$^{94}Zr(n,p)^{94}Y$	17.40	20 min	11 ± 2			262; 348
				8 ± 3		221; 333; (286)
					7 ± 2	49; 345; 354; 401
$^{96}Zr(n,p)^{96}Y$	2.80	2.3 min	13 ± 4			443
$^{92}Mo(n,p)^{92m}Nb$	15.84	10.2 d		62.5 ± 4.0		189; (221); (286)
					60 ± 10	49; 254
$^{94}Mo(n,p)^{94m}Nb$	9.04	6.3 min			6.0 ± 1.5	49
$^{95}Mo(n,p)^{95}Nb$	15.72	35 d			37 ± 6	254
$^{96}Mo(n,p)^{96}Nb$	16.53	23.4 h	16 ± 3			92
				21 ± 7		286
					19 ± 4	254; (49)
$^{97}Mo(n,p)^{97g}Nb$*	9.46	74 min	17.7 ± 1.5			92
				15.9 ± 1.3		189; (221; 286)
					11.7 ± 2.3	254
^{97m}Nb		1.0 min		7.4 ± 0.8		189
$^{98}Mo(n,p)^{98g}Nb$†	23.78	1.5 min			[2 ± 1]	[92] 2)
^{98m}Nb†		51 min	[6.7 ± 0.6]			[92]
				[4.1 ± 0.5]		[189]
					[13 ± 3] [2.6 ± 0.7]	[49; 92; 254; 401]
$^{99}Tc(n,p)^{99}Mo$		66.7 h	7 ± 1			122
$^{96}Ru(n,p)^{96}Tc$	5.51	4.3 d		146 ± 7		189
					170 ± 30	130

2) Decay scheme and association of measured $T_{1/2}$ to ground-state and metastable state not known.

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{99}Ru(n,p)^{99m}Tc$	12.72	6.0 h			<16 ± 4	130
$^{100}Ru(n,p)^{100}Tc$	12.62	17 s			17 ± 6	247; 401
$^{101}Ru(n,p)^{101}Tc$†	17.07	14.0 min		[2 ± 1.5]		[221]
					[36 ± 3]	[130]
$^{102}Ru(n,p)^{102}Tc$	31.61	5 s			2 ± 0.5	351; 401; (130)
$^{104}Ru(n,p)^{104}Tc$	18.58	18 min			7.2 ± 1.0	130
$^{103}Rh(n,p)^{103}Ru$	100	39.5 d		16.9 ± 1.5		189
$^{104}Pd(n,p)^{104g}Rh$	10.97	42 s			2.7 ± 8	346; (221)
^{104m}Rh		4.4 min			31 ± 6	346
$^{105}Pd(n,p)^{105g}Rh$†	22.23	35.5 h		[37.6 ± 2.0]		[189; 221]
					[50 ± 6]	[346; 401]
^{105m}Rh		45 s			23 ± 8	401
$^{106}Pd(n,p)^{106g}Rh$	27.33	30 s		16 ± 4		189
					16 ± 4	346
^{106m}Rh		2.2 h		6.0 ± 2		189
					9 ± 3	346; 401
$^{108}Pd(n,p)^{108}Rh$	26.71	17 s		8.3 ± 1.5		189
					9 ± 2	401
$^{107}Ag(n,p)^{107m}Pd$	51.35	21 s			15 ± 2	401
$^{109}Ag(n,p)^{109}Pd$	48.65	13.5 h	11 ± 2			18; 347; 348
				13 ± 2		18; 329
					15 ± 2	18; 345; (214; 401)
$^{106}Cd(n,p)^{106}Ag$	1.215	24.0 min	80 ± 20			43; 348; 446
					102 ± 16	43
$^{110}Cd(n,p)^{110}Ag$	12.39	24.4 s	27			324
					8 ± 2	401

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{111}Cd(n,p)^{111}Ag$	12.75	7.5 d	15 ± 4			324; 348; 446; [18]
			[22.5 ± 1.1]			
				[28.7 ± 1.4]		[18]
					[31 ± 1.5]	[18]
$^{112}Cd(n,p)^{112}Ag$	24,07	3.2 h	11 ± 3			324; 348; 446
				15 ± 1.3		189
$^{113}Cd(n,p)^{113}Ag$	12.26	5.3 h	8 ± 2			324; 348; 446 3)
$^{114}Cd(n,p)^{114}Ag$	28.86	5.2 s			3 ± 1.6	401
$^{116}Cd(n,p)^{116}Ag$	7.58	2.5 min	[0.2 ± 0.1]			[324]
				5.4 ± 1.5		67
$^{115}In(n,p)^{115g}Cd$	95.72	53.5 h	17 ± 3			348; (448)
				15.5 ± 4.0		329
					12.5 ± 1.5	345
^{115m}Cd		43 d		3.5 ± 0.2		187
					7.7 ± 1.2	345
$^{112}Sn(n,p)^{112g}In$	0.96	14.4 min	[35]			[447]
				13 ± 0.7		187
^{112m}In		21 min		9 ± 2		67; 187
$^{115}Sn(n,p)^{115m}In$	0.35	4.50 h		3.5 ± 0.2		187
$^{116}Sn(n,p)^{116g}In$	14.30	14 s			11 ± 4	51
^{116m}In		54.0 min		8 ± 1		187; 189; (67)
					11 ± 2	51
$^{117}Sn(n,p)^{117g}In$	7.61	38 min	9.2 ± 2.7			442
				9.8 ± 1.6		189; (187)
					13.6 ± 3	50, 134
^{117m}In		1.15 h	2.8 ± 0.8			442
				4.7 ± 1.0		187; 189
					5.1 ± 1.6	51; (134)
$^{118}Sn(n,p)^{118g}In$ ⊕	24.03	5 s			0.4 ± 0.2	51
^{118m}In ⊕		4.4 min		11 ± 2		67; 187
					[5.8 ± 0.2]	[51]

3) Association of measured $T_{1/2}$ not known.

⊕ *Checking of decay scheme is urgently recommended.*

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
^{119}Sn(n,p)^{119g}In	8.58	2.3 min		2.6 ± 0.3		187; (67)
					4.3 ± 1.5	51
^{119m}In		18 min		2.6 ± 0.3		187; (67)
					4.3 ± 1.4	51
^{120}Sn(n,p)^{120}In	32.85	44 s		4 ± 1		67; 400
					2.8 ± 1.0	239
^{121}Sb(n,p)^{121g}Sn	57.25	27 h			2.2 ± 0.4	346
^{123}Sb(n,p)^{123g}Sn	42.75	129 d			1.8 ± 0.4	346
^{123m}Sn		40 min			2.8 ± 0.9	346
^{122}Te(n,p)^{122}Sb	2.46	2.68 d			14 ± 2	346
^{124}Te(n,p)^{124g}Sb	4.61	60.3 d			9 ± 2	51; 346
^{124m}Sb		1.6 min			< 0.6	346
^{126}Te(n,p)^{126g}Sb	18.71	12.4 d			1.6 ± 0.3	346
^{126m}Sb		19 min			4.5 ± 0.6	346; (146)
^{128}Te(n,p)^{128g}Sb	31.79	9.32 h			1.3 ± 0.3	148; 346; (51)
^{128m}Sb		10 min			1.0 ± 0.2	148; 346; (51); (134)
^{130}Te(n,p)^{130g}Sb$^{\oplus}$	34.48	6 min			0.55 ± 0.18	346; (51); (134)
^{130m}Sb$^{\oplus}$		57 min			0.61 ± 0.09	346; (51)
^{127}I(n,p)^{127g}Te	100	9.4 h		11.7 ± 1.2		329; (221)
					9.8 ± 1.0 [3.8 ± 0.4]	252; [345]
^{127m}Te		109 d			5.3 ± 1	345
^{130}Xe(n,p)^{130}I	4.08	12.3 h		6.7 ± 0.8		175
^{131}Xe(n,p)^{131}I	21.18	8.05 d		5.3 ± 0.6		175
^{132}Xe(n,p)^{130}I	26.89	2.4 h		2.5 ± 0.3		175
^{134}Xe(n,p)^{134}I	10.44	52 min		2.2 ± 0.5		175
^{133}Cs(n,p)^{133g}Xe*	100	5.65 d			5.70 ± 2.35	253; (180)
^{133m}Xe		2.2 d			4.80 ± 0.75	253

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{136}Ba(n,p)^{136}Cs$	7.81	12.9 h	43 ± 10			348
				38.3 ± 3.8		329
					49 ± 10	317 (340)
$^{138}Ba(n,p)^{138}Cs$	71.66	32.3 min	2.3 ± 0.3			348
				3 ± 0.5		189; 329
					2.4 ± 0.4	317; 340
$^{139}La(n,p)^{139}Ba$	99.911	82.9 min	5 ± 1			317; 406
				5 ± 1		221; 400; (329)
					4.7 ± 0.5	132; 317; 340
$^{140}Ce(n,p)^{140}La$	88.48	40.2 h	11 ± 2			348
				9.5 ± 2.5		189; 329
					8 ± 2	132; 317
$^{142}Ce(n,p)^{142}La$	11.07	92.5 min	7 ± 2			348
				9.5 ± 0.9		329
					8 ± 2	317; 401
$^{141}Pr(n,p)^{141}Ce$	100	32.5 d		4.5 ± 1.0		400
					4.5 ± 1.0	317; (132)
$^{142}Nd(n,p)^{142}Pr$	27.11	19.2 h	13 ± 3,			348
				13.5 ± 2.7		329
$^{143}Nd(n,p)^{143}Pr$	12.17	13.6 d	11 ± 2			348
				11.5 ± 2.3		329
$^{148}Nd(n,p)^{148}Pr$	5.73	1.98 min	3.5 ± 1			348
					3.5 ± 0.8	317
$^{148}Sm(n,p)^{148g}Pm$	11.24	5.4 d	14.3 ± 2.3			336
^{148m}Pm		41.8 d	18.8 ± 4.4			336
$^{152}Sm(n,p)^{152}Pm$	26.72	6 min		3.7 ± 0.2		400
					3.7 ± 0.2	316; 317
$^{154}Sm(n,p)^{154}Pm$	22.71	1.6 min			3.5 ± 0.2	316; 317
$^{153}Eu(n,p)^{153}Sm$	52.18	46.8 h		7.4 ± 0.7		329
$^{156}Gd(n,p)^{156}Eu$	20.47	15.1 d			<15	132
$^{157}Gd(n,p)^{157}Eu$	15.68	15.1 h		11.3 ± 1.7		329

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{158}Gd(n,p)^{158}Eu$	24.87	46 min			2.6 ± 0.6	132
$^{159}Tb(n,p)^{159}Gd$	100	18.56 h	[15.8 ± 2.5]			[336]
					3.4 ± 1.5	49; 132
$^{160}Dy(n,p)^{160}Tb$	2.294	72.1 d			< 31	132
$^{163}Dy(n,p)^{163m}Tb$	24.97	7 min			3 ± 1	317
$^{165}Ho(n,p)^{165g}Dy^{\dagger}$	100	2.35 h	[40 ± 10]			[111]
$^{165m}Dy^{\dagger}$		1.3 min	< 1			111
$^{167}Er(n,p)^{167}Ho$	22.94	3.1 h			4 ± 1	317; 401
$^{168}Er(n,p)^{168}Ho$	27.07	3.3 min			2.5 ± 1.0	317
$^{170}Er(n,p)^{170}Ho$	14.88	45 s			1.8 ± 0.5	317
$^{175}Lu(n,p)^{175}Yb$	97.41	4.2 d		3.42 ± 0.52		329
$^{178}Hf(n,p)^{178g}Lu^{\oplus}$	27.1	30 min			1.72 ± 0.17	334
^{178m}Lu		20 min			1.02 ± 0.10	334
$^{181}Ta(n,p)^{181}Hf$	99.9877	42.5 d		3 ± 0.5		333; 400
$^{182}W(n,p)^{182}Ta$	26.41	115 d	2.3 ± 0.23			449
$^{183}W(n,p)^{183}Ta$	14.40	5.0 d	2.8 ± 0.3			449
$^{184}W(n,p)^{184}Ta$	30.64	8.7 h		4.8 ± 1.0		329; 333; (400)
					[14 ± 4]	[240]
$^{186}W(n,p)^{186}Ta$	28.41	10 min		2.3 ± 0.5		17; 329; 333; (240)
$^{187}Re(n,p)^{187}W$	62.93	23.8 h		3.9 ± 0.4		329
$^{188}Os(n,p)^{188}Re$	13.3	16.8 h	7.1 ± 1.9			406
				8.7 ± 1.3		216
$^{190}Os(n,p)^{190m}Re$	26.4	2.8 h	2.0 ± 0.5			406

TABLE I (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{193}Ir(n,p)^{193}Os$	62.7	31 h		2.7 ± 0.6		329
$^{194}Pt(n,p)^{194}Ir$	32.9	17.4 h		4.2 ± 0.5		135; 329
$^{195}Pt(n,p)^{195}Ir^{\oplus\dagger}$	33.8	4.2 h		[2.9 ± 0.3]		[329]
$^{196}Pt(n,p)^{196}Ir$	25.3	1.4 h	1.68 ± 0.25			450
				1.1 ± 0.2		135
$^{197}Au(n,p)^{197}Pt$	100	18 h	2.0 ± 1			18; (293)
				2.3 ± 0.2		18; 329
					2.4 ± 0.1	18
$^{198}Hg(n,p)^{198}Au$	10.02	2.70 d	4.7 ± 0.3			294
				4.5 ± 0.5		135
$^{199}Hg(n,p)^{199}Au$	16.84	3.15 d	4.6 ± 0.6			294
				2.3 ± 0.3		135
$^{200}Hg(n,p)^{200}Au$	23.13	48.4 min	< 12			294
				3.63 ± 0.36		329
$^{201}Hg(n,p)^{201}Au$	13.22	26 min	1.5 ± 0.7			294
				2.1 ± 0.3		329
$^{203}Tl(n,p)^{203}Hg$	29.50	46.9 d			[30 ± 10]	[240]
$^{205}Tl(n,p)^{205}Hg$	70.50	5.5 min		3 ± 1.6		221; (135; 329)
					3 ± 0.3	240
$^{208}Pb(n,p)^{208}Tl$	52.3	3.10 min		0.46 ± 0.06 [1 ± 1]		135; [221; 400]
$^{209}Bi(n,p)^{209}Pb$	100	3.30 h		1.3 ± 0.3		329
					0.75 ± 0.30	214; 238; 329
$^{235}U(n,p)^{235}Pa$	0.7205	24.4 min		1.86 ± 0.38		329
$^{237}Np(n,p)^{237}U$		6.75 d		1.3 ± 0.3		329
$^{238}U(n,p)^{238}Pa$	99.2739	2.3 min			1.5 ± 0.4	328

TABLE II. 14-MeV (n,α) CROSS-SECTIONS

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{9}Be(n,\alpha)^{6}He$	100	0.8 s	10 ± 1			390
$^{11}B(n,\alpha)^{8}Li$	80.39	0.84 s	≈ 30			389
					31 ± 6	13
$^{19}F(n,\alpha)^{16}N$	100	7.1 s	15 ± 5			236
					26 ± 6	159; 351
$^{23}Na(n,\alpha)^{20}F$	100	11.2 s	150 ± 20			236; 322; 344; 386
					150 ± 20	65; 322; (214)
$^{26}Mg(n,\alpha)^{23}Ne$	11.17	38 s	84 ± 10			39;
				77 ± 8		39;
					72 ± 10	39; 225; 351
$^{27}Al(n,\alpha)^{24g}Na$ *	100	15.05 h	120.5 ± 2			83; 124; 196; 309; 393; (93)
				116 ± 3		18; 56; 114; 116; 141; 196; 223; 286; 309; 321; (382);
					111 ± 4	18; 36; 56; 93; 114; 155; 196; 205; 223; 238; 276; 309; (382); (383);
^{24m}Na	100	20 ms			65 ± 6	384
$^{30}Si(n,\alpha)^{27}Mg$	3.09	9.46 min		70 ± 10		261; 361; 381; (221)
					[≈ 150]	[225 ; 338]
$^{31}P(n,\alpha)^{28}Al$	100	2.3 min	119 ± 16			35
				118 ± 15		35; 114; (232)
					115 ± 12	35; 114; (128); (159); (225)
$^{34}S(n,\alpha)^{31}Si$	4.22	2.62 h	126 ± 7			8;
				138 ± 35		221;
					163 ± 15	225; 338
$^{35}Cl(n,\alpha)^{32}P$	75.53	14.3 d	100 ± 20			348
				117 ± 15		216; 380
					122 ± 20	275
$^{37}Cl(n,\alpha)^{34}P$	24.47	12.4 s	120 ± 13			1
				112 ± 12		1
					90 ± 10	1; (275); (351)
$^{40}Ar(n,\alpha)^{37}S$	99.6	5.1 min	13 ± 1.5			289; (324)
				10 ± 1.5		376; 377
					10 ± 1.5	374; (379)

* m decays with 100% to g ($T^{g}_{1/2} > T^{m}_{1/2}$).

TABLE II (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{39}K(n,\alpha)^{36}Cl$	93.10	3.1×10^5 yr	84 ± 12			34
$^{41}K(n,\alpha)^{38}Cl$	6.88	37.3 min	46 ± 6			340
				39 ± 8		221; 232
					31 ± 5	49; 225; 338; 340
$^{44}Ca(n,\alpha)^{41}Ar$	2.06	1.83 h	35 ± 5			295
				35 ± 8		232
					35 ± 8	138; 335; (338); (341);
$^{45}Sc(n,\alpha)^{42}K$	100	12.36 h	55 ± 2.8			18
				56 ± 3		18
					54 ± 6	18; 49; 214; 340
$^{48}Ti(n,\alpha)^{45}Ca$	73.94	165 d	39 ± 6			324;
					23 ± 6	345
$^{50}Ti(n,\alpha)^{47}Ca$	5.34	4.54 d	9.4 ± 1.5			324
				9.5 ± 2		139; 375
					10 ± 2	345
$^{51}V(n,\alpha)^{48}Sc$	99.76	44.1 h	15 ± 2			71; 307
				17 ± 3		139; 307
					19 ± 4	49; 82; 345
$^{55}Mn(n,\alpha)^{52}V$	100	3.75 min	32 ± 5			37
				32 ± 5		37; 114; 232; 311
					32 ± 5	37; 370; 397; (338); (372)
$^{54}Fe(n,\alpha)^{51}Cr$	5.82	27.8 d	100 ± 20			80; 241; 273
				98 ± 15		79; 363;
					96 ± 10	80
$^{58}Fe(n,\alpha)^{55}Cr$	0.33	3.6 min			21.5 ± 2	65
$^{59}Co(n,\alpha)^{56}Mn$	100	2.57 h	30 ± 3			32; 38; 114; 184; 273; 343
				30 ± 2		184; 273; 311
					29 ± 3	114; 184; 273; 328; 340; 367
$^{58}Ni(n,\alpha)^{55}Fe$	67.88	2.6 yr	125 ± 16			392
$^{62}Ni(n,\alpha)^{59}Fe$	3.66	45 d	22 ± 3.5			324
					17 ± 4	340

TABLE II (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{64}Ni(n,\alpha)^{61}Fe$	1.08	6.1 min			5.2 ± 1.2	340
$^{63}Cu(n,\alpha)^{60g}Co$	69.09	5.26 yr	39.1 ± 2.7			227; (378)
				35.7 ± 2.5		227;
					32.7 ± 2.5	227; 369; (159); (398)
^{60m}Co		10.5 min			23 ± 3	369
$^{65}Cu(n,\alpha)^{62g}Co$	30.91	13.9 min	4.8 ± 1.4			101;
				[20 ± 10]		[356]
					10 ± 5	49; 159; (368)
^{62m}Co		1.5 min			1.9 ± 0.6	49
$^{68}Zn(n,\alpha)^{65}Ni$	18.57	2.56 h	7.6 ± 0.8			357
				9 ± 1		261; 361
					10 ± 1	365; (49); (367)
$^{70}Zn(n,\alpha)^{67}Ni$	0.62	50 s			7.8 ± 2.2	366
$^{69}Ga(n,\alpha)^{66}Cu$	60.4	5.1 min			18 ± 2	365
$^{71}Ga(n,\alpha)^{68}Cu$ †	39.6	30 s			[60 ± 4]	[351]
$^{72}Ge(n,\alpha)^{69g}Zn$	27.43	55 min			7 ± 1.5	321; 365
^{69m}Zn		13.9 h			8 ± 1.5	321, 365
$^{74}Ge(n,\alpha)^{71g}Zn$	36.54	2.4 min		[10 ± 1.5]		[154];
					[2.8 ± 0.6]	[365]
^{71m}Zn		4 h		3.32 ± 0.33		321
					3.3 ± 0.5	365
$^{75}As(n,\alpha)^{72}Ga$	100	14.1 h	12 ± 2			18; 41; 101; 250
				12 ± 2		18; 358
					11 ± 2.5	18; 41; 49; 243; 303
$^{78}Se(n,\alpha)^{75g}Ge$ †	23.52	83 min			[7 ± 1]	[303 ; 363]; (154); (364)
^{75m}Ge		48 s			7.6 ± 0.9	364
$^{80}Se(n,\alpha)^{77g}Ge$	49.82	11.3 h			6 ± 2	364; (153); (154); (303)
^{77m}Ge		54 s			6 ± 2	364
$^{79}Br(n,\alpha)^{76}As$	50.54	26.4 h	14 ± 5			35; 343
				16 ± 6		35; 358; 360
					15 ± 6	49; 128; 209; 303; 362

† No value recommended.

TABLE II (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{81}Br(n,\alpha)^{78}As$	49.46	1.5 h		[19 ± 2]		[358]
					6 ± 3	49; 128; 303; 362; (209); (363)
$^{86}Kr(n,\alpha)^{83g}Se$ ⊕	17.37	23 min		1.2 ± 0.1		175; 361
$^{85}Rb(n,\alpha)^{82}Br$	71.15 #	35.4 h	7 ± 2			41; (286)
				[4.9 ± 0.5]		[358]
					7 ± 2	41; 340
$^{87}Rb(n,\alpha)^{84g}Br$	27.85 #	31.8 min		1.8 ± 0.2		360; (358)
					2.1 ± 0.4	340
^{84m}Br		6 min			1.9 ± 0.4	340
$^{88}Sr(n,\alpha)^{85m}Kr$ †	82.56	4.4 h		[75 ± 30]		[221 ; 286]
$^{89}Y(n,\alpha)^{86g}Rb$ *	100	18.7 d	5 ± 0.5			18; (293)
				5 ± 1		18
					5.5 ± 1	18; 340; (286)
^{86m}Rb		1.0 min			0.91 ± 0.45	49
$^{90}Zr(n,\alpha)^{87m}Sr$	51.46	2.8 h	3.2 ± 0.3			262; 355; 357
				2.8 ± 0.4		356; (333)
					2.8 ± 0.3	49; 243; 355; (149)
$^{92}Zr(n,\alpha)^{89}Sr$	17.11	50.5 d	10 ± 1			18; 345; 348
					10 ± 1.2	18; 345
$^{94}Zr(n,\alpha)^{91}Sr$	17.40	9.7 h	4.8 ± 1			18; 262; 348; 355
				5 ± 1		18; 189; 333; 343
					5.5 ± 1.5	18; 49; 345; 355
$^{96}Zr(n,\alpha)^{93}Sr$	2.8	8 min	3 ± 1			262; 348; (333)
					3 ± 1	49; 345; 354
$^{93}Nb(n,\alpha)^{90g}Y$ *	100	64.1 h	9 ± 1			18; 293; 343
				9 ± 1		18; 293; 353
					9 ± 1	18; 391; (345)
^{90m}Y		3.19 h		5.5 ± 0.5		189
					5.8 ± 1	49; 149; 352; (345)
$^{92}Mo(n,\alpha)^{89g}Zr$ ⊕	15.84	78.4 h		18 ± 2		189
					20 ± 8	48; 92
^{89m}Zr ⊕		4.2 min			2.5 ± 0.3	134; (189)

⊕ Checking of decay scheme is urgently recommended.
Isotopic abundance not accurately known.

TABLE II (cont.)

Reaction	Isotopic abundance (%)	$T_{1/2}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
^{98}Mo(n,α)^{95}Zr	23.78	65.5 d	8.1 ± 1			189
^{100}Mo(n,α)^{97}Zr	9.63	16.8 h	25 ± 15			92
				[14 ± 6]		[286]
^{99}Tc(n,α)^{96}Nb		23.4 h	2.02 ± 0.22			122
^{104}Ru(n,α)^{101}Mo	18.58	14.6 min			2.6 ± 1	130
^{103}Rh(n,α)^{100}Tc	100	17 s			11	350; (351)
^{106}Pd(n,α)^{103}Ru	27.33	39.5 d		5.6 ± 0.7		189
^{108}Pd(n,α)^{105}Ru	26.71	4.4 h	2.6 ± 0.4			343
				2.6 ± 0.4		189; 333
					2.6 ± 0.5	346
^{110}Pd(n,α)^{107}Ru	11.81	4.2 min		13.8 ± 6.2		221
^{109}Ag(n,α)^{106}Rh	48.65#	2.2 h			12 ± 3	214; (164)
^{106}Cd(n,α)^{103}Pd†	1.22	17 d	[100 ± 40]			[324]
^{112}Cd(n,α)^{109}Pd	24.07	14 h	2.6 ± 0.3			18; 324; (348)
				3.1 ± 0.3		18;
					3.3 ± 0.2	18
^{114}Cd(n,α)^{111g}Pd⊕	28.86	22 min	0.5 ± 0.1			324; 347; 348
^{111m}Pd⊕		5.5 h	0.15 ± 0.05			324; 347
^{115}In(n,α)^{112}Ag	95.72	3.2 h		2.8 ± 0.5		216; 329; (324)
					2.6 ± 0.3	345
^{118}Sn(n,α)^{115g}Cd	24.03	53.5 h	0.95 ± 0.06			18
				1.1 ± 0.08		18
					1.15 ± 0.1	18; 345
^{115m}Cd		43 d			0.3 ± 0.1	345
^{124}Te(n,α)^{121g}Sn	4.61	27 h			0.76 ± 0.15	346; (198)
^{126}Te(n,α)^{123g}Sn	18.71	129 d			0.8 ± 0.1	148
^{123m}Sn		40 min			0.8 ± 0.4	198; 346

TABLE II (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{128}Te(n,\alpha)^{125g}Sn^{\oplus}$	31.79	9.4 d			0.53 ± 0.11	324
$^{125m}Sn^{\oplus}$		9.7 min			0.45 ± 0.1	148; 198
$^{130}Te(n,\alpha)^{127g}Sn^{\oplus}$	34.48#	2.1 h			0.39 ± 0.08	329; 346; (198)
$^{127}I(n,\alpha)^{124g}Sb^{\oplus}$	100	60.3 d			1.5 ± 0.5	132; 344; 345
^{124m}Sb		20 min			1.5 ± 0.2	252;
$^{133}Cs(n,\alpha)^{130}I$	100	12.3 h	1.0 ± 0.3			342; 343
				1.9 ± 0.3		189; 329
					2 ± 0.5	132; 340; (49)
$^{138}Ba(n,\alpha)^{135g}Xe^{*}$	71.66	9.15 h	3.6 ± 10			91; (111)
				[2.0 ± 0.2]		[189]
^{135m}Xe		15.6 min		0.55 ± 0.05		189; (111)
$^{139}La(n,\alpha)^{136}Cs$	99.91	12.9 d		2.0 ± 1		329; 330
					1.45 ± 1	132; 317
$^{140}Ce(n,\alpha)^{137m}Ba$	88.48	2.55 min	12.1 ± 1.15			39
				11 ± 1.1		39; 221
					10.5 ± 1.1	39; 317; (132)
$^{142}Ce(n,\alpha)^{139}Ba$	11.07	82.9 min		6.5 ± 1		189; 329
					6 ± 2	317; 340
$^{142}Nd(n,\alpha)^{139g}Ce$	27.11	140 d			10 ± 2	317; (219)
^{139m}Ce		56.5 s			2 ± 1	317
$^{144}Nd(n,\alpha)^{141}Ce$	23.85	32.5 d	9 ± 2			336
					<15.5	132
$^{146}Nd(n,\alpha)^{143}Ce^{\dagger}$	17.22	33.4 h		[2.6 ± 0.3]		[329]
					[8.3 ± 2.0]	[317]
$^{148}Nd(n,\alpha)^{145}Ce$	5.73	3.0 min			5 ± 1	317
$^{144}Sm(n,\alpha)^{141}Nd$	3.09	2.5 h	11			339
$^{152}Sm(n,\alpha)^{149}Nd$	26.72	1.73 h		9 ± 3		221; 317
$^{154}Sm(n,\alpha)^{151}Nd$	22.71	12 min			9 ± 3	317

TABLE II (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{151}Eu(n,\alpha)^{148m}Pm$ ⊕	47.82	41.8 d	19.1 ± 3.6			336
$^{153}Eu(n,\alpha)^{150}Pm$	52.18	2.7 h			9 ± 2	338
$^{156}Gd(n,\alpha)^{153}Sm$	20.47	46.8 h	8.5 ± 1.3			336; (329)
$^{158}Gd(n,\alpha)^{155}Sm$	24.87	22.4 min	2.4 ± 0.4			336
					2.18 ± 0.52	132
$^{160}Gd(n,\alpha)^{157}Sm$	21.90	0.5 min			2 ± 1	317
$^{159}Tb(n,\alpha)^{156}Eu$	100	15.1 d		2.2 ± 0.5		330
$^{162}Dy(n,\alpha)^{159}Gd$	25.53	18.56 h		3.56 ± 0.36		329
$^{164}Dy(n,\alpha)^{161}Gd$	28.18	3.6 min		[0.9]		[220]
					6 ± 1.5	132; 317; 338
$^{165}Ho(n,\alpha)^{162}Tb$	100	7.5 min	1.2 ± 0.4			336
$^{168}Er(n,\alpha)^{165g}Dy$ ⊕	27.07	2.35 h			0.5 ± 0.2	317
^{165m}Dy		1.26 min			1.0 ± 0.2	317
$^{170}Er(n,\alpha)^{167}Dy$	14.88	4.4 min			1.0 ± 0.2	317
$^{176}Yb(n,\alpha)^{173}Er$	12.73	12 min			0.2 ± 0.05	337
$^{178}Hf(n,\alpha)^{175}Yb$	27.14	4.2 d		2.1 ± 0.2		141; 329
$^{180}Hf(n,\alpha)^{177}Yb$	35.24	1.9 h		2.2 ± 0.2		141;
$^{181}Ta(n,\alpha)^{178g}Lu$	99.99	30 min	0.5 ± 0.3			333
					[0.14 ± 0.04]	[334]
^{178m}Lu		20 min	1.2 ± 0.2			333
					[0.3 ± 0.1]	[334]
$^{186}W(n,\alpha)^{183}Hf$ †	28.41	63 min		[0.85]		[333]
					[2.5 ± 1]	[240]
$^{187}Re(n,\alpha)^{184}Ta$	62.93	8.7 h		0.94 ± 0.15		329
$^{190}Os(n,\alpha)^{187}W$	26.4	23.8 h		0.5 ± 0.1		216; 329

TABLE II (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{191}Ir(n,\alpha)^{188}Re$	37.3	16.8 h		2.43 ± 0.3		329
$^{194}Pt(n,\alpha)^{191}Os$	32.9	15 d		1.26 ± 0.25		329
$^{196}Pt(n,\alpha)^{193}Os$	25.3	31 h		0.55 ± 0.11		329
$^{197}Au(n,\alpha)^{194}Ir$	100	17.4 h	0.27 ± 0.02			18
				0.35 ± 0.02		18; 329
					0.45 ± 0.02	18
$^{200}Hg(n,\alpha)^{197}Pt^{\oplus}$	23.13	18 h	0.2 ± 0.1			294
				1.77 ± 0.4		329
$^{202}Hg(n,\alpha)^{199}Pt$	29.8	31 min		1.0 ± 0.1		329
$^{203}Tl(n,\alpha)^{200}Au$	29.5	48.4 min		2.2 ± 0.4		135; 331; 332; (329)
$^{205}Tl(n,\alpha)^{202}Au$	70.50	30 s			0.75 ± 0.35	240
$^{206}Pb(n,\alpha)^{203}Hg$	23.6	46.9 d	2.7 ± 0.04			324
$^{208}Pb(n,\alpha)^{205}Hg$	52.3	5.5 min		1.58 ± 0.2		329
$^{209}Bi(n,\alpha)^{206}Tl$	100	4.3 min		1 ± 0.5		330; (329)
$^{230}Th(n,\alpha)^{227}Ra$	-	41 min		4.6 ± 1.2		329
$^{238}U(n,\alpha)^{235}Th^{\dagger}$	99.27	6.9 min		[1.5 ± 0.3]		[329]
					[0.6 ± 0.15]	[328]

TABLE III. 14-MeV (n, 2n) CROSS-SECTIONS

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{14}N(n,2n)^{13}N$	99.6337	9.96 min	6.1 ± 0.4			37; 47; 64; 78; 122; (15); (103)
				7.0 ± 0.5		47; 78; 87; 88; 221; 257
					8.2 ± 0.6	78; 104; 128; 225
$^{19}F(n,2n)^{18g}F$*	100	109.7 min	47 ± 4			15; 37; 64; 78; 88; 216; 236; 282; 327; (47)
				55 ± 4		87; 221; 257; 258; 282; 319;
					60 ± 5	70; 78; 82; 205; 282; (307)
^{18m}F		138 ± 10 ns 4)			2.7 ± 0.3	5
$^{23}Na(n,2n)^{22}Na$	100	2.62 yr	28 ± 2 [13.8]			185; [244]
				44 ± 3		185
					54 ± 5	185; 205
$^{27}Al(n,2n)^{26m}Al$	100	6.4 s		< 0.17		84
$^{31}P\ (n,2n)^{30}P$	100	2.5 min	5.1 [12.4]			64; (59) [35]
				10.9 ± 0.8		257
					10.0 ± 1	104; 127; 128; 159; 225; 247; (466)
$^{35}Cl(n,2n)^{34g}Cl$ †	75.529	1.57 s			[1.7 ± 0.3] [2.8 ± 0.5] [6.0 ± 0.6] [7.3 ± 1]	[161] [275] [1] [247]
^{34m}Cl		32.0 min		[3.47 ± 1.56] [5.42 ± 0.41]		[221] [257]
					[5.6 ± 2] [7 ± 0.2] [7.6 ± 0.7] [12 ± 2]	[275] [227] [161] [165; 248]
$^{39}K(n,2n)^{38g}K$	93.10	7.7 min	2.5 ± 0.3			24; 37; 295; 464
				3.5 ± 0.3		232; 257; 464
					5.1 ± 0.5	37; 161; 165; 225
^{38m}K		0.95 s			0.8 ± 0.2	161
$^{41}K(n,2n)^{40m}K$	6.88	294 ± 23 ns 4)			36 ± 16	5
$^{40}Ca(n,2n)^{39}Ca$	96.97	0.88 s			[8 ± 2] 2)	[53]
$^{48}Ca(n,2n)^{47}Ca$	0.185	4.54 d	900 ± 108			295
				920 ± 180		139
					1070 ± 360	138; (207)

* m decays with 100% to g ($T^{g}_{1/2} > T^{m}_{1/2}$).
† No value recommended.
Note: Handwritten numbers 1) to 21) refer to the List of comments which follows this table (page 129).

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{45}Sc(n,2n)^{44g}Sc$ 3)	100	4.0 h	140 ± 12			14; 64; 164, 246
				182 ± 15		14; 246
					199 ± 20	14; 49; 214; (165); (248)
^{44m}Sc		2.4 d	127 ± 12			14; 246; (231)
				149 ± 12		14; 246; 257; (231)
					155 ± 15	14; 214; (231)
$^{46}Ti(n,2n)^{45}Ti$	7.93	3.08 h	13.5 ± 1			38; 64; 246
				30 ± 2		246; 257; (87)
					50 ± 4	38; 82; 224; 238; 246
$^{50}Cr(n,2n)^{49}Cr$	4.31	42 min	10 ± 1.5			461
				[26.4 ± 2.2]		[257]
					28 ± 3	165; 214; 255; 287; 461, (66)
$^{52}Cr(n,2n)^{51}Cr$	83.76	27.8 d	278 ± 20			43; 314
					358 ± 25	43; 255
$^{55}Mn(n,2n)^{54}Mn$	100	303 d	855 ± 60			27; 44; 223; 308; (126); (314)
				890 ± 60		223; 311
					850 ± 60	26; 205; 223
$^{54}Fe(n,2n)^{53g}Fe$*	5.82	8.5 min	10.5 ± 1			9; 12; 59; 144; 241; (273)
				15.5 ± 1		12; 81; 87; 144; 257;
					22 ± 2	144; (65); (95); (255)
^{53m}Fe		2.5 min			[0.84 ± 0.15]	[255] 1)
$^{56}Fe(n,2n)^{55}Fe$	91.66	2.6 yr	440 ± 90			314
$^{59}Co(n,2n)^{58g}Co$*	100	71 d	655 ± 50			32; 40; 60; 69; 97; 126; 223; 305; 312; 313; (27); (112); (219)
				720 ± 50		69; 97; 223; 312; (112); (219); (311)
					735 ± 55	69; 97; 223; 312; (112); (155); (219); (287); (367)
^{58m}Co		9.15 h	428 ± 43			40; 97; (219); (367)
				402 ± 41		97; 311; (81); (219)
					423 ± 43	97; (219)

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{58}Ni(n,2n)^{57}Ni$	67.88	36.0 h	24.5 ± 2			39; 85; 119; 222; 246;465 ; (251)
				31.0 ± 2.5		85; 87; 119; 222; 246; 257; 463;465 ; (79); (221)
					34.9 ± 3	26; 39; 49; 85; 119; 222; 246;465 ; (155); (287);(367)
$^{63}Cu(n,2n)^{62}Cu$	69.09	9.76 min	480 ± 20			33; 44; 74; 85; 88;93; 110; 119; 171; 183; 184; 228; 241; 259; 270; 323; 327; (64; 78; 109)
				522 ± 20		74; 87; 93; 119; 184; 221; 228; 310; 410; (46; 78)
					585 ± 25	74; 76; 83; 85; 93; 119; 128; 184; 228; 255; 287; (78; 104; 225)
$^{65}Cu(n,2n)^{64}Cu$	30.91	12.8 h	913 ± 50			35; 44; 85; 93; 110; 216; 217; 222; 241; 246; 274; 327; (78; 323)
				956 ± 50		35; 85; 87; 93; 216; 222; 246; 257; 258; 274; 311; (221)
					975 ± 50	36; 83; 85; 95; 119; 222; 238;246; 255; 274; 287; 306; 307;
$^{64}Zn(n,2n)^{63}Zn$	48.89	38.4 min	119 ± 9			35; 44; 64; 113; 170; 222; 282; 312; 323; (74)
				165 ± 13		87; 113; 222; 257; 259; 261; 282; 312
					204 ± 16	44; 49; 88; 222; 255; 282; 312; 367; (74;466)
$^{66}Zn(n,2n)^{65}Zn$	27.81	245 d	620 ± 60			44; 313
				650 ± 60		88; 261
					740 ± 60	44; 255; 308
$^{70}Zn(n,2n)^{69g}Zn^{*}$	0.62	57 min			1307 ± 130	88; 161
^{69m}Zn		13.9 h		600 ± 40		261
					744 ± 100	161; 255
$^{69}Ga(n,2n)^{68}Ga$	60.4	68.3 min	850 ± 80			37; 64; 473
				957 ± 80		37; 257; (221)
					1070 ± 90	37; 88; 165; 466
$^{71}Ga(n,2n)^{70}Ga$	39.6	21.1 min		[700 ± 100]		[221]
					[961 ± 100]	[88]; (165)

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{70}Ge(n,2n)^{69}Ge$	20.52	39 h	508 ± 40			246
				610 ± 50		221; 246; 255; 257; 321
					700 ± 50	246; (165)
$^{72}Ge(n,2n)^{71m}Ge$	27.43	20 ms [4)]			487 ± 50	458
$^{76}Ge(n,2n)^{75g}Ge$*	7.76	83 min	1157 ± 100			219; 288
				1210 ± 100		219; 321; (221)
					1232 ± 100	165; 199; 219; 288
^{75m}Ge		48 s	914 ± 80			1; 219
				967 ± 80		1; 219
					1042 ± 80	1; 219; (199)
$^{75}As(n,2n)^{74g}As$* ⊕	100	17.7 d	1020 ± 75			39; 43; 126; 145; 246;(250)
				1060 ± 75		246; 302; (221)
					1085 ± 75	39; 43; 88; 145; 246; 255
$^{74}Se(n,2n)^{73g}Se$ [5)]	0.87	7.1 h	140 ± 20			2; 40; 144
				185 ± 30		257; 301
					220 ± 35	2; 40; 144; (154); (226)
^{73m}Se [5)]		42 min	165 ± 40			2; 40; 144
				210 ± 50		257; 301
					235 ± 55	2; 40; 144; (226)
$^{76}Se(n,2n)^{75}Se$	9.02	120 d	845 ± 60			145
				808 ± 81		301
					944 ± 65	145; (226)
$^{78}Se(n,2n)^{77m}Se$ [6)]	23.52	17.5 s	760 ± 70			63; 226; 268
				804 ± 70		63; 226; 268
					885 ± 70	63; 226; 268
$^{80}Se(n,2n)^{79m}Se$	49.82	3.9 min		[680 ± 100]		[301]; (1)
					[125 ± 10] [255 ± 20]	[200] [226]; (1)
$^{82}Se(n,2n)^{81g}Se$	9.19	18 min		225 ± 45		301
					345 ± 25	28; 134; 226; (200)
^{81m}Se		57 min		894 ± 89		301; (221)
					960 ± 50	134; 226; (154); (200)

⊕ Checking of decay scheme is urgently recommended.

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{79}Br(n,2n)^{78}Br$	50.337	6.4 min	862 ± 50			1; 64; 171; 219; (59)
				932 ± 60		1; 219; 257; (221); (302)
					1010 ± 50	1; 128; 209
$^{81}Br(n,2n)^{80g}Br$	49.463	17.6 min	390 ± 39			111; 219
				410 ± 41		219; 286
					430 ± 43	94; 128; 209; 219
^{80m}Br		4.4 h	719 ± 94			33; (111); (219)
				730 ± 80		33; 257; 286; 302
					750 ± 50	128; 209; (219)
$^{78}Kr(n,2n)^{77}Kr$	0.354	1.2 h		[245 ± 20]		[175]
$^{80}Kr(n,2n)^{79g}Kr$*	2.27	34.9 h		810 ± 60		175
^{79m}Kr		55 s		415 ± 50		175
$^{82}Kr(n,2n)^{81m}Kr$	11.56	13 s		160 ± 15		175
$^{86}Kr(n,2n)^{85m}Kr$	17.37	4.4 h		350 ± 35		175
$^{85}Rb(n,2n)^{84g}Rb$*	72.15	33 d	[1447 ± 72]			[246]
8) †			[964 ± 58]			[43]; (88); (293)
				[1093 ± 79]		[310]
				[1509 ± 76]		[246]; (286); (293); (302)
					[1530 ± 77]	[246]
					[1430 ± 71]	[264]
					[1174 ± 94]	[43]
					[1682 ± 161]	[210]
					[1335 ± 90]	[149]
^{84m}Rb †		21 min	[341 ± 21]			[43] 7)
				[478 ± 48]		[302]
				[505 ± 34]		[310]
					[374 ± 28]	[43]
					[926 ± 61]	[210]
					[714 ± 50]	[149]
$^{87}Rb(n,2n)^{86g}Rb$* †	27.85	18.7 d	[1170 ± 59]			[246]
			[1394 ± 139]			[264]; (293)
				[1202 ± 60]		[246]
				[1832 ± 276]		[310]; (286); (293); (302)
					[1191 ± 60]	[246]
					[1560 ± 156]	[264]
					[1417 ± 72]	[149]; (210)
^{86m}Rb †		1.0 min				
					[932 ± 150]	[210]
					[584 ± 40]	[149]

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{84}Sr(n,2n)^{83}Sr$ †	0.56	33 h	[142 ± 7]			[246]; (39)
				[482 ± 80]		[302]
				[380 ± 50]		[286]
				[166 ± 8]		[246]
					[395 ± 75]	[149]
					[140 ± 80]	[243]
					[181 ± 9]	[246]; (39); (165)
$^{86}Sr(n,2n)^{85m+g}Sr$	9.86	65 d 9)	787 ± 50			213; 264; 456; (88); (286)
					1060 ± 105	210; 264
^{85m}Sr		70 min	220 ± 20			456; (213)
				247 ± 25		302; (286)
					276 ± 30	149; 210; 264;
$^{88}Sr(n,2n)^{87m}Sr$ 6)	82.56	2.8 h	222 ± 15			37; 456
				(225 ± 24)		(286; 302)
					354 ± 30	149; 210; (354)
$^{89}Y(n,2n)^{88}Y$ 10)	100	108 d	850 ± 45			202; 264; 425; (126); (213); (293)
				930 ± 84		456; (286); (118)
					1015 ± 70	88; 161; 254; 264; 459
$^{90}Zr(n,2n)^{89g}Zr$* 11)	51.46	78.4 h	630 ± 45			2; 246; 262; 264
				714 ± 50		2; 246; 257; 315; (286)
					790 ± 50	2; 161; 210; 246; 254; 264; (149); (199); (210)
^{89m}Zr †		4.2 min	[74 ± 3]			[262]
			[123]			[2]
				[79.5 ± 5.6]		[221; 315]
				[138]		[2]
					[84 ± 12]	[49]
					[143 ± 15]	[2; 149; 161; 264]
					[168 ± 20]	[199]; (210)
$^{96}Zr(n,2n)^{95}Zr$	2.80	65.5 d		1456 ± 80		315
					1529 ± 141	254
$^{93}Nb(n,2n)^{92m}Nb$ 12)	100	10.2 d	440 ± 30			229; 264; 293; 304
				480 ± 30		118; 229; 293; 315; (286)
					450 ± 30	30; 49; 149; 171; 229; 254; 264; 473

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{92}Mo(n,2n)^{91g}Mo$ ⊕	15.84	15.5 min	135 ± 10			2; 87; 92; 144; 323
				170 ± 13		2; 87; 144; 221; 315; (46); (257)
					195 ± 15	2; 49; 83; 210; 248; 255; (134); (161); (451)
^{91m}Mo		65 s	7.8 ± 1			2
				13 ± 1.2		2; 315
					17 ± 1.5	2; 161; 255; 295; (94); (134) (210); (248)
$^{94}Mo(n,2n)^{93m}Mo$	9.04	6.9 h	3 ± 1			115
$^{100}Mo(n,2n)^{99}Mo$	9.63	66.7 h	1510 ± 180			92
				[2039 ± 210] 1389 ± 84		[286] 315; (221)
					[1910 ± 191] [1762 ± 200] 1390 ± 60	[165] [88] 255
$^{96}Ru(n,2n)^{95}Ru$	5.51	1.65 h	774 ± 66			30
				[610 ± 50]		[189; 257]
					870 ± 50	30; 264; (130); (221)
$^{98}Ru(n,2n)^{97}Ru$	1.87	2.9 d		1169 ± 96		315
$^{104}Ru(n,2n)^{103}Ru$	18.58	39.5 d	1460 ± 145			30
				1440 ± 80		315; (130)
$^{103}Rh(n,2n)^{102g}Rh$ ⊕	100	206 d	563 ± 40			229; (293)
				530 ± 40 [690 ± 67]		229; 315 [30]; (293)
^{102m}Rh ⊕		2.9 yr [13]	383 ± 30			229
				400 ± 27		229; 315
$^{102}Pd(n,2n)^{101}Pd$	0.96	8.3 h		[637 ± 45]		[315]
					1030 ± 105	30
$^{108}Pd(n,2n)^{107m}Pd$	26.7	21 s			517 ± 80	210
$^{110}Pd(n,2n)^{109g}Pd^{*}$	11.81	13.5 h		1975 ± 140		30; 221; 315; (36); (199); (208)
^{109m}Pd		4.7 min		498 ± 45		30; 315
					510 ± 30	208; (199)

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{107}Ag(n,2n)^{106g}Ag$ †	51.35	24 min	[1000 ± 100]			[93]
			[852 ± 80]			[259]
			[818 ± 75]			[59]; (64); (110);(179);(306); (270); (221); (293); (323)
				[1000 ± 100]		[93]
				[889 ± 66]		[257]
				[520]		[67]; (221)
					[601 ± 90]	[466]
					[870 ± 40]	[210]
					[657 ± 100]	[165]
					[662 ± 66]	[214]
^{106m}Ag 4)		8.3 d	580 ± 30			307; (293)
				605 ± 30		307; (293)
					630 ± 31	210; 306; 307; (214)
$^{109}Ag(n,2n)^{108g}Ag$	48.65	2.4 min	740 ± 80			93; 164; 306; 323; (110); (179)
				740 ± 80		93; (67); (221)
					740 ± 80	93; 165; 210; 214
$^{106}Cd(n,2n)^{105}Cd$	1.215	55 min	640 ± 60			(260); (43)
				928 ± 85		188; 257; 260;
					[980 ± 100]	[260]; (43)
$^{108}Cd(n,2n)^{107}Cd$	0.875	6.5 h	[504 ± 48]			[324]
				915 ± 85		315; 349
$^{110}Cd(n,2n)^{109}Cd$	12.39	453 d		1221 ± 150		315; 349
$^{112}Cd(n,2n)^{111m}Cd$	24.07	49 min	624 ± 75			465
				[725 ± 50] 6)		[315]
					576 ± 69	465
$^{116}Cd(n,2n)^{115g}Cd$	7.58	53.5 h	850 ± 70			246; 324
				830 ± 80		246; 315
					790 ± 80	246; (165)
^{115m}Cd		43 d	760 ± 60			246; 324
				790 ± 80		246; 315
					770 ± 80	246; (165)

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{113}In(n,2n)^{112g}In$ 15)	4.28	14.4 min		316 ± 40		462; (131)
					320 ± 25	211; 267; (176)
^{112m}In 15)		21 min		1317 ± 200		462; (131); (94)
					1450 ± 100	211; 267; (176)
$^{112m+g}In$				[1527 ± 56] [1633 ± 21]		[131] [462]
					[1790 ± 150] [1753 ± 110] [1540 ± 140]	[267] [211] [176]
$^{115}In(n,2n)^{114g}In$	95.72	72 s		295		131
					323 ± 50	211; 247; 248; 267; (176)
^{114m}In		50.0 d	1557 ± 100			246
				1515 ± 100		131; 246; (116)
					1515 ± 100	26; 211; 246; 248; 267; (176); (205)
$^{112}Sn(n,2n)^{111}Sn$ 16)	0.96	35 min	[1200 ± 150]			[43; 88; 260]; (167); (293)
				[1300 ± 150]		[187; 257; 463]
					[1400 ± 150]	[43; 260]
$^{114}Sn(n,2n)^{113g}Sn$* 17)	0.66	115 d		[1239 ± 130] [1800 ± 100]		[315] [187]
$^{118}Sn(n,2n)^{117m}Sn$ 6)	24.03	14 d		966 ± 100		187; 315
					[1230 ± 340]	[51]
$^{120}Sn(n,2n)^{119m}Sn$	8.58	245 d		1444 ± 210		187
$^{122}Sn(n,2n)^{121g}Sn$	4.72	27 h		875 ± 135		187
$^{124}Sn(n,2n)^{123g}Sn$	5.94	129 d	900 ± 180			167
^{123m}Sn		40 min		547 ± 23		187
$^{121}Sb(n,2n)^{120g}Sb$ 10)	57.25	15.9 min	1010 ± 80			43; 162; 171; 259; (59); (78); (164)
				1080 ± 90		171; 257; 259; 315; (78); (221)
					1110 ± 90	43; 162; 165; 211; (78)
^{120m}Sb†		5.8 d	[432 ± 105] [611 ± 58]			[162] [43]
				[427 ± 20]		[315]
					[597 ± 35] [564 ± 132] [695 ± 64]	[211] [162] [43]

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{123}Sb(n,2n)^{122g}Sb^{*}$ † 10)	42.75	2.68 d	[1706 ± 120] [1263 ± 135]			[164] [43]
				[1245 ± 312] [1542 ± 80]		[221] [315]
					[1270 ± 70]	43, 457, (165,211)
^{122m}Sb		4.2 min	547 ± 79			43
				731 ± 73		268
					686 ± 60 [1013]	217 [199]
$^{120}Te(n,2n)^{119g}Te$	0.089	16 h			685 ± 100	148
^{119m}Te		4.7 d			535 ± 85	148
$^{122}Te(n,2n)^{121g}Te$	2.46	17 d		725 ± 40		315
					750 ± 100	148
^{121m}Te		154 d		890 ± 100		315
					530 ± 80	148
$^{124}Te(n,2n)^{123m}Te$ 6)	4.61	117 d		980 ± 100		315
$^{128}Te(n,2n)^{127g}Te$	31.79	9.4 h		780 ± 60		30; 221; 315
					660 ± 50	36; 134; 148; (198)
^{127m}Te		109 d		940 ± 100		30; 315;(148)
$^{130}Te(n,2n)^{129g}Te$ †	34.48	69 min		[599 ± 120] [812 ± 50] [570 ± 30]		[51] [221] [30] [315]
					[664 ± 40] [580 ± 27] [435 ± 50]	[134] [36] [148]; (198)
^{129m}Te †		34 d		[1000 ± 61] [885 ± 45]		[30] (51) [315]
					[528 ± 100]	[198]; (148)
$^{127}I(n,2n)^{126}I$	100	12.8 d		1649 ± 80		(33); (192) 315; (221); (310)
					1650 ± 140	26; 132; (252)
$^{124}Xe(n,2n)^{123}Xe$	0.096	2.1 h		1130 ± 110		175
$^{126}Xe(n,2n)^{125g}Xe^{*}$	0.090	16.8 h		1355 ± 165		175
^{125m}Xe		55 s		700 ± 200		175

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{128}Xe(n,2n)^{127g}Xe^{*}$	1.919	36.4 d		1530 ± 170		175
^{127m}Xe		70 s		840 ± 65		175
$^{130}Xe(n,2n)^{129m}Xe$ [6]	4.08	8.0 d		1435 ± 130		175
$^{132}Xe(n,2n)^{131m}Xe$ [6]	26.89	11.8 d		775 ± 65		175
$^{134}Xe(n,2n)^{133g}Xe^{*}$	10.41	5.65 d		2360 ± 240		175
^{133m}Xe		2.2 d		665 ± 80		175
$^{136}Xe(n,2n)^{135g}Xe^{*}$	8.87	9.15 h		1700 ± 100		175
^{135m}Xe		15.6 min		750 ± 50		175
$^{133}Cs(n,2n)^{132}Cs$	100	6.5 d	[1450 ± 130]			[33; 304]; (216); (241)
				1520 ± 110		216; 310; 315
					1600 ± 110	132; 253
$^{130}Ba(n,2n)^{129}Ba$ [6]	0.101 #	32.1 h (^{129}Cs) [11]		1371 ± 70		315
$^{132}Ba(n,2n)^{131}Ba$	0.097 #	12 d		1574 ± 100		315
$^{134}Ba(n,2n)^{133m}Ba$	2.42 #	38.9 h		783 ± 56		315
					940 ± 80	317
$^{136}Ba(n,2n)^{135m}Ba$ [6]	7.81 #	28.7 h		[1149 ± 80]		[315]
					[700 ± 80]	[317]
$^{138}Ba(n,2n)^{137m}Ba$ [6]	71.66 #	2.55 min	1020 ± 70			91
				1048 ± 100		268
					1250 ± 100	317
$^{136}Ce(n,2n)^{135}Ce$	0.193	17.2 h		1318 ± 90		315
$^{138}Ce(n,2n)^{137m}Ce$	0.250	34.4 h		958 ± 100		315

Isotopic abundance not accurately known.

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{140}Ce(n,2n)^{139g}Ce^*$	88.48	140 d	1800 ± 120			43; 453; (91)
				[1593 ± 130]		[315]
					1760 ± 110	43; 99;457 ; (317)
^{139m}Ce		56.5 s	1240 ± 120			39; 91; 241
				1200 ± 110		39; (206); (315)
					1160 ± 120	39; 247; 317
$^{142}Ce(n,2n)^{141}Ce$	11.07	32.5 d	1695 ± 102			43
				1730 ± 170		315
					1850 ± 160	43; 99; 317; 457
$^{141}Pr(n,2n)^{140}Pr$	100	3.4 min	1800 ± 140			43; 91; 171; 260; (64)
				1840 ± 140		171; 221; 257; 260; (206)
					1860 ± 150	43; 104; 260; 317;464 ; (165)
$^{142}Nd(n,2n)^{141g}Nd^*$	27.11	2.5 h	1640 ± 130 [2075]			30; (91) [452]
				1640 ± 130		30; 206
				[2411]		[257]
					1640 ± 130 [2060]	99; 129 [317]
^{141m}Nd		64 s	670 ± 60			91; 452
				610 ± 60		50; 206
					674 ± 70	129
$^{148}Nd(n,2n)^{147}Nd$	5.73	11.1 d	1626 ± 200			452
					[2160 ± 200]	[317]
$^{150}Nd(n,2n)^{149}Nd$	5.62	1.73 h		1728 ± 276		206
					[2200 ± 300]	[317]
$^{144}Sm(n,2n)^{143g}Sm^*$	3.09	8.83 min	1380 ± 138			43; 91; 260; 452
				1478 ± 148		206; 257; 260
					1620 ± 162	10; 43; 161; 260; (316)
^{143m}Sm		64 s	550 ± 50			43; 452; (91)
				540 ± 70		50; 206
					[800 ± 200]	[10; 94; 161]
$^{154}Sm(n,2n)^{153}Sm$	22.71	46.8 h		[2250]		[221]
					1500 ± 300	316; 317

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{151}Eu(n,2n)^{150m}Eu$	47.82	12.6 h			540 ± 70	165; 284; 317
$^{153}Eu(n,2n)^{152m_1}Eu$ †	52.18	9.3 h	[652 ± 90]			[452]
					[164 ± 25] [750 ± 200]	[165] [317]
$^{152m_2}Eu$		96 min	[91 ± 12]			[452]
$^{154}Gd(n,2n)^{153}Gd$	2.15	242 d			1855 ± 140	99
$^{160}Gd(n,2n)^{159}Gd$	21.90	18.56 h	1675 ± 160			452
				[1470]		[221]
					1660 ± 170	132; 165; 317
$^{159}Tb(n,2n)^{158m}Tb$ †	100	10.5 s	[524 ± 70]			[452]
				[160 ± 19]		[50]
					[1250 ± 300]	[247]
$^{156}Dy(n,2n)^{155}Dy$	0.0524 #	10.2 h		1943 ± 194		220
$^{158}Dy(n,2n)^{157}Dy$	0.0902 #	8.06 h		2047 ± 205		220
$^{160}Dy(n,2n)^{159}Dy$	2.294	144 d			2015 ± 120	99
$^{165}Ho(n,2n)^{164m}Ho$ ⊕	100	39 min 13)	1050 ± 100			280
					1110 ± 150	99; 205; 288
$^{164m+g}Ho$ ⊕		24 min (g) 13)	1780 ± 140			280
					1740 ± 200 [2110 ± 300]	43; 288; [99]; (165); (36)
$^{162}Er(n,2n)^{161}Er$	0.136	3.1 h	1870 ± 300			452
					1750 ± 120	132
$^{166}Er(n,2n)^{165}Er$	33.41	10.3 h			1965 ± 155 [1000 ± 400]	99 [317]
$^{168}Er(n,2n)^{167m}Er$ 6)	27.07	2.3 s	[1080 ± 100]			[63]
				[190 ± 24] [1125 ± 92] [403 ± 40]		[50] [63] [268]
					[690 ± 110] [973 ± 120]	[247] [63]

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{170}Er(n,2n)^{169}Er$	14.88	9.5 d			1895 ± 133 [1200 ± 500]	284 [317]
$^{169}Tm(n,2n)^{168}Tm$	100	93.1 d		[1030 ± 400]		[293]
					2000 ± 115	99
$^{170}Yb(n,2n)^{169}Yb$	3.03	32 d			2080 ± 110	99
$^{176}Yb(n,2n)^{175}Yb$	12.73	101 h			1810 ± 130	284; (165); (317)
$^{175}Lu(n,2n)^{174g}Lu$ ⊕	97.41	3.6 yr			1285 ± 140	99
^{174m}Lu		140 d			655 ± 55	99; (317)
$^{174}Hf(n,2n)^{173}Hf$	0.18#	23.6 h		[860 ± 60]		[141]
$^{176}Hf(n,2n)^{175}Hf$	5.20	70 d		2000 ± 100		141
					2220 ± 115	99
$^{179}Hf(n,2n)^{178m}Hf$ 6)	13.75	4.3 s			[880 ± 100]	[247]
$^{180}Hf(n,2n)^{179m}Hf$ 6)	35.24	18.6 s		[690 ± 70]		[268]
					[570 ± 50]	[247]
$^{181}Ta(n,2n)^{180m}Ta$ 48)	99.9877	8.1 h	[1140 ± 80] [2074 ± 47] [1825 ± 90]			[43; 246] [327] [54]
				[1130 ± 80] [1810 ± 100]		[43; 246] [54]; (221)
					[1820 ± 100]	[54]; (239)
$^{182}W(n,2n)^{181}W$	26.41	130 d			2230 ± 150	99; 102
$^{184}W(n,2n)^{183m}W$ 6)	30.64	5.3 s			[790 ± 90]	[247]; (325)
$^{186}W(n,2n)^{185g}W$*	28.41	74 d			[2290 ± 230]	[102]
^{185m}W		1.6 min			540 ± 80	240; 247

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{185}Re(n,2n)^{184g}Re$	37.07	38 d	[1910 ± 600] 20)			[160]
					1430 ± 220	468
^{184m}Re		165 d 13)	[1120 ± 400] 19)			[160]
					260 ± 100	468
$^{187}Re(n,2n)^{186}Re$	62.93	90 h	1440 ± 410			160
					1580 ± 160	165; 468
$^{192}Os(n,2n)^{191g}Os$*	41.0	15 d	2233 ± 199			30
				1993 ± 200		135
					2120 ± 220	320
^{191m}Os		13 h			831 ± 116	320; (174)
$^{191}Ir(n,2n)^{190m2}Ir$	37.3	3.2 h	164 ± 14			30
					204 ± 20	30; 255; (165)
$^{190g+m1}Ir$		11.0 d (g)		1960 ± 230		30
					1723 ± 130	99; 255
$^{193}Ir(n,2n)^{192}Ir$ 24)	62.7	74.2 d			2062 ± 121	255
$^{192}Pt(n,2n)^{191}Pt$	0.78	3.0 d		2035 ± 150		135
					2026 ± 168	255
$^{196}Pt(n,2n)^{195m}Pt$ 6)	25.3	4.1 d		460 ± 55		135
$^{198}Pt(n,2n)^{197g}Pt$	7.21	18 h		1128 ± 125		30; (135); (221)
					1030 ± 160	255; 320; (200)
^{197m}Pt		86 min		1080 ± 90		30; 135
					980 ± 100	200; 255; 320
$^{197}Au(n,2n)^{196g}Au$*	100	6.2 d	2403 ± 120			246; (15; 123; 293); (469)
				2270 ± 120		135; 246; (221; 293)
					2250 ± 120	99; 246; 255; 307; (200)
^{196m}Au		9.7 h	134 ± 7 [175]			246; [293]
				143 ± 10 [210]		135; 246 [293]
					147 ± 10 [230]	99; 246 [200]

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{196}Hg(n,2n)^{195g}Hg$	0.146	9.5 h	[< 1100]			[294]
				363 ± 54		135
^{195m}Hg		40 h	[1060 ± 70]			[294]
				1617 ± 160		135
$^{198}Hg(n,2n)^{197g}Hg$	10.02	64.14 h	940 ± 100			294
				1125 ± 100		135
					1010 ± 140	255; (99)
^{197m}Hg		23.8 h	900 ± 70			294
				885 ± 80		135
					910 ± 85	255
$^{200}Hg(n,2n)^{199m}Hg$ 6)	23.13	43 min	880 ± 60			294
				789 ± 120		135
$^{204}Hg(n,2n)^{203}Hg$	6.85	46.9 d	2060 ± 190			294
				2050 ± 160		135; 456
					2190 ± 150	99; 233; 255
$^{203}Tl(n,2n)^{202}Tl$	29.50	12.4 d	[1350 ± 150]			[246; 277; 293]
				1950 ± 200		135; (246; 293)
					1850 ± 180	99; 226;233 ; (240)
$^{205}Tl(n,2n)^{204}Tl$	70.50	3.8 yr			1990 ± 140	284
$^{204}Pb(n,2n)^{203g}Pb$*	1.48	52.1 h	1840 ± 120			98; 202; 300
				1740 ± 140		135
					1840 ± 130	88; 99; 161;226 ; 470
^{203m}Pb†		6 s	[1260 ± 270]			[1]
				[1330 ± 220]		[1]
					[1340 ± 120] [860 ± 180]	[1] [161]
$^{206}Pb(n,2n)^{205m}Pb$	23.6	4 ms			1100 ± 200	117
$^{208}Pb(n,2n)^{207m}Pb$ 6)	52.3	0.80 s	1444 ± 100			63; 281
				1631 ± 150		63;116
					1700 ± 150	63; 118; 161; (247)
$^{209}Bi(n,2n)^{208}Bi$	100	3.7 10^5 yr	2220 ± 150			4; 15; 106; 123; 182; 266
				[2420]		[108]
^{208m}Bi†		2.6 ms		[290 ± 30] [630 ± 120]		[471] [116; 118]

TABLE III (cont.)

Reaction	Isotopic abundance (%)	$T_{\frac{1}{2}}$	Cross-sections (mb) 14.1 MeV	14.5 MeV	14.9 MeV	References
$^{226}Ra(n,2n)^{225}Ra$	unstable	14.8 d			1600 ± 200	218
$^{232}Th(n,2n)^{231}Th$	100	25.6 h	1390 ± 130			230; 246; 292
				1320 ± 130		55; 246; 292
					1210 ± 120	234; 246; (326)
$^{238}U(n,2n)^{237}U$	99.2739	6.75 d	750 ± 50			125; 237; 454;
				680 ± 40		125; 230; 472
					640 ± 150	125; (11)
$^{237}Np(n,2n)^{236m}Np$	unstable	22 h		390 ± 70		230

LIST OF COMMENTS TO TABLE III

1) Taken from Ref. 5.
2) Threshold energy exceeds projectile energy by more than 1 MeV!
3) See also Refs 88, 257 and 290.
4) Ref. 458.
5) Cross-sections are renormalized, taking into account the 73% isomeric transition of 42 min ^{73m}Se (see Ref. 460).
6) Including that part of the (n, n' γ) reaction with the neighbouring isotope that populates the same metastable state.
7) See also Ref. 169.
8) Assuming 100% isomeric transition.
9) Half-life of the cumulative $\sigma^g + 0.86\ \sigma^m$ decay.
10) See also Ref. 246.
11) Cumulative ground-state cross-section: $\sigma^g + 0.94\ \sigma^m$.
12) See also Ref. 133 (σ^{m+g} = 1.35 b) and Ref. 246.
13) Half-life not accurately known.
14) See also Refs 87, 246.
15) The references cited mainly differ in the separation of σ^m and σ^g due to the similar half-lives.
16) See also Refs 246, 315.
17) Cumulative ground-state cross-section: $\sigma^g + 0.91\ \sigma^m$.
18) Contribution from $^{180}Ta(n, n')^{180m}Ta$ negligible. For $\sigma^{(m+g)}$ see also Refs 15, 266.
19) Cross-section for the production of 2.2-d ^{184m}Re.
20) Cross-section for the production of 50-d ^{184g}Re.
21) Without decay of the 161-keV ^{192}Ir isomer (half-life ≈ 650 yr).

REFERENCES TO TABLES I-III

1 ABELS, C., BORMANN, M., CARSTENS, W., Rep. EANDC(E)76"U", NEA, Paris (1967) 51.
2 ABBOUD, A., DECOWSKI, P., GROCHULSKI, W., MARCINKOWSKI, A., PIOTROWSKI, J., SIWEK, K., WILHELMI, Z., Nucl. Phys. A139 (1969) 42.
3 ADLER, H., HUBER, P., HÄLG, W., Helv. Phys. Acta 26 (1953) 349.
4 ÁDÁM, A., HRASKO, P., PÁLLA, G., QUITTNER, P., Nucl. Phys. 49 (1963) 489.
5 ÁDÁM, A., HORVÁTH, D., KISS, Á, MAYR, E., Nucl. Phys. A180 (1972) 587.
6 AGODI, A., PAPPALARDO, G., RICAMO, R., VINLIGUERRA, D., Nuovo Cim. X23 (1962) 1136.
7 ALLEN, K.W., BURCHAM, W.E., WILKINSON, D.H., Proc. R. Soc. A 192 (1947) 114.
8 ALLEN, L., Jr., BIGGERS, W.A., PRESTWOOD, R.J., SMITH, R.K., Phys. Rev. 107 (1957) 1363.
9 ALLAN, D.L., Proc. Phys. Soc. A 70 (1957) 195.
10 ALFORD, W.L., KOEHLER, D.R., Phys. Rev. 129 (1963) 703.
11 ANTROPOV, G.P., ZUSIN, I.A., KOVRIZHNYKH, A.A., LBOV, A.A., At. Ehnerg. 5 (1958) 456.
12 ANDREEV, M.F., SEROV, V.I., Sov. J. Nucl. Phys. 7 (1968) 454.
13 ARMSTRONG, A.H., FREYE, G.M., Phys. Rev. 103 (1956) 335.
14 ARNOLD, D.M., RAYBURN, L.A., Bull. Am. Phys. Soc. 9 (1964) 352.
15 ASHBY, V.J., CARON, H.C., NEWKIRK, L.L., TAYLOR, C.J., Phys. Rev. 111 (1958) 616.
16 BATCHELOR, R., AVES, R., SKYRME, T.H.R., Rev. Sci. Instrum. 26 (1955) 1037.
17 BARRY, J., COLEMAN, R., HAWKER, B., PERKIN, J., Proc. Phys. Soc. 74 (1959) 632.
18 BAYHURST, B.P., PRESTWOOD, R.J., J. Inorg. Nucl. Chem. 23 (1961) 173.
19 BASS, R., BONNER, T.W., HAENNI, H.P., Nucl. Phys. 23 (1961) 122.
20 BARRY, J., J. Nucl. Energy AB 16 (1962) 467.
21 BARRY, J., J. Nucl. Energy AB 17 (1963) 273.
22 BASS, R., FANGER, U., SALEH FATMA, M., Nucl. Phys. 56 (1964) 569.
23 BARDOLLE, G., CABE, J., LAURAT, M., C.R. 261 (1965) 1266.
24 BASS, R., BINDHARDT, C., KRÜGER, K., EANDC(E)57"U", NEA, Paris (1965) 1.
25 BASS, R., KRÜGER, K., STAGINNUS, B., HAUG, P., EANDC(E)66"U", NEA, Paris (1966) 64.
26 BARRALL, R.C., SILBERGELD, M., GARDNER, D.G., Nucl. Phys. A138 (1969) 387.
27 BENVENISTE, J., 2nd Int. Conf. Peaceful Uses At. Energy (Proc. Conf. Geneva, 1958) 15, UN, New York (1958) 3.
28 BERGMANN, H., Acta Phys. Austriaca 31 (1970) 354.
29 BIRK, M., GOLDRING, G., HILLMAN, P., Nucl. Instrum. Methods 21 (1963) 197.
30 BORMANN, M., BISSEM, H.H., MAGIERA, E., WARNEMÜNDE, R., Nucl. Phys. A157 (1970) 481.
31 BOSTROM, N.A., HUDSPETH, E.L., MORGAN, I.L., Phys. Rev. 99 (1955) 643 A.
32 BORMANN, M., CIERJACKS, S., LANGKAU, R., NEUERT, H., POLLEHN, H., J. Phys. Rad. 22 (1961) 602.
33 BORMANN, M., CIERJACKS, S., LANGKAU, R., NEUERT, H., Z. Phys. 166 (1962) 477.
34 BORMANN, M., Z. Naturforsch. 17a (1962) 479.
35 BORMANN, M., CIERJACKS, S., FRETWURST, E., GIESECKE, K.-J., NEUERT, H., POLLEHN, H., Z. Phys. 174 (1963) 1.
36 BONAZZOLA, G.C., BROUETTO, P., CHIAVASSA, E., SPINOGLIO, R., PASQUARELLI, A., Nucl. Phys. 51 (1964) 337.
37 BORMANN, M., FRETWURST, E., SCHEHKA, P., WREGE, G., BÜTTNER, H., LINDNER, A., MELDNER, H., Nucl. Phys. 63 (1965) 438.
38 BORMANN, M., SCHEHKA, P., DREYER, F., FRETWURST, E., Rep. EANDC(E)57"U", NEA, Paris (1965) 17.
39 BORMANN, M., ZIELINSKI, U., DREYER, F., Rep. EANDC(E)66"U", NEA, Paris (1966) 42.
40 BORMANN, M., DREYER, F., SEEBECK, U., VOIGTS, W., Z. Naturforsch. 21a (1966) 988.
41 BORMANN, M., DREYER, F., NEUERT, H., RIEHLE, I., ZIELINSKI, U., Nuclear Data for Reactors – 1966 (Proc. Conf. Paris, 1966) 1, IAEA, Vienna (1967) 225.
42 BORMANN, M., RIEHLE, I., Z. Phys. 207 (1967) 64.
43 BORMANN, M., BEHREND, A., RIEHLE, I., VOGEL, O., Nucl. Phys. A115 (1968) 309.
44 BORMANN, M., LAMMERS, B., Nucl Phys. A130 (1969) 195.
45 RAO, P., WOOD, R.E., PALMS, J.M., FINK, R.W., Phys. Rev. 3C (1971) 629.
46 BROLLEY, J.E., FOWLER, J.L., SCHLACKS, L.K., Phys. Rev. 88 (1952) 618.
47 BRILL, O.D., VLASOV, N.A., KALININ, S.P., SOKOLOV, L.S., Sov. Phys. – Dokl. 6 (1961) 24.
48 BRAMLITT, E.T., FINK, R.W., J. Inorg. Nucl. Chem. 24 (1962) 1321.
49 BRAMLITT, E.T., FINK, R.W., Phys. Rev. 131 (1963) 2649.

50 BROADHEAD, K.G., SHANKS, D.E., HEADY, H.H., Phys. Rev. 139 (1965) B 1525.
51 BRZOSKO, J., DECOWSKI, P., SIWEK-DIAMENT, K., WILHELMI, Z., Nucl. Phys. 74 (1965) 438.
52 BRZOSKO, J., IBJ Rep. 795/I/PL (1967)
53 BRAUN, H., SCHULZE, W., Radiochem. Acta 9 (1968) 22.
54 BRZOSKO, J., GIERUK, E., SOLTAN, A., WILHELMI, Z., Nucl. Phys. A123 (1969) 603.
55 BUTLER, J.P., SANTRY, D.C., Can. J. Chem. 39 (1961) 689.
56 BUTLER, J.P., SANTRY, D.C., Can. J. Phys. 41 (1963) 372.
57 CATRON, H.C., GOLDBERG, M.D., HILL, R.W., LeBLANC, J.M., STOERING, J.P., TAYLOR, C.J., WILLIAMSON, M.A., Phys. Rev. 123 (1961) 218.
58 CALVI, G., POTENZA, R., RICAMO, R., VINCIGUERRA, D., Nucl. Phys. 39 (1962) 621.
59 CARLES, C., C.R. 257 (1963) 659.
60 CABE, J., LAURAT, M., YUON, P., Rep. EANDC(E)49, NEA, Paris (1963) L 82.
61 CARROLL, E.E., Jr., SMITH, G.C., STOOKSBERRY, R.W., Trans. Am. Nucl. Soc. 7 (1964) 268.
62 CARROLL, E.E., Jr., SMITH, G.C., Nucl. Sci. Eng. 22 (1965) 411.
63 CARSTENS, W., Diplomarbeit, Hamburg (1967).
64 CEVOLANI, M., PETRALIA, S., Nuovo Cim. 26 (1962) 1328.
65 CHITTENDEN, D.M., GARDNER, D.G., FINK, R.W., Phys. Rev. 122 (1961) 860.
66 CHITTENDEN, D.M., GARDNER, D.G., Annu. Prog. Rep. Nucl. Chem. (1961).
67 CHURSIN, G.P., GONCHAR, V.Y., ZALYUBOVSKIJ, I.I., KLUCHAREV, A.P., Sov. Phys. - JETP 44 (1963) 472.
68 CHOJNACKI, S., Int. Conf. Study of Nuclear Structure with Neutrons, Antwerp (1965).
69 CHOJNACKI, S., DECOWSKI, P., GIERUK, E., GROCHULSKI, W., MARCINKOWSKI, A., SIWEK, K., SLEDZINSKA, I., WILHELMI, Z., Int. Conf. Study of Nuclear Structure with Neutrons, Antwerp (1965).
70 CHATTERJEE, A., MITRA, B., GHOSE, A.M., Symp. Nuclear Physics and Solid State, Kanpur, India (1967) 363.
71 CIERJACKS, S., Diplomarbeit, Hamburg (1962).
72 COON, J.H., Phys. Rev. 80 (1950) 488.
73 COHEN, B.C., Phys. Rev. 81 (1952) 184.
74 COHEN, A.V., WHITE, P.H., Nucl. Phys. 1 (1956) 73.
75 COCHRAN, D.R.F., HENKEL, R.L., private communication (1958).
76 COX, A.J., CRUMPTON, D., Nature (London) 216 (1967) 996.
77 CRANBERG, L., LEVIN, J.S., private communication (1960).
78 McCRARY, J.H., MORGAN, I.L., Bull. Am. Phys. Soc. 5 (1960) 246.
79 CROSS, W.G., CLARKE, R.L., MORIN, K., SLINN, G., AHMED, N.M., BEG, K., Bull. Am. Phys. Soc. 7 (1962) 335.
80 CROSS, W.G., CLARKE, R.L., Prog. Rep. AECL-1542 (1962).
81 CROSS, W.G., CLARKE, R.L., MORIN, K., SLINN, G., AHMED, N.M., BEG, K., Rep. EANDC(CAN)16L, NEA, Paris (1963).
82 CRUMPTON, D., J. Inorg. Nucl. Chem. 31 (1969) 3727.
83 CRUMPTON, D., COX, A.J., COOPER, P.N., FRANÇOIS, P.E., HUNT, S.E., J. Inorg. Nucl. Chem. 31 (1969) 1.
84 CSIKAI, J., GYARMATI, B., HUNYADI, I., Nucl. Phys. 46 (1963) 141.
85 CSIKAI, J., Int. Conf. Study of Nuclear Structure with Neutrons, Antwerp (1965) 102.
86 CSIKAI, J., Acta Phys. Hung. 21 (1966) 229.
87 CSIKAI, J., ATOMKI (At. Kut. Intez.) Kozl. 8 (1966) 79.
88 CSIKAI, J., PETŐ, G., Acta Phys. Hung. 23 (1967) 87.
89 CUZZOCREA, P., Nuovo Cim. 16 (1960) 450.
90 CUZZOCREA, P., PAPPALARDO, P., Nucl. Phys. 48 (1963) 686.
91 CUZZOCREA, P., NOTARRIGO, S., PERILLO, E., Nuovo Cim. 52B (1967) 476.
92 CUZZOCREA, P., PERILLO, E., NOTARRIGO, S., Nucl. Phys. A103 (1967) 616.
93 CUZZOCREA, P., PERILLO, E., NOTARRIGO, S., Nuovo Cim. 54B (1968) 53.
94 CURZIO, G., SONA, P., Nuovo Cim. 54B (1968) 319.
95 DEPRAZ, M.J., LEGROS, G., SALIN, R., J. Phys. Rad. 21 (1960) 377.
96 DEBERTIN, K., RÖSSLE, E., Nucl. Phys. 70 (1965) 89.
97 DECOWSKI, P., GROCHULSKI, W., MARCINKOWSKI, A., SIWEK, K., SLEDZINSKA, I., WILHELMI, Z., Nucl. Phys. A112 (1968) 513.
98 DECOWSKI, P., GROCHULSKI, W., MARCINKOWSKI, A., KAROLYI, J., PIOTROWSKI, J., SAAD, E., SIWEK-WILCZYNSKA, K., TURKIEWICZ, I.M., WILHELMI, Z., Inst. Badan Jadrowych, Rep. IBJ 1197/I/PL (1970).

99 DILG, W., VONACH, H., WINKLER, G., HILLE, P., Nucl. Phys. A118 (1968) 9.
100 DILG, W., VONACH, H., Rep. EANDC(E)89"U", NEA, Paris (1968).
101 DREYER, F., Diplomarbeit, Hamburg (1966).
102 DRUZHININ, A.A., LBOV, A.A., BILIBIN, L.P., Sov. J. Nucl. Phys. 4 (1967) 366.
103 DUDLEY, J.M., CLASS, C.M., Phys. Rev. 94 (1954) 807.
104 FERGUSON, J.M., THOMPSON, W.E., Phys. Rev. 118 (1960) 228.
105 FERGUSON, J.M., ALBERGOTTI, J., Nucl. Phys. A98 (1967) 65.
106 FEICHT, E., VONACH, H., Nukleonik 10 (1967) 58.
107 FISCHER, G.J., Phys. Rev. 108 (1957) 99.
108 FLEROV, N., J. Nucl. Energy 11 (1959) 174.
109 FOWLER, J.L., SLYE, J.M., Phys. Rev. 77 (1950) 787.
110 FORBES, S.G., Phys. Rev. 88 (1952) 1309.
111 FUKUZAWA, F., J. Phys. Soc. Jap. 16 (1961) 2371.
112 GABBARD, F., private communication (1961), quoted in J. Nucl. Energy AB 19 (1965) 907.
113 GABBARD, F., private communication (1961), quoted in Rep. BNL-325 (1965).
114 GABBARD, F., KERN, B.D., Phys. Rev. 128 (1962) 1276.
115 GANGRSKIJ, Y.P., KHARISOV, I.F., Sov. J. Nucl. Phys. 12 (1971) 611.
116 GLAGOLEV, V.L., KOVRIZHNYKH, O.M., MAKATZOV, Y.V., YAMPOLSKIJ, P.A., Sov. Phys. – JETP 9 (1959) 742.
117 GLAGOLEV, V.L., MOROZOV, A.M., YAMPOLSKIJ, P.A., Sov. Phys. – JETP 12 (1961) 1131.
118 GLAGOLEV, V.L., YAMPOLSKIJ, P.A., Sov. Phys. – JETP 13 (1961) 520.
119 GLOVER, R.N., WEIGOLD, E., Nucl. Phys. 29 (1962) 309.
120 GONZÁLEZ, L., RAPAPORT, J., LOEF, J.J. van, Phys. Rev. 120 (1960) 1319.
121 GONZÁLEZ, L., TRIER, A., LOEF, J.J. van, Phys. Rev. 126 (1961) 271.
122 GOLCHERT, N.W., GARDNER, D.G., SEDLET, J., Nucl. Phys. 73 (1965) 349.
123 GRAVES, E.R., DAVIS, R.W., Phys. Rev. 97 (1955) 1205.
124 GRUNDL, J.A., HENKEL, R.L., PERKINS, B.L., Phys. Rev. 109 (1958) 425.
125 GRAVES, CONNOR, FORD, WARREN, cited in VANDENBOSCH, R., HUIZENGA, J.R., MILLER, W.F., KEBERLE, E.M., Nucl. Phys. 25 (1961) 511.
126 GRANGER, B., LONGUEVE, M., Rep. EANDC(E)49, NEA, Paris (1963) 8.
127 GRIMELAND, B., OPSAHL-ANDERSEN, P., Nucl. Phys. 51 (1964) 302.
128 GRIMELAND, B., KJELLSBY, E., VINES, J., Phys. Rev. 137 (1965) B 878.
129 GRISSOM, J.T., KOEHLER, D.R., Phys. Rev. 142 (1966) 725.
130 GRAY, P.R., ZANDER, A.R., EBREY, T.G., Nucl. Phys. 75 (1966) 215.
131 GROCHULSKI, W., KAROLYI, J., MARCINKOWSKI, A., PIOTROWSKI, J., SAAD, E., SIWEK, K., WILHELMI, Z., Rep. INR 1197/I/PL (1970).
132 HAVLIK, E., Acta Phys. Austriaca 34 (1971) 209.
133 HÄRING, H., VONACH, H., FEICHT, E.J., Z. Phys. 244 (1971) 352.
134 HASAN, S.S., PRASAD, R., SEGHAL, M.L., Nucl. Phys. A181 (1972) 101.
135 HANKLA, A.K., FINK, R.W., Nucl. Phys. A180 (1972) 157.
136 HENKEL, R.L., Private communication (1954), cited in Rep. BNL-325, Suppl. 2 (1964).
137 HEERTJE, I., DEVENNE, L., NAGEL, W., ATEN, A.H.W., Jr., Physica (NL) 30 (1964) 1762.
138 HILLE, P., Österr. Akad. Wiss. 98 (1961) 200, Anz. 12.
139 HILLMAN, M., Nucl. Phys. 37 (1962) 78.
140 HILLMAN, M., SHIKATA, E., Rep. BNL-11506 (1967).
141 HILLMAN, M., SHIKATA, E., J. Inorg. Nucl. Chem. 31 (1969) 909.
142 HOPKINS, J., DRAKE, D., Nucl. Phys. A107 (1968) 139.
143 HOLMBERG, M., HANSÉN, J., Nucl. Phys. A129 (1969) 305.
144 HÖLSCHER, H.H., Diplomarbeit, Hamburg (1972).
145 HILLE, P., MÜNZER, H., Acta Phys. Austriaca 23 (1966) 44.
146 HUGHES, D., SCHWARTZ, R., private communication (1958), cited in LISKIEN, H., PAULSEN, A., Rep. EUR 119e (1968).
147 HUDSON, O.M., MORGAN, I.L., Bull. Am. Phys. Soc. II 4 (1959) 97.
148 HUSAIN, L., KURODA, P.K., Nucl. Phys. A114 (1968) 663.
149 HUSAIN, L., BARI, A., KURODA, P.K., Phys. Rev. 1C (1970) 1233.
150 HÜRLIMANN, T., HUBER, P., Helv. Phys. Acta 28 (1955) 33.
151 IMHOF, W.L., private communication (1960), cited in Rep. BNL-325 (1965).
152 IMHOF, W.L., private communication (1961), cited in Rep. BNL-325 (1965).
153 IVANENKO, V.V., PETRZHAK, K.A., POTAMANOV, V.I., Sov. J. Nucl. Phys. 6 (1968) 7.
154 IVANENKO, V.V., PETRZHAK, K.A., Sov. J. Nucl. Phys. 9 (1969) 152.

155 JERONYMO, J.M.F., MANI, G.S., OLKOWSKY, J., SADEGHI, A., WILLIAMSON, C.F., Nucl. Phys. 47 (1963) 157.
156 JERONYMO, J.M.F., MANI, G.S., OLKOWSKY, J., SADEGHI, A., WILLIAMSON, C.F., J. Phys. (Paris) 24 (1963) 816.
157 JOHNSON, R.G., SALISBURY, S., VAUGHN, F.J., Rep. LMSC-4-50-62-1 (Oct. 1962).
158 DeJUREN, J.A., STOOKSBERRY, R.W., WALLIS, M., Phys. Rev. 127 (1962) 1229.
159 KANTELE, J., GARDNER, D.G., Nucl. Phys. 35 (1962).
160 KARAM, R.A., PARKINSON, T.F., PANCZYK, M.F., Rep. NP-12336 (1962).
161 KAROLYI, J., CSIKAI, J., PETŐ, G., Nucl Phys. A122 (1968) 234.
162 KANDA, Y., J. Phys. Soc. Jap. 24 (1968) 17.
163 KERN, B.D., THOMPSON, W.E., FERGUSON, J.M., Nucl. Phys. 10 (1959) 226.
164 KHURANA, C.S., HANS, H.S., Nucl. Phys. 13 (1959) 88.
165 KHURANA, C.S., HANS, H.S., Nucl. Phys. 28 (1961) 560.
166 KLEMA, E., HANSON, A., Phys. Rev. 73 (1948) 106.
167 KLYUCHAREV, A.P., USHAKOV, U.V., CHURSIN, G.P., Sov. Phys. – JETP 19 (1964) 1002.
168 KNIGHT, J.D., SMITH, R.K., WARREN, B., Phys. Rev. 112 (1958) 259.
169 KNEISSL, K., SCHNEIDER, H., VÖLPEL, R., WÖLCKEN, K., Nucl.Phys. A135 (1969) 395.
170 KOEHLER, D.R., ALFORD, W.L., Phys. Rev. 119 (1960) 311.
171 KOEHLER, D.R., ALFORD, W.L., Bull. Am. Phys. Soc. 5 (1960) 443 C11.
172 KONIJN, J., LAUBER, A., Nucl. Phys. 48 (1963) 191.
173 KÖNIG, V., Nucl. Phys. 71 (1965) 497.
174 KOLAR, Z., STROHAL, P., CINDRO, N., J. Inorg. Nucl. Chem. 27 (1965) 2471.
175 KONDAIAH, E., RANAKUMAR, N., FINK, R.W., Nucl. Phys. A120 (1968) 337.
176 KOZLOWSKI, T., MOROZ, Z., RURARZ, E., WOJTKOWSKA, J., Acta Phys. Pol. 33 (1968) 409.
177 KREGER, W., KERN, B.D., Phys. Rev. 113 (1959) 890.
178 KUMABE, I., POULARIKAS, A.D., PREISS, I.L., GARDNER, D.G., FINK, R.W., Phys. Rev. 117 (1960) 1568.
179 LANGMANN, J., private communication (1962), quoted in Rep. BNL-325 (1966).
180 LANGKAU, R., Z. Naturforsch. 18a (1963) 914.
181 LAUBER, A., MALMSKOG, S., Nucl. Phys. 73 (1965) 234.
182 LEBEDEV, P., J. Nucl. Energy 11 (1959) 39.
183 LETESSIER, J., DALMAS, J., C.R. 259 (1964) 4620.
184 LISKIEN, H., PAULSEN, A., J. Nucl. Energy AB 19 (1965) 73.
185 LISKIEN, H., PAULSEN, A., Nucl. Phys. 63 (1965) 393.
186 LISKIEN, H., PAULSEN, A., Nukleonik 8 (1966) 315.
187 LULIĆ, S., STROHAL, P., ANTOLKOVIĆ, B., PAIC, G., Nucl. Phys. A119 (1968) 517.
188 LU, W.-D., FINK, R.W., Radiochem. Acta 12 (1969) 61.
189 LU, W.-D., RANAKUMAR, N., FINK, R.W., Phys. Rev. 1C (1970) 358.
190 LÜSCHER, E., RICAMO, R., SCHERRER, P., ZÜNTI, W., Helv. Phys. Acta 23 (1950) 561.
191 MARTIN, H.C., DIVEN, B.C., Phys. Rev. 86 (1952) 565.
192 MARTIN, H.C., TASCHEK, R.F., Phys. Rev. 89 (1953) 1302.
193 MARTIN, H.C., Phys. Rev. 93 (1954) 498.
194 MARION, J.B., BRUGGER, R.M., Phys. Rev. 100 (1955) 69.
195 MARION, J.B., BRUGGER, R.M., CHAPMAN, R.A., Phys. Rev. 101 (1956) 247.
196 MANI, G.S., McCALLUM, G.J., FERGUSON, A.T.G., Nucl. Phys. 19 (1960) 535.
197 MANI, G.S., TOMBRELLO, T.A., RAO, D.A.A.S.N., Nucl. Phys. 21 (1960) 344.
198 MAJUMDAR, N.K., CHATTERJEE, A., Nucl. Phys. 41 (1963) 192.
199 MANGAL, S.K., GILL, P.S., Nucl. Phys. 49 (1963) 510.
200 MANGAL, S.K., KHURANA, C.S., Nucl. Phys. 69 (1965) 158.
201 MATHUR, S.C., MORGAN, I.L., Nucl. Phys. 75 (1966) 561.
202 MATHER, D.S., PAIN, L.F., Rep. AWRE-O-47 (1969).
203 METZGER, J., ALDER, F., HUBER, P., Helv. Phys. Acta 21 (1948) 278.
204 MEADOWS, J.W., WHALEN, J.F., Phys. Rev. 130 (1963) 2022.
205 MENLOVE, H.O., COOP, K.L., GRENCH, H.A., Phys. Rev. 163 (1967) 1308.
206 MENON, M.P., CUYPERS, M.Y., Phys. Rev. 156 (1967) 1340.
207 MINETTI, B., PASQUARELLI, A., Nuovo Cim. 44 (1966) 460.
208 MINETTI, B., PASQUARELLI, A., Z. Phys. 207 (1967) 132.
209 MINETTI, B., PASQUARELLI, A., Nuovo Cim. 50 2B (1967) 367.
210 MINETTI, B., PASQUARELLI, A., Nucl. Phys. A118 (1968) 449.
211 MINETTI, B., PASQUARELLI, A., Z. Phys. 217 (1968) 83.

212 MORITA, S., J. Phys. Soc. Jap. 13 (1958) 431.
213 MÜNZER, H., VONACH, H., Österr. Akad. Wiss. 96 (1959) 120.
214 MUKHERJEE, S.K., GANGULY, A.K., MAJUMBER, N.K., Proc. Phys. Soc. 77 (1961) 508.
215 NAKAI, K., GOTOH, H., AMANO, H., J. Phys. Soc. Jap. 17 (1962) 1215.
216 NAGEL, W., ATEN, A.H.W., Jr., Physica 31 (1965) 1091.
217 NAGEL, W., ATEN, A.H.W., Jr., J. Nucl. Energy AB 20 (1966) 475.
218 O'CONNOR, L.P., PERKIN, J.L., J. Inorg. Nucl. Chem. 13 (1960) 5.
219 OKUMURA, S., Nucl. Phys. A93 (1967) 74.
220 OMS, L.A., PALMS, J.A., RAO, P., WOOD, R.E., FINK, R.W., Bull. Am. Phys. Soc. 13 (1968) 1699.
221 PAUL, E.B., CLARKE, K.L., Can. J. Phys. 31 (1953) 267.
222 PAULSEN, A., LISKIEN, H., Nukleonik 7 (1965) 117.
223 PAULSEN, A., LISKIEN, H., J. Nucl. Energy AB 19 (1965) 907.
224 PAI, H.L., Can. J. Phys. 44 (1966) 2337.
225 PASQUARELLI, A., Nucl. Phys. A93 (1967) 218.
226 DRUZHININ, A.A., IVANOVA, N.I., LBOV, A.A., Yad. Fiz. 14 (1971) 682.
227 PAULSEN, A., Nukleonik 10 (1967) 91.
228 PARTINGTON, D., CRUMPTON, D., HUNT, S.E., Analyst 95 (1970) 257.
229 PAULSEN, A., WIDERA, R., Z. Phys. 238 (1970) 23.
230 PERKIN, J.L., COLEMAN, R.F., J. Nucl. Energy AB 14 (1961) 69.
231 PERKIN, J.L., private communication (1961), quoted in Rep. BNL-325, Suppl. 2 (1966).
232 PEIL, A., Nucl. Phys. 66 (1965) 419.
233 PETÖ, G., BORNEMISZA-PAUSPERTL, P., KAROLYI, J., Acta Phys. Hung. 25 (1967) 91.
234 PHILLIPS, J.A., private communication (1956), quoted in Ref. 230.
235 PICARD, J., WILLIAMSON, C.F., J. Phys. (London) 24 (1963) 813.
236 PICARD, J., WILLIAMSON, C.F., Nucl. Phys. 63 (1965) 673.
237 POOLE, M.J., private communication (1954), quoted in Ref. 230.
238 POULARIKAS, A., FINK, R.W., Phys. Rev. 115 (1959) 989.
239 POULARIKAS, A., CUNNINGHAM, J., McMILLAN, W., FINK, R.W., J. Inorg. Nucl. Chem. 13 (1966) 196.
240 POULARIKAS, A., FINK, R.W., GARDNER, D.G., Annu. Prog. Rep. Nucl. Chem. (1960).
241 POLLEHN, H., NEUERT, H., Z. Naturforsch. 16a (1961) 227.
242 POLLEHN, H., Diplomarbeit, Hamburg (1961).
243 POULARIKAS, A., GARDNER, D.G., private communication (1962), quoted in NEUERT, H., POLLEHN, H., Rep. EUR-122e (1963).
244 PRESTWOOD, R.J., Phys. Rev. 98 (1955) 47.
245 PREISS, I.L., FINK, R.W., Nucl. Phys. 15 (1960) 326.
246 PRESTWOOD, R.J., BAYHURST, B.P., Phys. Rev. 121 (1961) 1438.
247 PRASAD, R., SARKAR, D.C., KHURANA, C.S., Nucl. Phys. 88 (1966) 349.
248 PRASAD, R., SARKAR, D.C., Nucl. Phys. A94 (1967) 476.
249 PRESSER, G., BASS, R., KRÜGER, K., Nucl. Phys. A131 (1969) 679.
250 RAMA PRASAD, P., RAO, J.R., KONDAIAH, E., Nucl. Phys. A138 (1969) 85.
251 PURSER, K.H., TITTERTON, E., Aust. J. Phys. 12 (1959) 103.
252 QAIM, S.M., EJAZ, M., J. Inorg. Nucl. Chem. 30 (1968) 2577.
253 QAIM, S.M., J. Inorg. Nucl. Chem. 32 (1970) 1799.
254 QAIM, S.M., WÖLFLE, R., STÖCKLIN, G., in Chemical Nuclear Data, Measurements and Applications (Proc. Conf. Canterbury, 1971), Inst. of Civil Engineers, London (1971).
255 QAIM, S.M., Nucl. Phys. A185 (1972) 614.
256 RAPAPORT, J., LOEF, J.J., van, Phys. Rev. 114 (1958) 565.
257 RAYBURN, L.A., Phys. Rev. 122 (1961) 168.
258 RAYBURN, L.A., Bull. Am. Phys. Soc. 7 (1962) 335.
259 RAYBURN, L.A., Phys. Rev. 130 (1963) 731.
260 RAYBURN, L.A., Bull. Am. Phys. Soc. 8 (1963) 60, 121.
261 RAMAKUMAR, N., KONDAIAH, E., FINK, R.W., Nucl. Phys. A122 (1968) 679.
262 REED, C.H., Rep. TID-11929 (1960).
263 RICAMO, R., Nuovo Cim. 8 (1951) 383.
264 RIEDER, R., MÜNZER, H., Acta Phys. Austriaca 23 (1966) 42.
265 RIMMER, E., FISHER, P., Nucl. Phys. A108 (1968) 567.
266 ROSEN, L., STEWART, L., Phys. Rev. 107 (1957) 824.
267 ROETZER, P., Nucl. Phys. A109 (1968) 694.
268 RURARZ, E., HARATYM, Z., PIETRZYKOWSKI, M., SULIK, A., IBJ Rep. 1197/I/PL (1970).

269 SAYRES, A.R., JONES, K.W., WU, C.S., Phys. Rev. 122 (1961) 1853.
270 SAKISAKA, M., SAEKI, E., TOMITA, M., FUKUZAWA, F., J. Phys. Soc. Jap. 16 (1961) 1869.
271 SANTRY, D.C., BUTLER, J.P., Can. J. Chem. 41 (1963) 123.
272 SANTRY, D.C., BUTLER, J.P., Can. J. Phys. 42 (1964) 1030.
273 SALISBURY, S.R., CHALMERS, R.A., Phys. Rev. 140 (1965) B 305.
274 SANTRY, D.C., BUTLER, J.P., Can. J. Phys. 44 (1966) 1183.
275 SCALAN, R.S., FINK, R.W., Nucl. Phys. 9 (1958) 334.
276 SCHMITT, H.W., HALPERIN, J., Phys. Rev. 121 (1961) 827.
277 SCHEIMBAUER, P., HILLE, P., Nucl. Phys. A102 (1967) 534.
278 SCOBEL, W., BORMANN, M., Z. Naturforsch. 25a (1970) 1406.
279 SEEMANN, K.W., MOORE, W.E., Bull. Am. Phys. Soc. 6 (1961) 237.
280 SETHI, B., MUKHERJEE, S.K., Nucl. Phys. 85 (1966) 227.
281 SHUNK, E.R., WAGNER, R.T., HEMMENDINGER, A., Bull. Am. Phys. Soc. 7 (1962) 334.
282 SHIOKAWA, T., YAGI, M., KAJI, H., SASAKI, T., J. Inorg. Nucl. Chem. 30 (1968) 1.
283 SMITH, D.M., BOSTROM, N.A., HUDSPETH, E.L., Phys. Rev. 117 (1960) 514.
284 SPENKE, H., Nucl. Phys. 51 (1964) 329.
285 STELSON, P.H., CAMPBELL,E.C., Phys. Rev. 106 (1957) 1252.
286 STROHAL, P., CINDRO, N., EMAN, B., Nucl. Phys. 30 (1962) 49.
287 STRAIN, J.E., ROSS, W.J., Rep. ORNL-3672 (1965).
288 STEINER, E., HUBER, P., SALATHE, W., WAGNER, R., Helv. Phys. Acta. 43 (1970) 17.
289 SURESH, C., MATHUR, S.C., MORGAN, I.L., Nucl. Phys. 75 (1966) 561.
290 TARTARCZUK, J.R., MEDICUS, H.A., Phys. Rev. 143 (1966) 818.
291 TERRELL, J., HOLM, D.M., Phys. Rev. 109 (1958) 2031.
292 TEWES, H.A., CARETTO, A.A., MILLER, A.E., Bull. Am. Phys. Soc. 4 (1959) 445.
293 TEWES, H.A., CARETTO, A.A., MILLER, A.E., NETHAWAY, D.R., Rep. UCRL-6028T (1960).
294 TEMPERLEY, J.K., Phys. Rev. 178 (1969) 1904.
295 TIWARI, P.N., KONDAIAH, E., Phys. Rev. 167 (1968) 1091.
296 TRIER, A., Z. Naturforsch. 17a (1962) 275.
297 URECH, S., JEANUET, E., ROSSEL, J., Helv. Phys. Acta 34 (1961) 954.
298 VANDENBOSCH, R., HUIZENGA, J.R., Phys. Rev. 120 (1960) 1313.
299 LOEF, J.J., van, Nucl. Phys. 24 (1961) 340.
300 VAUGHN, F.J., private communication (1963), cited in Rep. BNL-325 (1965).
301 VENUGOPALA RAO, P., FINK, R.W., Phys. Rev. 154 (1967) 1023.
302 VENUGOPALA RAO, P., WOOD, R.E., PALMS, J.M., FINK, R.W., Phys. Rev. 3C (1971) 629.
303 VINITSKAYA, G.P., LEVKOVSKIJ, V.N., SOKOL'SKIJ, V.V., Sov. J. Nucl. Phys. 6 (1968) 174.
304 VONACH, H., MÜNZER, H., Österr. Akad. Wiss. 96 (1959) 120.
305 VONACH, H., Proc. 26. Physikertagung, Vienna (1961) 67.
306 VONACH, H., Österr. Akad. Wiss. 9 (1961) 116.
307 VONACH, H., VONACH, W.G., MÜNZER, H., SCHRAMMEL, P., Rep. EANDC(E)89"U", NEA, Paris (1968) 37.
308 VONACH, H., private communication, cited in Nucl. Phys. A130 (1969) 195.
309 VONACH, H., HILLE, M., STENGL, G., BREUNLICH, W., WERNER, E., Z. Phys. 237 (1970) 155.
310 WAGENER, H.H., Diplomarbeit, Hamburg (1972).
311 WEIGOLD, E., Aust. J. Phys. 13 (1960) 186.
312 WEIGOLD, E., GLOVER, R.N., Nucl. Phys. 32 (1962) 106.
313 WENUSCH, R., VONACH, H., Österr. Akad. Wiss., Anz. 99 (1962) 1.
314 WENUSCH, R., VONACH, H., Österr. Akad. Wiss., Anz. 1 (1962) 1.
315 WEN-DEH LU, RANA KUMAR, N., FINK, R.W., Phys. Rev. 1C (1970) 350.
316 WILLE, R.G., FINK, R.W., Phys. Rev. 112 (1958) 1950.
317 WILLE, R.G., FINK, R.W., Phys. Rev. 118 (1960) 242.
318 WILLIAMSON, C.F., Phys. Rev. 122 (1961) 1877.
319 WILLIAMSON, C.F., PICARD, J., J. Phys. Rad. 22 (1961) 651.
320 WINIWARTER, P., Nucl. Phys. A158 (1970) 77.
321 WOOD, R.E., COOK, W.S., GOODGAME, J.R., FINK, R.W., Phys. Rev. 154 (1967) 1108.
322 WÖLFER, G., BORMANN, M., Z. Phys. 194 (1966) 75.
323 YASUMI, S., J. Phys. Soc. Jap. 12 (1957) 443.
324 YU-WEN YU, GARDNER, D.G., Nucl. Phys. A98 (1967) 451.
325 ZIELINSKI, U., Diplomarbeit, Hamburg (1965).
326 ZYSIN, Yu. A., KOVRIZHNYKH, A.A., LBOV, A.A., SEL'CHKOV, L.I., At. Ehnerg. 8 (1960) 360.
327 MOGHARRAB, R., NEUERT, H., Atomkernenergie 19 (1972) 107.

328 TRAUTMANN, N., DENIG, R., HERRMANN, G., Radiochim. Acta 11 (1969) 168.
329 COLEMAN, R.F., HAWKER, B.E., O'CONNOR, L.P., PERKIN, J.L., Proc. Phys. Soc. 73 (1959) 215.
330 KULISIĆ, P., CINDRO, N., STROHAL, P., LALOVIĆ, B., Nucl. Phys. 73 (1965) 548.
331 HANKLA, A.K., HAMILTON, J.H., FINK, R.W., Bull. Am. Phys. Soc. 15 (1970) 1372 EH8.
332 HANKLA, A.K., HAMILTON, J.H., FINK, R.W., Bull. Am. Phys. Soc. 13 (1968) 1421, 10.
333 MUKHERJEE, S.K., BAKHRU, H., Proc. Symp. Nuclear Physics and Solid State Physics, Bombay (1963) 244.
334 MEASON, J.L., GANAPATHY, R., KURODA, P.K., Radiochim. Acta 6 (1966) 26.
335 MINETTI, B., PASQUARELLI, A., Nuovo Cim. 44B (1966) 5336.
336 RAMA PRASAD, P., RAMA RAO, J., KONDAIAH, E., Nucl. Phys. A125(1969) 57.
337 IHOCHI, J., WARD, T.E., Phys. Rev. 166 (1968) 1173.
338 KHURANA, C.S., GOVIL, I.M., Nucl. Phys. 69 (1965)153.
339 ALFORD, W.L., KOEHLER, D.R., Bull. Am. Phys. Soc. 10 (1965) 260 T5.
340 LEVKOVSKIJ, V.N., KOVEL'SKAYA, G.E., VINITSKAYA, G.P., STEPANOV, V.M., SOKOLSKIJ, V.V., Sov. J. Nucl. Phys. 8 (1969) 4.
341 LAGERWALL, T., Z. Naturforsch. 20a (1965) 1583.
342 MARCAZZAN, G.M., MENICHELLA SAETTA, E., TONOLINI, F., Nuovo Cim. 20 (1961) 903.
343 BLOSSER, H.G., GOODMAN, C.D., HANDLEY, T.H., Phys. Rev. 110 (1958) 531.
344 BIZETTI, P.G., BIZETTI-SONA, A.M., BOCCIOLINI, M., Nucl. Phys. 36 (1962) 38.
345 LEVKOVSKIJ, V.N., VINITSKAYA, G.P., STEPANOV, V.M., Sov. J. Nucl. Phys. 10 (1969) 25.
346 LEVKOVSKIJ, V.N., ARTEM'EV, O.I., Sov. J. Nucl. Phys. 13 (1971) 529.
347 DZANTIEV, B.G., LEVKOVSKIJ, V.N., MALIEVSKIJ, A.D., Sov. Phys. – Dokl. 2 (1958) 135.
348 LEVKOVSKIJ, V.N., Sov. Phys. – JETP 18 (1964) 213.
349 LU, W.-D., FINK, R.W., Bull. Am. Phys. Soc. 13 (1968) 1422 DB 15.
350 CSIKAI, J., BACSÓ, J., DARÓCZY, A., Nucl. Phys. 41 (1963) 316.
351 PRASAD, R., SARKAR, D.C., KHURANA, C.S., Nucl. Phys. 85 (1966) 476.
352 ALFORD, W.L., KOEHLER, D.R., MANDEVILLE, C.E., Phys. Rev. 123 (1961) 1365.
353 BRAMLITT, E.T., FINK, R.W., Annu. Rep. Arkansas (1962).
354 BRAMLITT, E.T., GARDNER, D.G., Annu. Prog. Rep. Nucl. Chem. (1961).
355 BROLLEY, J.E., BUNKER, M.E., COCHRAN, D.R.F., HENKEL, R.L., MIZE, J.P., STARNER, J.W., Phys. Rev. 99 (1955) 330.
356 BRAMLITT, E.T., FINK, R.W., GARDNER, D.G., POULARIKAS, A., Phys. Rev. 125 (1962) 297.
357 BLOSSER, H.G., GOODMAN, C.D., HANDLEY, T.H., RANDOLPH, M.L., Phys. Rev. 100 (1955) 422.
358 FINK, R.W., RAO, P.V., WOOD, R.E., PALMS, J.M., Phys. Rev. 3C (1971) 629.
359 FINK, R.W., private communication (1961), quoted in NEUERT, H., POLLEHN, H., Rep. EUR-122e (1963).
360 RAO, P.V., WOOD, R.E., PALMS, J.M., FINK, R.W., Bull. Am. Phys. Soc. 13 (1968) 602 II DE5.
361 FINK, R.W., KONDAIAH, E., RANAKUMAR, N., Bull. Am. Phys. Soc. 13 (1968) 602 II DE6.
362 KJELBERG, A., PAPPAS, A.L., STEINNES, E., Radiochim. Acta 5 (1966) 28.
363 RAO, P.V., FINK, R.W., Phys. Rev. 154 (1966) 1023.
364 MINETTI, B., PASQUARELLI, A., Nucl. Phys. A100 (1967) 186.
365 VINITSKAYA, G.P., LEVKOVSKIJ, V.N., SOKOL'SKIJ, V.V., KAZACHEVSKIJ, I.V., Sov. J. Nucl. Phys. 5 (1967) 839.
366 MEASON, J.L., KURODA, P.K., Phys. Rev. 138 (1965) B 1390.
367 PREISS, J.L., FINK, R.W., Nucl. Phys. 15 (1960) 326.
368 PREISS, J.L., FINK, R.W., GARDNER, D.G., Annu. Prog. Rep. Nucl. Chem. (1960).
369 PAULSEN, A., Z. Phys. 205 (1967) 226.
370 MINETTI, B., PASQUARELLI, A., Z. Phys. 199 (1967) 275.
371 FREVERT, E., Acta Phys. Austriaca 20 (1967) 304.
372 NIX, J., CHITTENDEN, D., GARDNER, D.G., Annu. Prog. Rep. Nucl. Chem. (1961).
373 VONACH, H., MÜNZER, H., Österr. Akad. Wiss. Nov. 13 (1958) 199.
374 HUSAIN, L., KURODA, P.K., J. Inorg. Nucl. Chem. 30 (1968) 355.
375 CROSS, W.G., PAI, H.L., private communication (1963), quoted in Rep. BNL-325 (1966).
376 KARDONSKY, S., FINSTON, H.L., WILLIAMS, E.T., Phys. Rev. 4C (1971) 840.
377 RANAKUMAR, N., KARTTUNEN, E., FINK, R.W., Nucl. Phys. A128(1969) 333.
378 CZAPP, B., VONACH, H., Österr. Akad. Wiss. 2 (1960) 13.
379 GRAY, P.R., ZANDER, A.R., EBREY, T.G., Nucl. Phys. 62 (1965) 172.
380 NAGEL, W., Rep. EANDC(E)76"U", NEA, Paris (1967) 59.
381 SINGH, J.J., Bull. Am. Phys. Soc. 15 (1970) 1328.
382 ARON, P.M., At. Ehnerg. 16 (1964) 370.
383 HEMINGWAY, J.D., JAMES, R.H., MARTIN, E.B.M., MARTIN, G.R., Proc. R. Soc. A 292 (1966) 180.
384 SALAITA, G.N., Nucl. Phys. A170(1971) 193.

385 NURMIA, M.J., FINK, R.W., Nucl. Phys. 8 (1958) 139.
386 KAUL, O.N., Nucl. Phys. 33 (1962) 177.
387 BORMANN, M., JEREMIE, H., ANDERSSON-LINDSTRÖM, G., NEUERT, H., POLLEHN, H., Z. Naturforsch. 15a (1960) 200.
388 KANTELE, J., FINK, R.W., Bull. Am. Phys. Soc. 6 (1961) 252.
389 HEIBERG, S.A., Phys. Rev. 96 (1954) 856.
390 BATTAT, M.E., RIBE, F.L., Phys. Rev. 89 (1953) 80.
391 KULISIĆ, P., AJDAČIĆ, V., CINDRO, N., LALOVIĆ, B., STROHAL, P., Nucl. Phys. 54 (1964) 17.
392 SEEBECK, U., BORMANN, M., Rep. EANDC(E)57"U", NEA, Paris (1965) 18.
393 SEEBECK, U., BORMANN, M., Nucl. Phys. 68 (1965) 387.
394 KUMABE, I., TAKEKOSHI, E., OGATA, H., TSUNEOKA, Y., Phys. Rev. 106 (1957) 155.
395 DAVIS, E.A., BASS, R., BONNER, T.W., WORLEY, D.M., Jr., Bull. Am. Phys. Soc. 5 (1960) 110.
396 KNELLWOLF, T., ROSSEL, J., Helv. Phys. Acta 39 (1966) 376.
397 KUMABE, I., TAKEKOSHI, E., OGATA, H., TSUNEOKA, Y., J. Phys. Soc. Jap. 13 (1958) 325.
398 IRFAN, M., JACK, W., Proc. Phys. Soc. 81 (1963) 808.
399 FRYE, G., Phys. Rev. 93 (1953) 1086.
400 CHATTERJEE, A., Nucl. Phys. 60 (1964) 273.
401 PRASAD, R., SARKAR, D., Nuovo Cim. 3A 3 (1971) 467.
402 BORNEMISZA, G., Nucl. Sci. Abstr. 17 (1963) 932, No. 7198.
403 ALBURGER, D.E., ELWYN, A., GALLMANN, A., KANE, J.V., OFER, S., PIXLEY, R.E., Phys. Rev. Lett. 2 (1959) 110.
404 MILLER, D.G., private communication (1961), quoted in Rep. BNL-325, Suppl. 2 (1964).
405 FERGUSON, J.M., THOMPSON, W.E., KERN, B.D., cited in Nucl. Phys. 29 (1962) 373.
406 CSIKAI, J., NAGY, S., Nucl. Phys. A91 (1967) 222.
407 PAIC, G., SLANS, J., THOMAS, P., Phys. Lett. 9 (1964) 147.
408 MITRA, B., GHOSE, A.M., Nucl. Phys. 83 (1966) 157.
409 LILLIE, A.B., Phys. Rev. 87 (1952) 716.
410 DeJUREN, J.A., STOOKSBERRY, R.W., Phys. Rev. 120 (1960) 901.
411 HILLE, P., Österr. Akad. Wiss. 177 (1969) 467.
412 ALLAN, D.L., Nucl. Phys. 24 (1961) 274.
413 DEPRAZ, M.J., LEGROS, G., SALIN, M.R., J. Phys. Rad. 21 (1960) 377.
414 HASSLER, F.L., PECK, R.A., Phys. Rev. 125 (1962) 1011.
415 BROWN, G., MORRISON, G.C., MUIRHEAD, H., MORTON, W.T., Phil. Mag. 2 (1957) 785.
416 HALING, R., PECK, R.A., EUBANK, H.P., Phys. Rev. 106 (1957) 971.
417 STOREY, R., JACK, W., WARD, A., Proc. Phys. Soc. A75 (1960) 526.
418 TIWARI, P.N., KONDAIAH, E., Proc. Conf. Nuclear Data, Microscopic Cross-Sections and other Data Basic for Reactors, Paris (1966).
419 PEETERS, E., Phys. Lett. 7 (1963) 142.
420 EUBANK, H.P., PECK, R.A., HASSLER, F.L., Nucl. Phys. 9 (1958) 273.
421 COLLI, L., IORI, I., MARCAZZAN, G., MERZARI, F., SONA, A.M., SONA, P.G., Nuovo Cim. 17 (1960) 634.
422 ANTOLKOVIĆ, B., Nucl. Phys. 44 (1963) 123.
423 HEERTJE, I., DELVENNE, L., NAGEL, W., ATEN, A.H.W., Jr., Physica 30 (1964) 2290.
424 ANDERSSON-LINDSTRÖM, G., NEUERT, H., Z. Naturforsch. 13a (1958) 826.
425 ABBOUD, A., DECOWSKI, P., GROCHULSKI, W., MARCINKOWSKI, A., SIWEK, K., TURKIEWICZ, I., WILHELMI, Z., Rep. IBJ 1147/I/PL (1969).
426 KOEHLER, D.R., ALFORD, W.L., J. Nucl. Energy 18 (1964) 81.
427 CHITTENDEN, D.M., private communication (1961).
428 ALLAN, D.L., Nucl. Phys. 10 (1959) 348.
429 MARCH, P.V., MORTON, W.T., Phil. Mag. 3 (1958) 143.
430 STROHAL, P., KULIŠIĆ, P., KOLAR, Z., CINDRO, N., Phys. Lett. 10 (1964) 104.
431 McCLURE, G., KENT, D., J. Franklin Inst. 260 (1955) 238.
432 BORMANN, M., FRETWURST, E., WREGE, G., private communication (1963), quoted in Rep. BNL-325 (1965).
433 KUMABE, I., FINK, R.W., Nucl. Phys. 15 (1960) 316.
434 VONACH, H., MUNRO, J., Nucl. Phys. 68 (1965) 445.
435 VAL'TER, A.K., GONCHAR, V.Y., ZALYUBOVSKIJ, I.I., LATYSHEV, G.D., CHRUSIN, G.P., Izv. Akad. Nauk. SSSR, Ser. Fiz. 26 (1962) 1079.
436 ARMSTRONG, A.H., ROSEN, L., Nucl. Phys. 19 (1960) 40.
437 BLOSSER, H.G., HANDLEY, T.H., Rep. WASH-191 (1956) 48.

438 RAYBURN, L.A., Bull. Am. Phys. Soc. 6 (1961) 462 F1.
439 ZHEREBTSOVA, K.I., MAKAROVA, T.P., NEMILOV, Y.A., FUNSHTEIN, B.L., Sov. Phys. – JETP 35 (1959) 947.
440 DEMICHELIS, F., GUIDETTI, M., MIRALDI, E., OLDANO, C., Nuovo Cim. 58 XB (1968) 176.
441 COX, A.J., FRANÇOIS, P.E., J. Inorg. Nucl. Chem. 31 (1969) 2957.
442 BRZOSKO, J., DECOWSKI, P., WILHELMI, Z., Nucl. Phys. 45 (1963) 579.
443 VALLIS, D.G., PERKIN, J.L., J. Inorg. Nucl. Chem. 22 (1961) 1.
444 GUJRATHI, S., MUKHERJEE, S., Nucl. Phys. 85 (1966) 288.
445 RAMA PRASAD, P., RAMA RAO, J., KONDAIAH, E., Nucl. Phys. A138 (1969) 85.
446 LEVKOVSKIJ, V.N., Sov. Phys. – Dokl. 2 (1957) 182.
447 KLYUCHAREV, A.P., USHAKOV, U.V., CHURSIN, G.P., Sov. Phys. – JETP 19 (1964) 1002.
448 EUBANK, H., PECK, R., ZATZICK, M., Nucl. Phys. 10 (1959) 418.
449 SAKISAKA, M., J. Phys. Soc. Jap. 14 (1959) 554.
450 VONACH, H., MÜNZER, H., HILLE, P., Acta Phys. Austriaca 23 (1966) 183.
451 BACSÓ, J., CSIKAI, J., PAZSIT, A., Acta Phys. Hung. 18 (1965) 295.
452 RAMA PRASAD, P., RAMA RAO, J., KONDAIAH, E., Nucl. Phys. A125 (1969) 57.
453 US ARMY ROCKET AND GUIDE MISSILE AGENCY, Rep. ARGMA-TN-2, HIN 30 (1962).
454 PHILLIPS, J.A., Rep. AERE NP/R 2033 (1965).
455 KUMABE, I., TAKEKOSHI, E., OGATA, H., TSUNEOKA, Y., OKI, S., J. Phys. Soc. Jap. 13 (1958) 129.
456 FEDDERSEN, K.-H., Diplomarbeit, Hamburg (1972).
457 CSIKAI, J., Magy. Fiz. Foly. 16 (1968) 123.
458 RURARZ, E., HARATYM, Z., KOZLOWSKI, T., WOJKOWSKA, J., Inst. Badan Jadrowych, Rep. IBJ 1091/IA/PL (1970).
459 HUDSON, O.M., MORGAN, I.L., Bull. Am. Phys. Soc. 6 (1961) 506.
460 MARLOW, K.W., FAAS, A., Nucl. Phys. A132 (1969) 339.
461 JESSEN, P., BORMANN, M., DREYER, F., NEUERT, H., Nucl. Data 1A (1965) 103.
462 KAROLYI, J., private communication, cited by BODY, Z.T., Thesis, Debrecen (1972).
463 LU, W., FINK, R.W., Bull. Am. Phys. Soc. 15 (1970) 1372.
464 PETŐ, G., BORNEMISZA-PAUSPERTL, P., KAROLYI, J., Acta Phys. Hung. 24 (1968) 93.
465 TEMPERLEY, J.K., Nucl. Sci. Eng. 32 (1968) 195.
466 MITRA, B., Ind. J. Phys. 41 (1967) 752.
467 CHURSIN, G.P., GONCHAR, V.Yu., ZALYUBOVSKIJ, I.I., KLYUCHAREV, A.P., Zh. Ehksp. Teor. Fiz. 44 (1963) 472.
468 DRUZHININ, A.A., LBOV, A.A., BILIBIN, L.P., Yad. Fiz. 5 (1967) 18.
469 BAK, M.A., PETRZHAK, K.A., CHENG, T-IA-Mei, Izv. Akad. Nauk SSSR, Ser. Fiz. 24 (1960) 818.
470 KAROLYI, J., private communication, cited by BÖDY, Z.T., Thesis, Debrecen (1972).
471 MONNAND, E., PISTON, J., C.R. 263 (1966) 712.
472 DAROCZY, A., RAICS, P., CSIKAI, J., Conf. Neutron Physics, Kiev, 1971.
473 CINDA 71, An Index to the Literature on Microscopic Neutron Data, IAEA, Vienna (1971).

Part 2

GRAPHS OF EXCITATION FUNCTIONS

(Range: 1 - 37 MeV)

ABSTRACT. The compilation is restricted to excitation functions that can be measured by activation techniques. For practical purposes, mainly absolute cross-sections are needed; therefore, excitation functions given only in relative units were excluded. As the excitation functions given in the literature frequently differ for several reasons, less in shape but more in the absolute cross-section values, we desisted from deducing mean excitation functions by averaging over the published data. Where there are significant differences in the absolute values, the excitation functions should be renormalized by using the 14-MeV cross-section values given in Part 1.

INTRODUCTION

The last survey on excitation functions of neutron-induced reactions was published in 1965 [1]. In the meantime, a considerable number of precise measurements on these topics has been performed, mainly with neutrons of the 12- to 20-MeV region.

The following compilation is restricted to excitation functions that can be measured with activation techniques. In particular, the excitation functions of reaction transitions leading to single-energy states of the residual nucleus – e.g. (n, α_0), (n, α_1) transitions – are excluded from this compilation.

As to the intention of this compilation, the user is referred to the introductory comments of Part 1. The same applies to the nomenclature of the reaction types and abbreviation symbols. In contrast to the procedure used in the tables to derive the set of recommended cross-section values for neutron energies of about 14 MeV, we did not want to deduce mean excitation functions by averaging over or calculating from the published data.

The totality of the excitation functions presented here is to be understood as a critical compilation that has been worked out in the following way. Starting from some older compilations (Refs [1-3]) and using the CINDA Report [4], all available published excitation functions were gathered together. Often the excitation functions are published in graphic form only; therefore, the graphs given here may contain small errors which arise when estimating the values from the original graphs.

From this stock, first all those excitation functions were excluded that were given in relative units only. This concerns mainly the papers of Prestwood and Bayhurst [5] and Ferguson and Albergotti [6]. Second, those excitation functions were omitted that showed strong and unexplainable deviations from the majority of the other measurements for the same reaction or that were in contrast to reliable theoretical calculations or predictions (this applies mainly to some (n, 2n) excitation functions compared with statistical model calculations). Third, excitation functions for the small neutron energy interval 13.5 - 15 MeV were excluded because this information is already contained in the tables of Part 1.

The remaining excitation functions are included in the following compilation. If more than one excitation function is given for a reaction, these mostly concentrate around a mean value. In rare cases great differences between two excitation functions can be found, usually, however, not in the form but in the absolute magnitude. These excitation functions should be renormalized by using the recommended 14-MeV cross-section values given in the tables.

ACKNOWLEDGEMENT

The authors would like to thank Miss M. Brauer for her help in preparing the graphs and tables.

REFERENCES TO INTRODUCTION

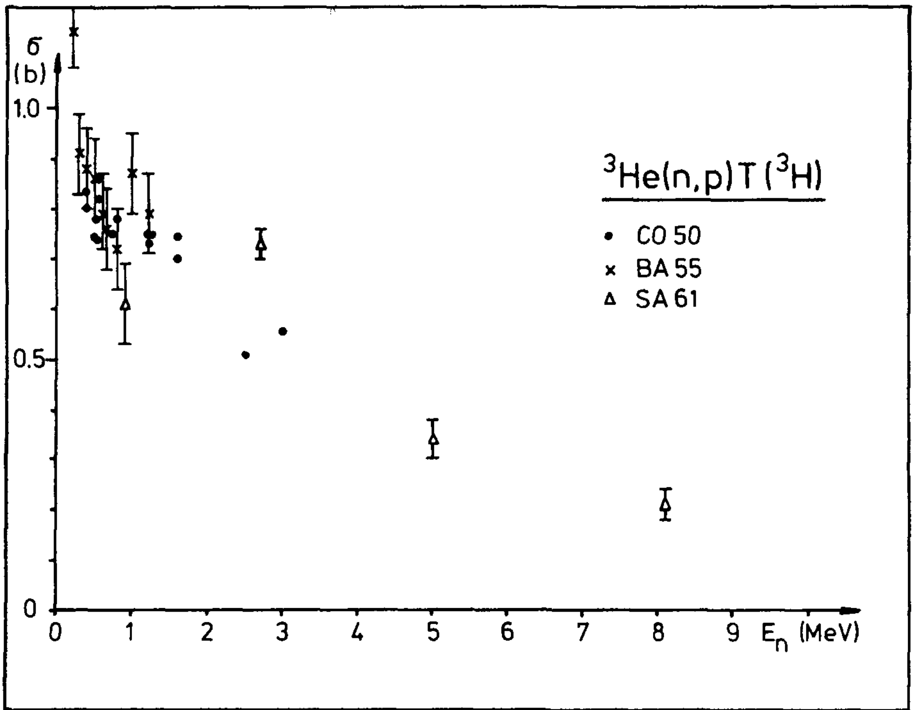
[1] JESSEN, P., BORMANN, M., DREYER, F., NEUERT, H., Nucl. Data 1A (1965) 103.
[2] LISKIEN, H., PAULSEN, A., EURATOM Rep. EUR 119e (1968).
[3] BROOKHAVEN NATIONAL LABORATORY, Neutron Cross Sections, Rep. BNL-325, 2nd Edn (1966).
[4] CINDA 71, An Index to the Literature on Microscopic Neutron Data, published by the IAEA on behalf of the four CINDA centres, IAEA, Vienna (1971).
[5] PRESTWOOD, R.J., BAYHURST, B.P., Phys. Rev. 121 (1961) 1438.
[6] FERGUSON, J.M., ALBERGOTTI, J.C., Nucl. Phys. A98 (1967) 65.

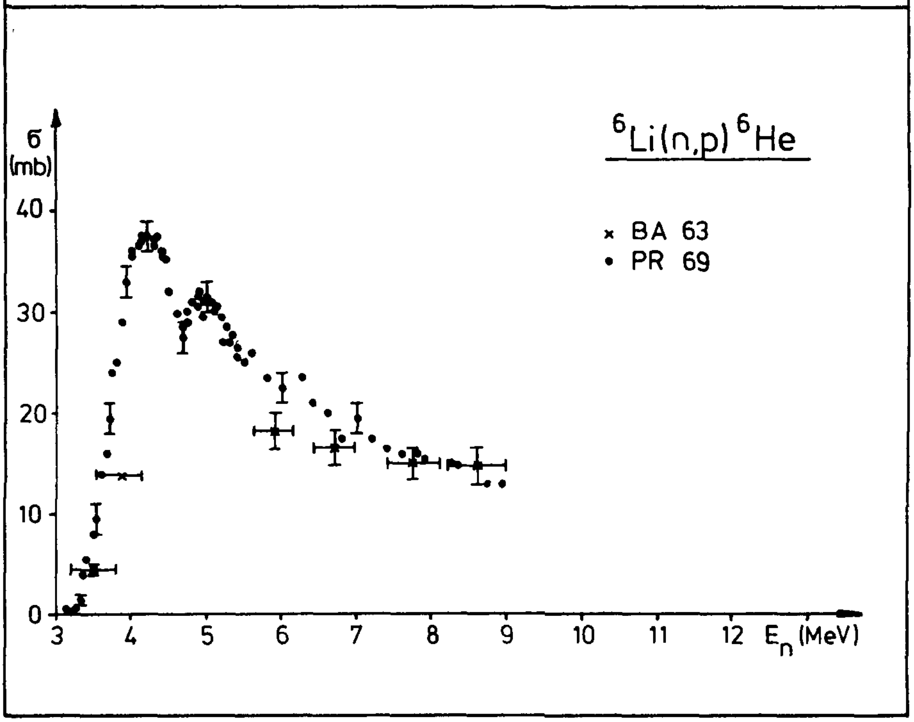
GRAPHS OF (n, p) CROSS-SECTIONS

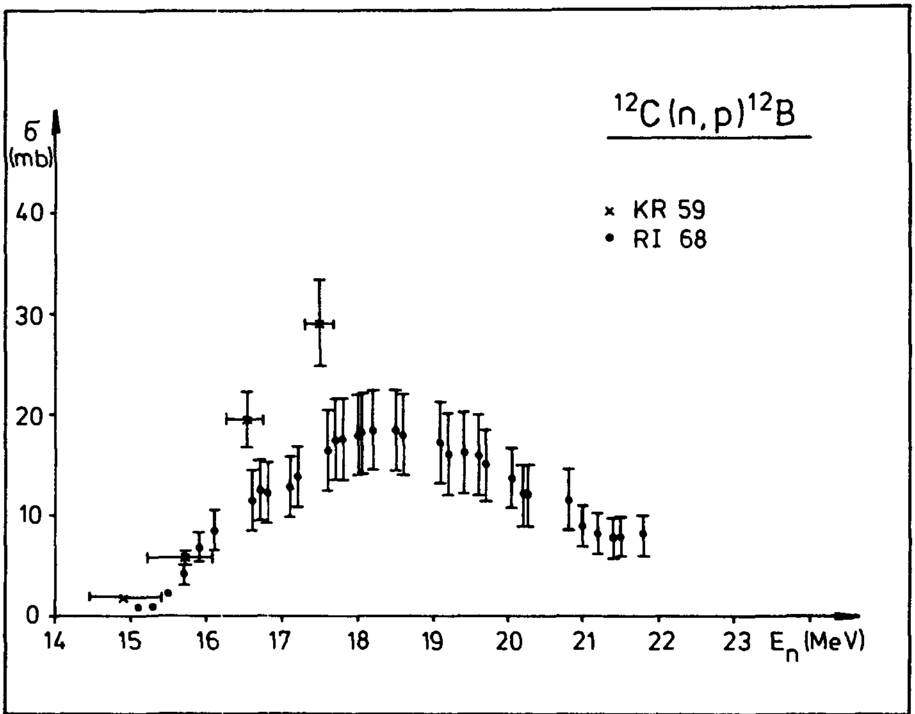
Excitation functions of (n, p) reactions for the target nuclei:

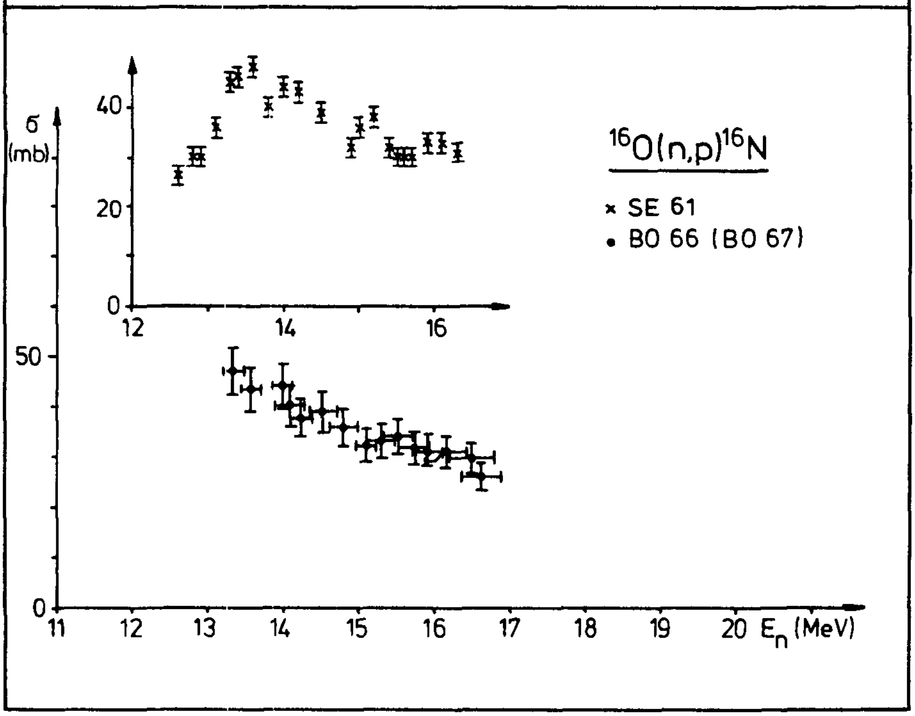
^{3}He, ^{6}Li, ^{12}C, ^{16}O, ^{19}F, ^{23}Na, ^{24}Mg, ^{25}Mg, ^{27}Al, ^{28}Si, ^{31}P,
^{32}S, ^{34}S, ^{37}Cl, ^{39}K, ^{41}K, ^{40}Ca, ^{42}Ca, ^{44}Ca, ^{45}Sc, ^{46}Ti,
^{47}Ti, ^{48}Ti, ^{49}Ti, ^{50}Ti, ^{51}V, ^{52}Cr, ^{54}Fe, ^{56}Fe, ^{59}Co, ^{58}Ni,
^{60}Ni, ^{65}Cu, ^{64}Zn, ^{66}Zn, ^{69}Ga, ^{75}As, ^{74}Se, ^{85}Rb, ^{86}Sr, ^{88}Sr,
^{89}Y, ^{90}Zr, ^{109}Ag, ^{106}Cd, ^{111}Cd, ^{127}I, ^{133}Cs, ^{186}W, ^{197}Au

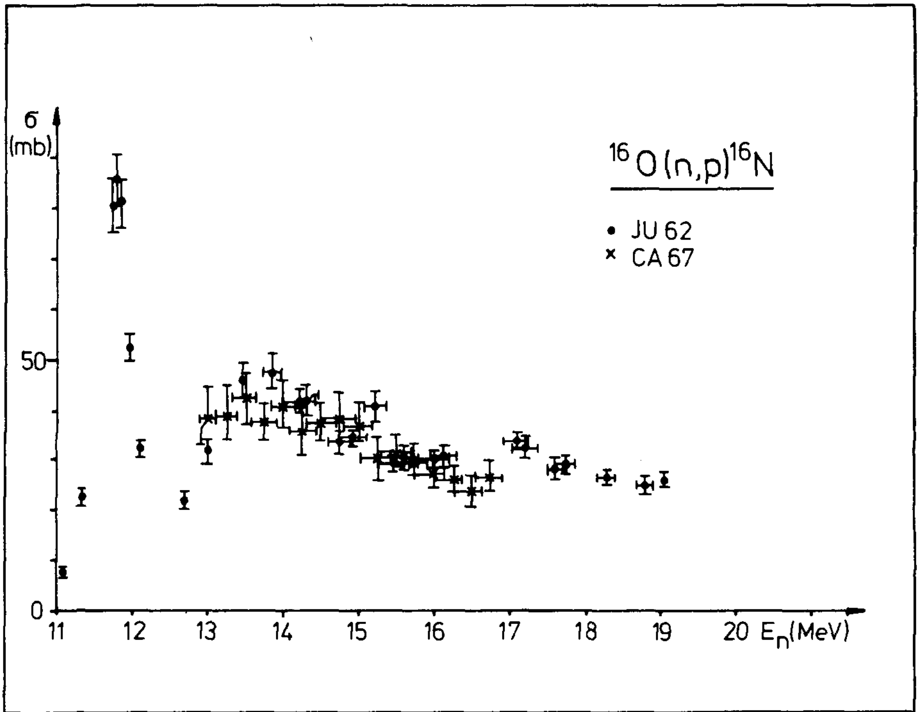
(The abbreviations of references (e.g. CO 50) are constructed from the name of the first author and the year of publication. A list of references is given on pages 270-272.)

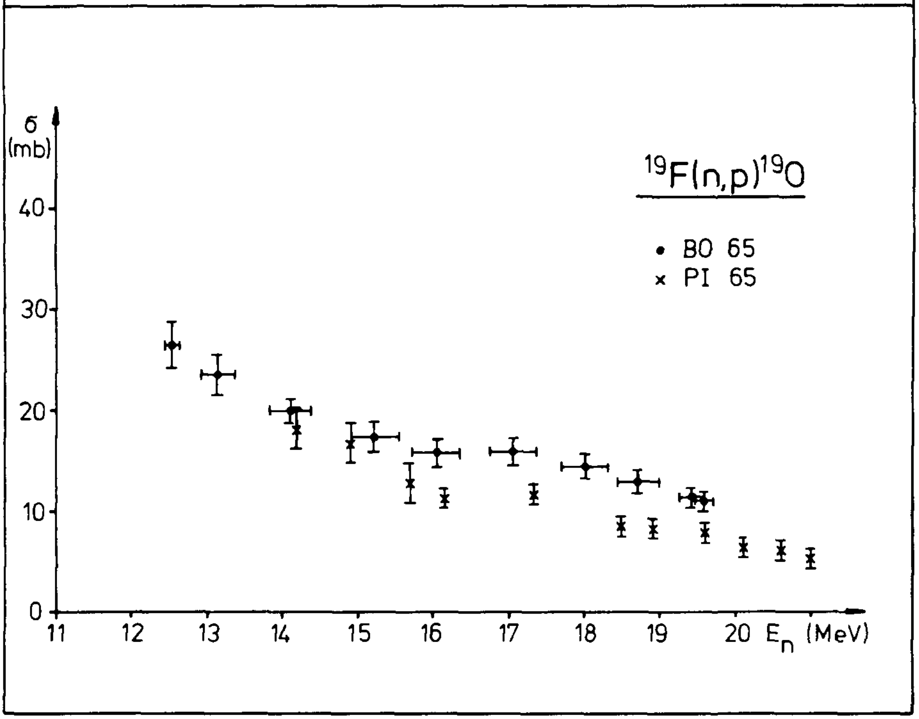

σ
(b)
1.0
0.5
0
0 1 2 3 4 5 6 7 8 9 E_n (MeV)
$^3He(n,p)T(^3H)$
• CO 50
× BA 55
Δ SA 61

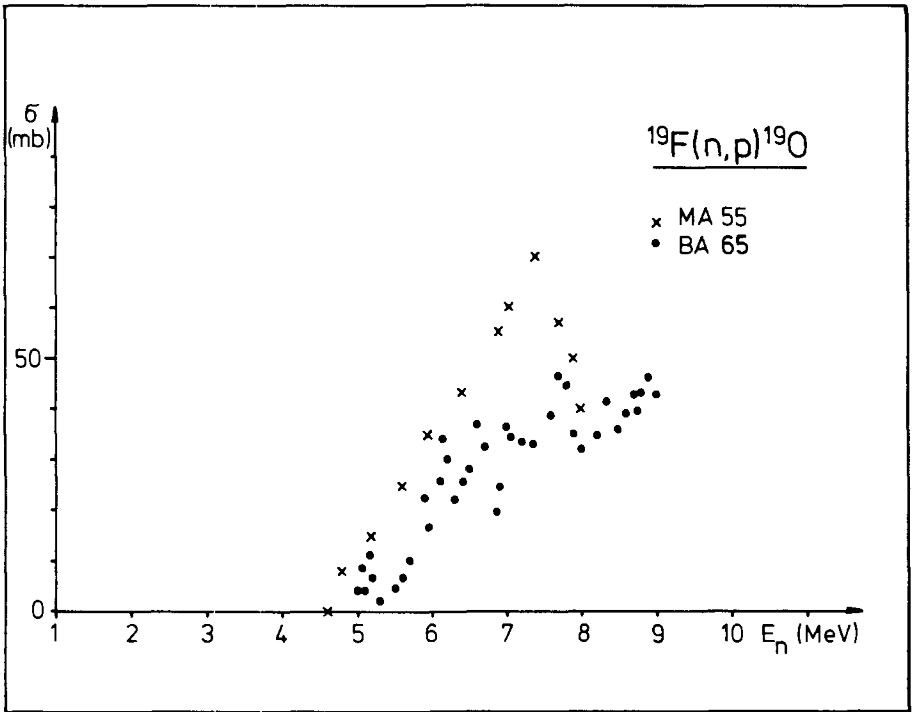

σ
(mb)
40
30
20
10
0
3 4 5 6 7 8 9 10 11 12 E_n (MeV)
$^6Li(n,p)^6He$
× BA 63
• PR 69


$^{12}C(n,p)^{12}B$
× KR 59
• RI 68
σ (mb)
0
10
20
30
40
14
15
16
17
18
19
20
21
22
23
E_n (MeV)

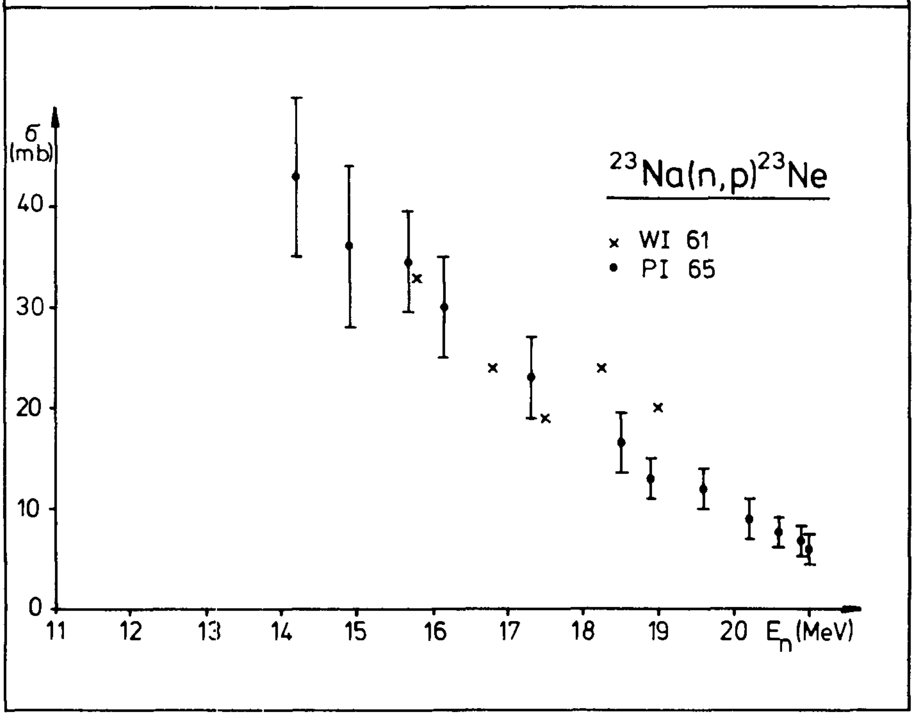

$^{16}O(n,p)^{16}N$
× SE 61
• BO 66 (BO 67)
σ (mb)
0
50
11
12
13
14
15
16
17
18
19
20
E_n (MeV)
0
20
40
12
14
16


$^{16}O(n,p)^{16}N$
• JU 62
× CA 67
σ (mb)
50
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)

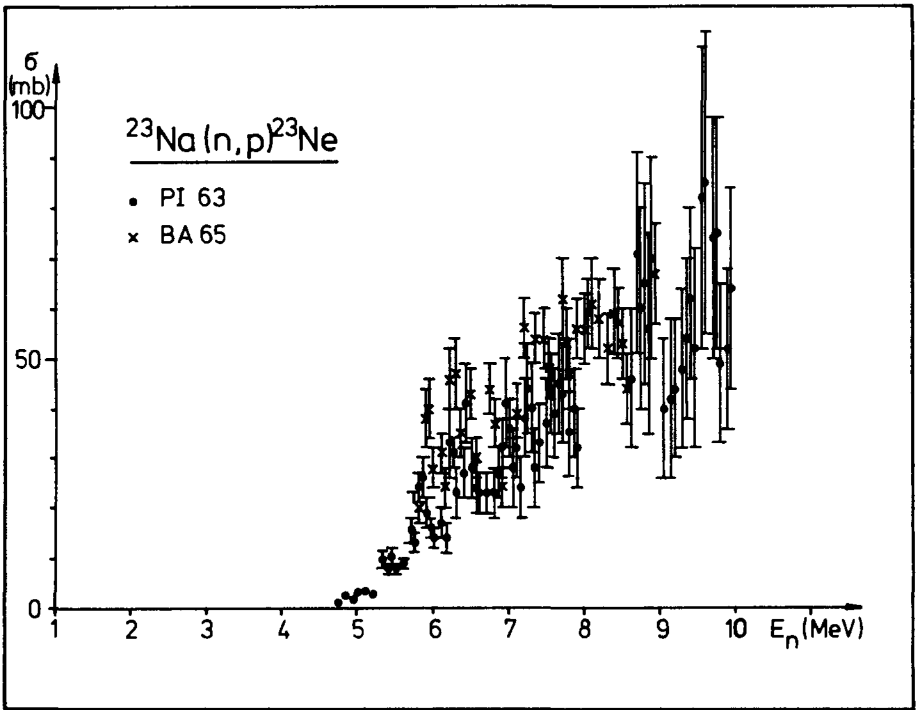

$^{19}F(n,p)^{19}O$
• BO 65
× PI 65
σ (mb)
40
30
20
10
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)

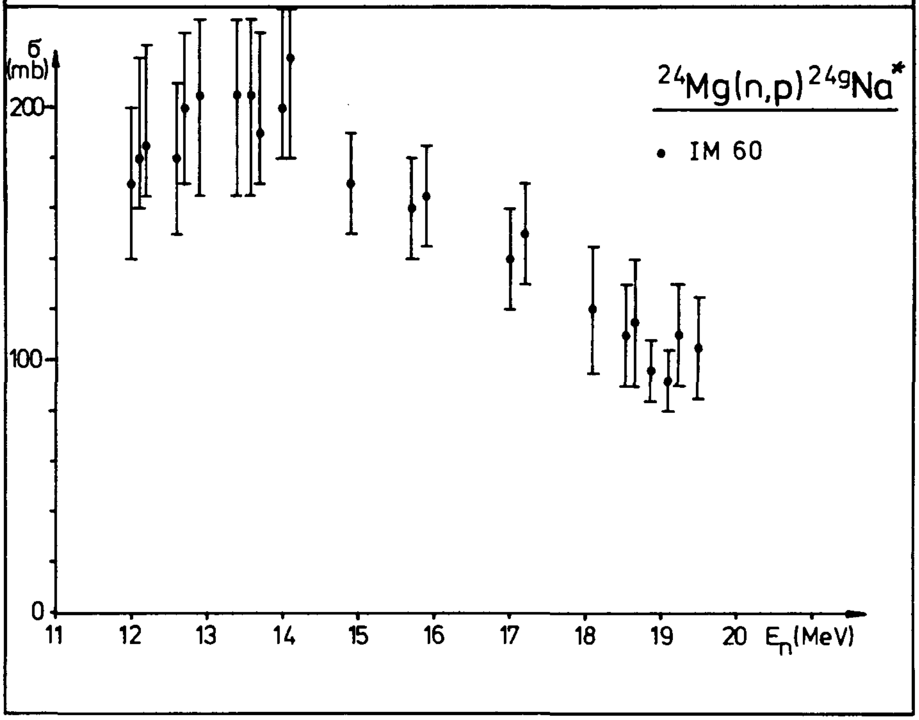


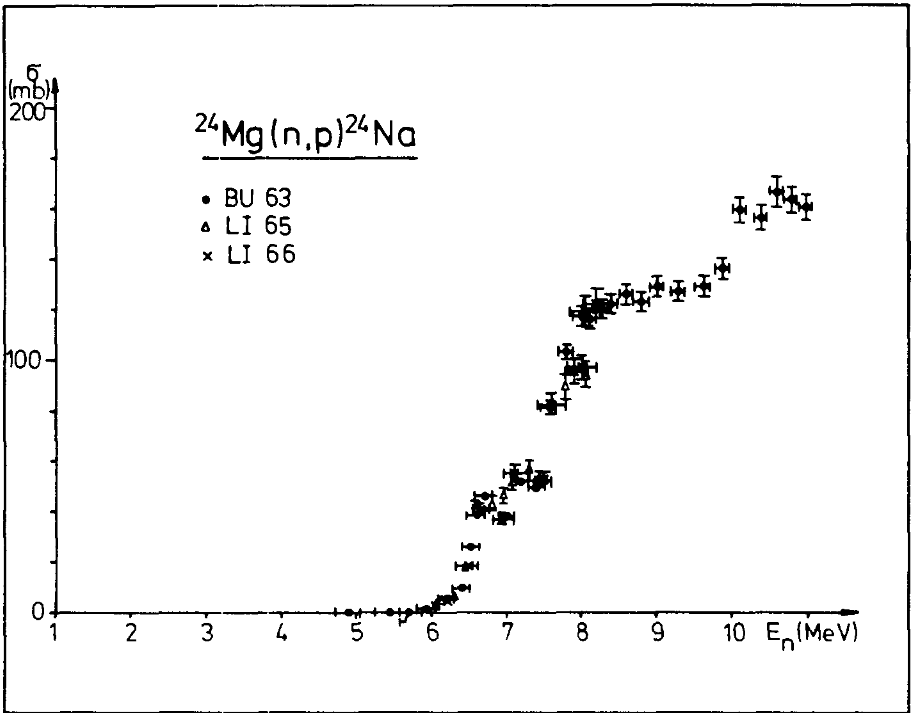
$^{19}F(n,p)^{19}O$
× MA 55
• BA 65
σ (mb)
50
0
1 2 3 4 5 6 7 8 9 10
E_n (MeV)



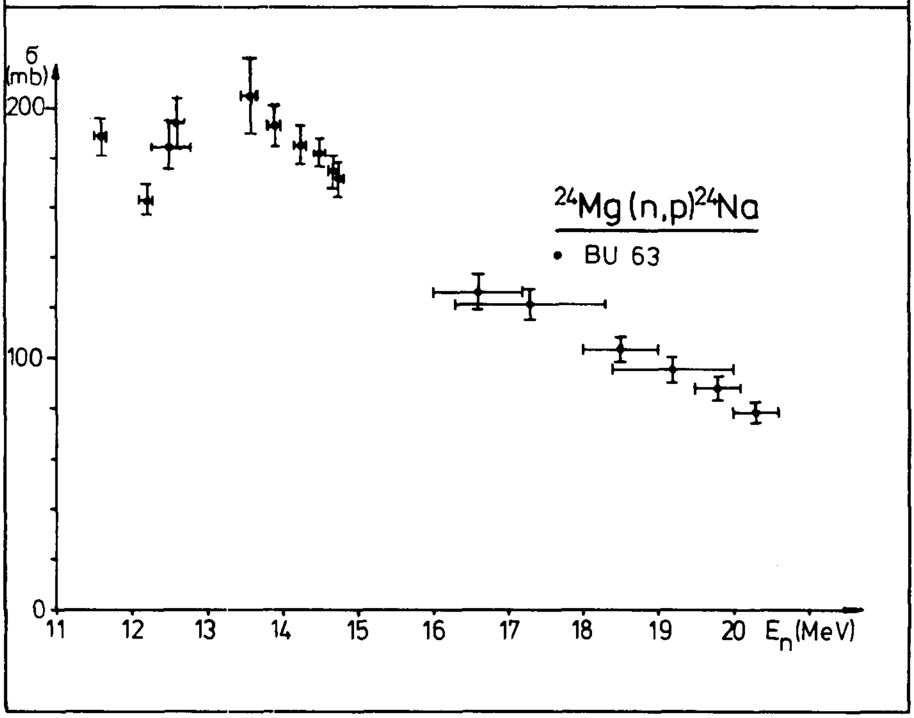
$^{23}Na(n,p)^{23}Ne$
× WI 61
• PI 65
σ (mb)
40
30
20
10
0
11 12 13 14 15 16 17 18 19 20
E_n (MeV)


^{23}Na (n,p)^{23}Ne
• PI 63
× BA 65
σ (mb)
100
50
0
1
2
3
4
5
6
7
8
9
10
E_n(MeV)

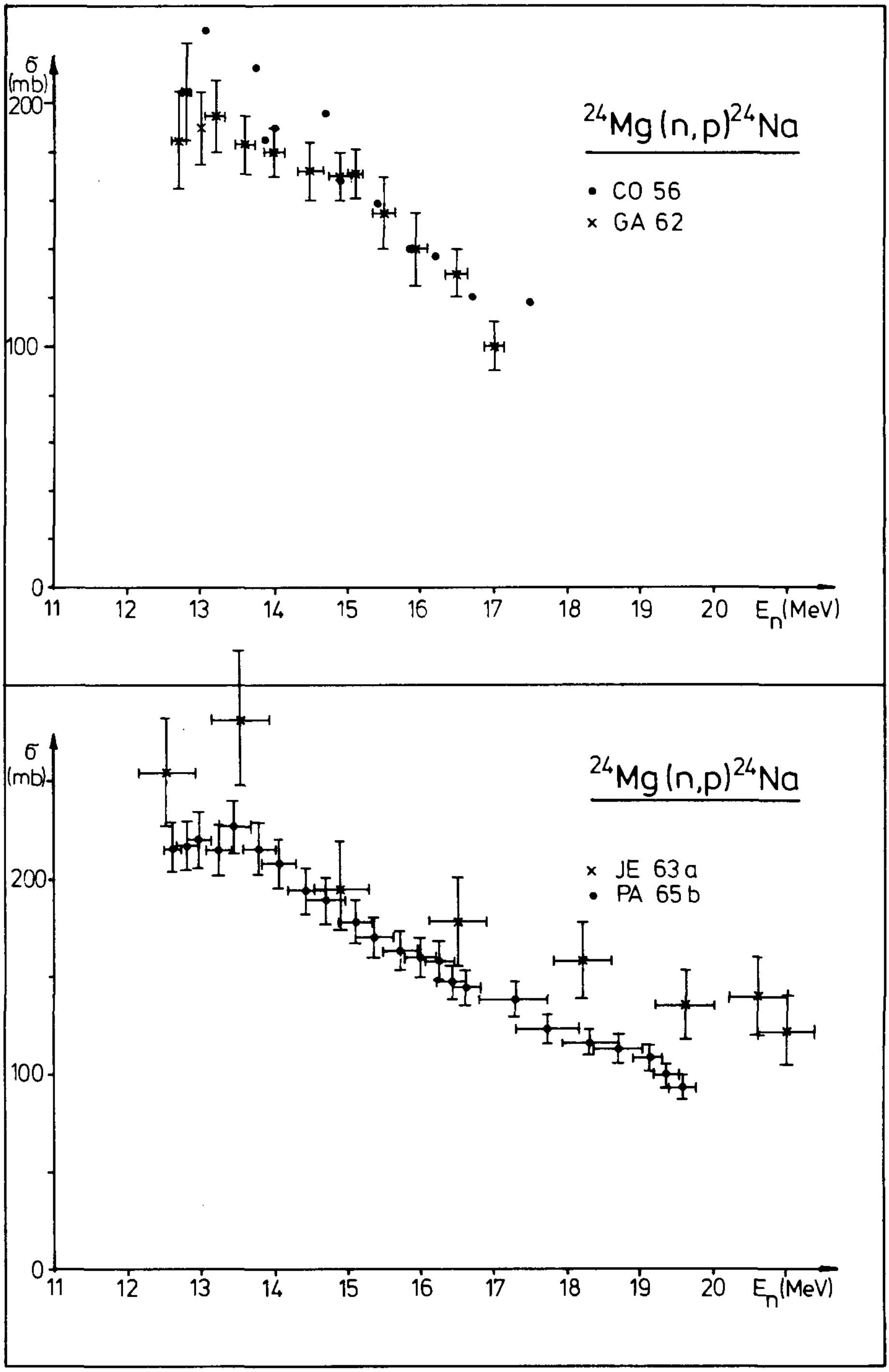

^{24}Mg(n,p)^{24g}Na*
• IM 60
σ (mb)
200
100
0
11
12
13
14
15
16
17
18
19
20
E_n(MeV)

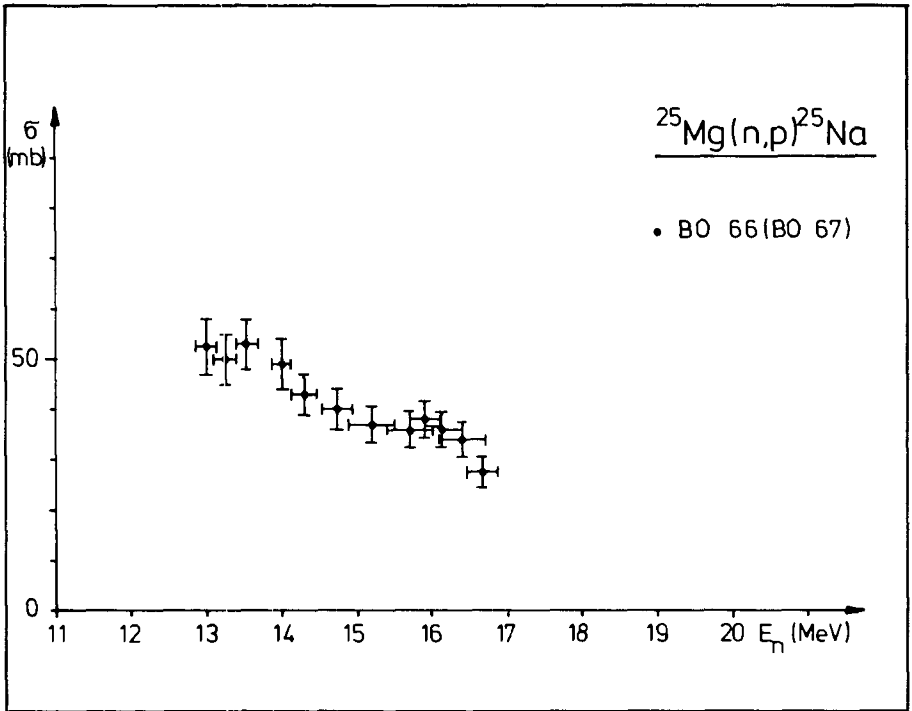


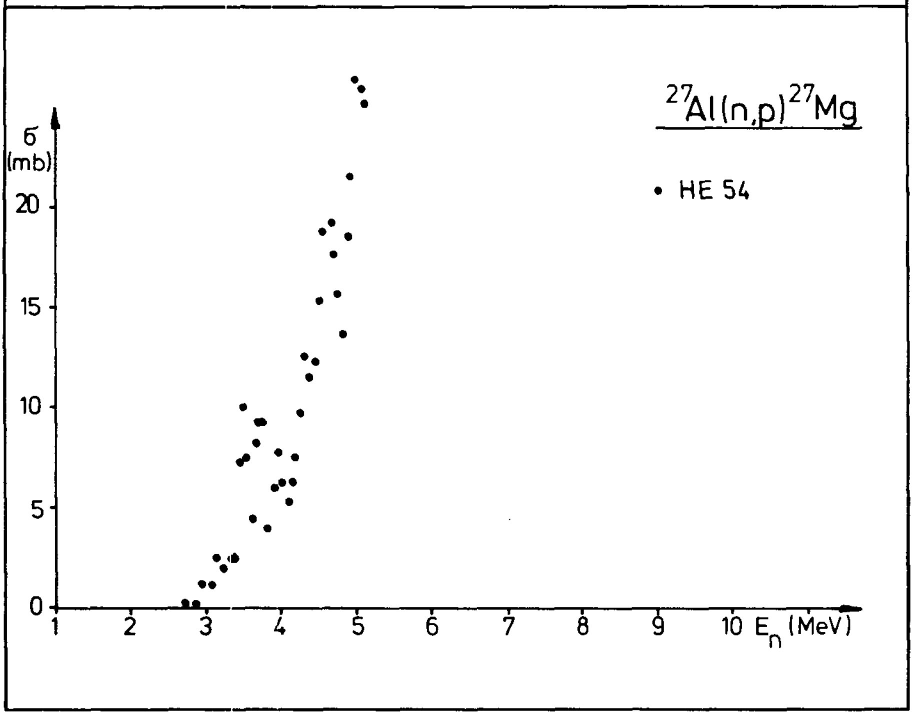
σ (mb)
200
100
0
$^{24}Mg(n,p)^{24}Na$
• BU 63
△ LI 65
× LI 66
1 2 3 4 5 6 7 8 9 10 E_n (MeV)

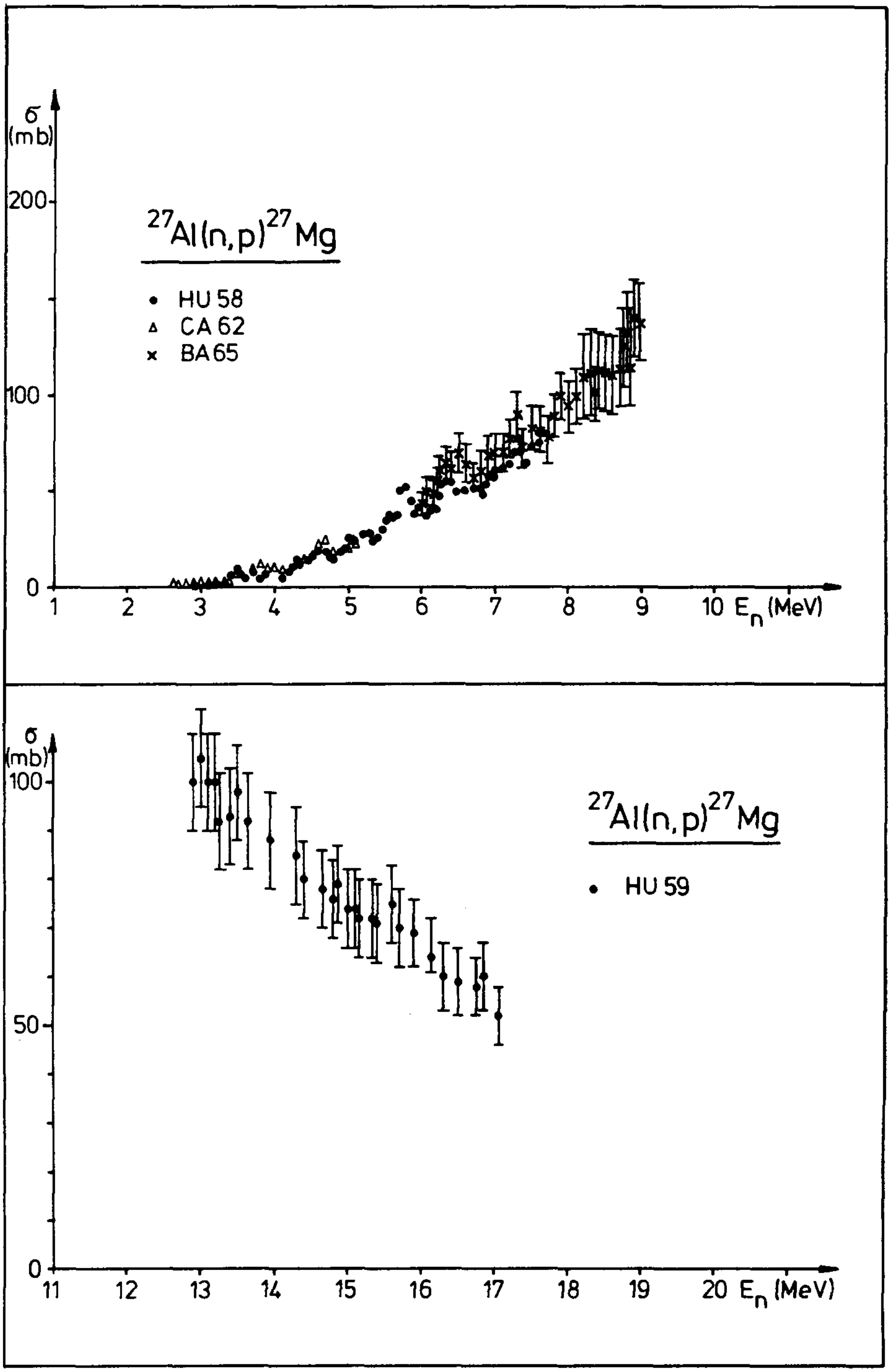


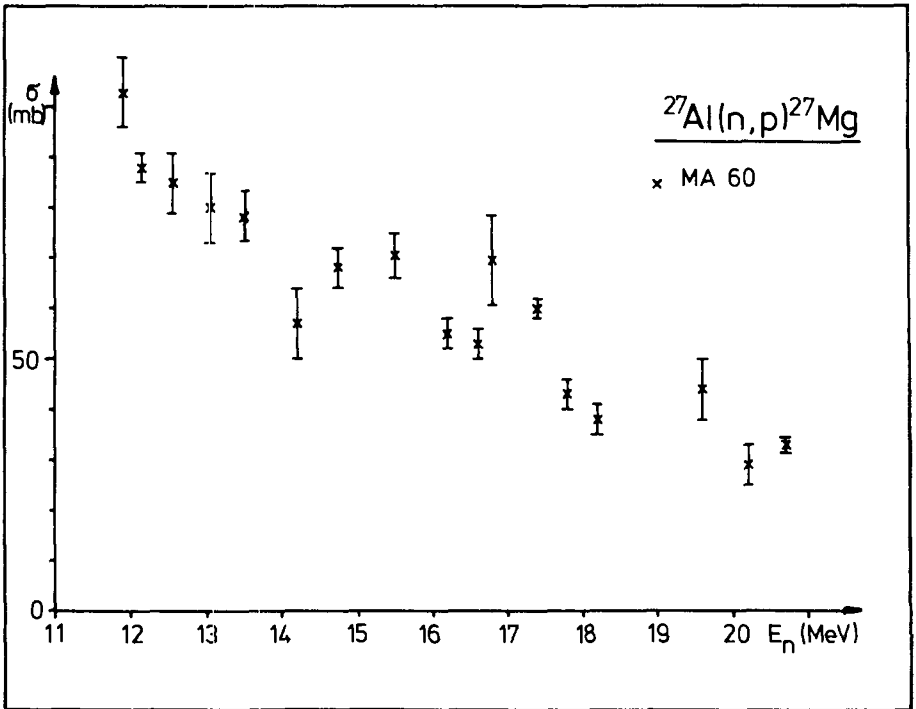
σ (mb)
200
100
0
$^{24}Mg(n,p)^{24}Na$
• BU 63
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


$^{24}Mg(n,p)^{24}Na$
• CO 56
× GA 62
σ (mb)
200
100
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)
$^{24}Mg(n,p)^{24}Na$
× JE 63 a
• PA 65 b
σ (mb)
200
100
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)

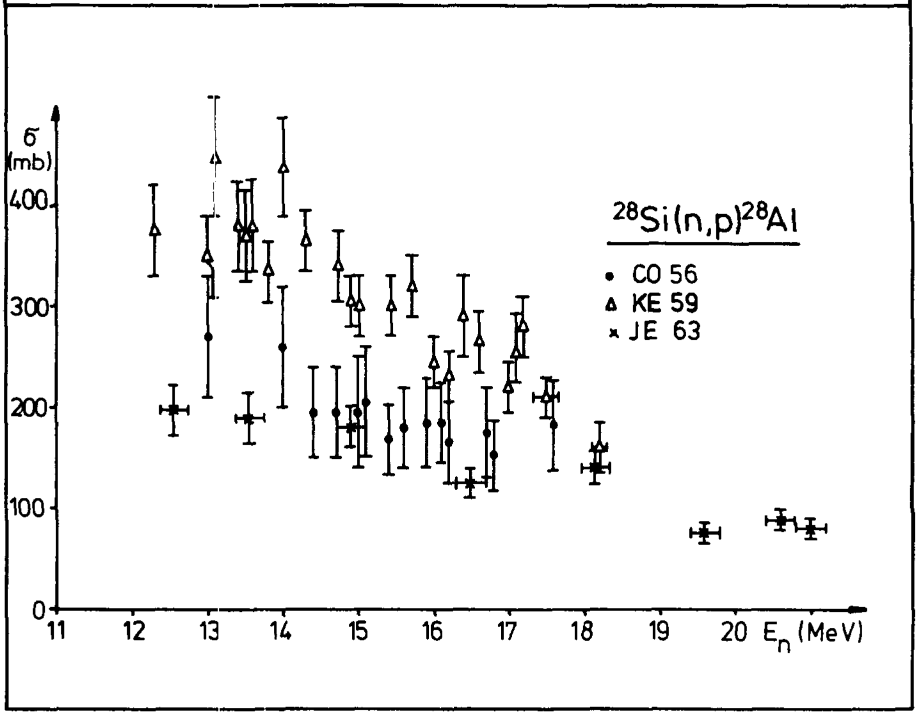

$^{25}Mg(n,p)^{25}Na$
• BO 66(BO 67)
σ (mb)
50
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)


$^{27}Al(n,p)^{27}Mg$
• HE 54
σ (mb)
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
E_n (MeV)

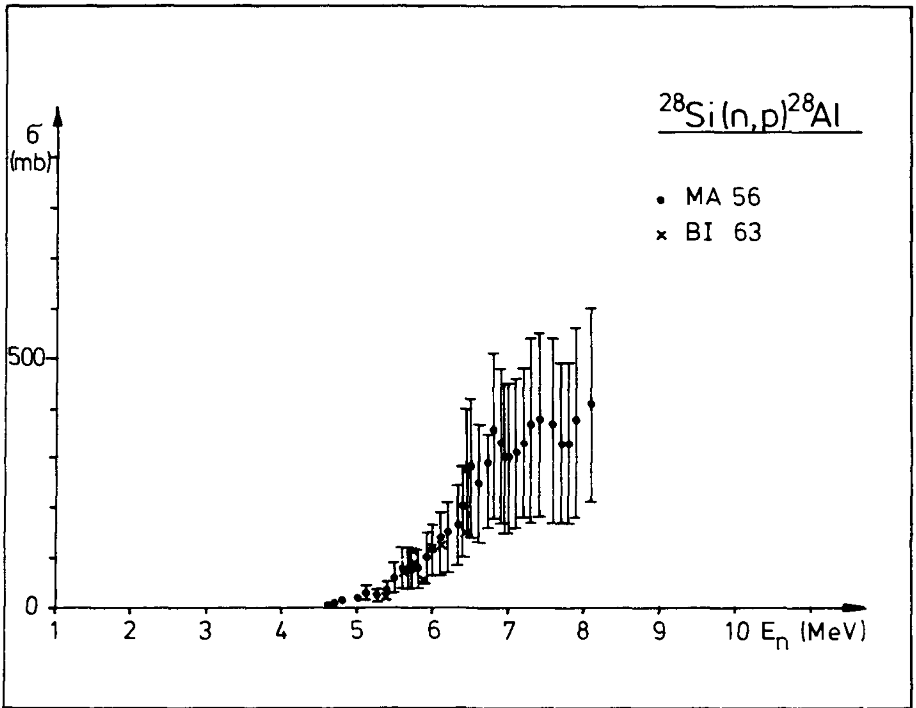

σ (mb)
200
100
0
$^{27}Al(n,p)^{27}Mg$
HU 58
CA 62
BA 65
1 2 3 4 5 6 7 8 9 10 E_n (MeV)
σ (mb)
100
50
0
$^{27}Al(n,p)^{27}Mg$
HU 59
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



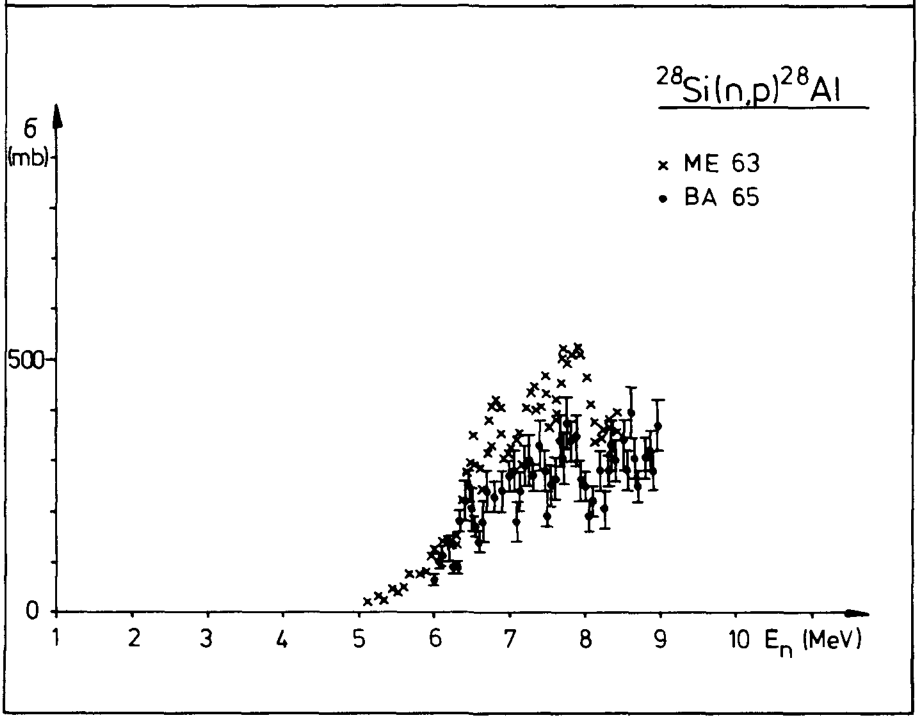
σ (mb)
50
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)
$^{27}Al(n,p)^{27}Mg$
× MA 60



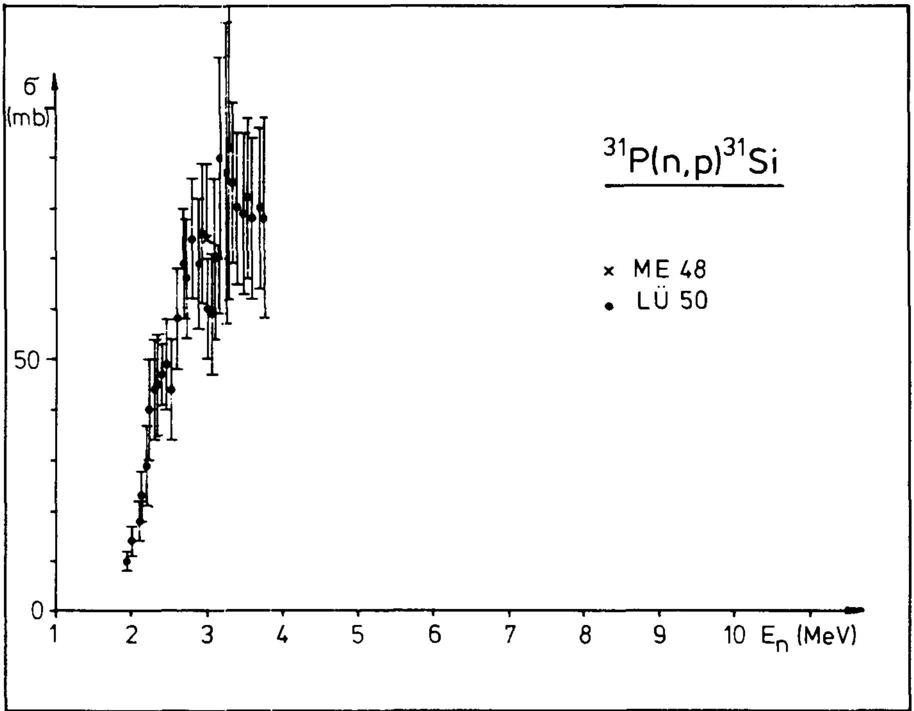
σ (mb)
400
300
200
100
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)
$^{28}Si(n,p)^{28}Al$
• CO 56
Δ KE 59
× JE 63



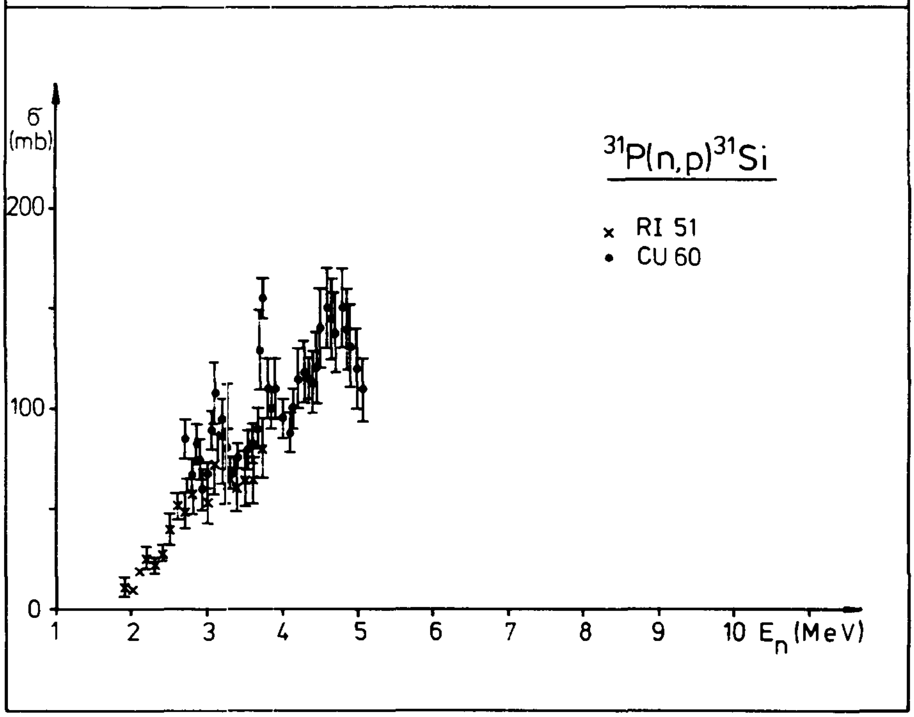
$^{28}Si(n,p)^{28}Al$
• MA 56
× BI 63
σ (mb)
500
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)



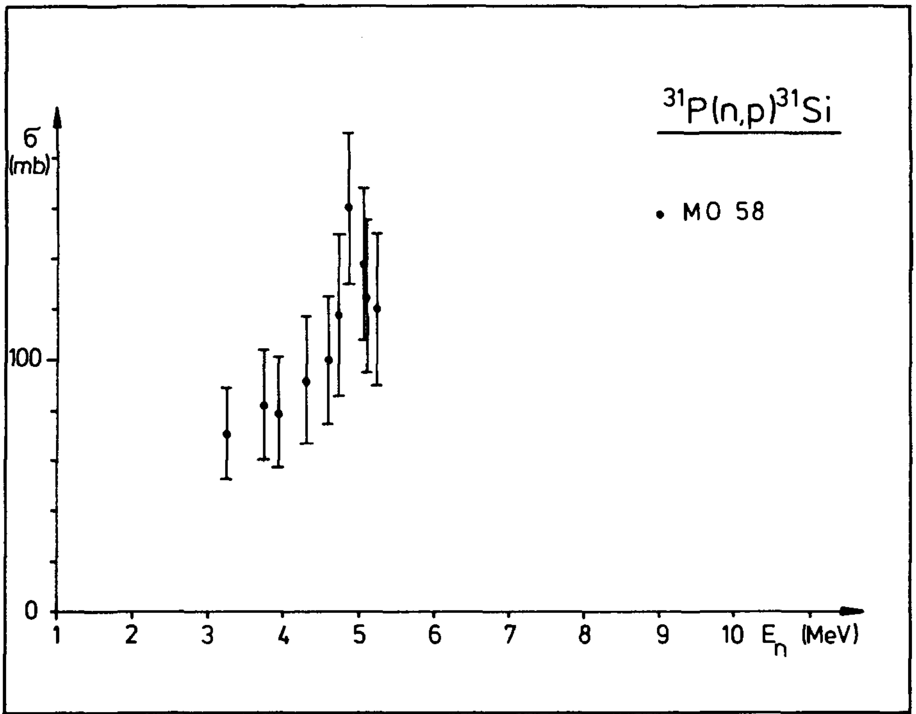
$^{28}Si(n,p)^{28}Al$
× ME 63
• BA 65
σ (mb)
500
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)



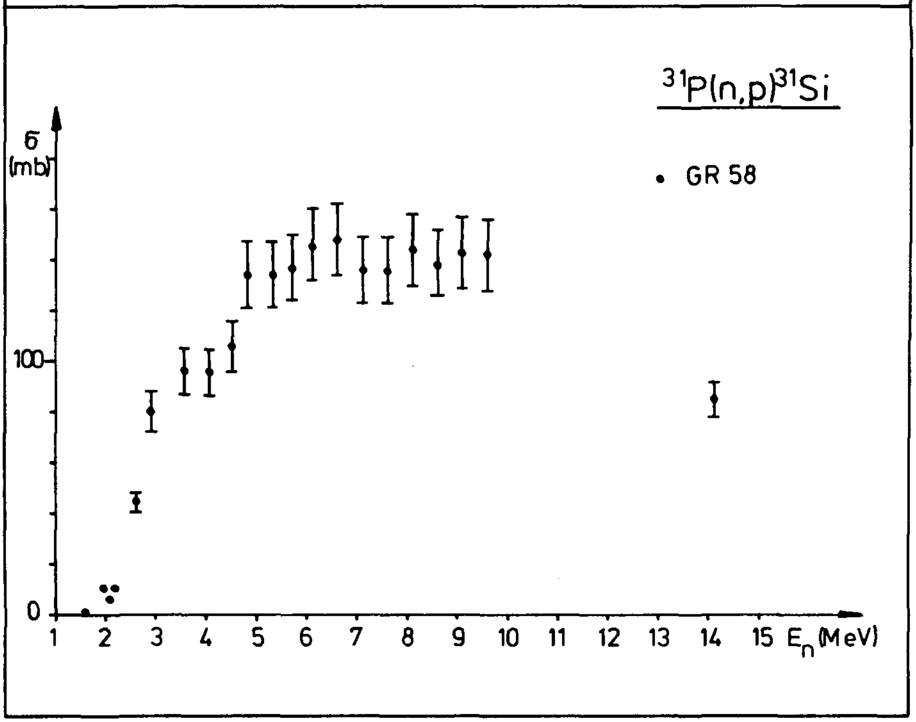
σ (mb)
50
0
1
2
3
4
5
6
7
8
9
10
E_n (MeV)
$^{31}P(n,p)^{31}Si$
× ME 48
• LÜ 50



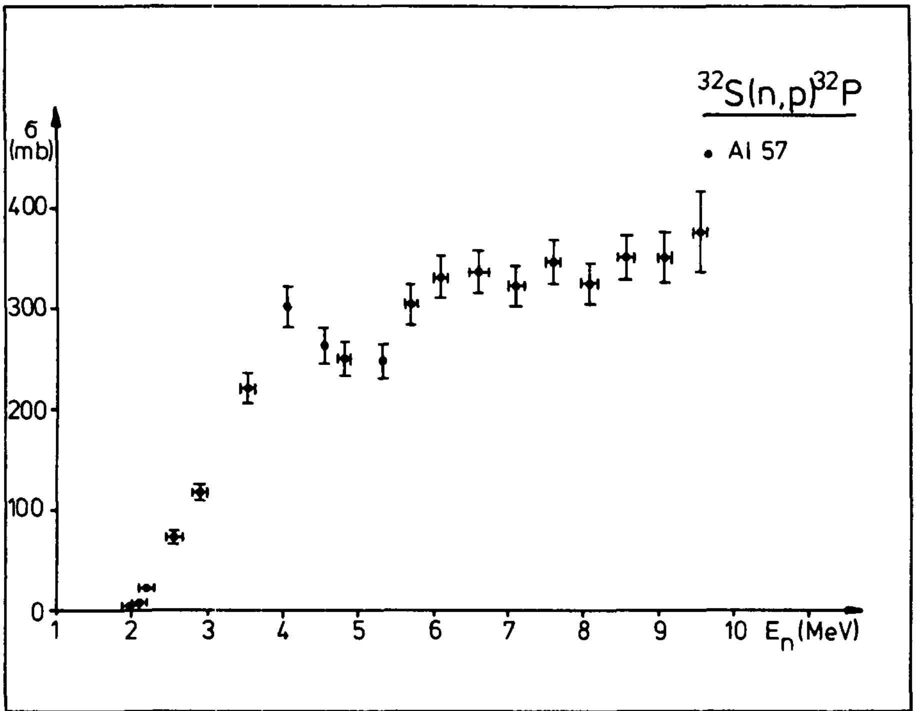
σ (mb)
200
100
0
1
2
3
4
5
6
7
8
9
10
E_n (MeV)
$^{31}P(n,p)^{31}Si$
× RI 51
• CU 60



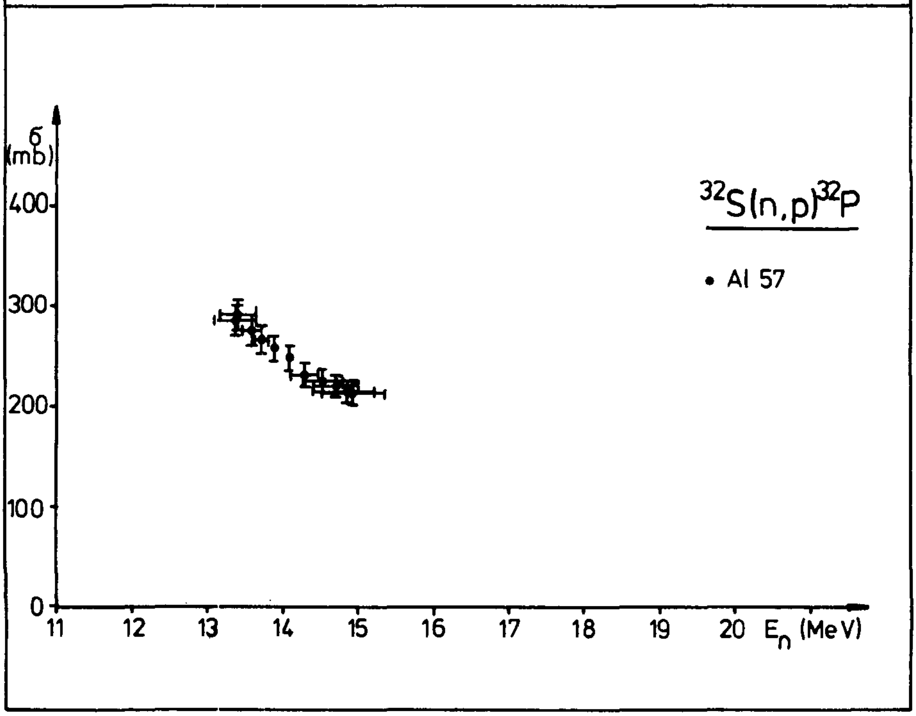
$^{31}P(n,p)^{31}Si$
• MO 58
σ (mb)
100
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)



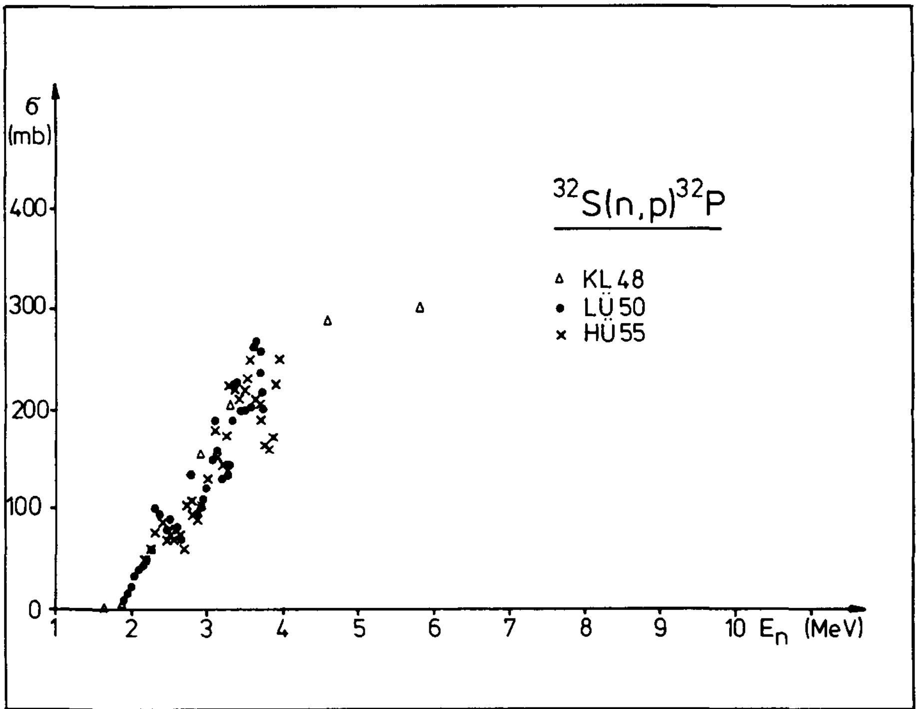
$^{31}P(n,p)^{31}Si$
• GR 58
σ (mb)
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 E_n (MeV)

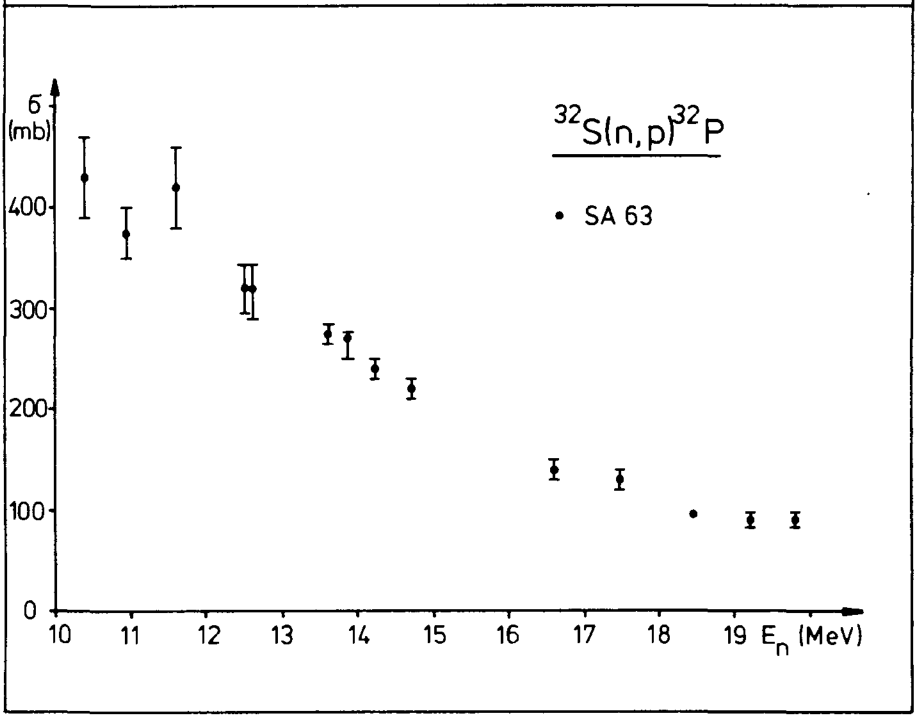


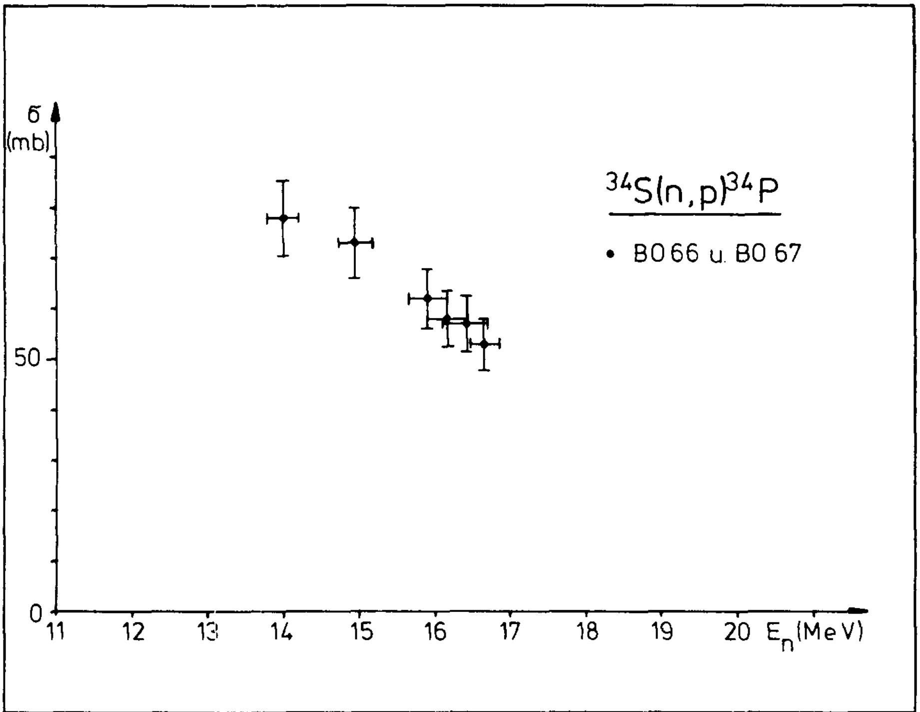
$^{32}S(n,p)^{32}P$
• Al 57
σ (mb)
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)

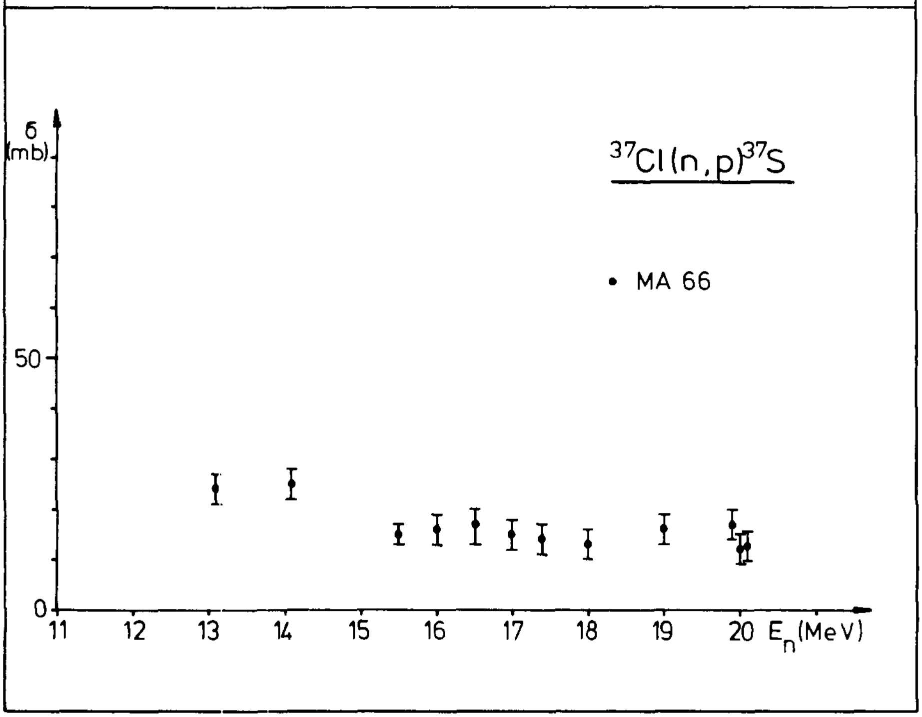


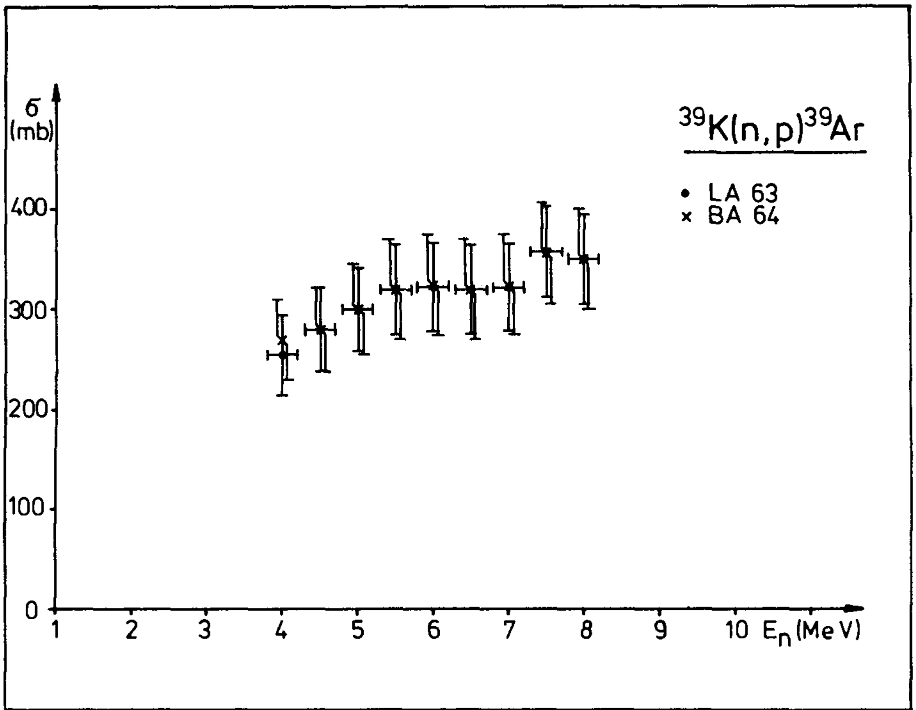
$^{32}S(n,p)^{32}P$
• Al 57
σ (mb)
400
300
200
100
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


σ (mb)
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
E_n (MeV)
$^{32}S(n,p)^{32}P$
KL 48
LÜ 50
HÜ 55

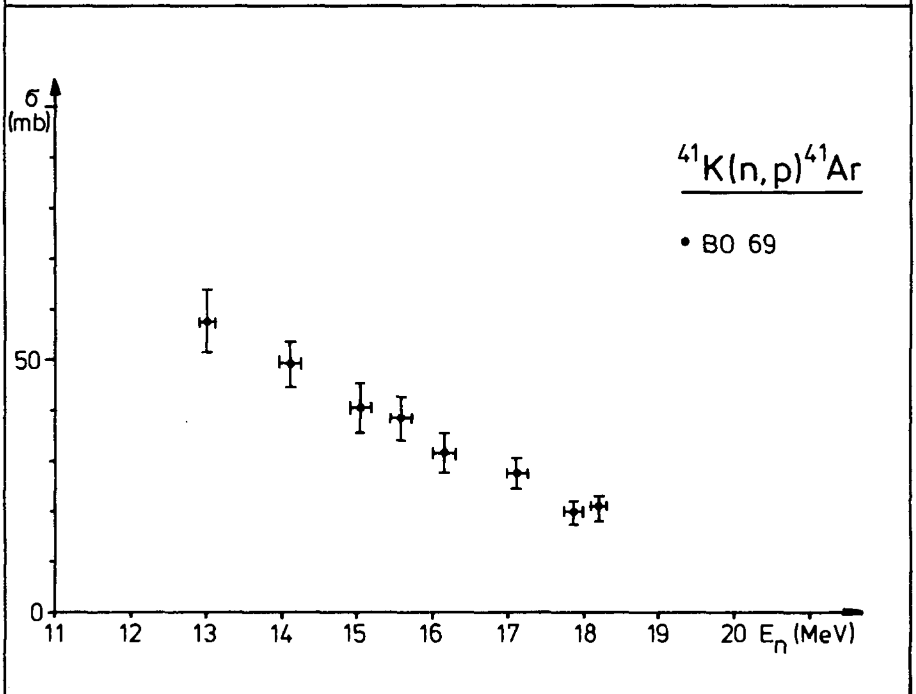

σ (mb)
400
300
200
100
0
10
11
12
13
14
15
16
17
18
19
E_n (MeV)
$^{32}S(n,p)^{32}P$
SA 63


σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)
$^{34}S(n,p)^{34}P$
• BO 66 u. BO 67

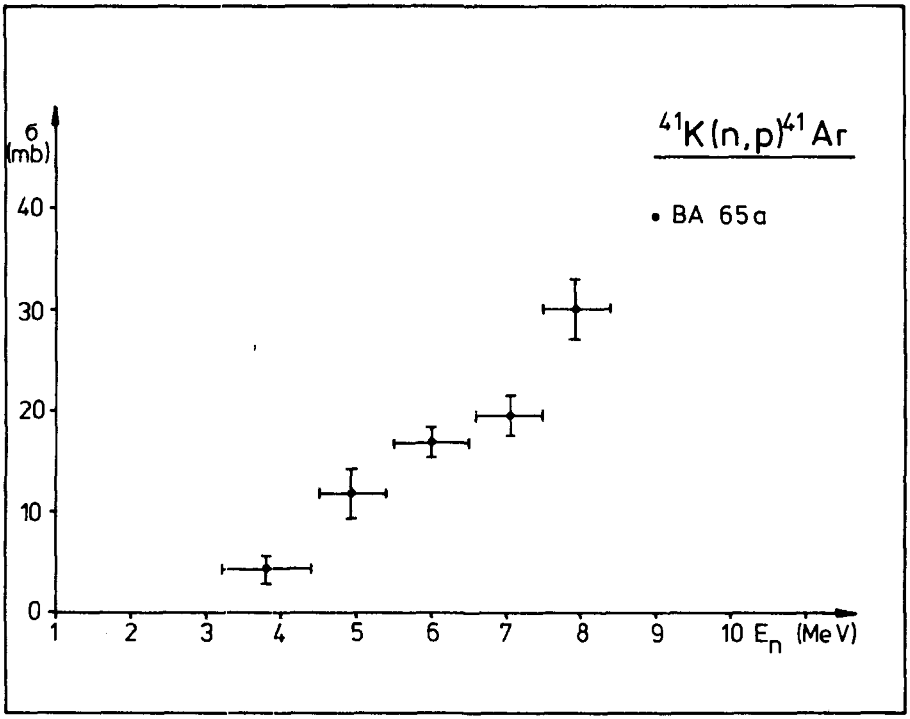

σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)
$^{37}Cl(n,p)^{37}S$
• MA 66



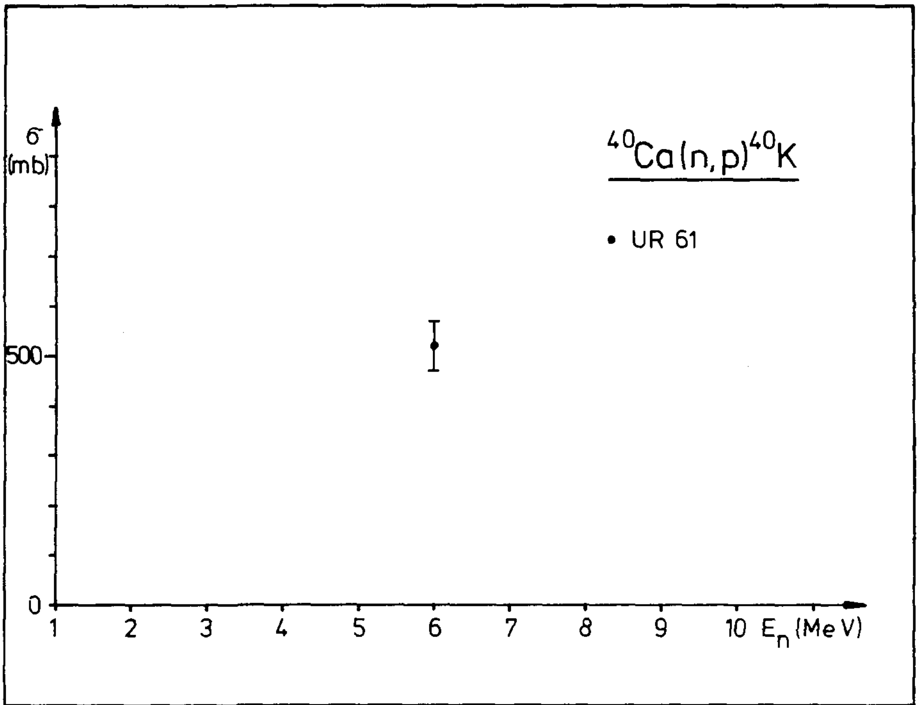
σ (mb)
$^{39}K(n,p)^{39}Ar$
• LA 63
× BA 64
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)

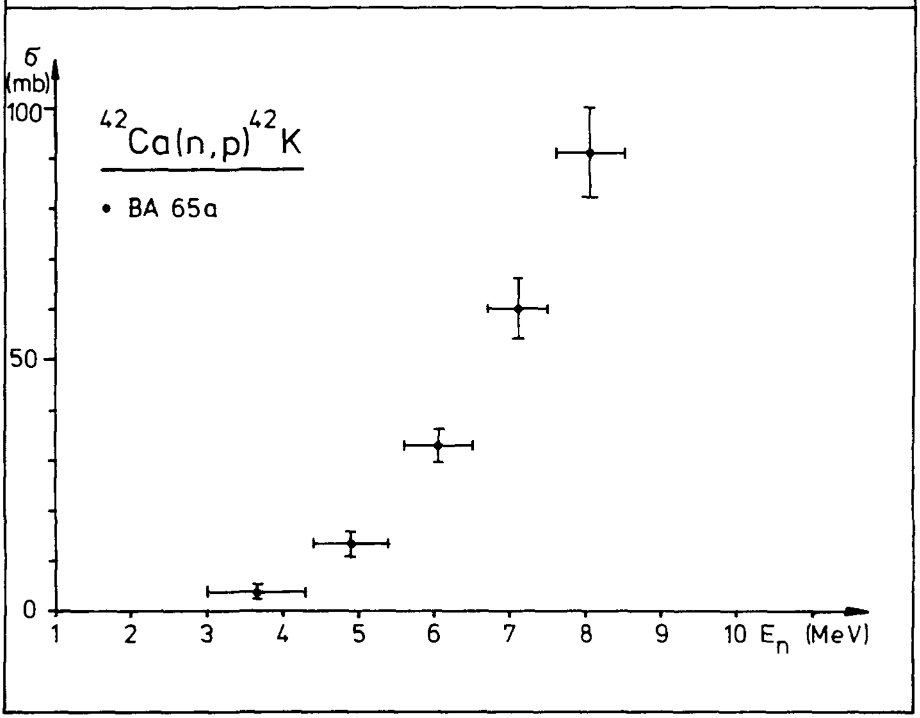


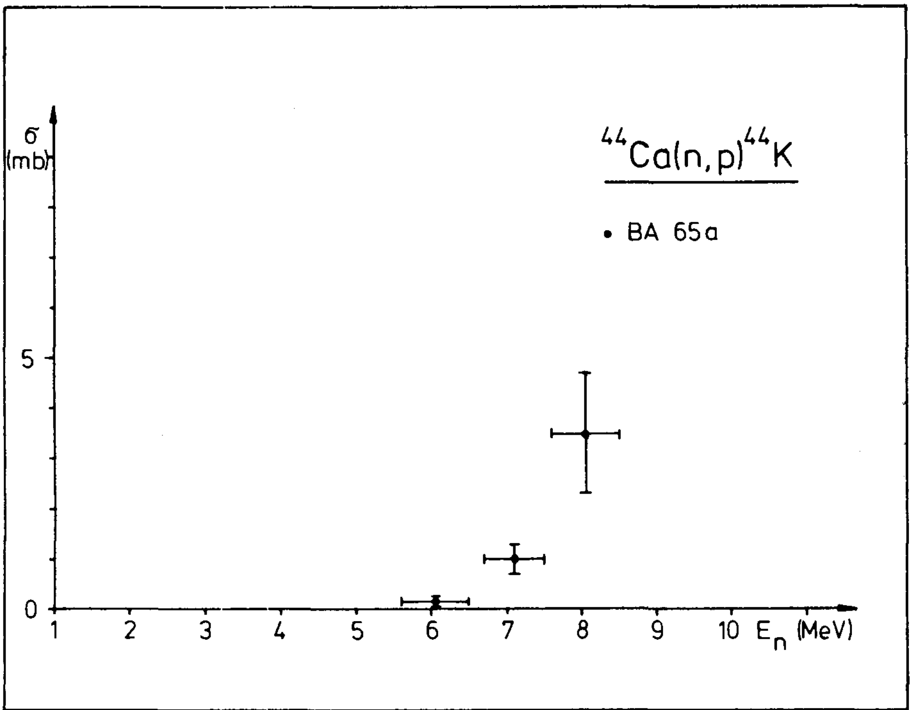
σ (mb)
$^{41}K(n,p)^{41}Ar$
• BO 69
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



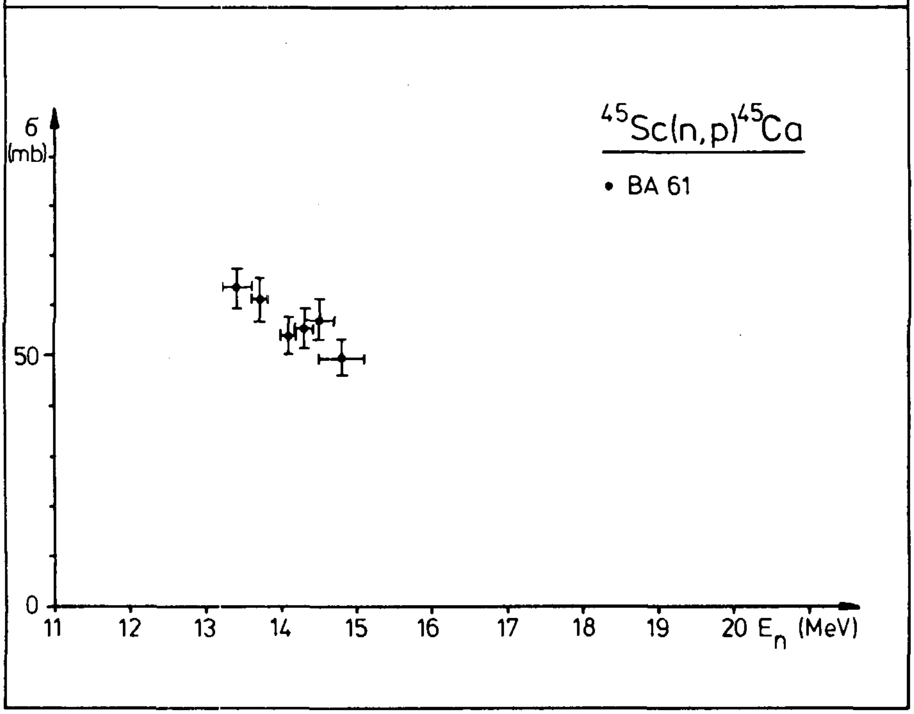
$^{41}K(n,p)^{41}Ar$
• BA 65a
σ (mb)
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10 E_n (MeV)


$^{40}Ca(n,p)^{40}K$
• UR 61
σ (mb)
500
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)

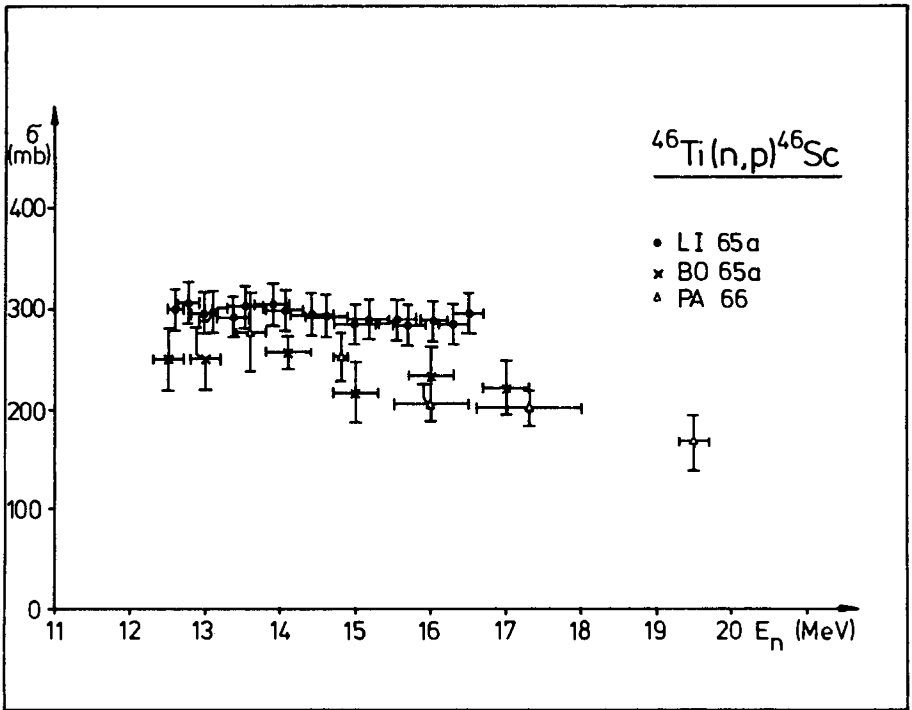

$^{42}Ca(n,p)^{42}K$
• BA 65a
σ (mb)
100
50
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)



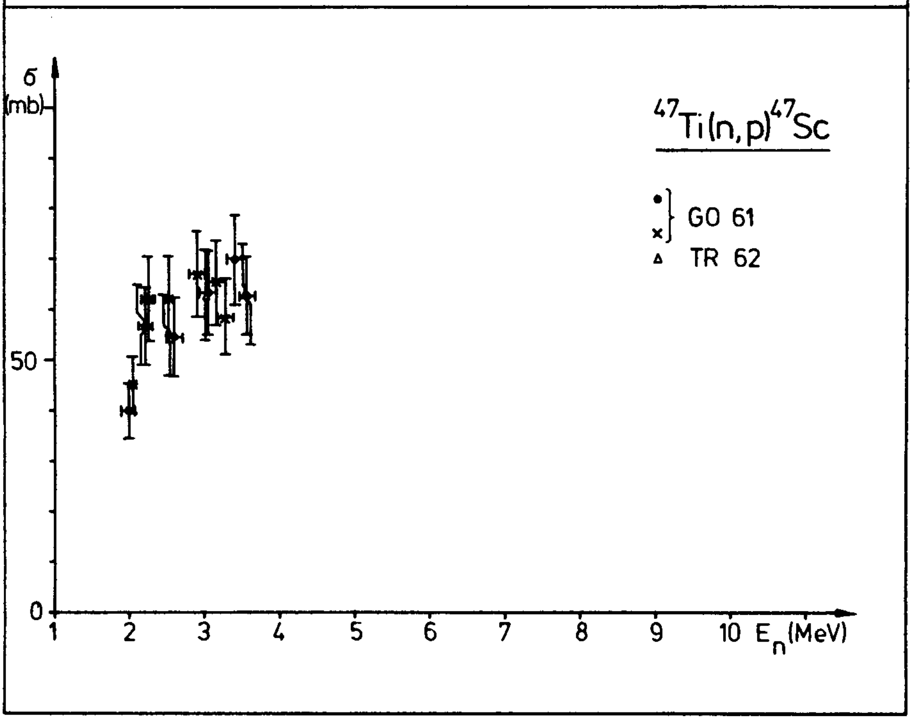
$^{44}Ca(n,p)^{44}K$
• BA 65a
σ (mb)
5
0
1
2
3
4
5
6
7
8
9
10
E_n (MeV)



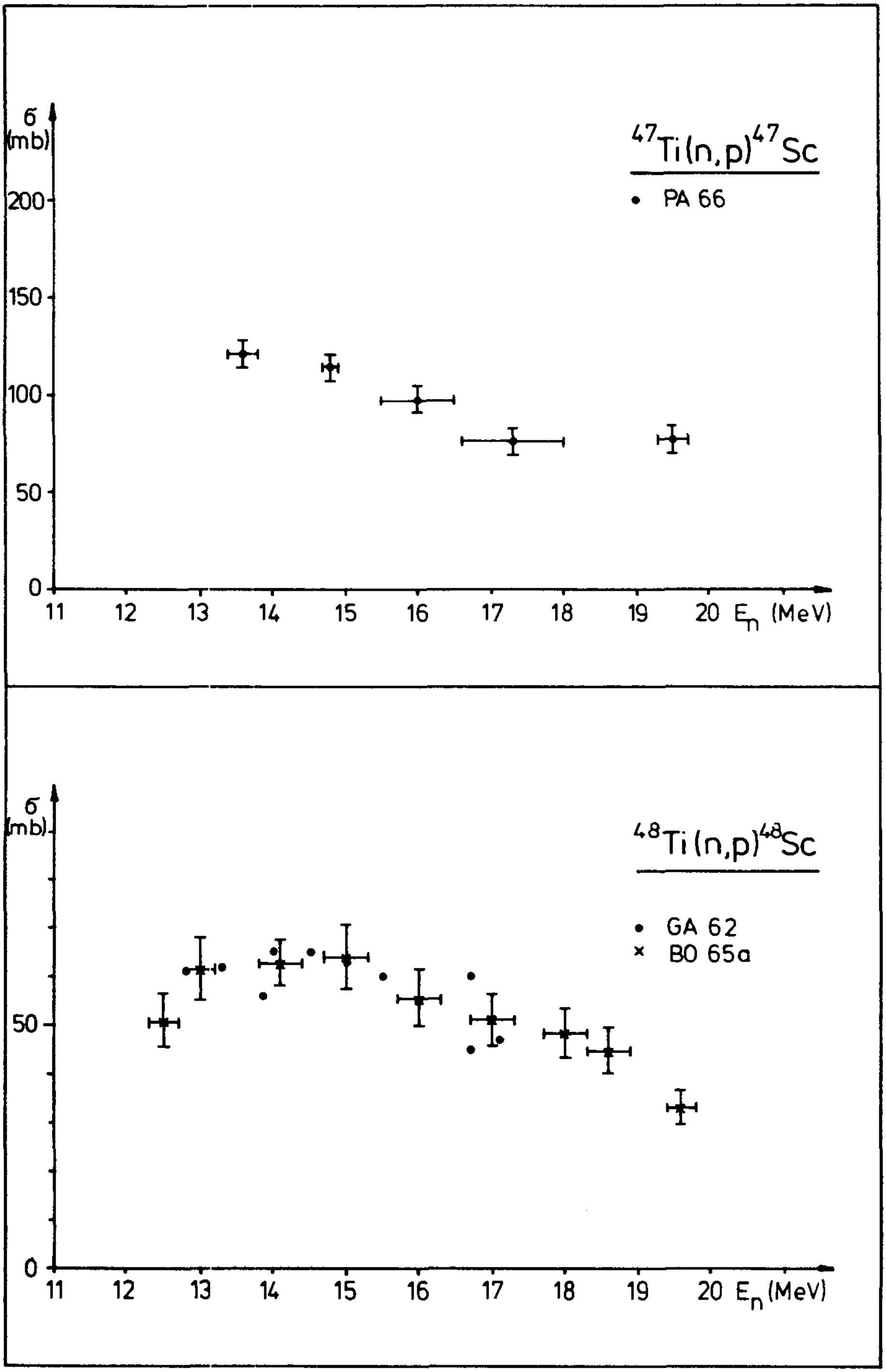
$^{45}Sc(n,p)^{45}Ca$
• BA 61
σ (mb)
50
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)



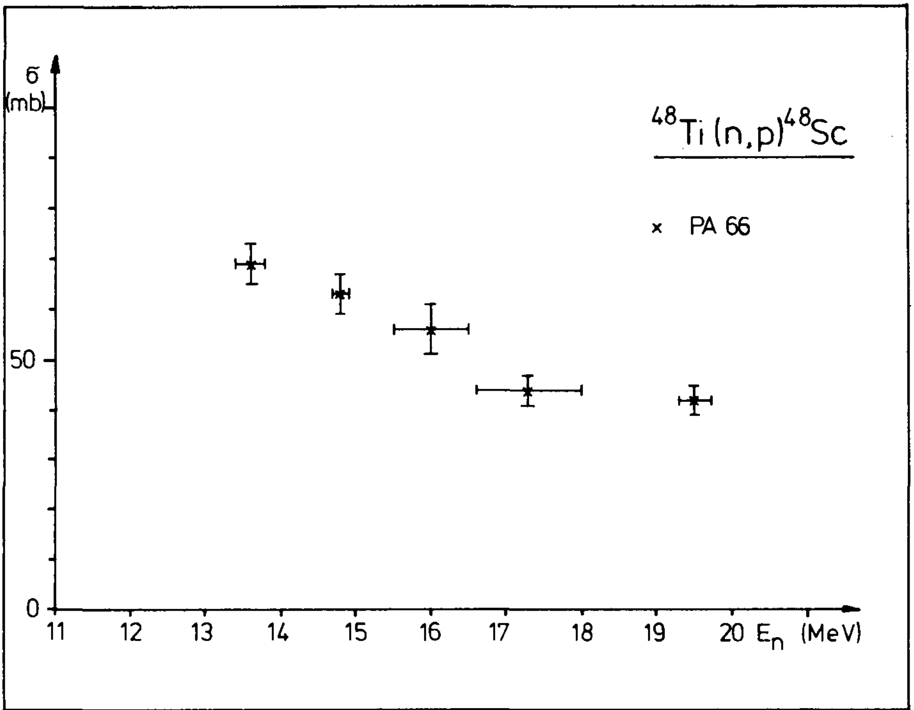
σ (mb)
400
300
200
100
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{46}Ti(n,p)^{46}Sc$
LI 65a
BO 65a
PA 66



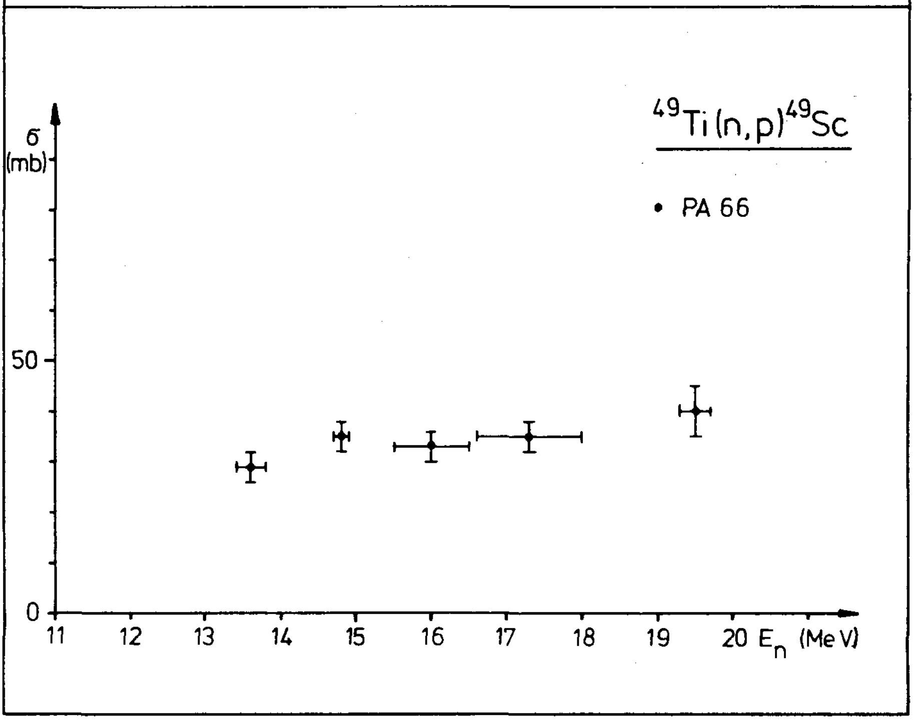
σ (mb)
50
0
1 2 3 4 5 6 7 8 9 10 E_n(MeV)
$^{47}Ti(n,p)^{47}Sc$
GO 61
TR 62



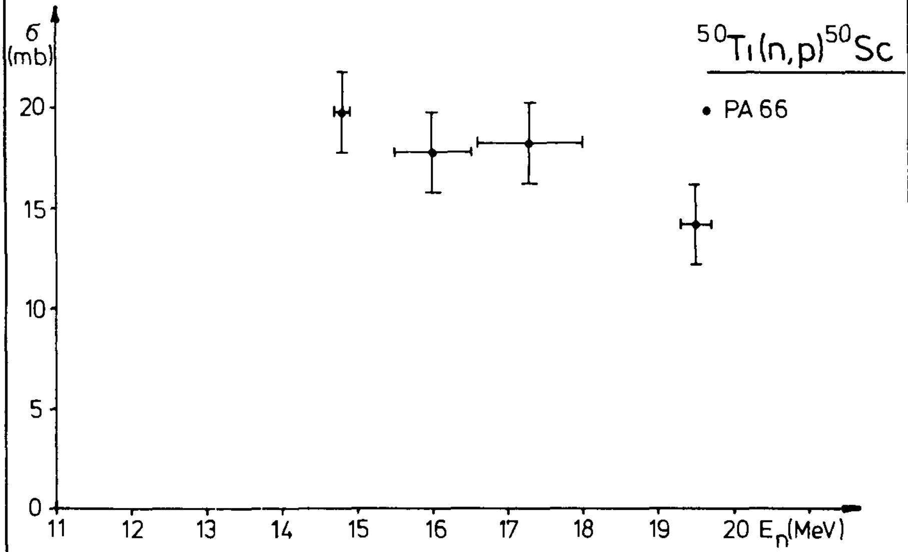
σ (mb)
200
150
100
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{47}Ti(n,p)^{47}Sc$
• PA 66
σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{48}Ti(n,p)^{48}Sc$
• GA 62
× BO 65a



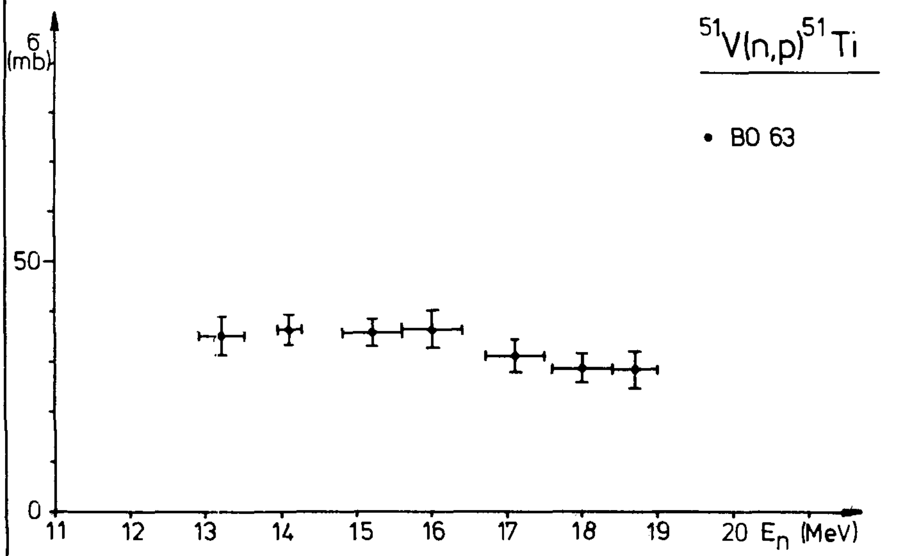
$^{48}Ti(n,p)^{48}Sc$
× PA 66
σ (mb)
50
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)



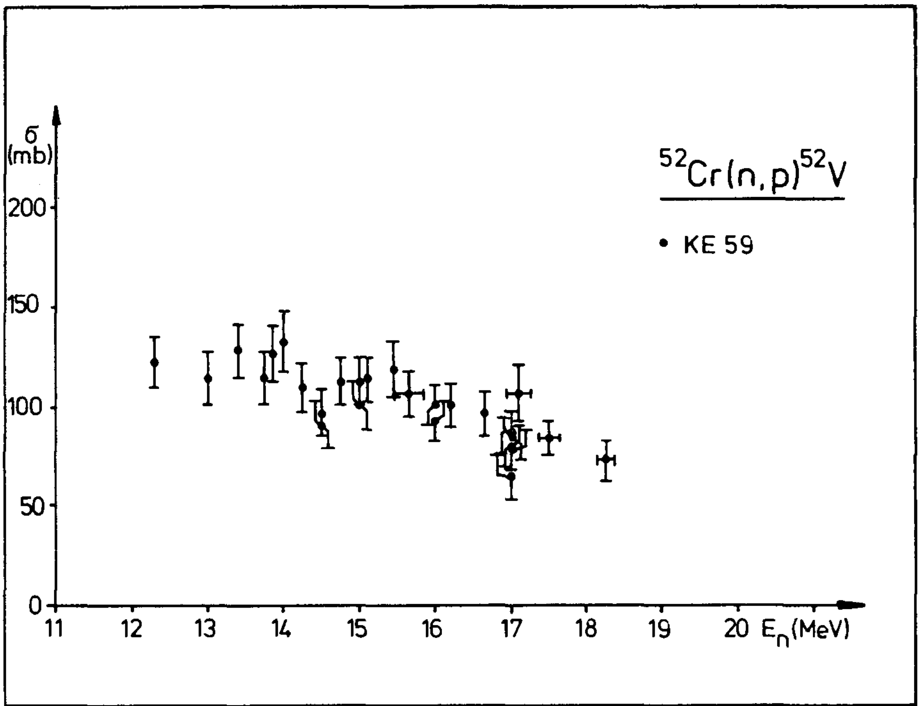
$^{49}Ti(n,p)^{49}Sc$
• PA 66
σ (mb)
50
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)

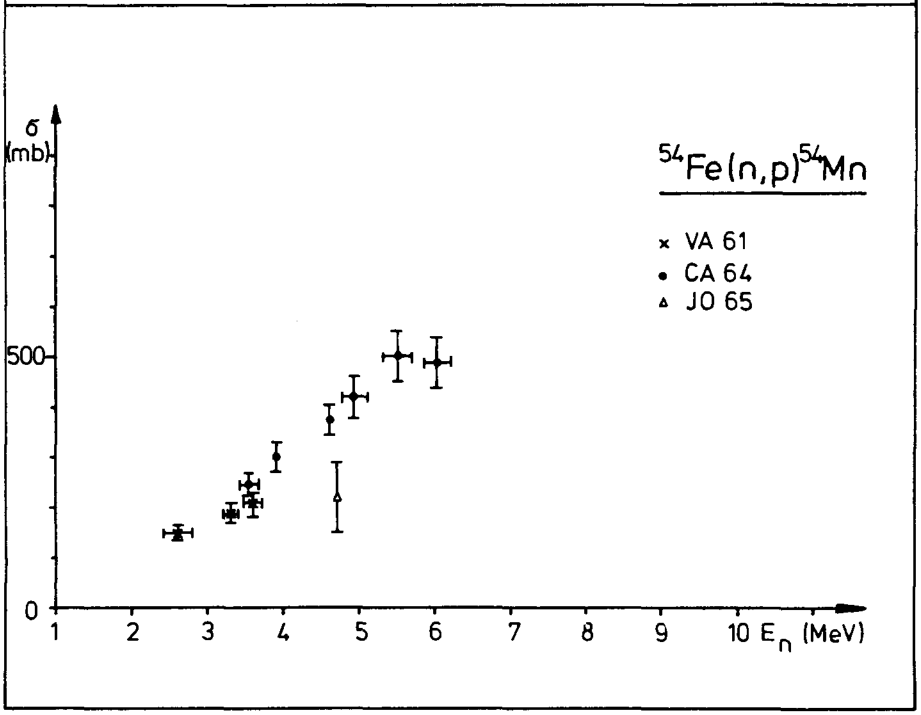


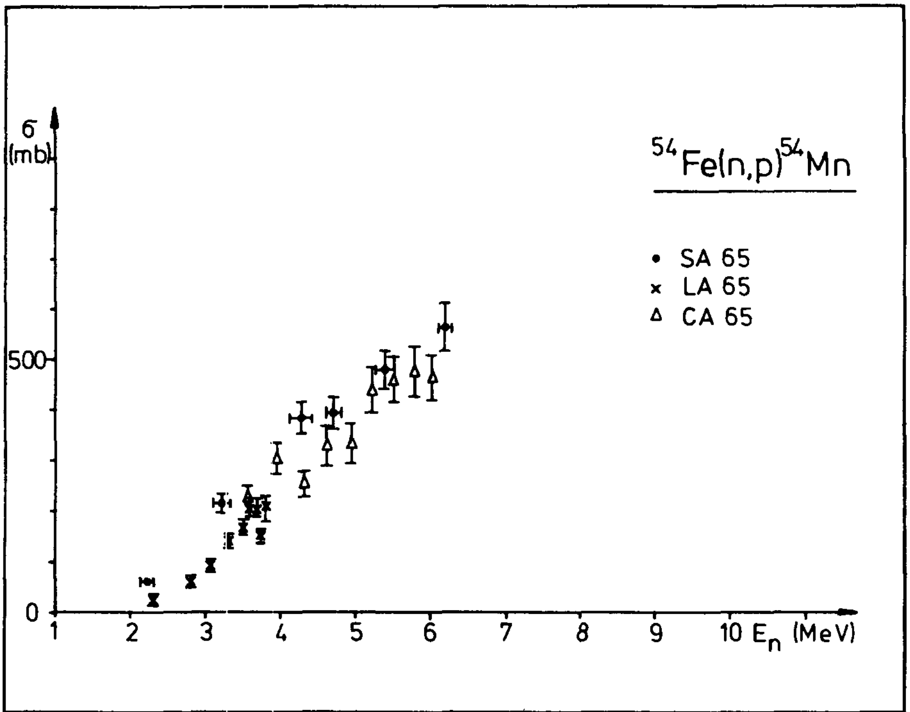
$^{50}Ti(n,p)^{50}Sc$
• PA 66
σ (mb)
20
15
10
5
0
11
12
13
14
15
16
17
18
19
20 E_n(MeV)



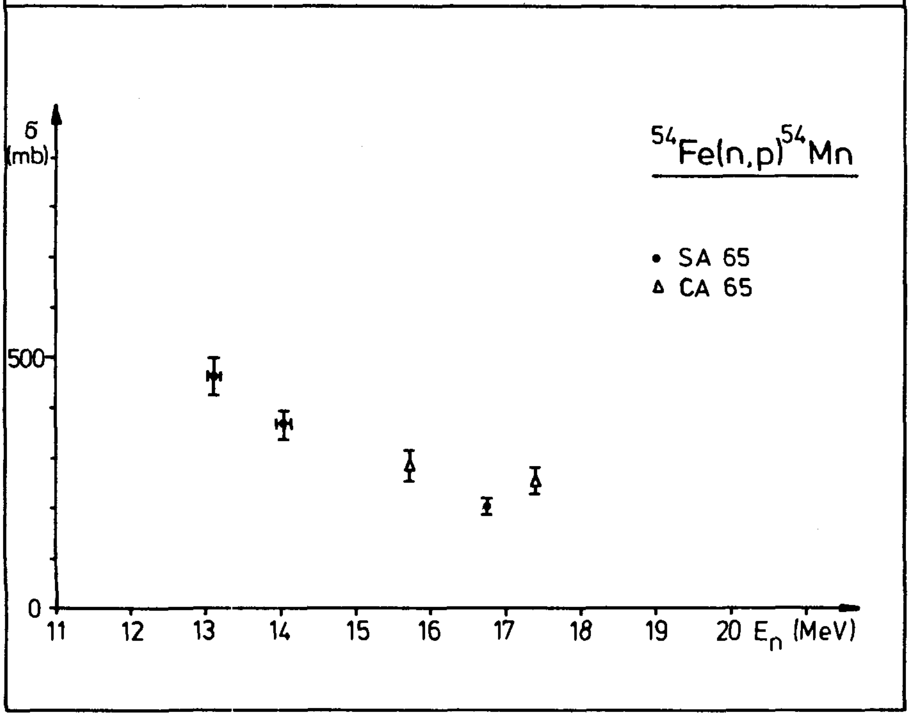
$^{51}V(n,p)^{51}Ti$
• BO 63
σ (mb)
50
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)


σ (mb)
200
150
100
50
0
11
12
13
14
15
16
17
18
19
20 E_n(MeV)
$^{52}Cr(n,p)^{52}V$
• KE 59

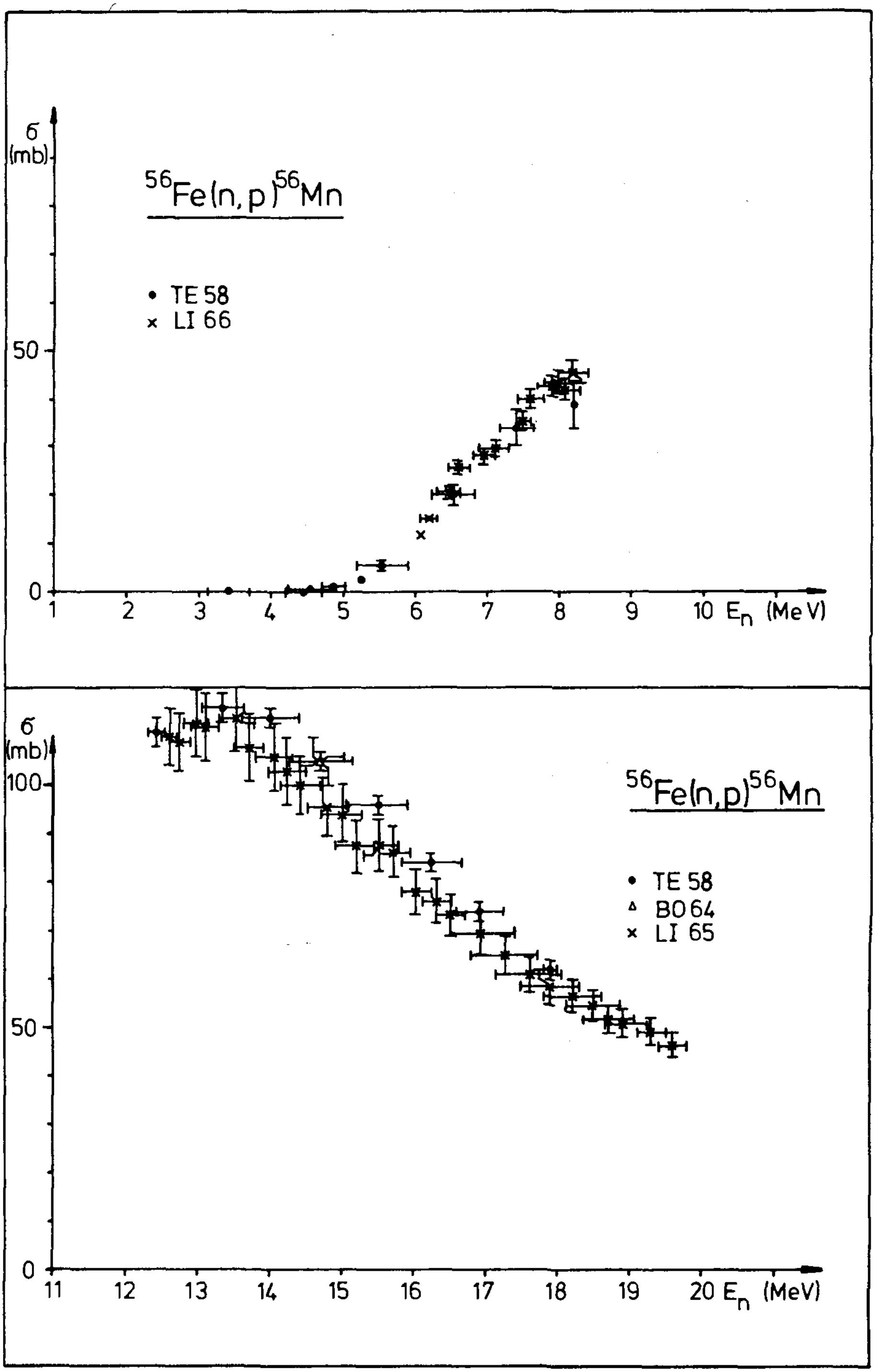

σ (mb)
500
0
1
2
3
4
5
6
7
8
9
10 E_n (MeV)
$^{54}Fe(n,p)^{54}Mn$
× VA 61
• CA 64
▵ JO 65



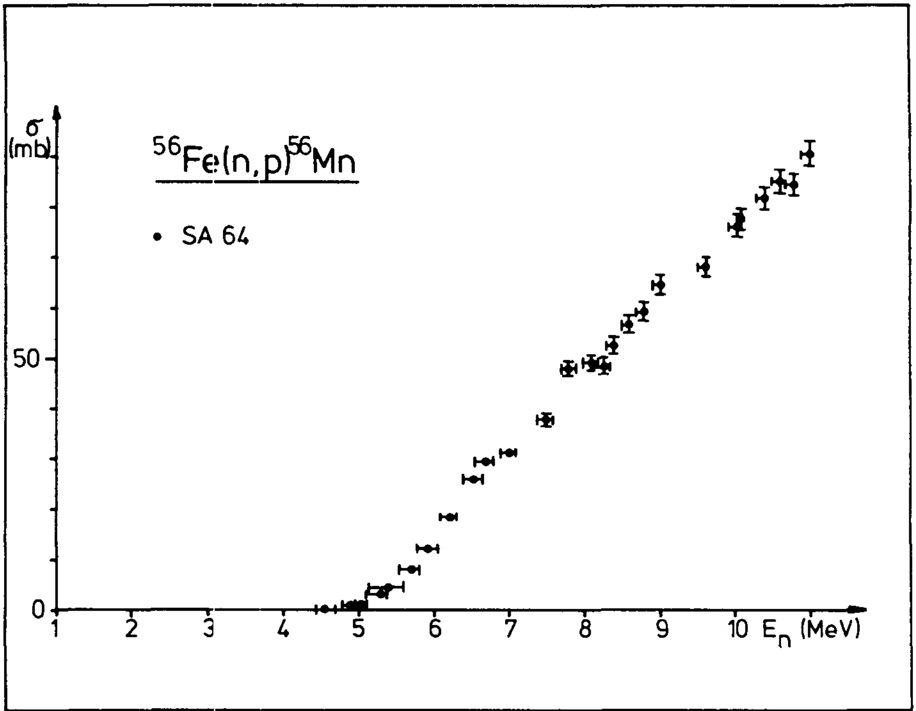
$^{54}Fe(n,p)^{54}Mn$
• SA 65
× LA 65
Δ CA 65
σ (mb)
500
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)



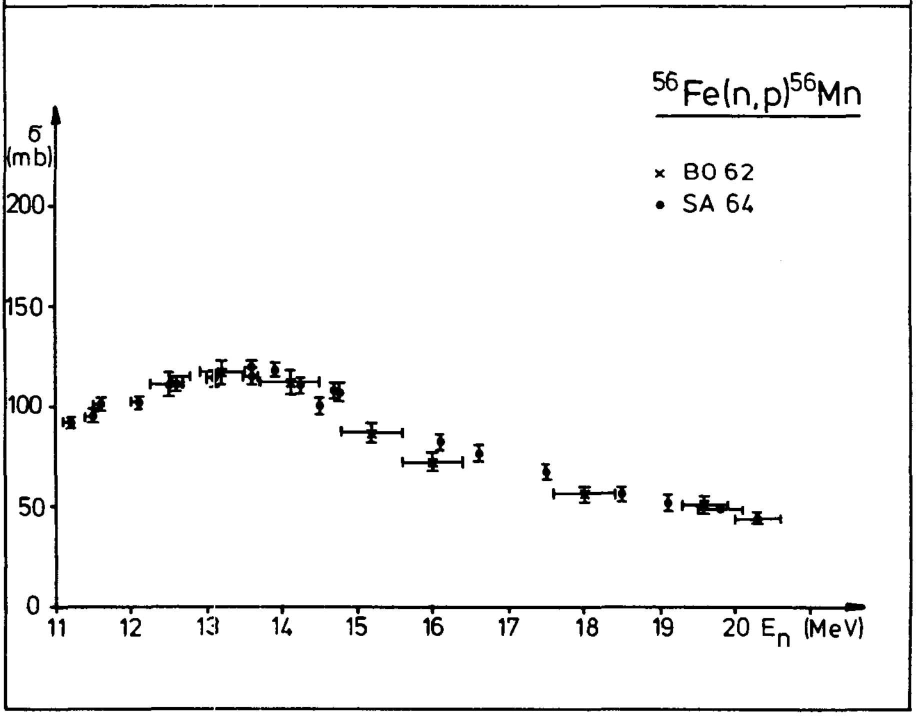
$^{54}Fe(n,p)^{54}Mn$
• SA 65
Δ CA 65
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



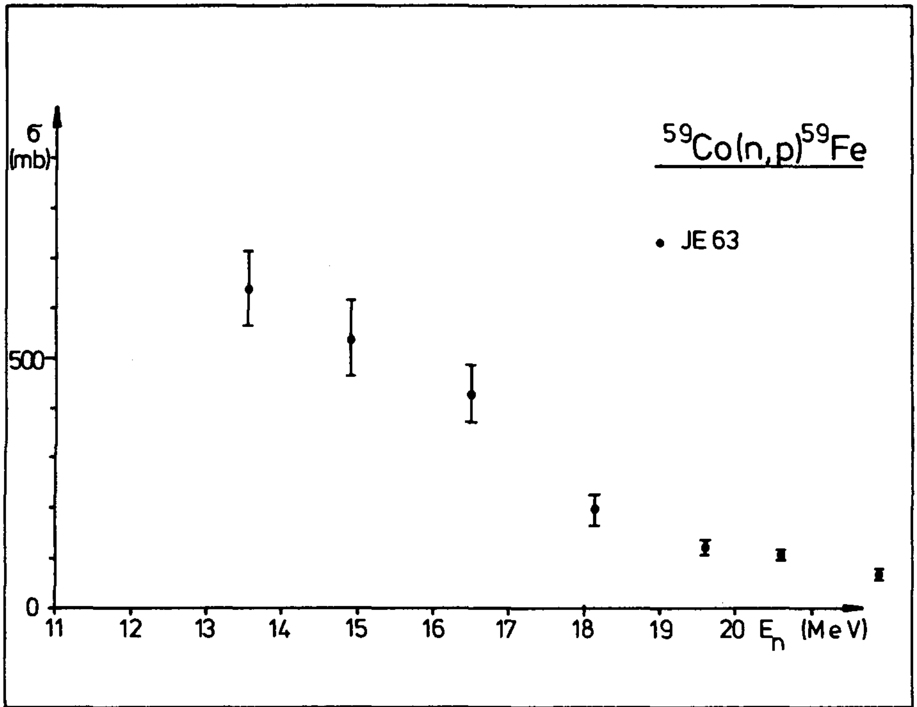
$^{56}Fe(n,p)^{56}Mn$
• TE 58
× LI 66
σ (mb)
50
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)
$^{56}Fe(n,p)^{56}Mn$
• TE 58
▵ BO 64
× LI 65
σ (mb)
100
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



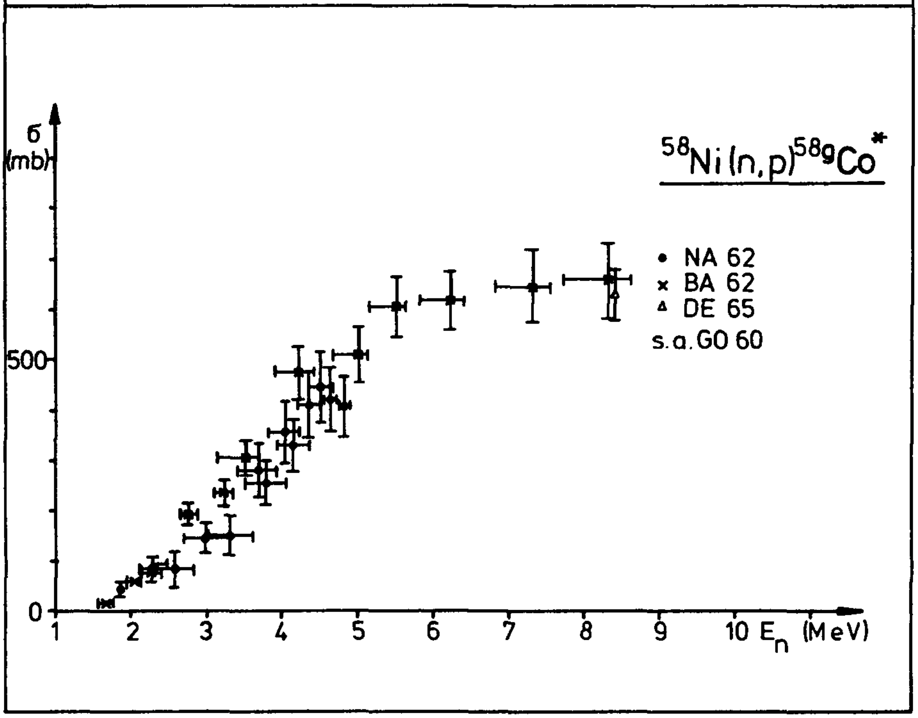
$^{56}Fe(n,p)^{56}Mn$
• SA 64
σ (mb)
50
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)



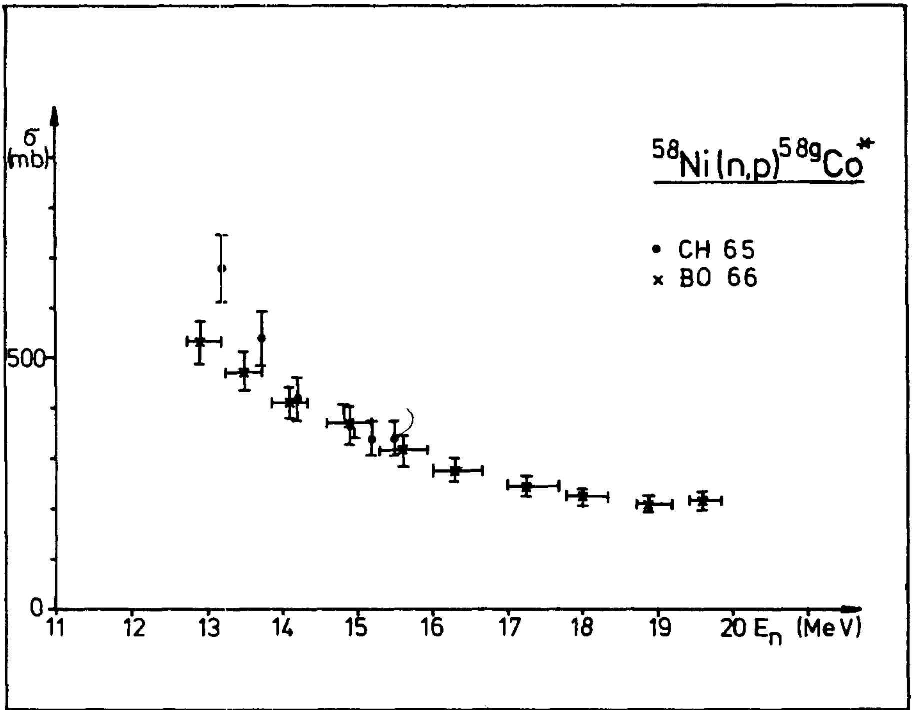
$^{56}Fe(n,p)^{56}Mn$
× BO 62
• SA 64
σ (mb)
200
150
100
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

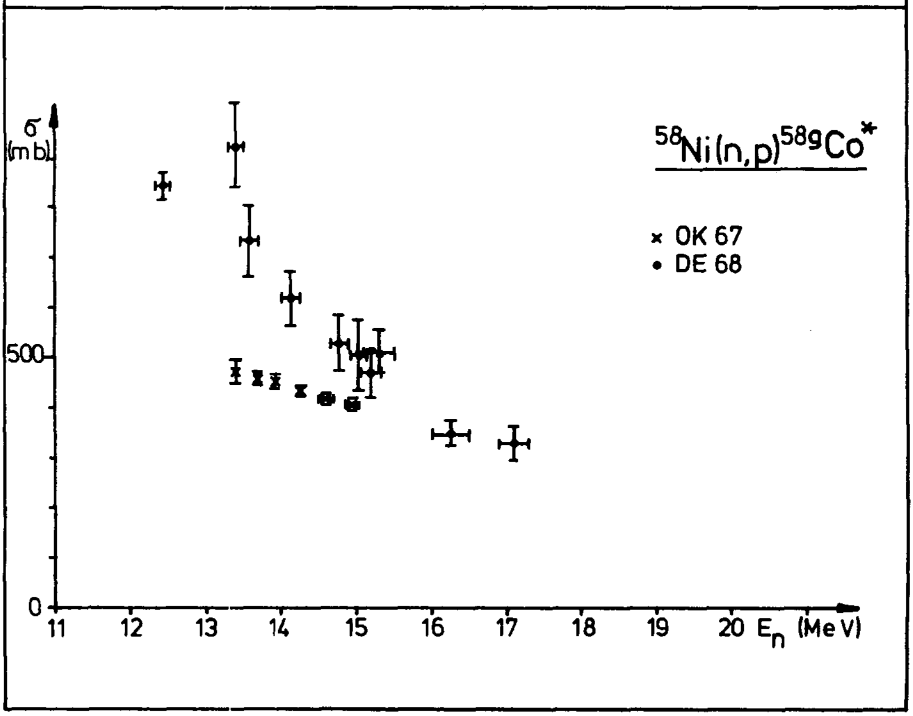


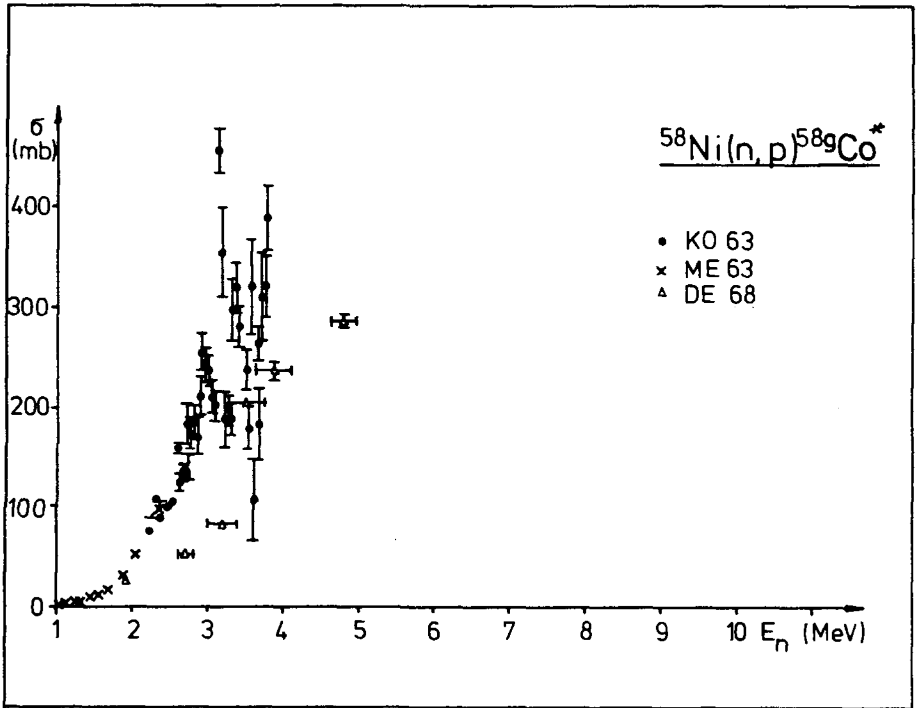
$^{59}Co(n,p)^{59}Fe$
• JE 63
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

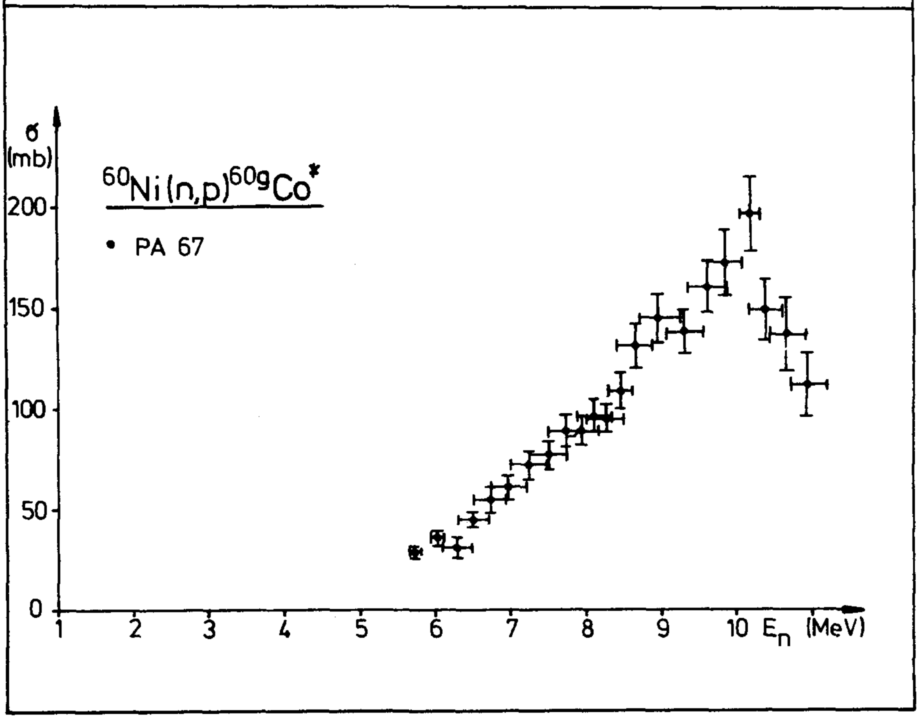


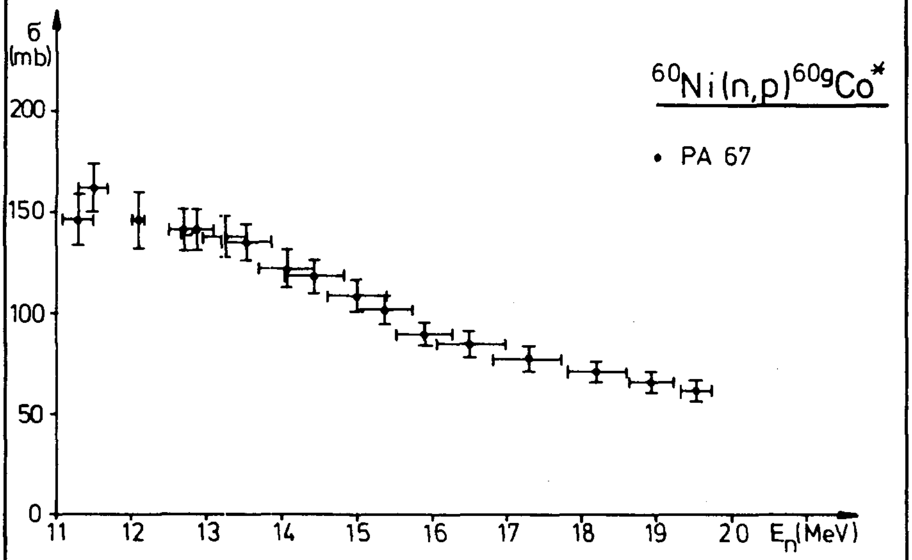
$^{58}Ni(n,p)^{58g}Co^*$
• NA 62
× BA 62
▵ DE 65
s.a. GO 60
σ (mb)
500
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)

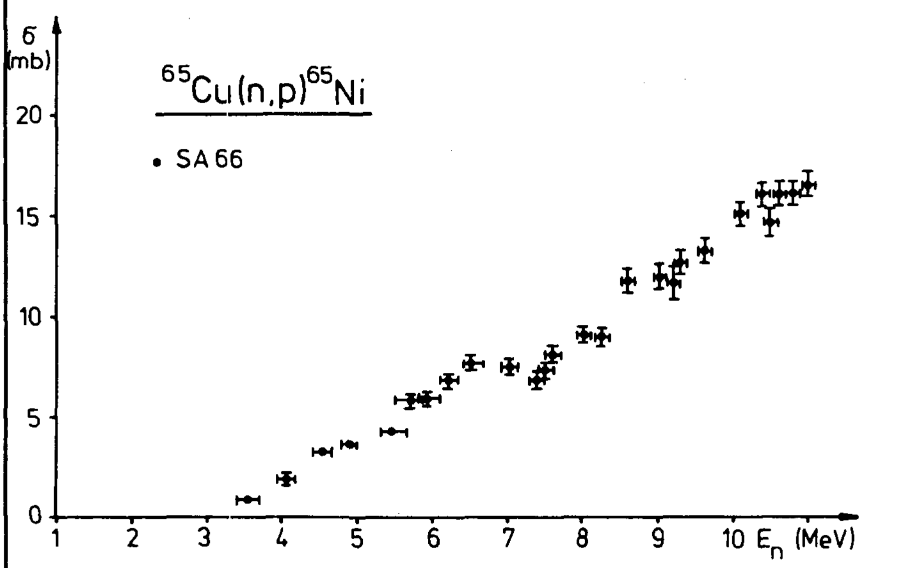

$^{58}Ni(n,p)^{58g}Co^{*}$
• CH 65
× BO 66
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

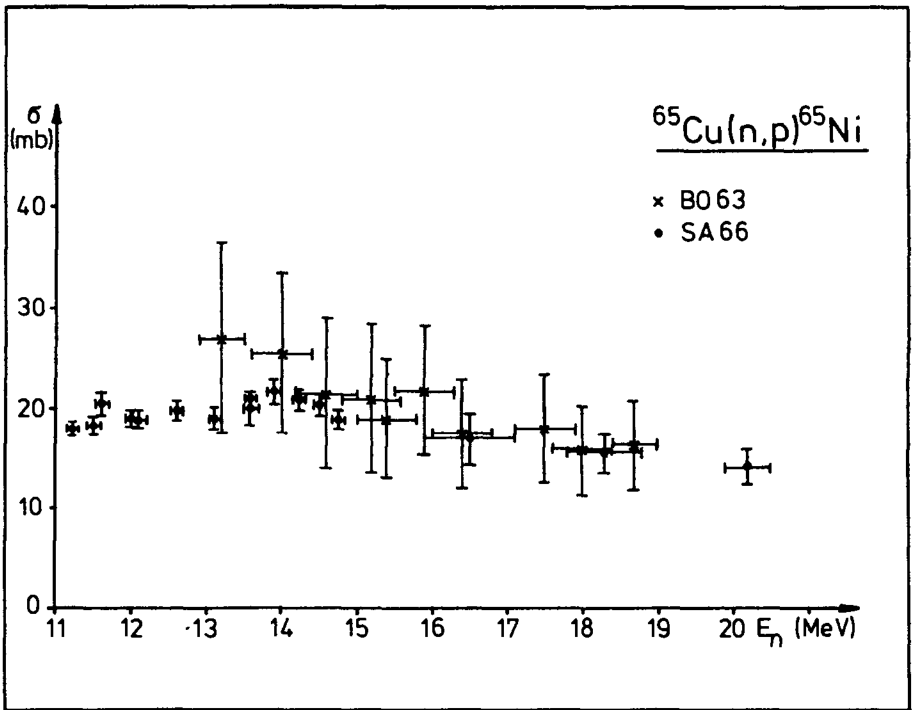

$^{58}Ni(n,p)^{58g}Co^{*}$
× OK 67
• DE 68
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

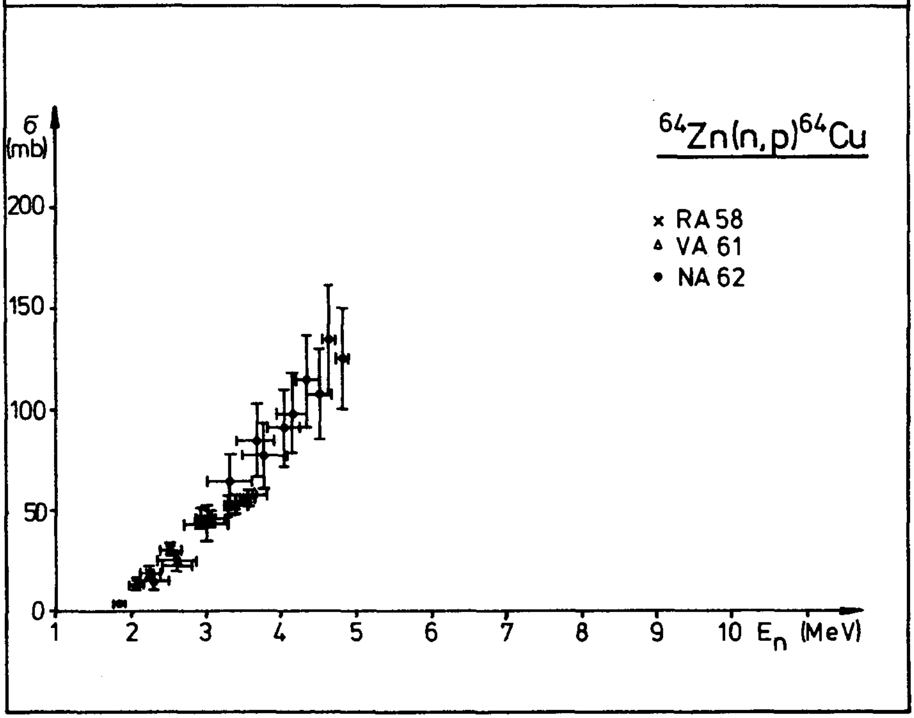

σ (mb)
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10 E_n (MeV)
$^{58}Ni(n,p)^{58g}Co^*$
• KO 63
× ME 63
△ DE 68

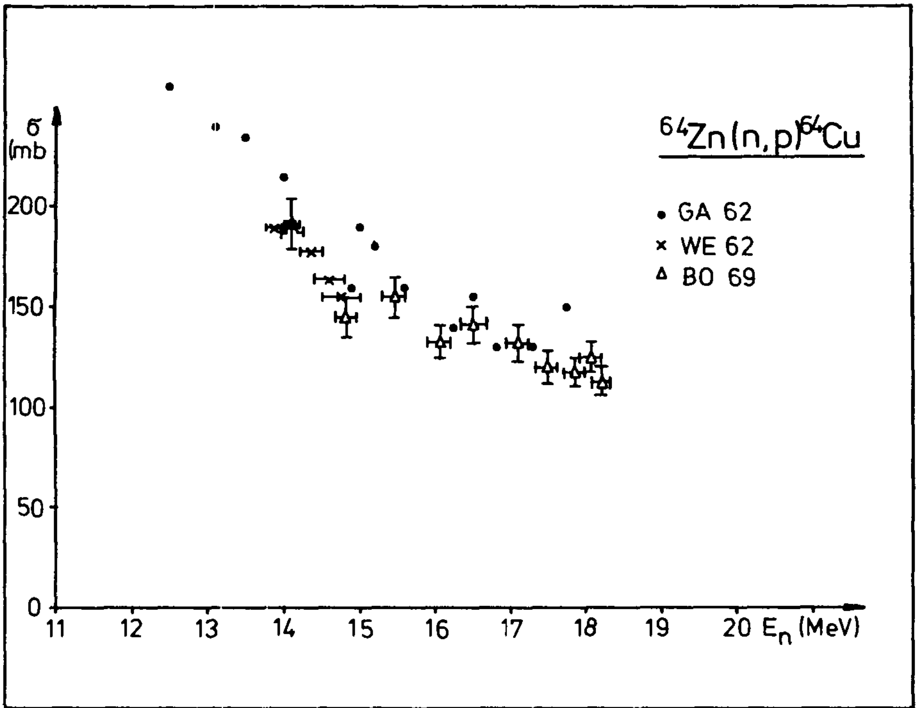

σ (mb)
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10 E_n (MeV)
$^{60}Ni(n,p)^{60g}Co^*$
• PA 67

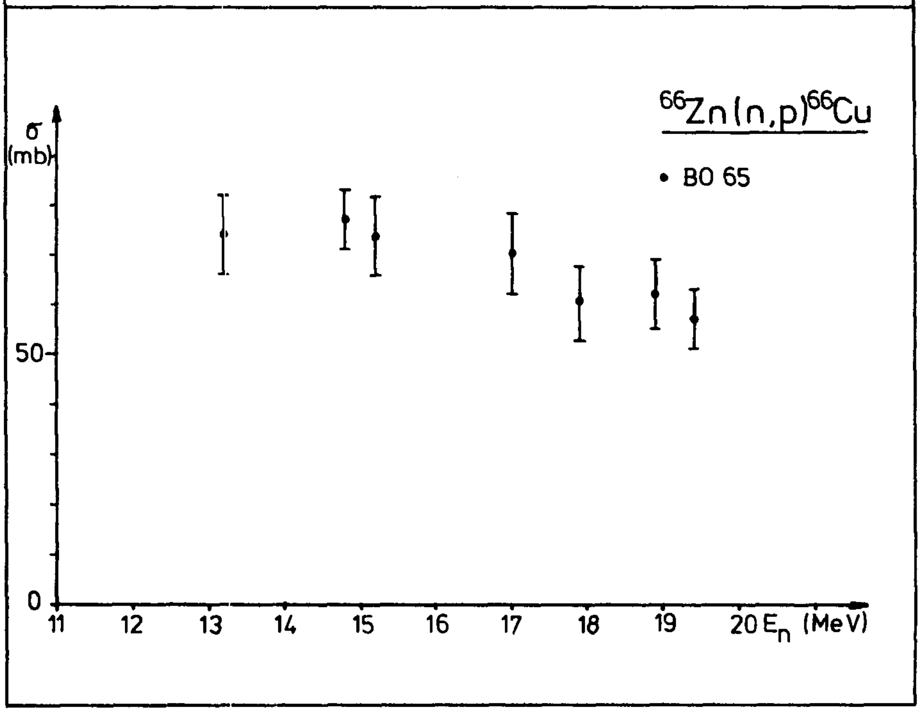

σ (mb)
200
150
100
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{60}Ni(n,p)^{60g}Co^*$
• PA 67

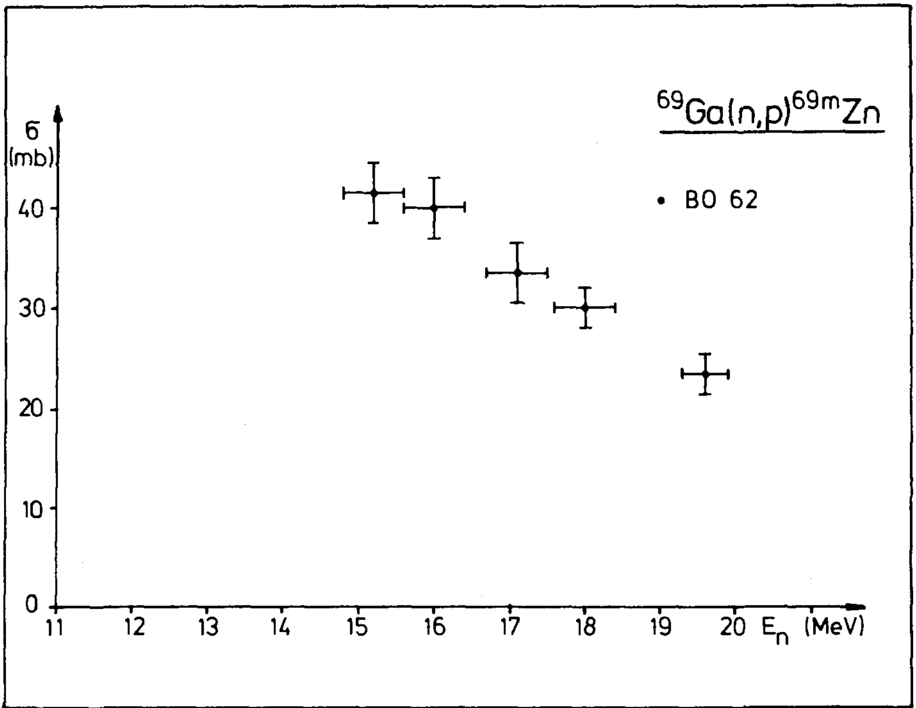

σ (mb)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)
$^{65}Cu(n,p)^{65}Ni$
• SA 66


$^{65}Cu(n,p)^{65}Ni$
× BO 63
• SA 66
σ (mb)
40
30
20
10
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)

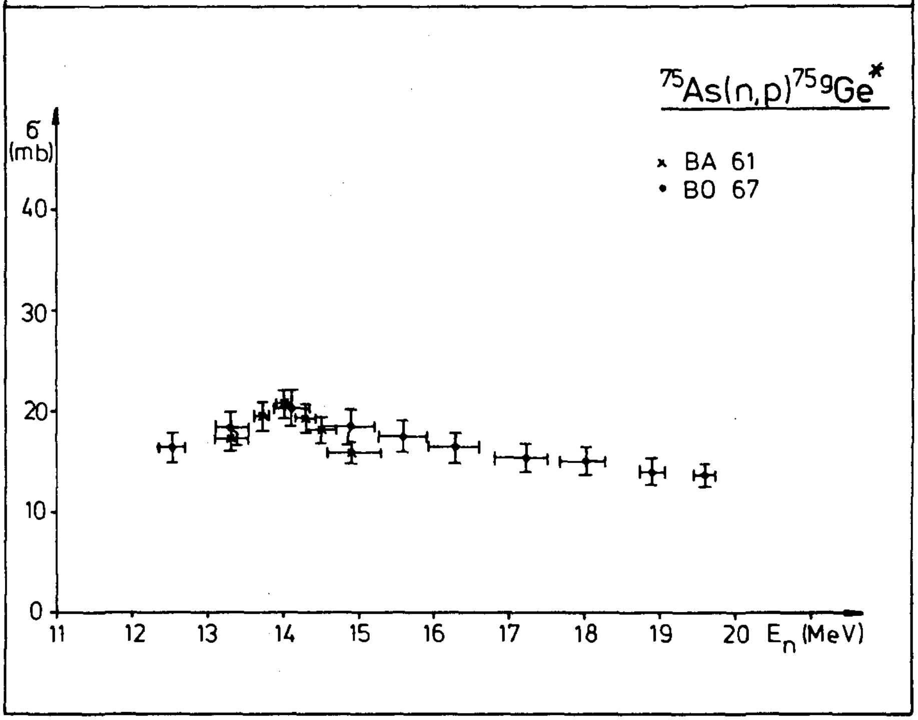

$^{64}Zn(n,p)^{64}Cu$
× RA 58
▵ VA 61
• NA 62
σ (mb)
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10 E_n (MeV)


$^{64}Zn(n,p)^{64}Cu$
• GA 62
× WE 62
Δ BO 69
σ (mb)
200
150
100
50
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)

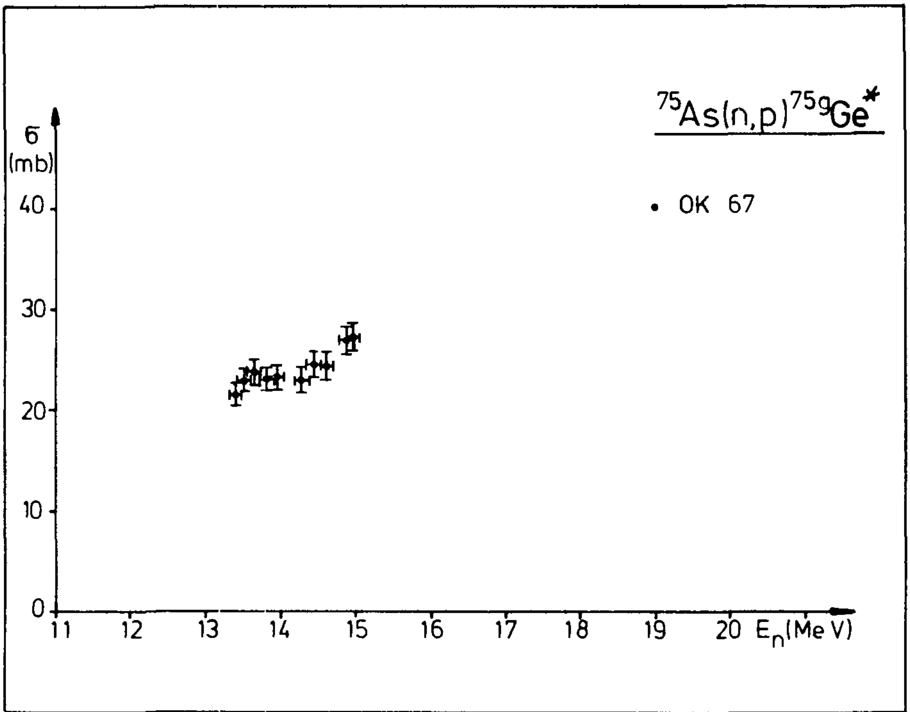

$^{66}Zn(n,p)^{66}Cu$
• BO 65
σ (mb)
50
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)

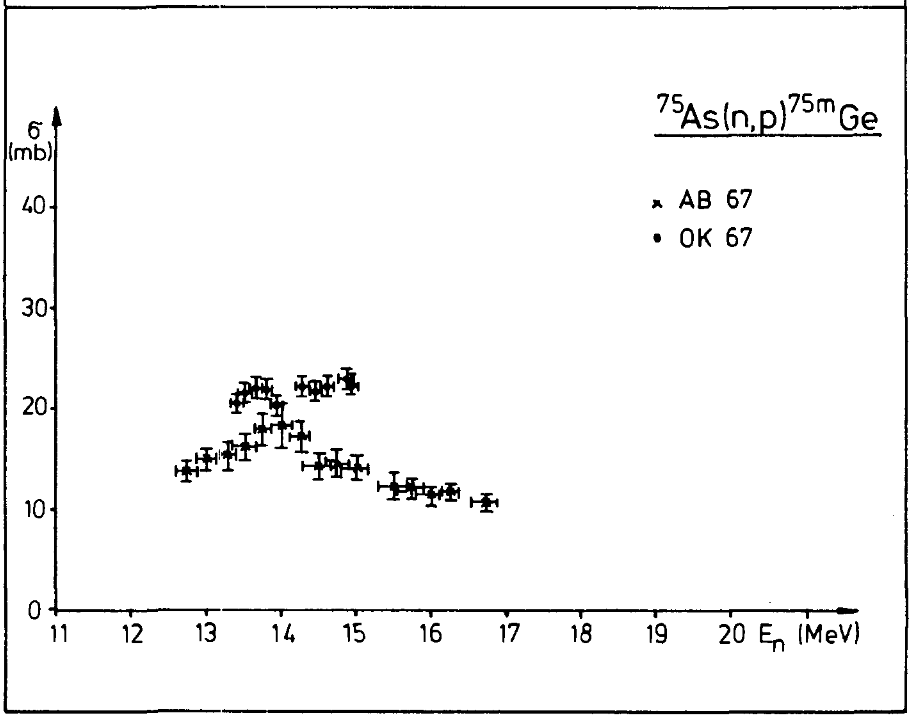


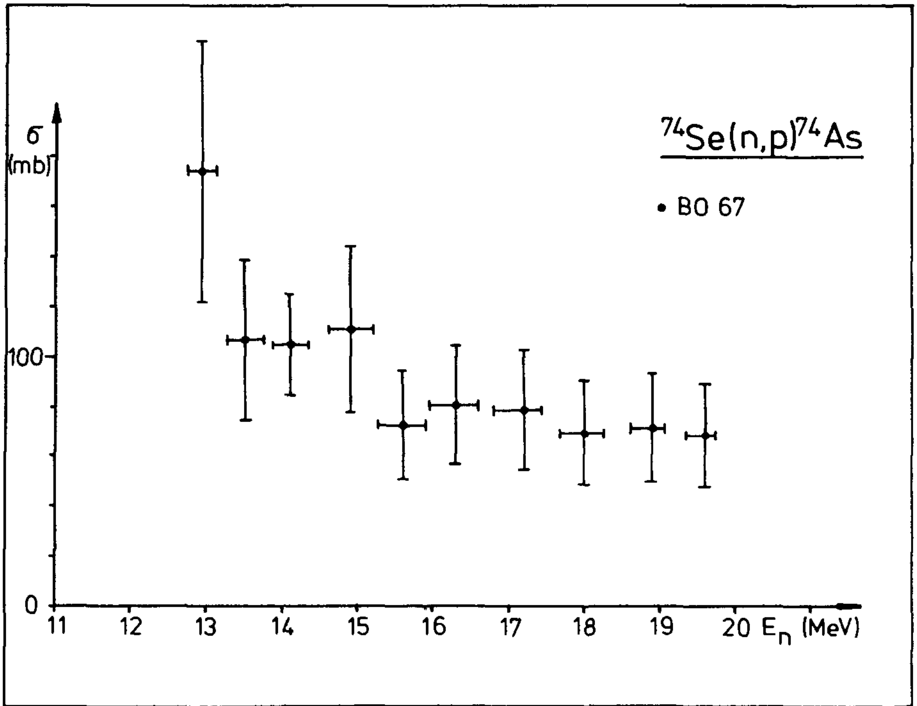
69Ga(n,p)69mZn
• BO 62
σ (mb)
40
30
20
10
0
11 12 13 14 15 16 17 18 19 20 En (MeV)



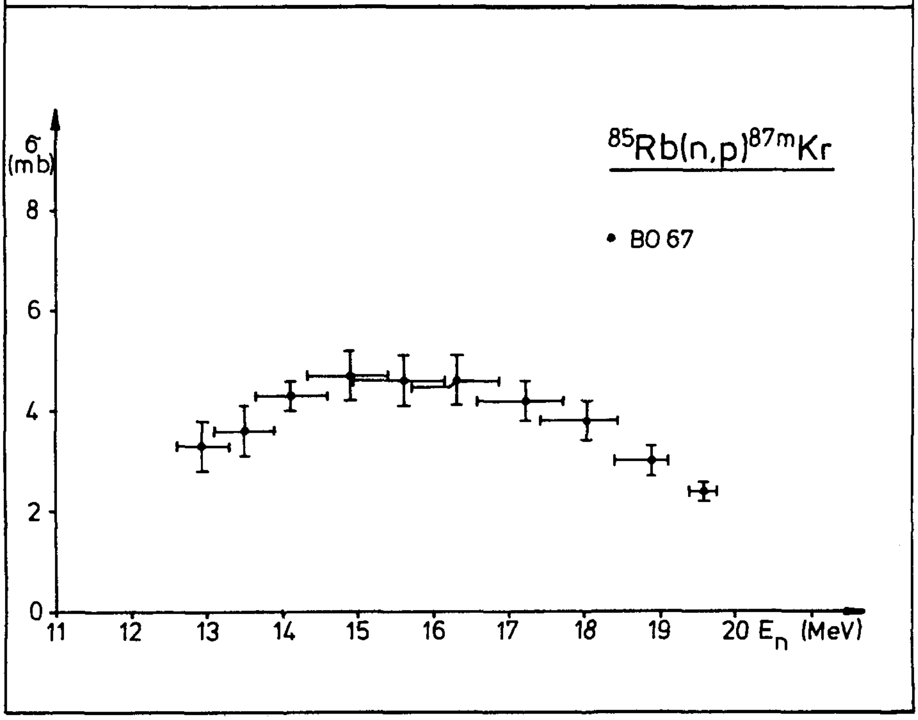
75As(n,p)75gGe*
x BA 61
• BO 67
σ (mb)
40
30
20
10
0
11 12 13 14 15 16 17 18 19 20 En (MeV)


$^{75}As(n,p)^{75g}Ge^{*}$
• OK 67
σ (mb)
0
10
20
30
40
11
12
13
14
15
16
17
18
19
20 E_n(MeV)

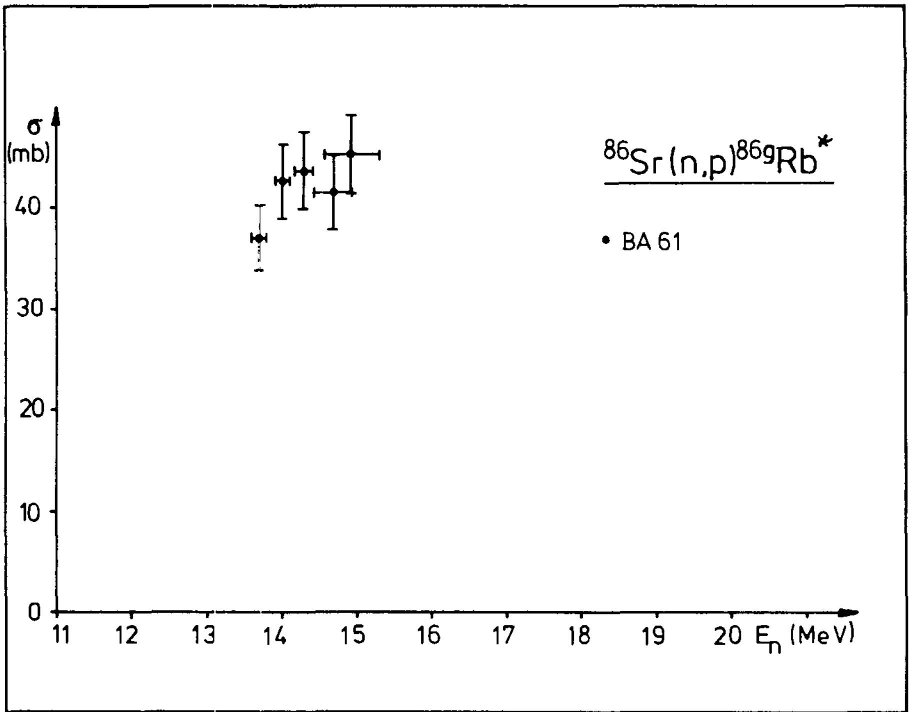

$^{75}As(n,p)^{75m}Ge$
x AB 67
• OK 67
σ (mb)
0
10
20
30
40
11
12
13
14
15
16
17
18
19
20 E_n (MeV)

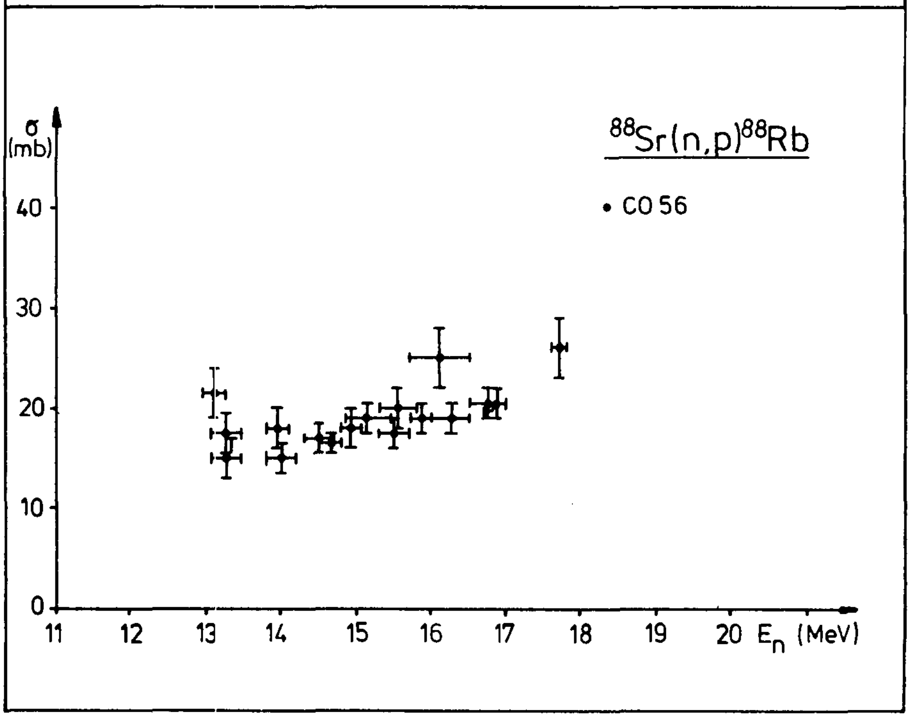


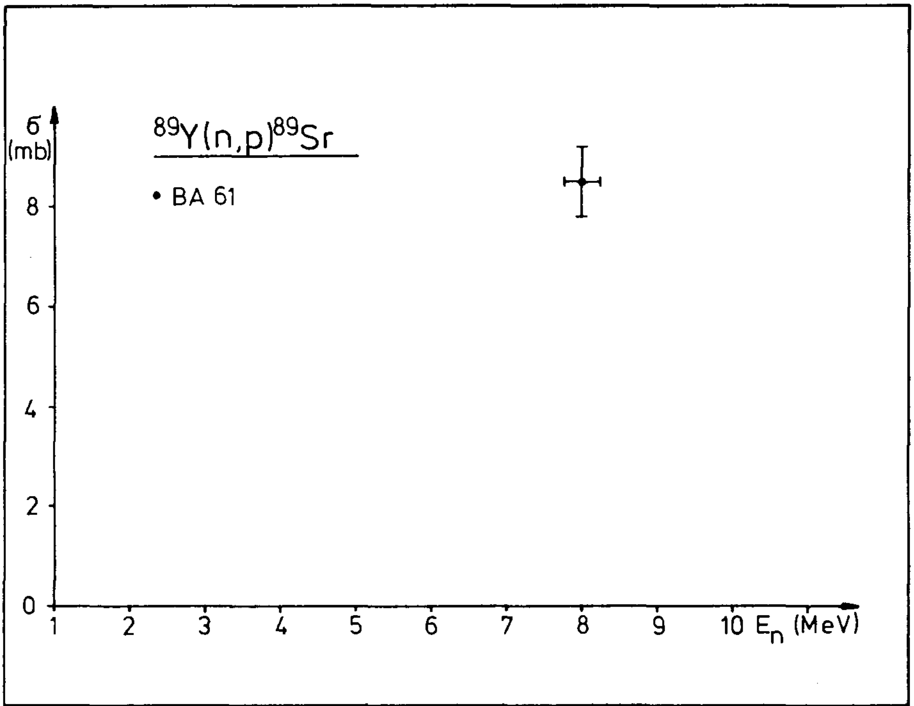
$^{74}Se(n,p)^{74}As$
• BO 67
σ (mb)
100
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



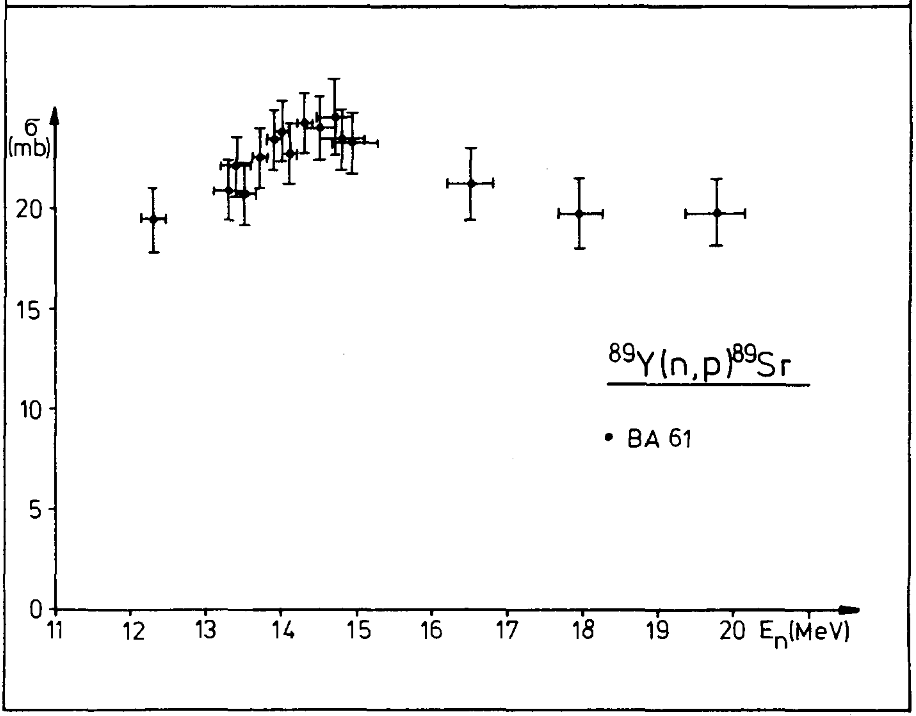
$^{85}Rb(n,p)^{87m}Kr$
• BO 67
σ (mb)
8
6
4
2
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


σ (mb)
40
30
20
10
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{86}Sr(n,p)^{86g}Rb^*$
• BA 61

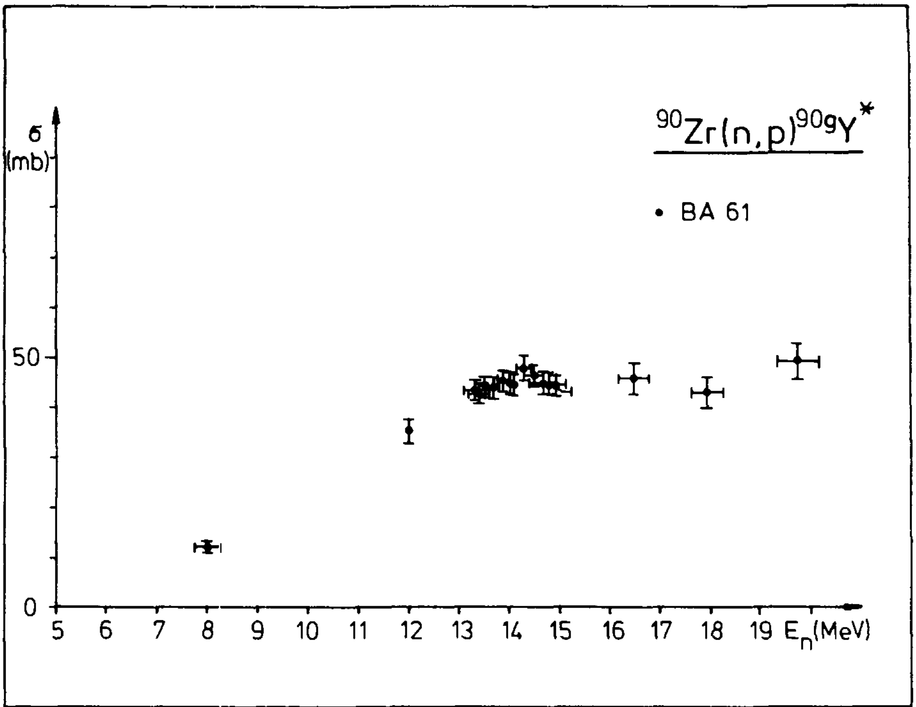

σ (mb)
40
30
20
10
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{88}Sr(n,p)^{88}Rb$
• CO 56

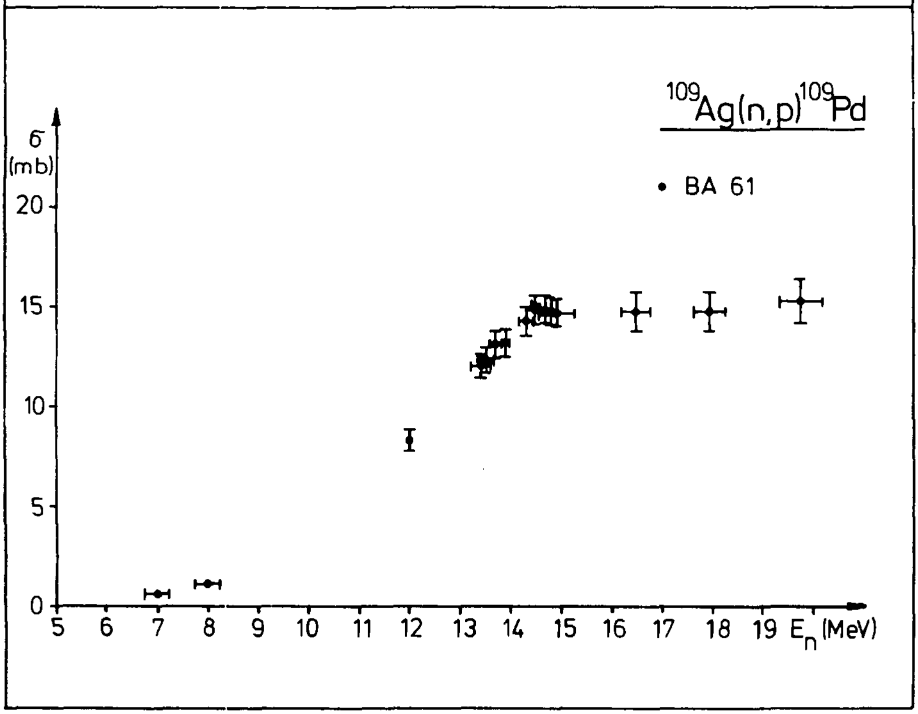


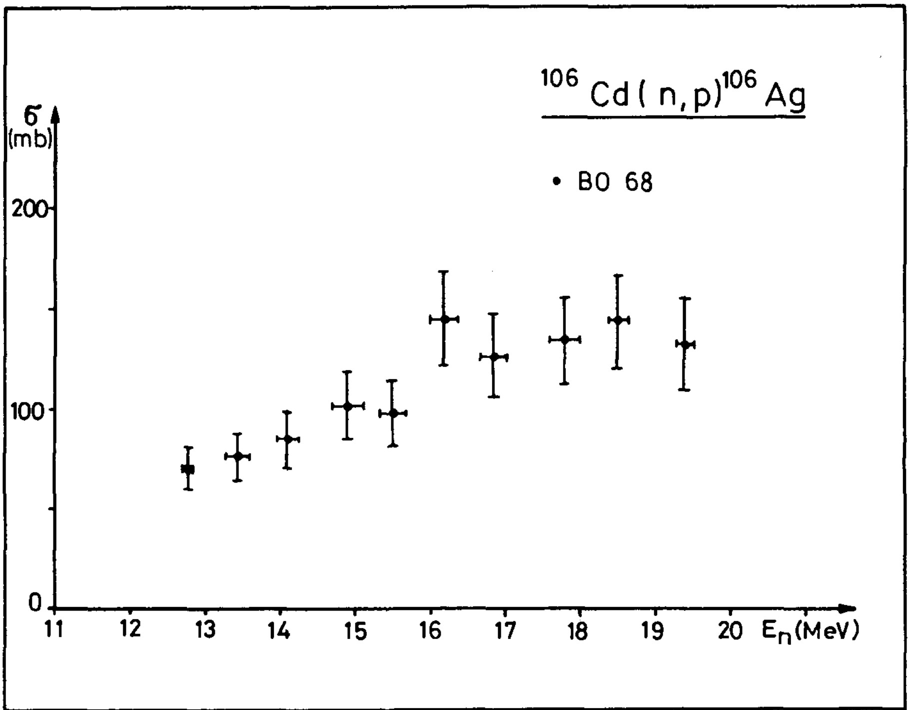
$^{89}Y(n,p)^{89}Sr$
• BA 61
σ (mb)
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)



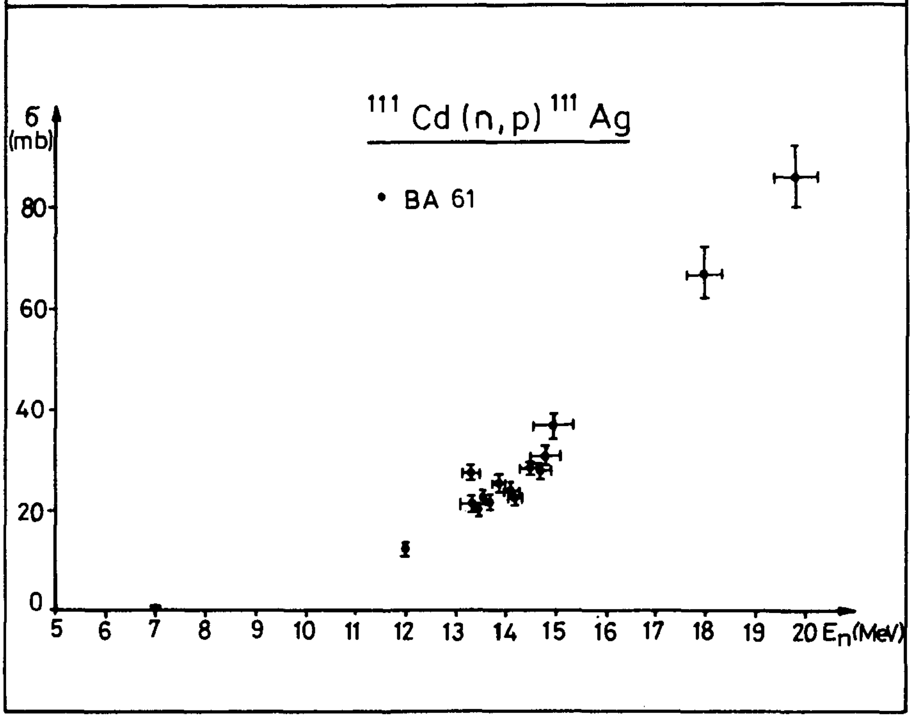
$^{89}Y(n,p)^{89}Sr$
• BA 61
σ (mb)
20
15
10
5
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)


$^{90}Zr(n,p)^{90g}Y^*$
• BA 61
σ (mb)
0
50
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 E_n(MeV)

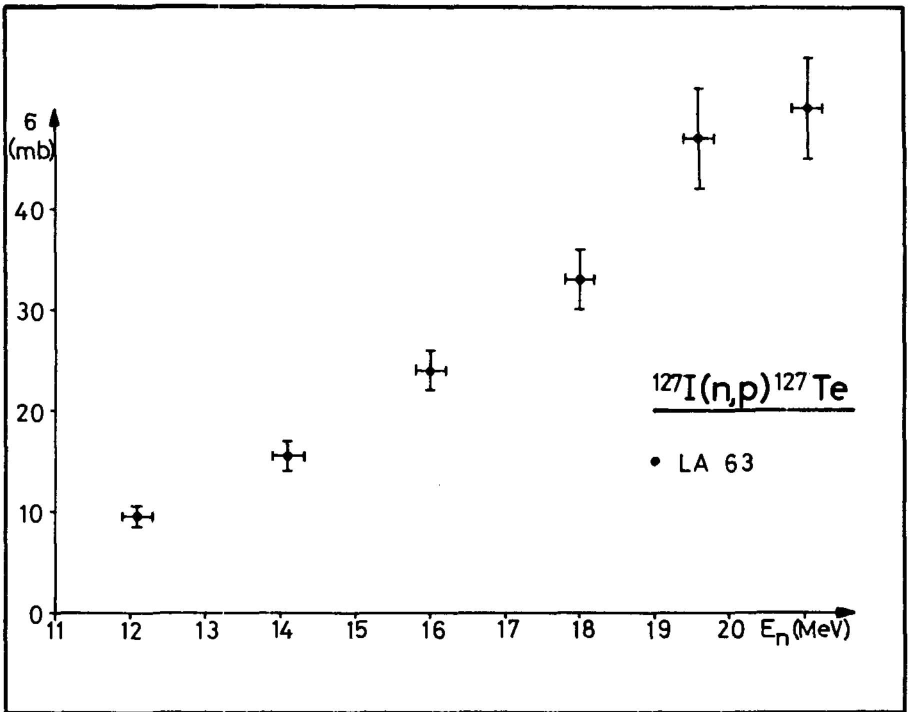

$^{109}Ag(n,p)^{109}Pd$
• BA 61
σ (mb)
0
5
10
15
20
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 E_n (MeV)

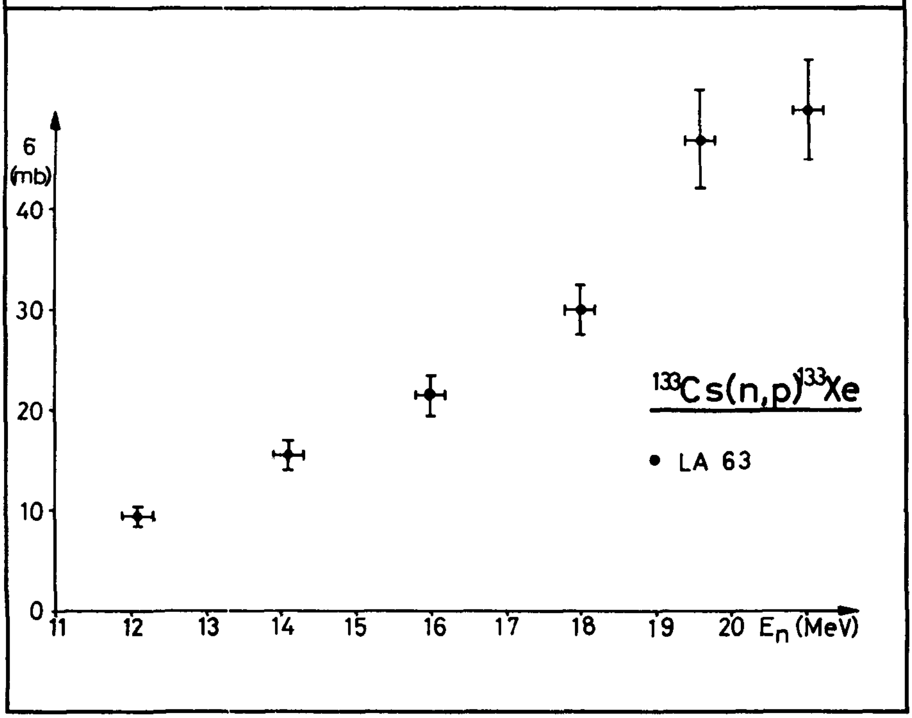


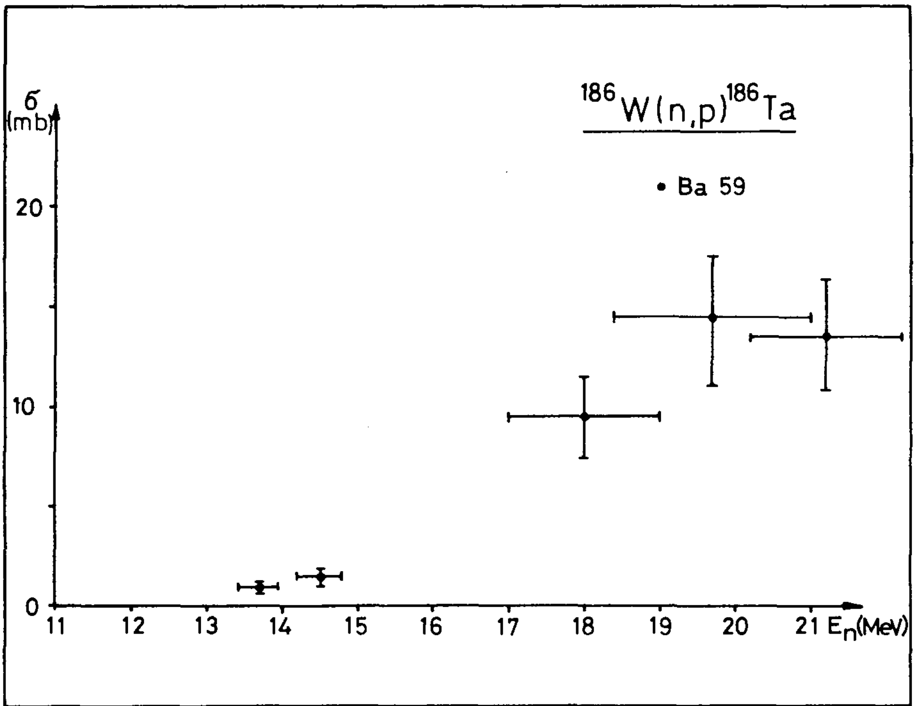
$^{106}Cd(n,p)^{106}Ag$
• BO 68
σ (mb)
200
100
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)



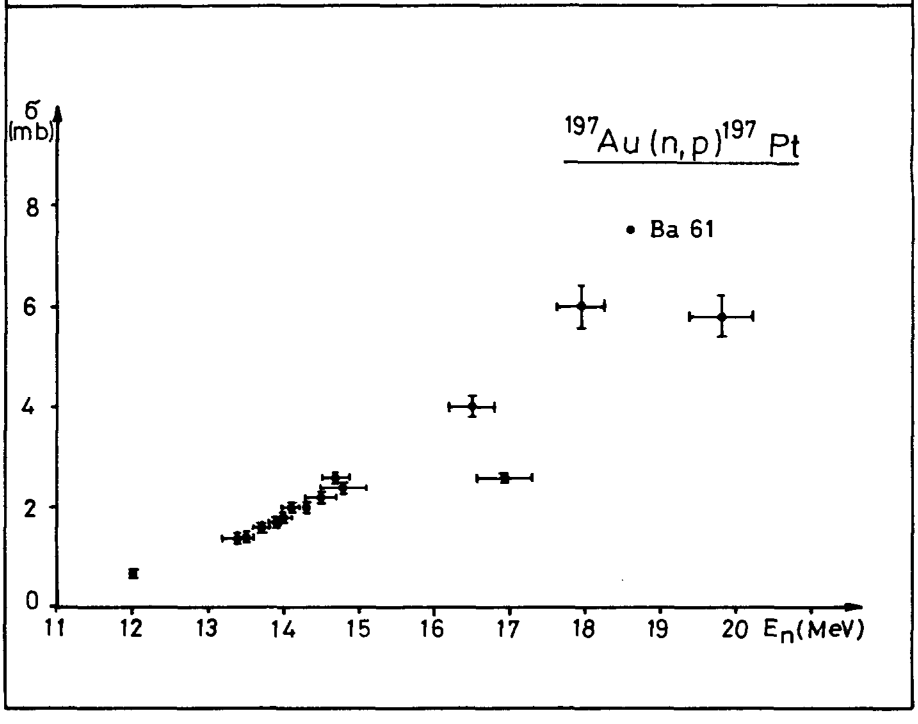
$^{111}Cd(n,p)^{111}Ag$
• BA 61
σ (mb)
80
60
40
20
0
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
E_n (MeV)


6 (mb)
40
30
20
10
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{127}I(n,p)^{127}Te$
• LA 63


6 (mb)
40
30
20
10
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{133}Cs(n,p)^{133}Xe$
• LA 63



$^{186}W(n,p)^{186}Ta$
• Ba 59
σ (mb)
0
10
20
11 12 13 14 15 16 17 18 19 20 21
E_n(MeV)



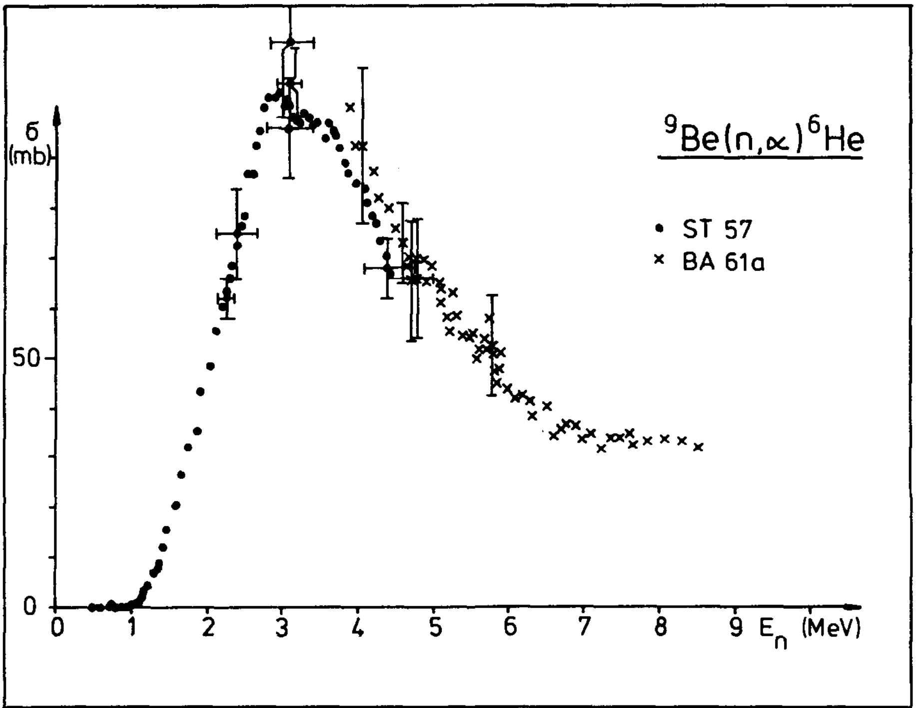
$^{197}Au(n,p)^{197}Pt$
• Ba 61
σ (mb)
0
2
4
6
8
11 12 13 14 15 16 17 18 19 20
E_n(MeV)

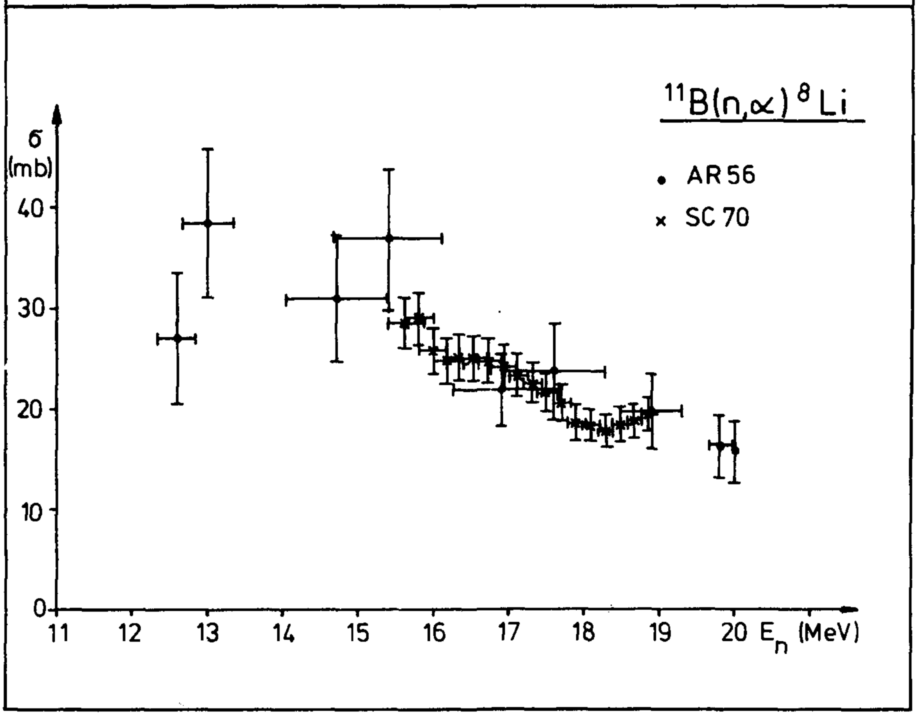
GRAPHS OF
(n, α) CROSS-SECTIONS

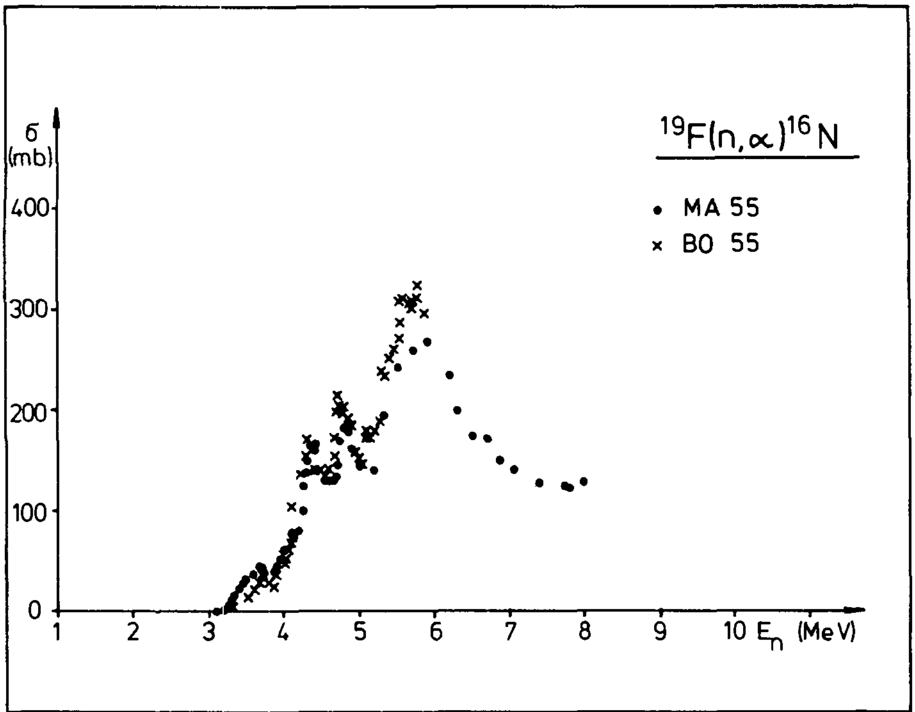
Excitation functions of (n, α) reactions for the target nuclei:

^{9}Be, ^{11}B, ^{19}F, ^{23}Na, ^{26}Mg, ^{27}Al, ^{31}P, ^{34}S, ^{35}Cl, ^{37}Cl, ^{40}Ar, ^{39}K, ^{41}K, ^{40}Ca, ^{44}Ca, ^{45}Sc, ^{51}V, ^{55}Mn, ^{54}Fe, ^{59}Co, ^{63}Cu, ^{75}As, ^{79}Br, ^{85}Rb, ^{89}Y, ^{92}Zr, ^{94}Zr, ^{93}Nb, ^{112}Cd, ^{118}Sn, ^{127}I, ^{133}Cs, ^{140}Ce, ^{197}Au

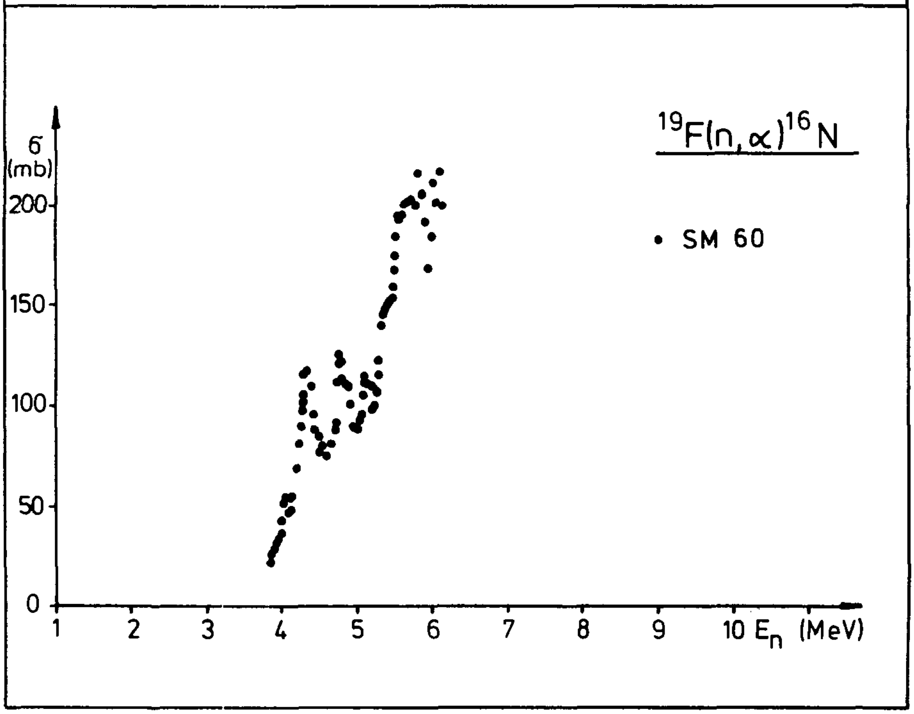
(The abbreviations of references (e.g. ST 57) are constructed from the name of the first author and the year of publication. A list of references is given on pages 270-272.)


$^{9}Be(n,\alpha)^{6}He$
• ST 57
× BA 61a
σ (mb)
0
50
0 1 2 3 4 5 6 7 8 9 E_n (MeV)

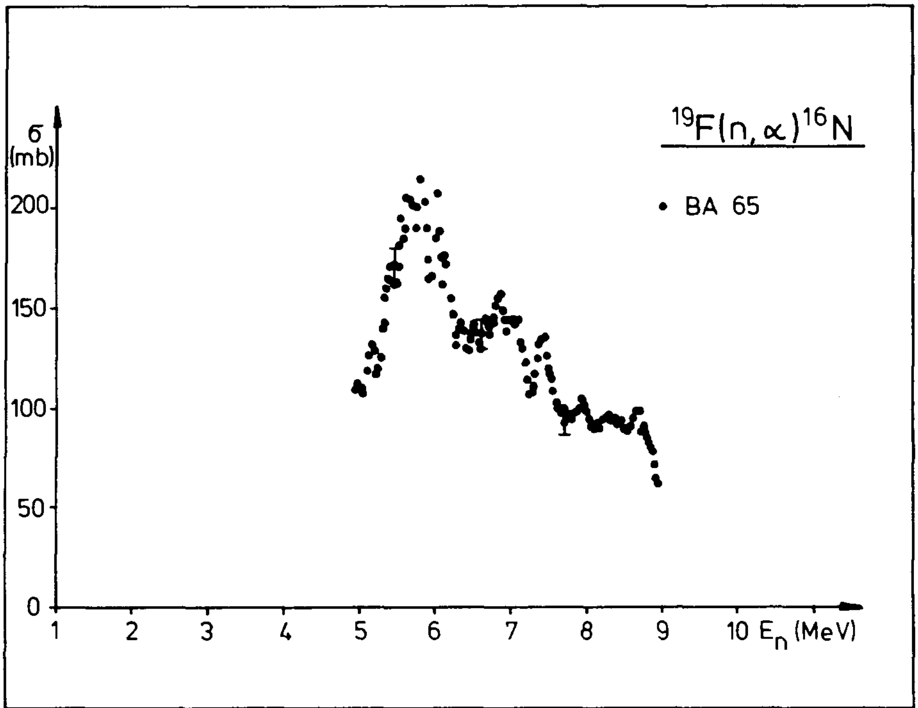

$^{11}B(n,\alpha)^{8}Li$
• AR 56
× SC 70
σ (mb)
0
10
20
30
40
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

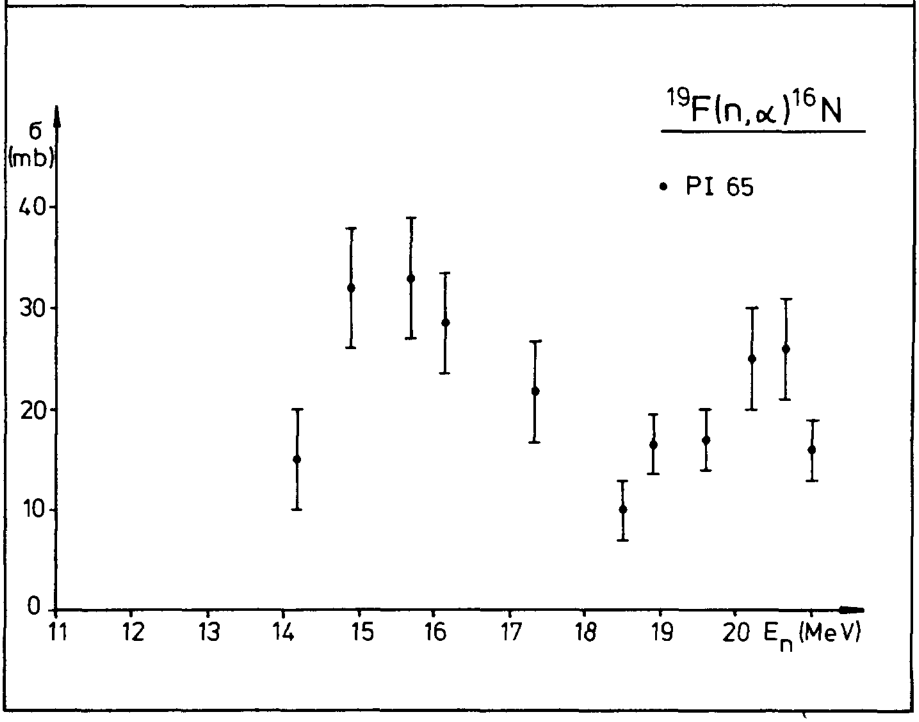


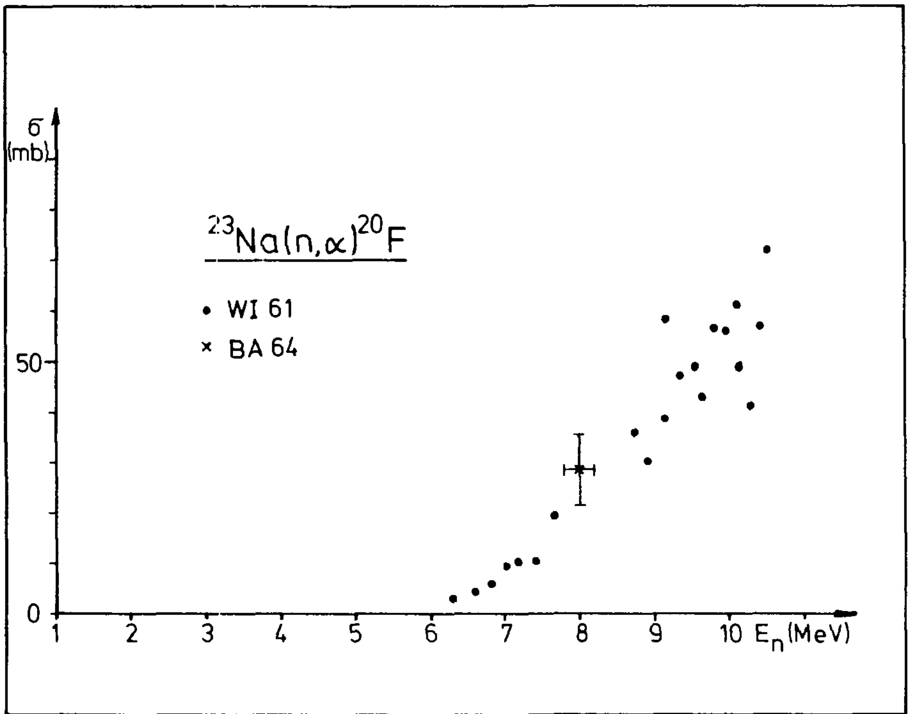
$^{19}F(n,\alpha)^{16}N$
• MA 55
× BO 55
б (mb)
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10 E_n (MeV)

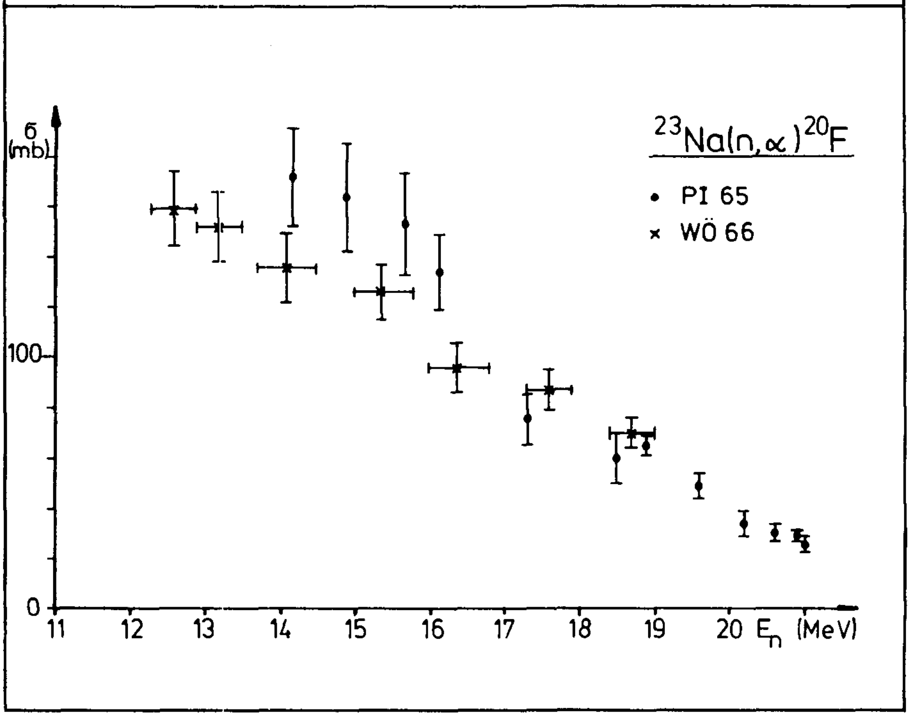


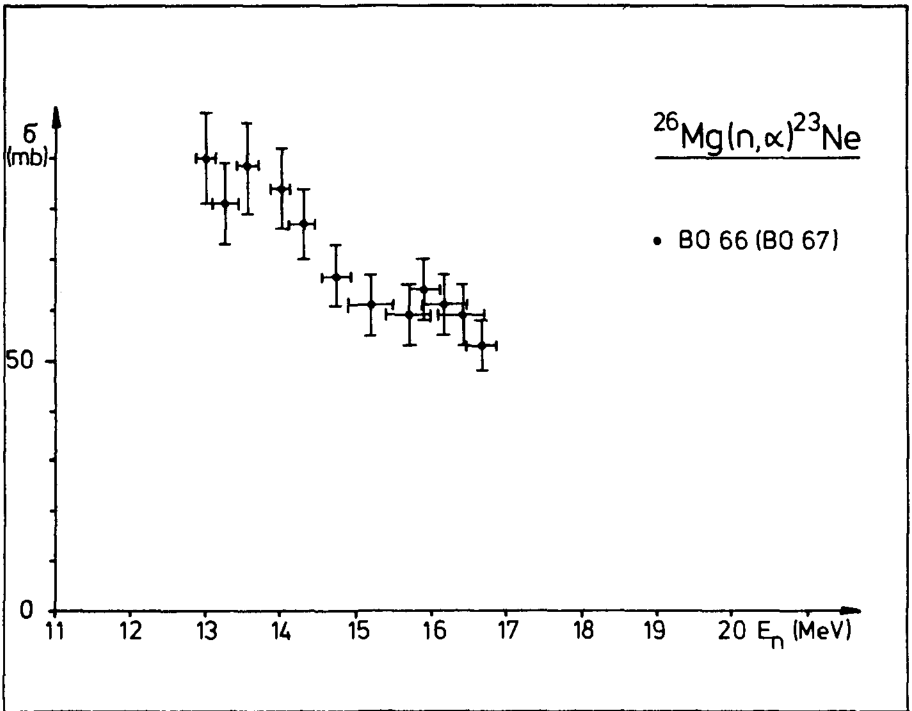
$^{19}F(n,\alpha)^{16}N$
• SM 60
б (mb)
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10 E_n (MeV)

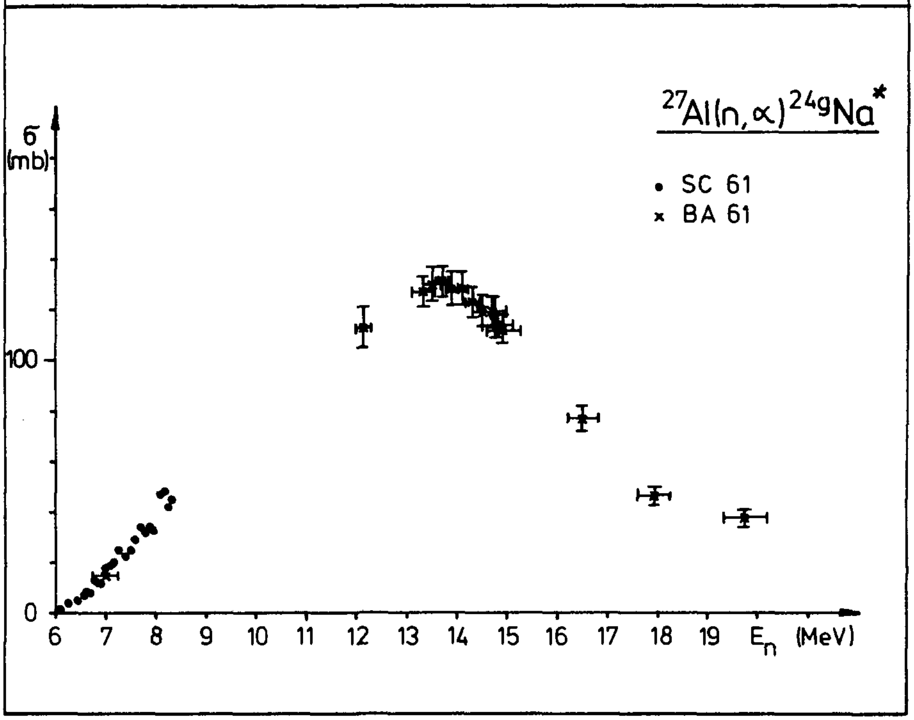

$^{19}F(n,\alpha)^{16}N$
• BA 65
σ (mb)
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10 E_n (MeV)

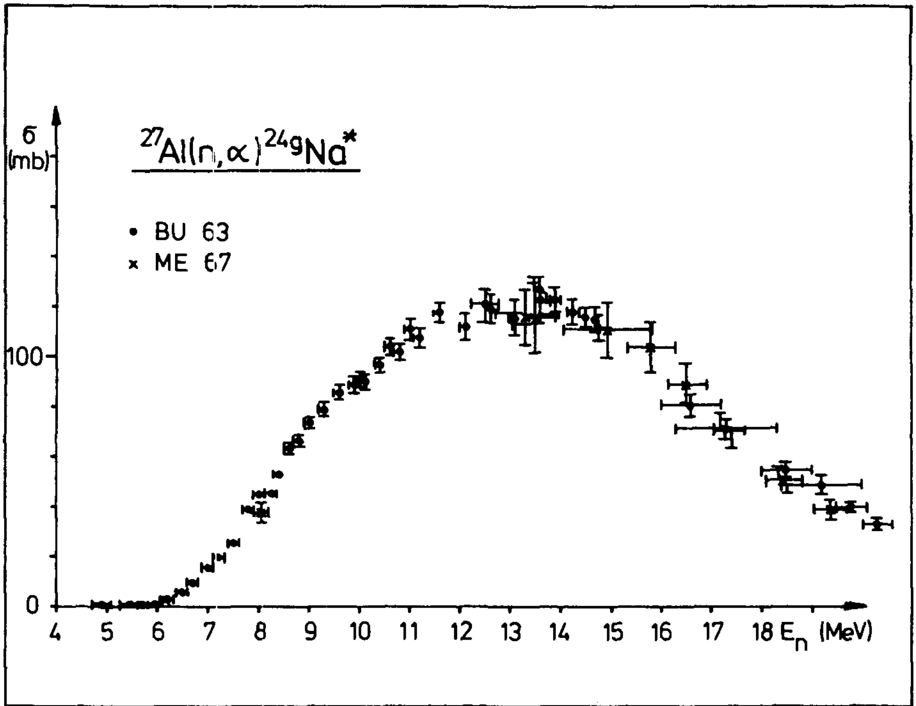

$^{19}F(n,\alpha)^{16}N$
• PI 65
σ (mb)
40
30
20
10
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)


σ (mb)
$^{23}Na(n,\alpha)^{20}F$
• WI 61
× BA 64
50
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)

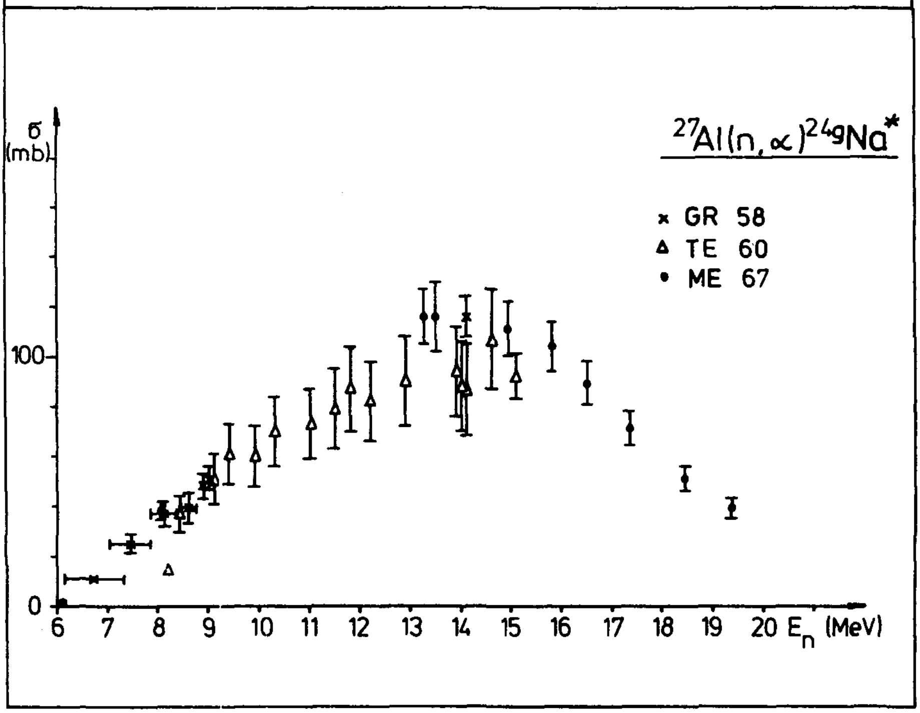

σ (mb)
$^{23}Na(n,\alpha)^{20}F$
• PI 65
× WÖ 66
100
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


$^{26}Mg(n,\alpha)^{23}Ne$
• BO 66 (BO 67)
σ (mb)
50
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)

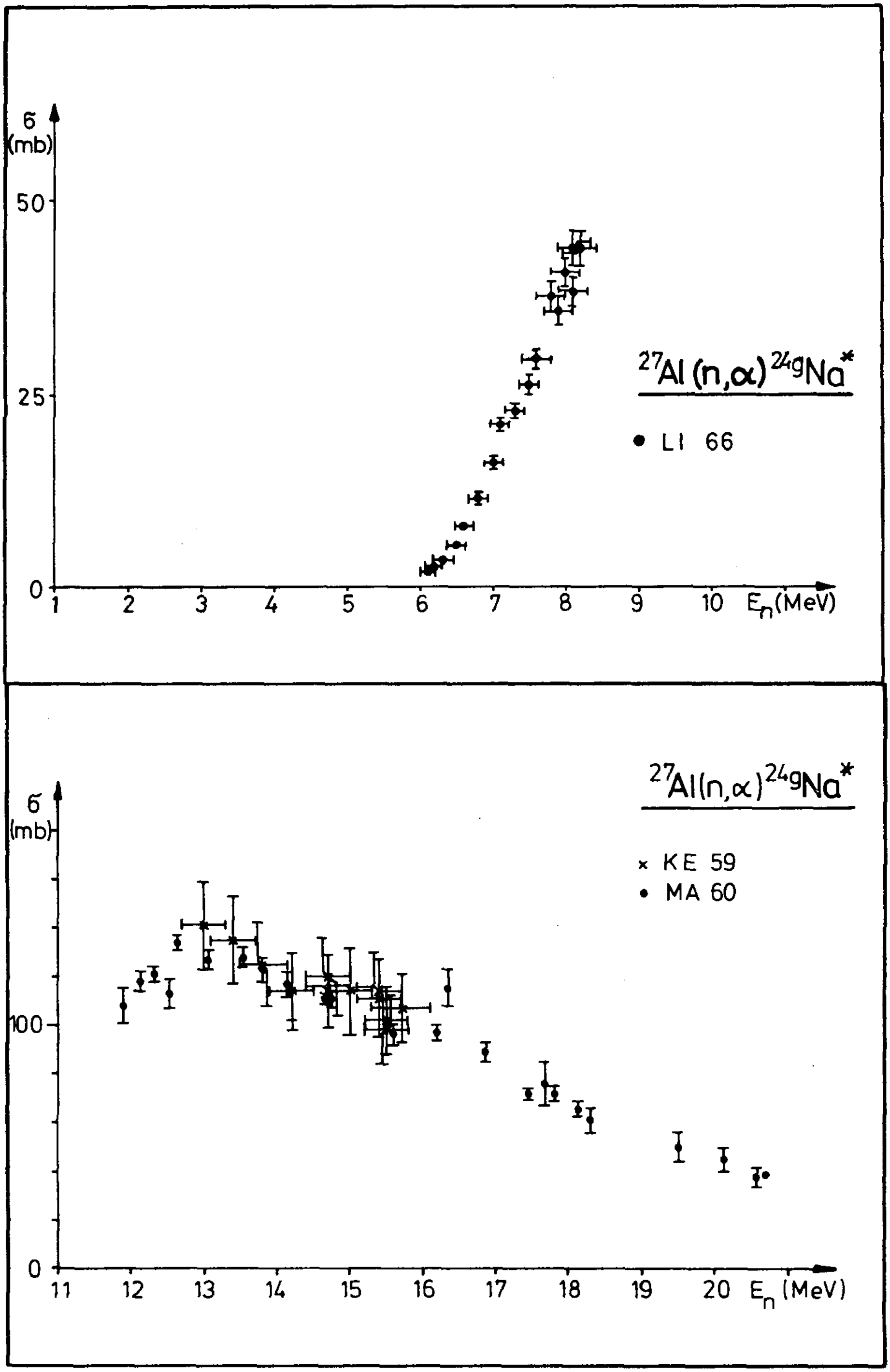

$^{27}Al(n,\alpha)^{24g}Na^*$
• SC 61
× BA 61
σ (mb)
100
0
6
7
8
9
10
11
12
13
14
15
16
17
18
19
E_n (MeV)

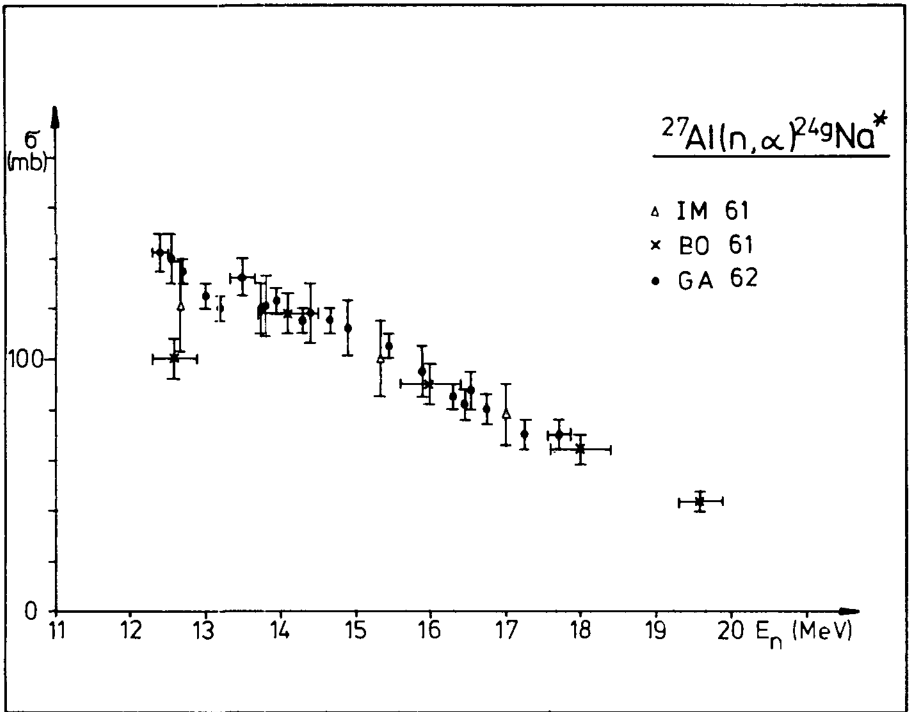


σ (mb)
$^{27}Al(n,\alpha)^{24g}Na^*$
• BU 63
× ME 67
100
0
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 E_n (MeV)

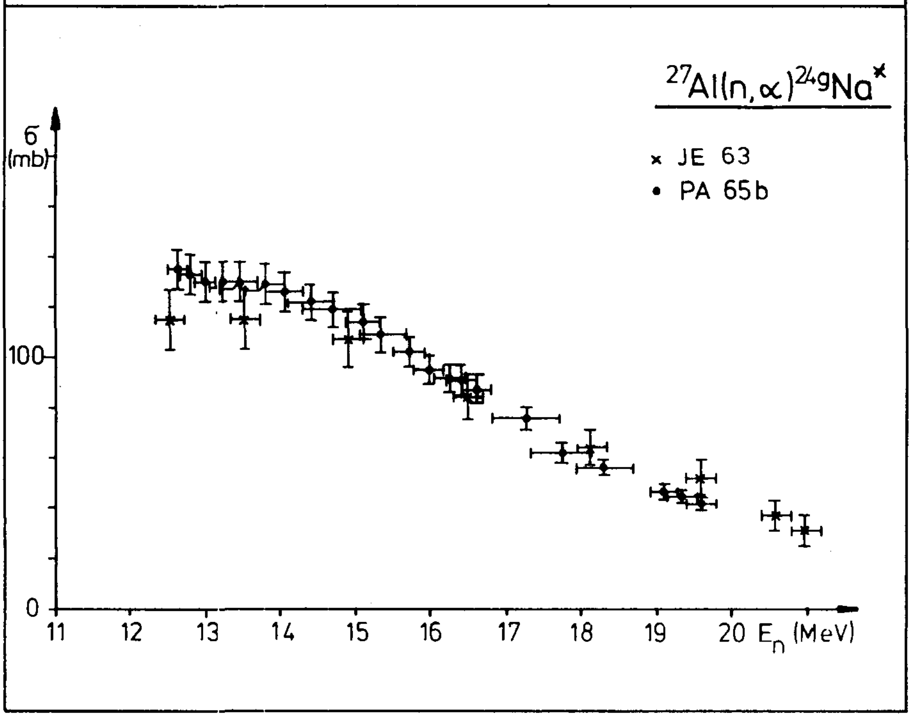


σ (mb)
$^{27}Al(n,\alpha)^{24g}Na^*$
× GR 58
Δ TE 60
• ME 67
100
0
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 E_n (MeV)

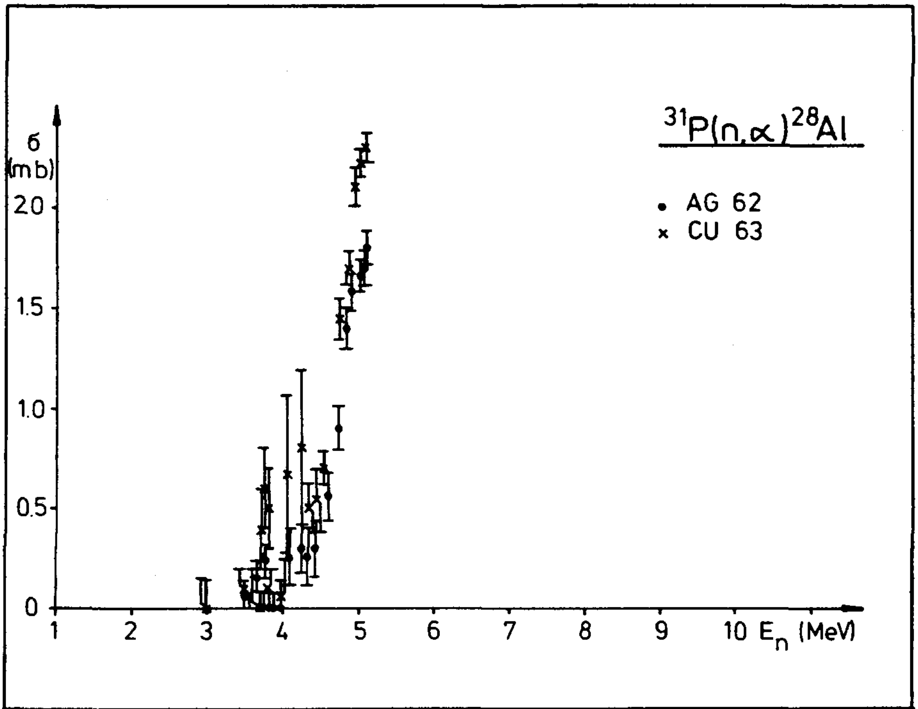

σ (mb)
50
25
0
1 2 3 4 5 6 7 8 9 10 E_n(MeV)
$^{27}Al(n,\alpha)^{24g}Na^*$
LI 66
σ (mb)
100
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{27}Al(n,\alpha)^{24g}Na^*$
KE 59
MA 60

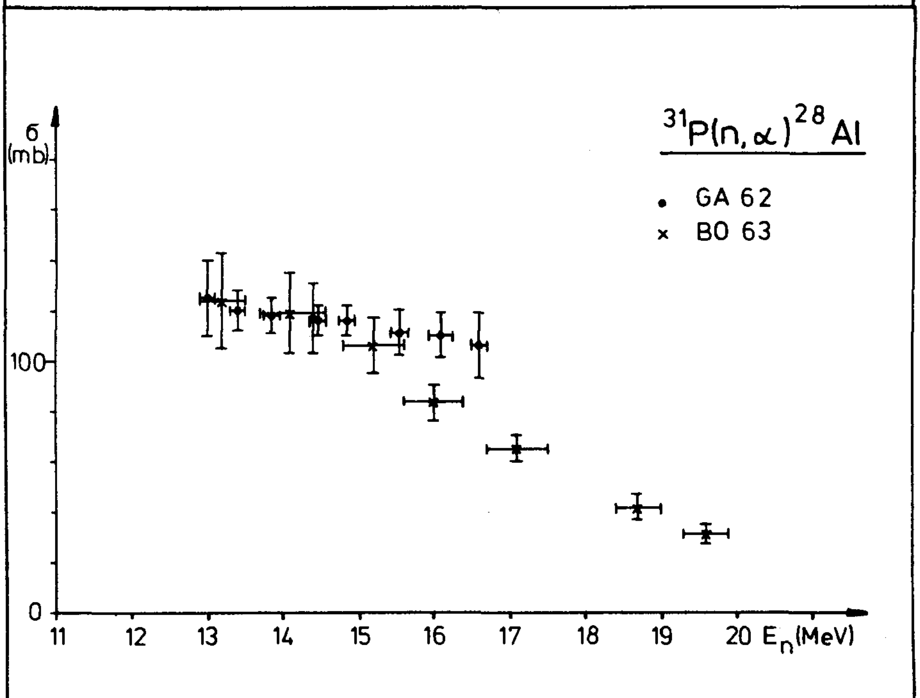


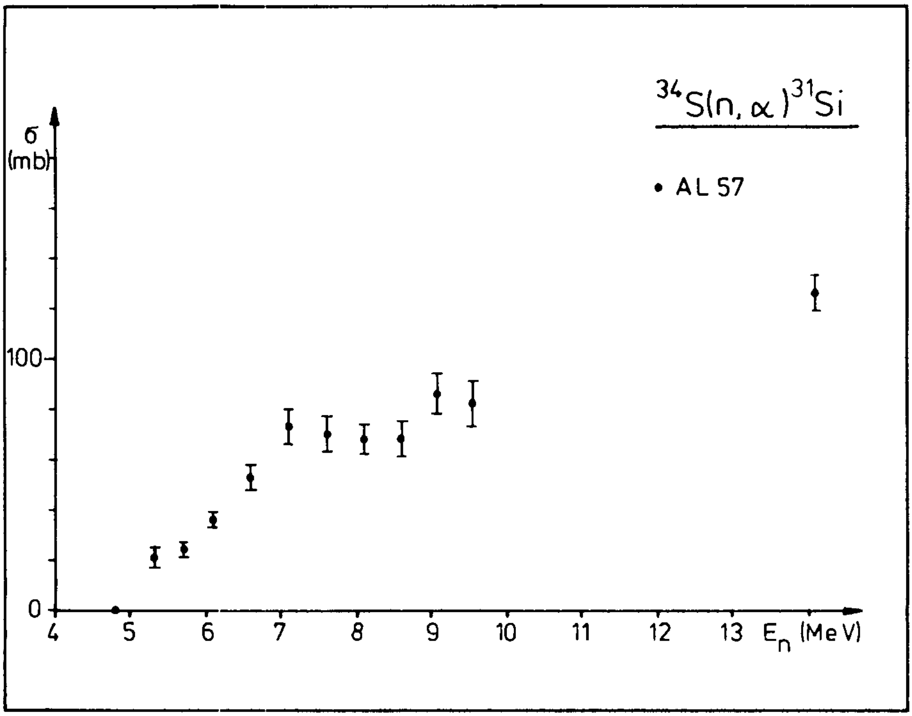
$^{27}Al(n,\alpha)^{24g}Na^*$
IM 61
BO 61
GA 62
σ (mb)
100
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)

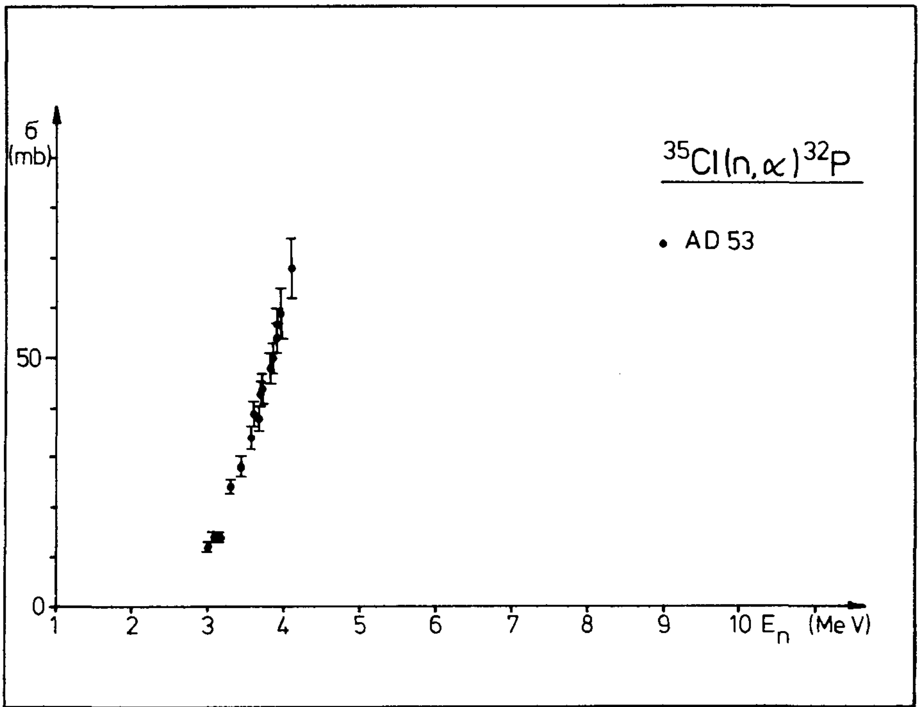


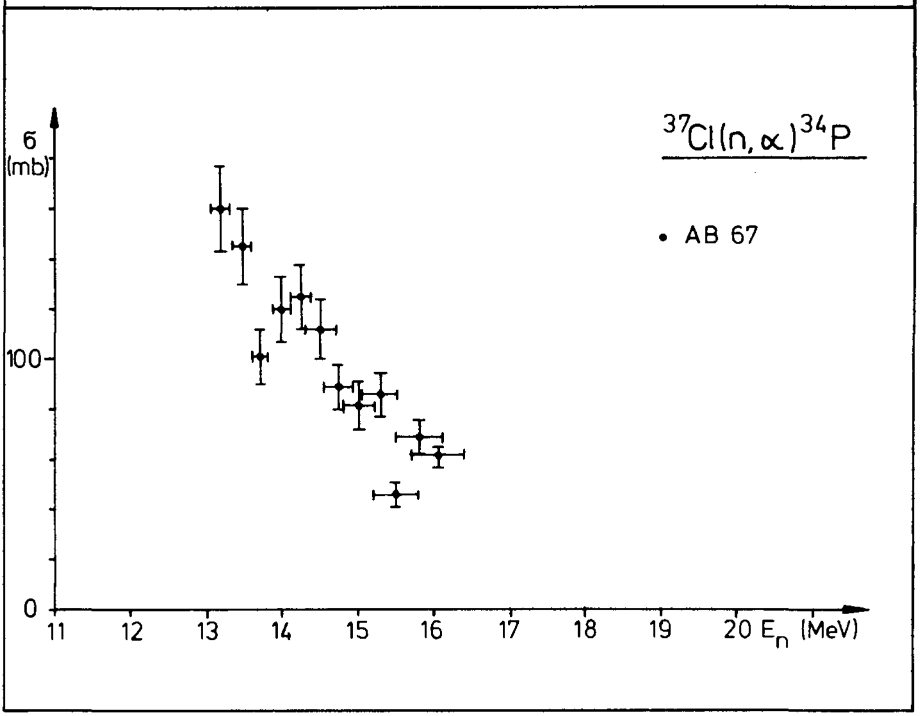
$^{27}Al(n,\alpha)^{24g}Na^*$
JE 63
PA 65b
σ (mb)
100
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)

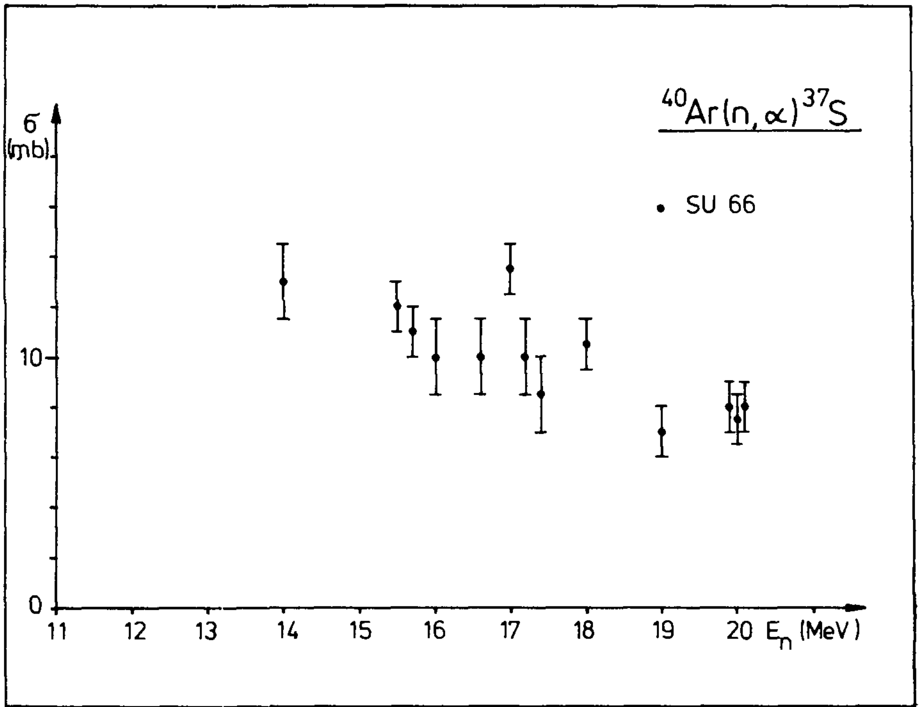

$^{31}P(n,\alpha)^{28}Al$
• AG 62
× CU 63
σ (mb)
2.0
1.5
1.0
0.5
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)

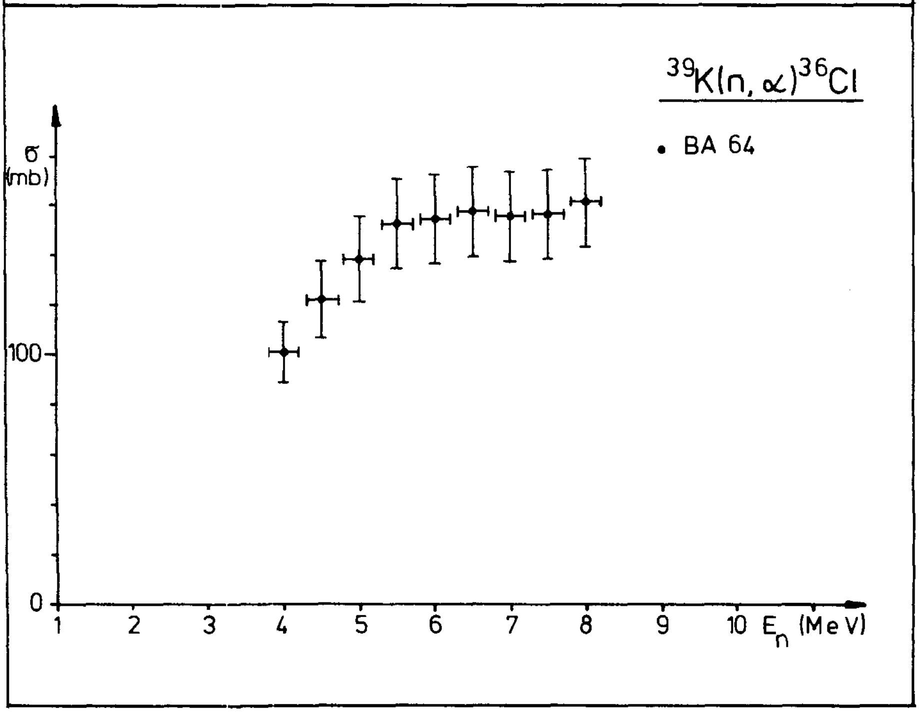

$^{31}P(n,\alpha)^{28}Al$
• GA 62
× BO 63
σ (mb)
100
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)

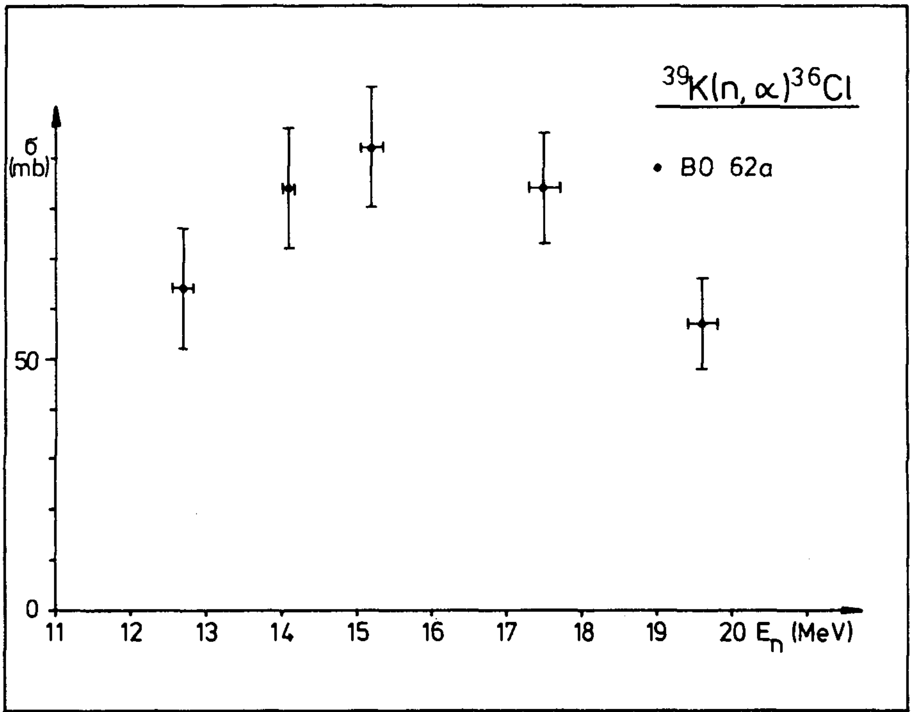

$^{34}S(n,\alpha)^{31}Si$
• AL 57
σ (mb)
100
0
4
5
6
7
8
9
10
11
12
13
E_n (MeV)


$^{35}Cl(n,\alpha)^{32}P$
• AD 53
σ (mb)
50
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)

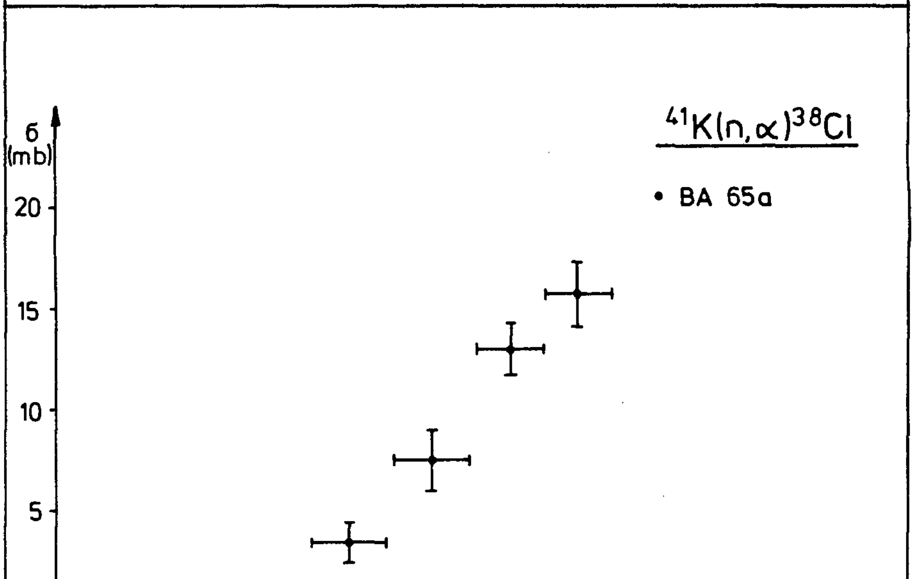

$^{37}Cl(n,\alpha)^{34}P$
• AB 67
σ (mb)
100
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


$^{40}Ar(n,\alpha)^{37}S$
• SU 66
σ (mb)
10
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

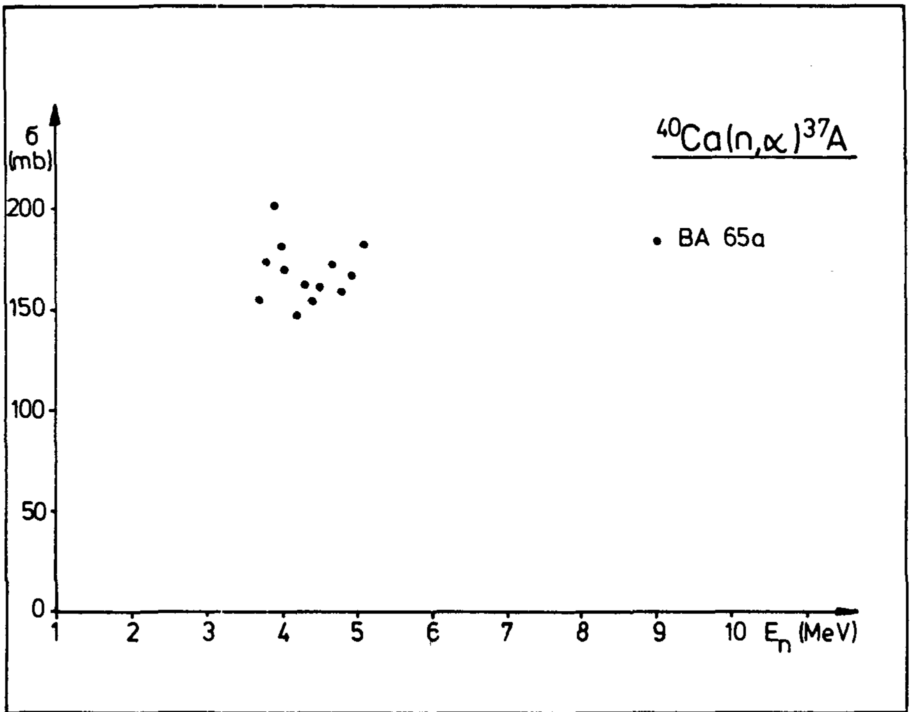

$^{39}K(n,\alpha)^{36}Cl$
• BA 64
σ (mb)
100
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)

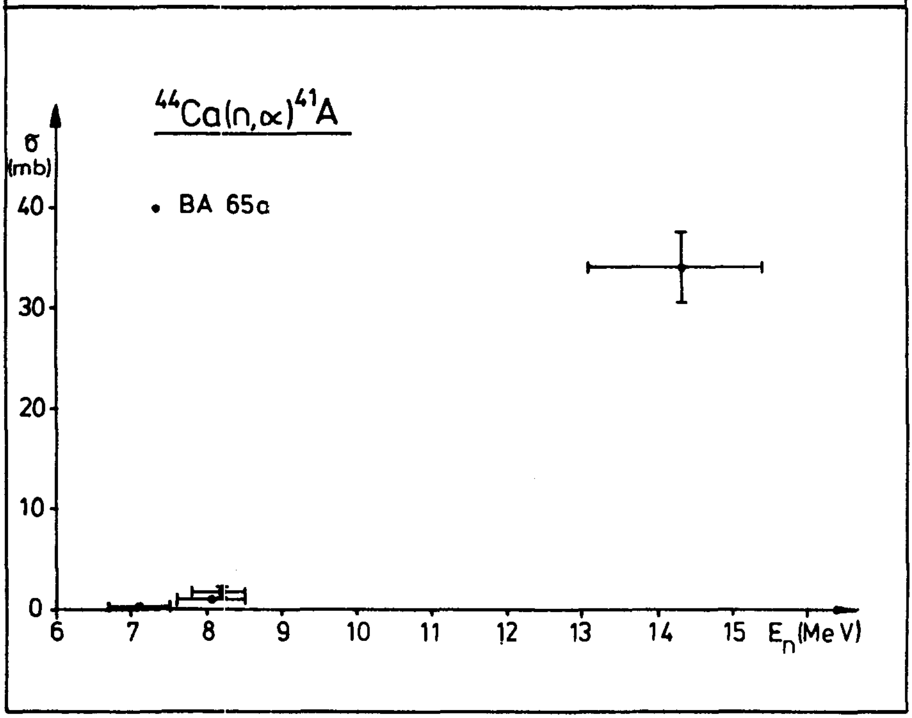


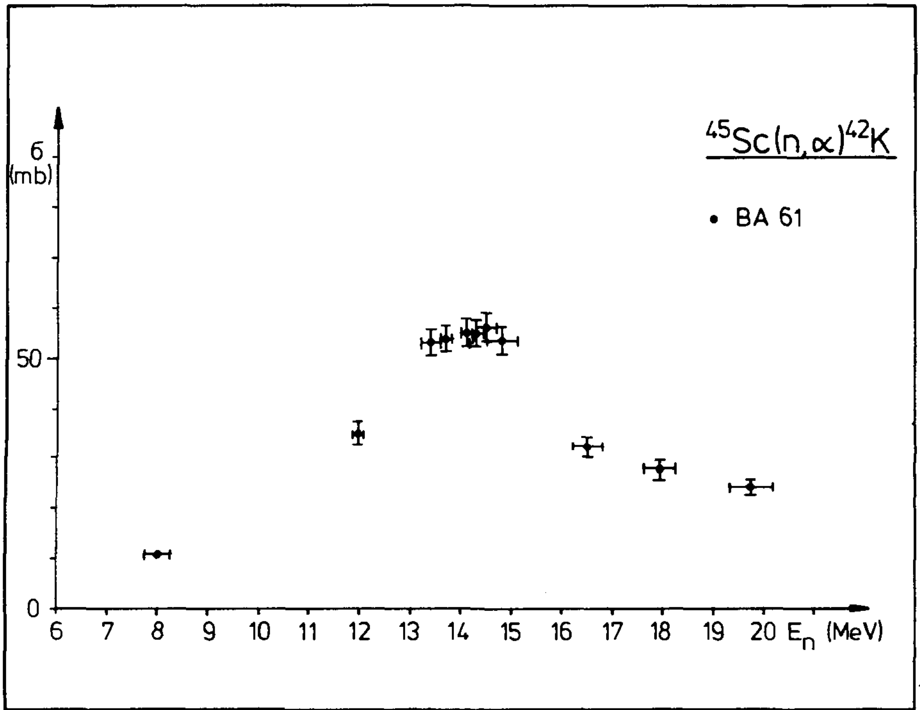
$^{39}K(n,\alpha)^{36}Cl$
• BO 62a
σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

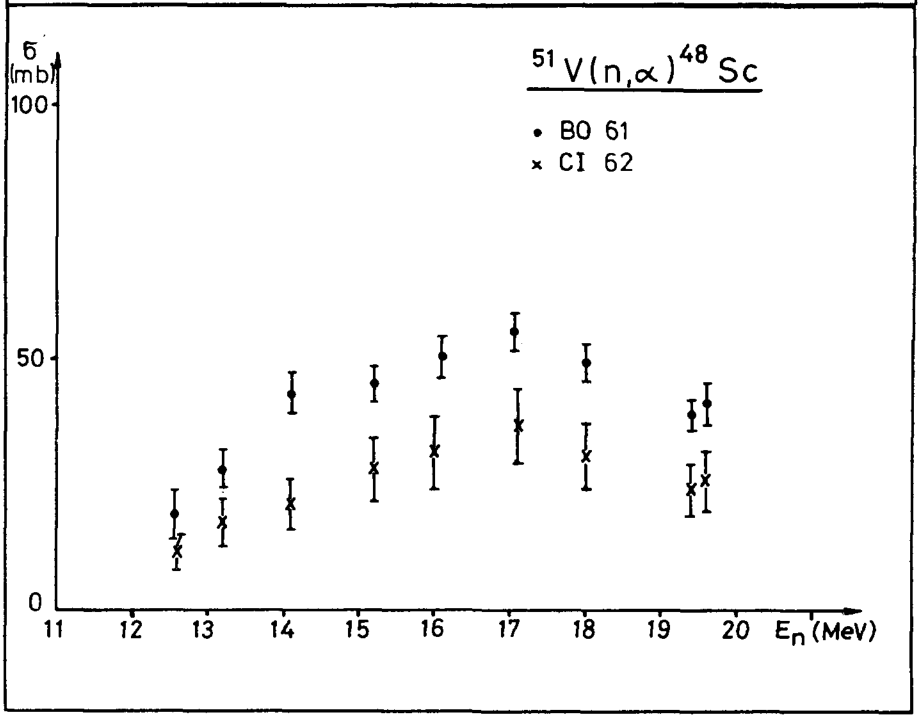


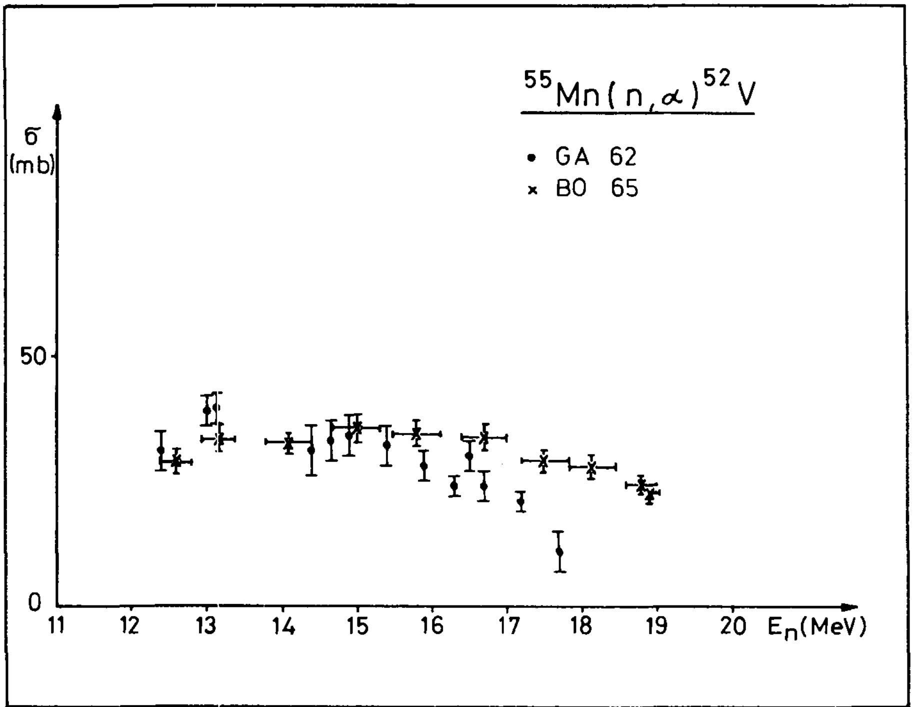
$^{41}K(n,\alpha)^{38}Cl$
• BA 65a
σ (mb)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)


$^{40}Ca(n,\alpha)^{37}A$
• BA 65a
σ (mb)
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
E_n (MeV)

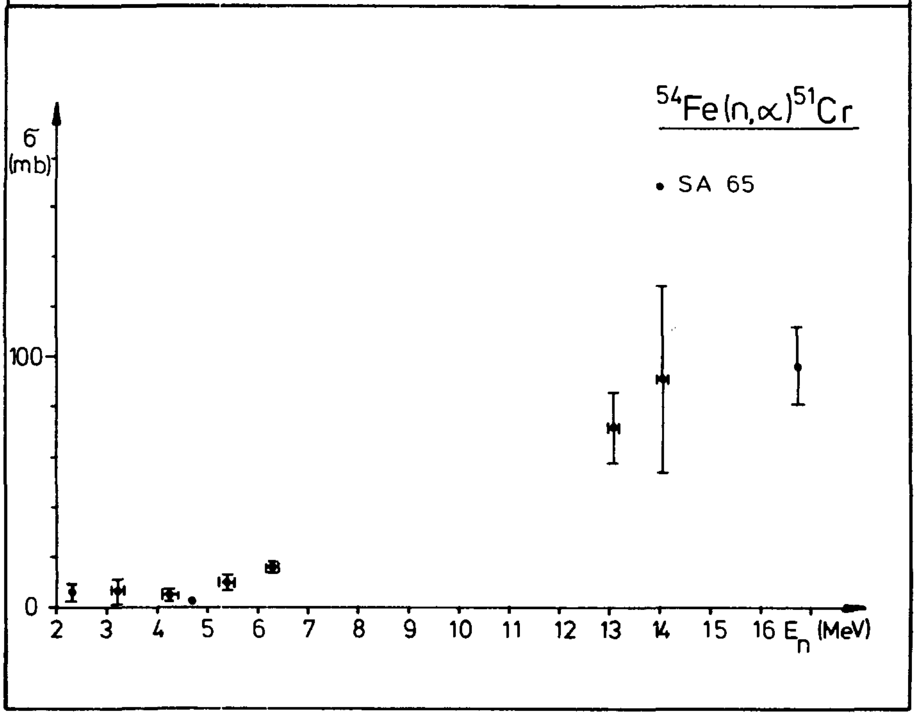

$^{44}Ca(n,\alpha)^{41}A$
• BA 65a
σ (mb)
40
30
20
10
0
6
7
8
9
10
11
12
13
14
15
E_n (MeV)


$^{45}Sc(n,\alpha)^{42}K$
• BA 61
σ (mb)
6
50
0
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 E_n (MeV)

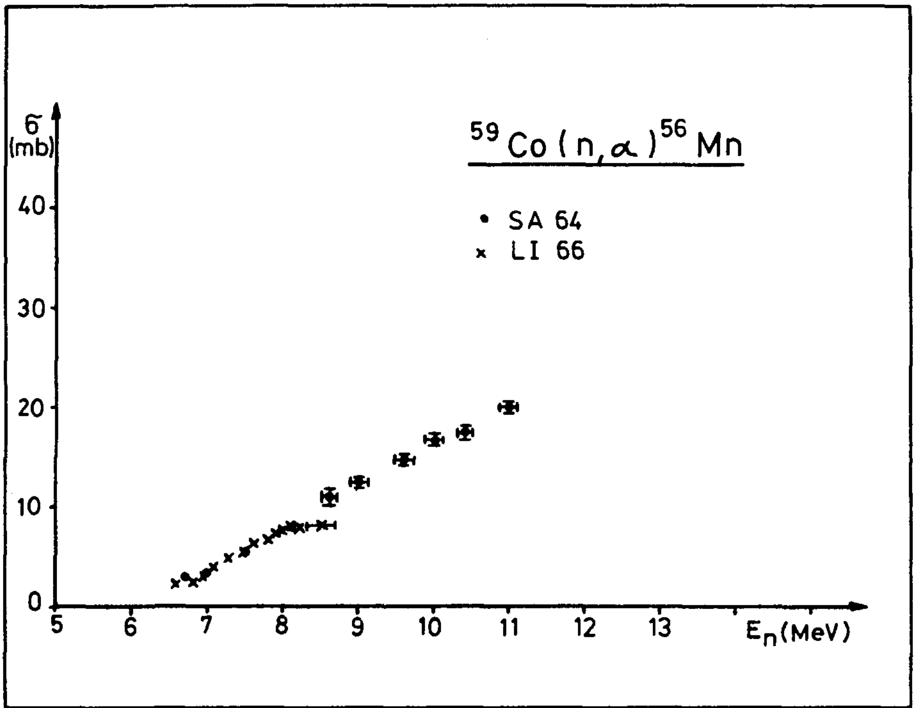

$^{51}V(n,\alpha)^{48}Sc$
• BO 61
× CI 62
σ (mb)
100
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

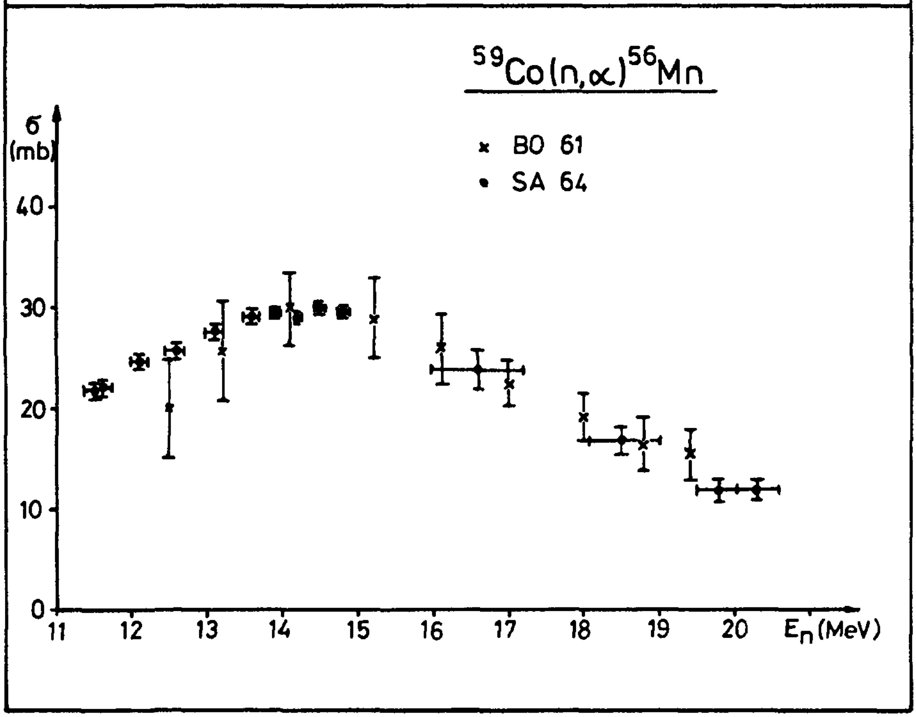


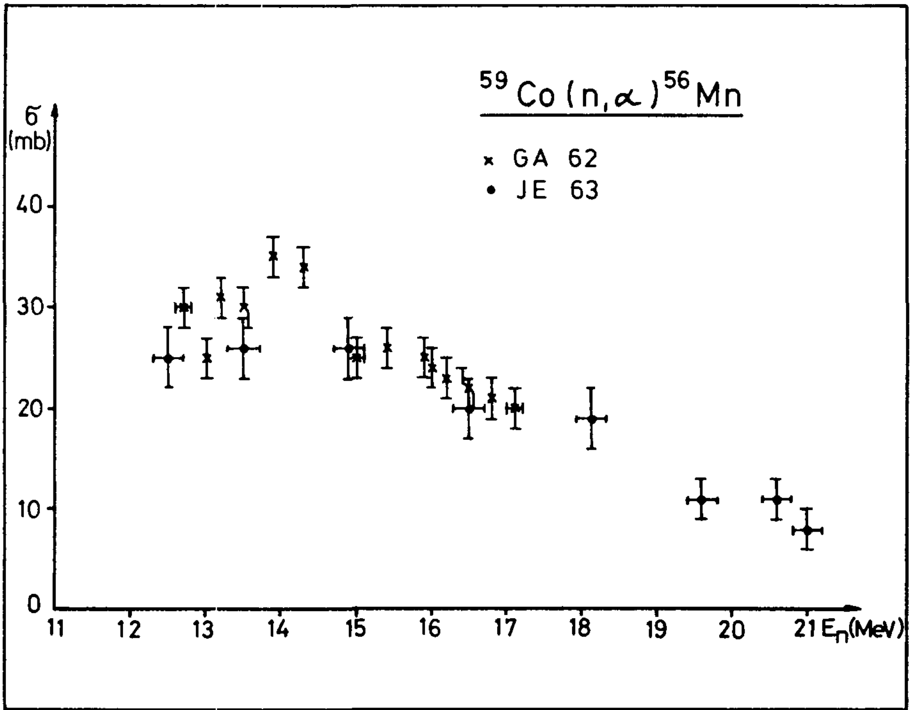
$^{55}Mn(n,\alpha)^{52}V$
• GA 62
× BO 65
σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)



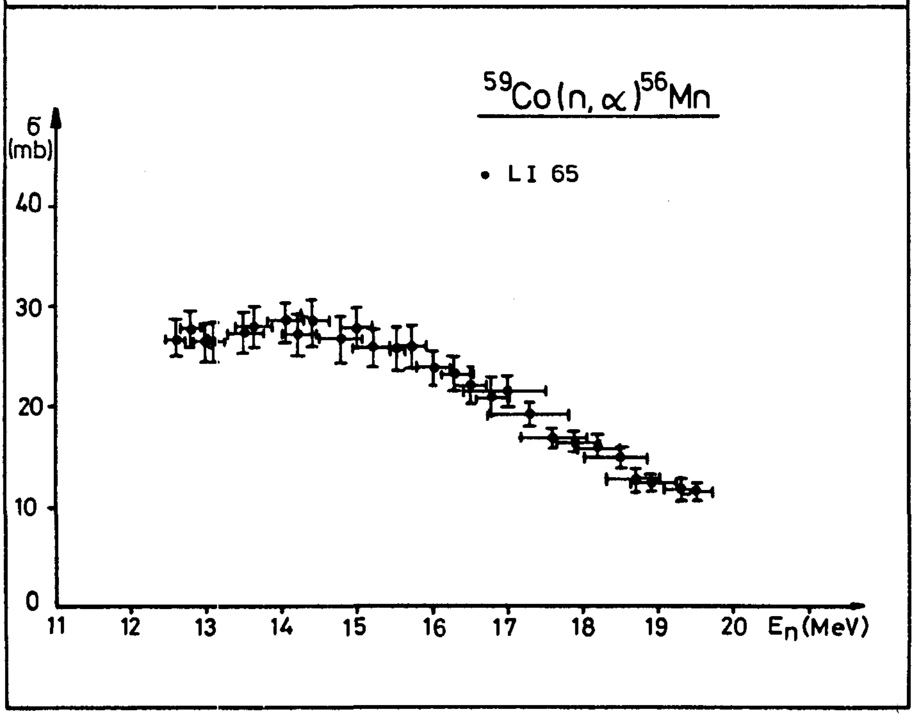
$^{54}Fe(n,\alpha)^{51}Cr$
• SA 65
σ (mb)
100
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 E_n (MeV)


$^{59}Co(n,\alpha)^{56}Mn$
• SA 64
× LI 66
σ (mb)
40
30
20
10
0
5
6
7
8
9
10
11
12
13
E_n (MeV)

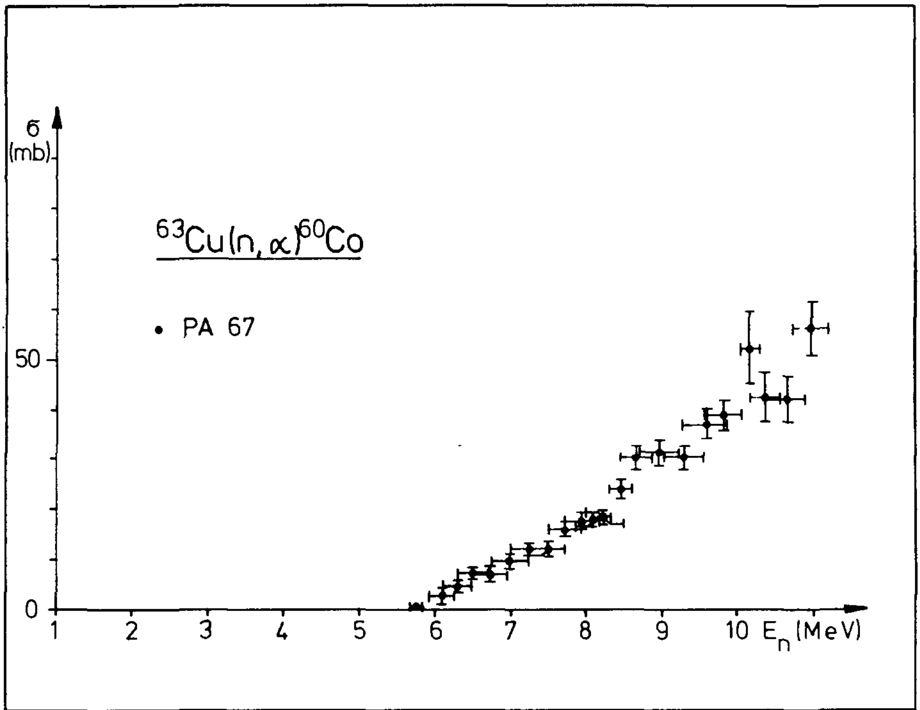

$^{59}Co(n,\alpha)^{56}Mn$
× BO 61
• SA 64
σ (mb)
40
30
20
10
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)



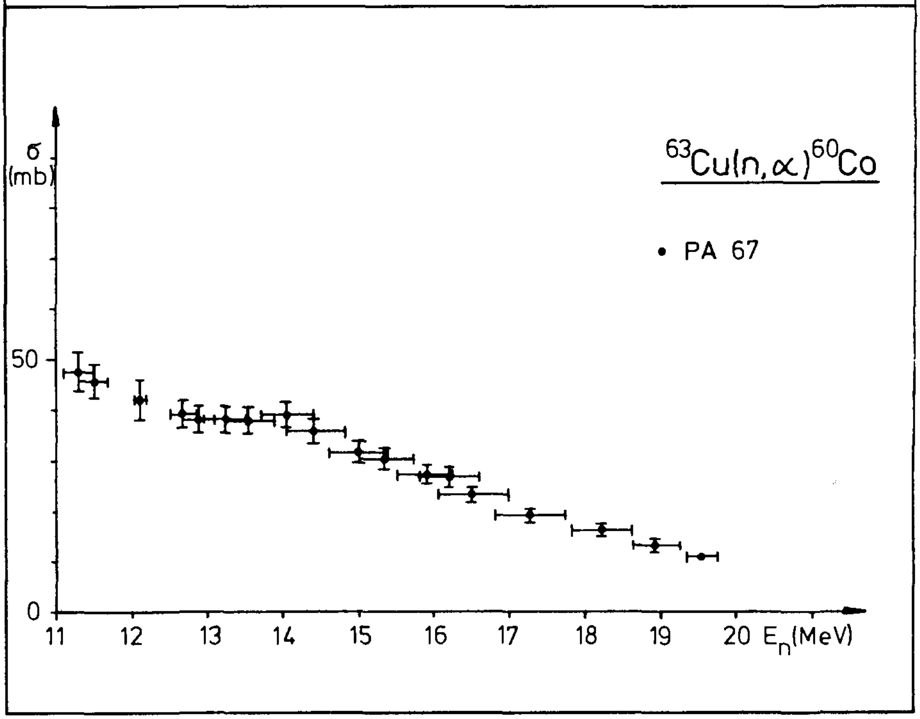
$^{59}Co(n,\alpha)^{56}Mn$
× GA 62
• JE 63
σ (mb)
40
30
20
10
0
11
12
13
14
15
16
17
18
19
20
21 E_n(MeV)



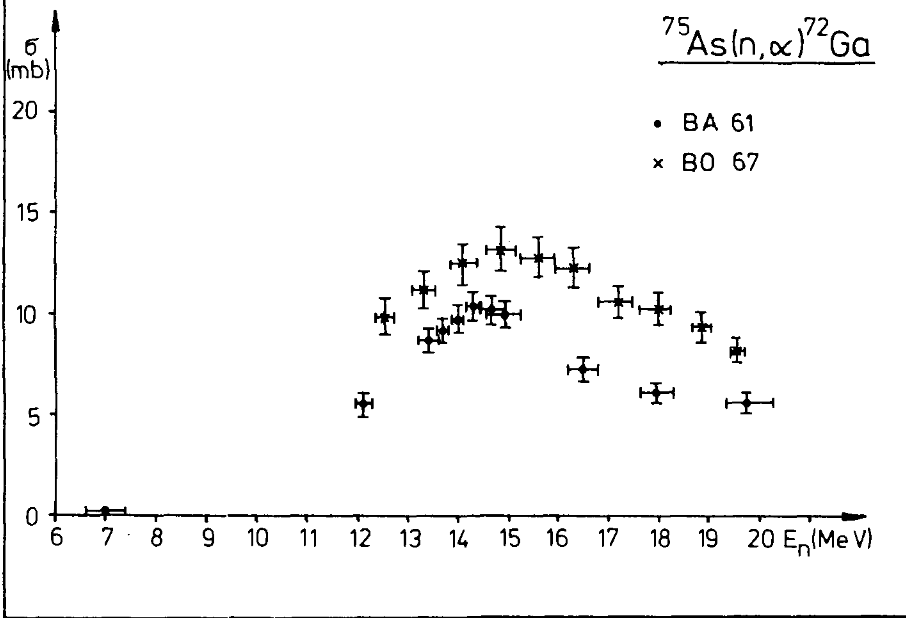
$^{59}Co(n,\alpha)^{56}Mn$
• LI 65
σ (mb)
40
30
20
10
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)



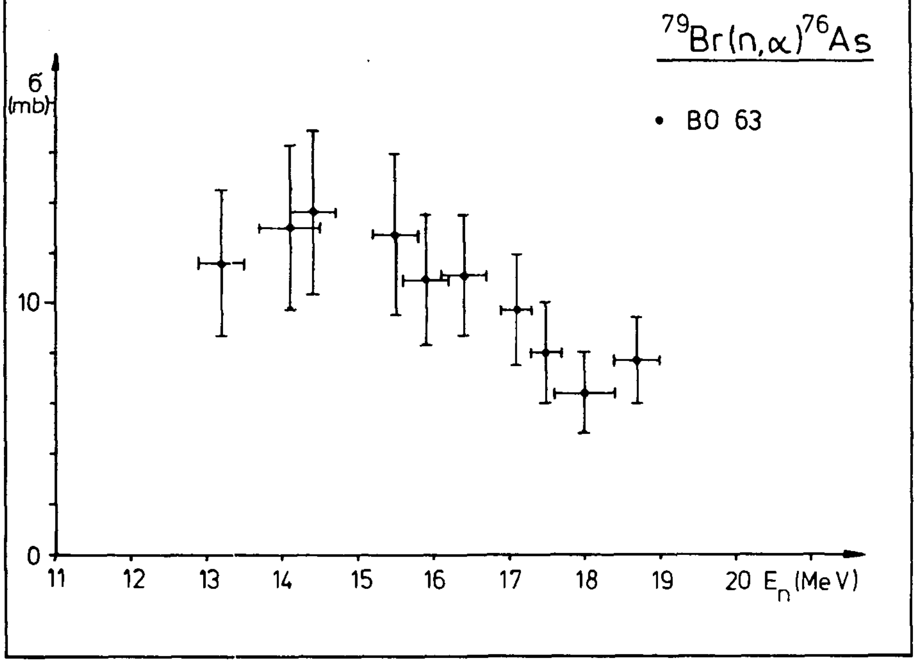
$^{63}Cu(n,\alpha)^{60}Co$
• PA 67
σ (mb)
50
0
1 2 3 4 5 6 7 8 9 10 E_n (MeV)



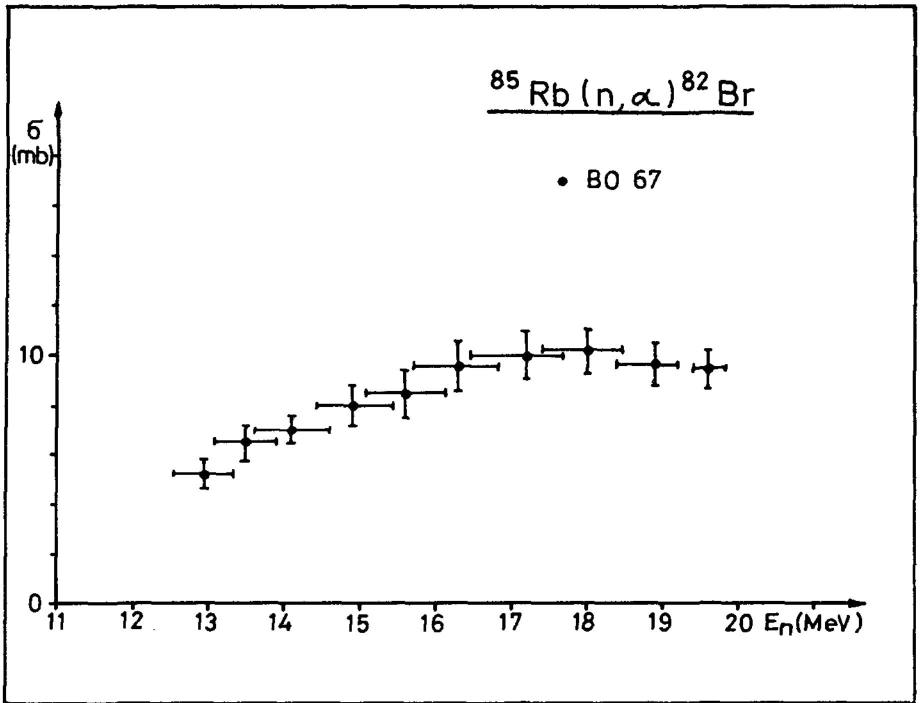
$^{63}Cu(n,\alpha)^{60}Co$
• PA 67
σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

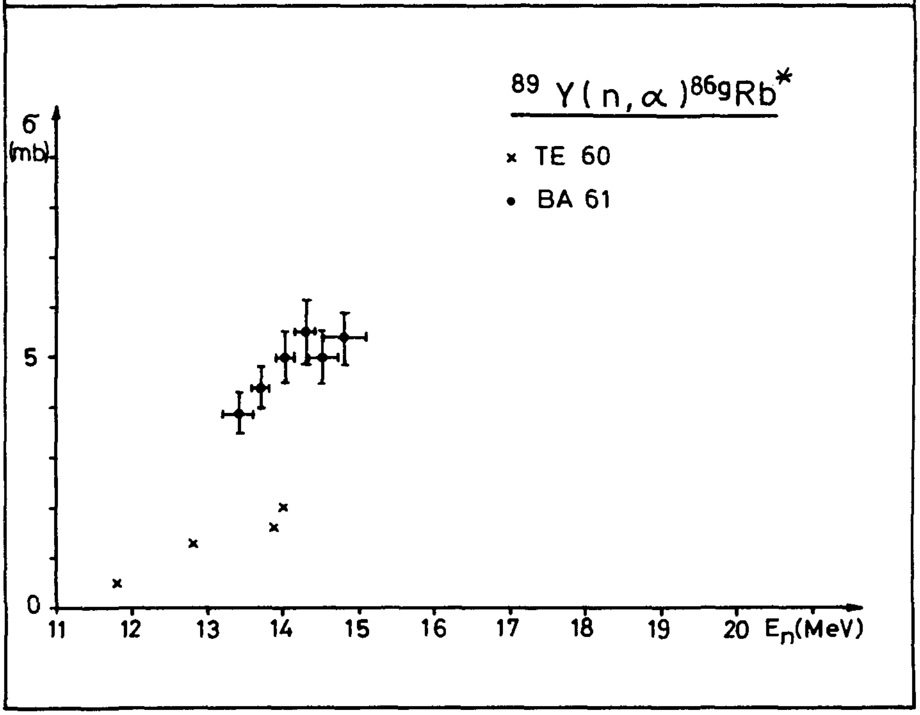


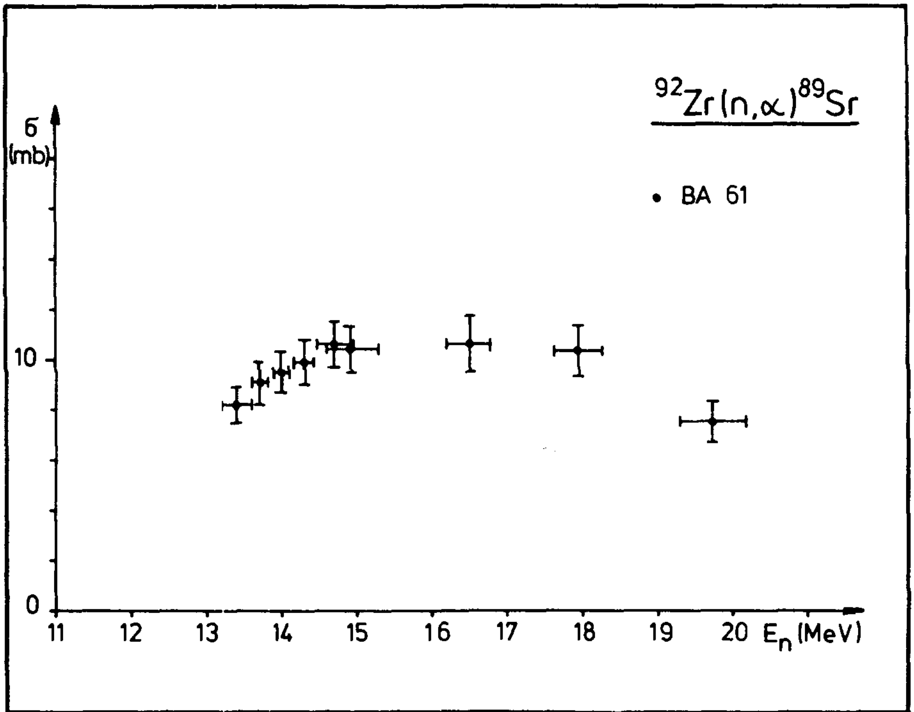
$^{75}As(n,\alpha)^{72}Ga$
• BA 61
× BO 67
σ (mb)
20
15
10
5
0
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 E_n(MeV)

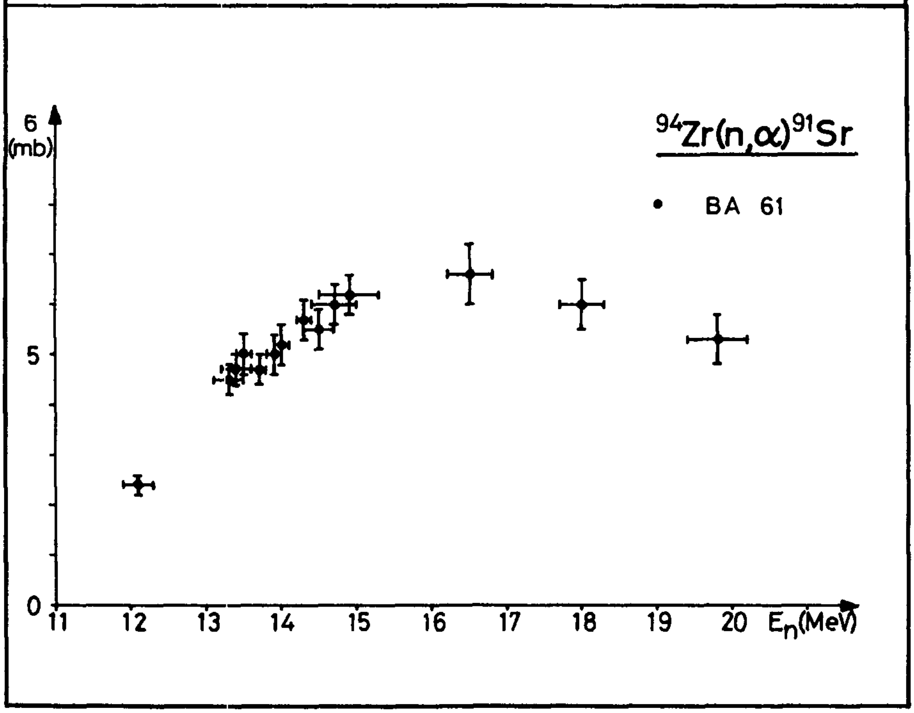


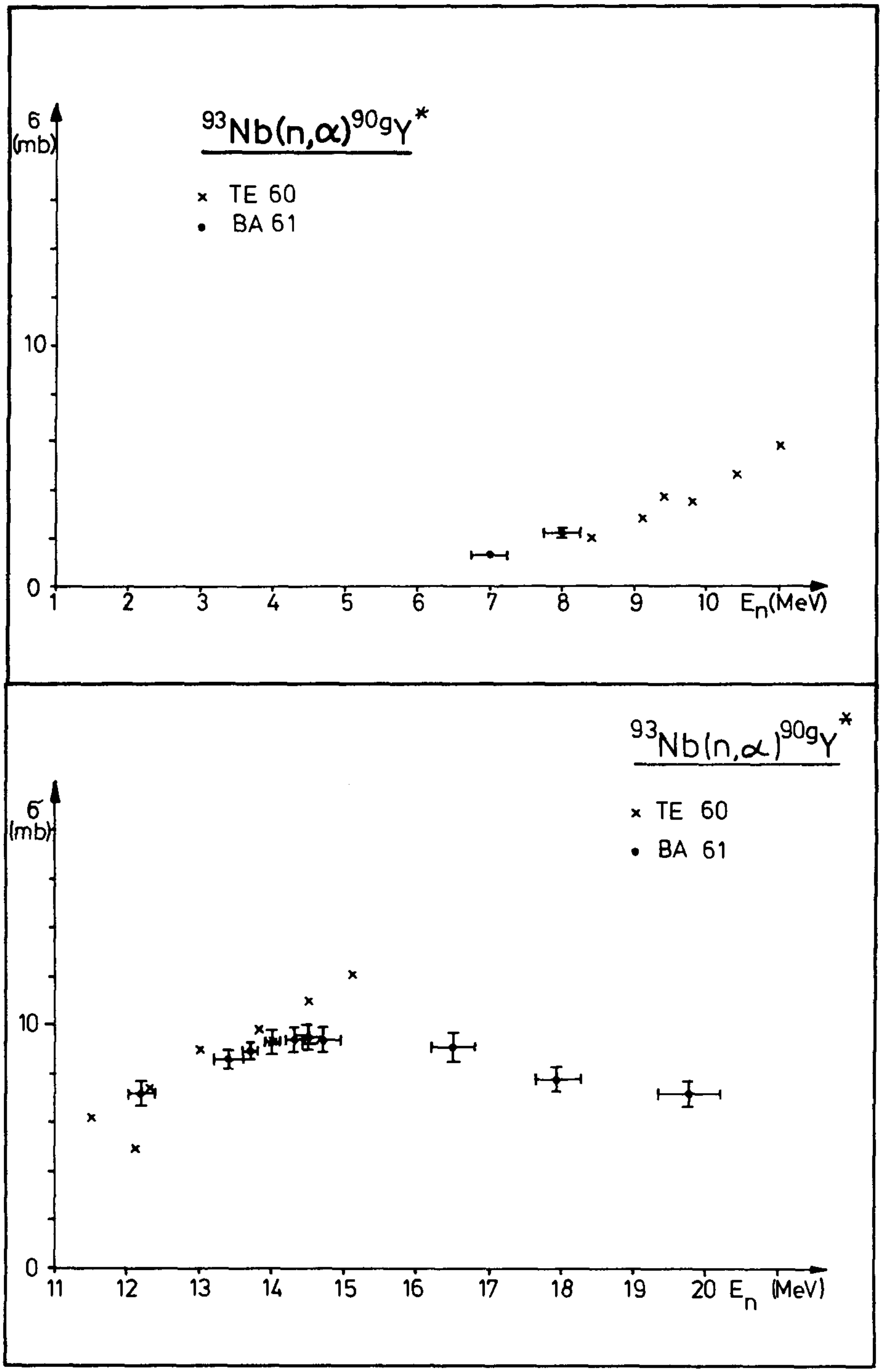
$^{79}Br(n,\alpha)^{76}As$
• BO 63
σ (mb)
10
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)


$^{85}Rb(n,\alpha)^{82}Br$
• BO 67
σ (mb)
10
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)

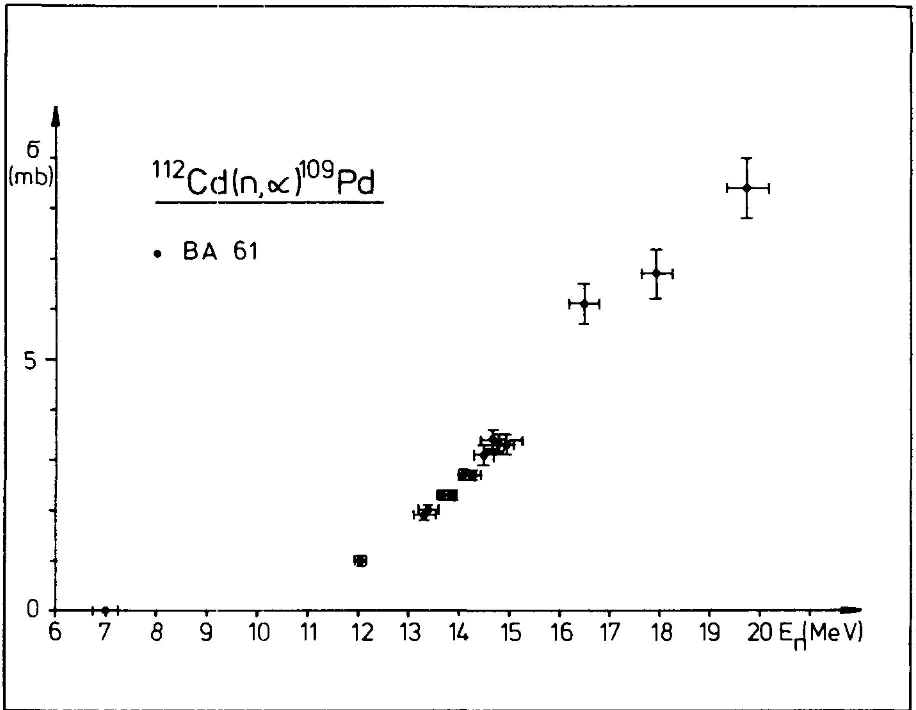

$^{89}Y(n,\alpha)^{86g}Rb^{*}$
× TE 60
• BA 61
σ (mb)
5
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)


$^{92}Zr(n,\alpha)^{89}Sr$
• BA 61
σ (mb)
0
10
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

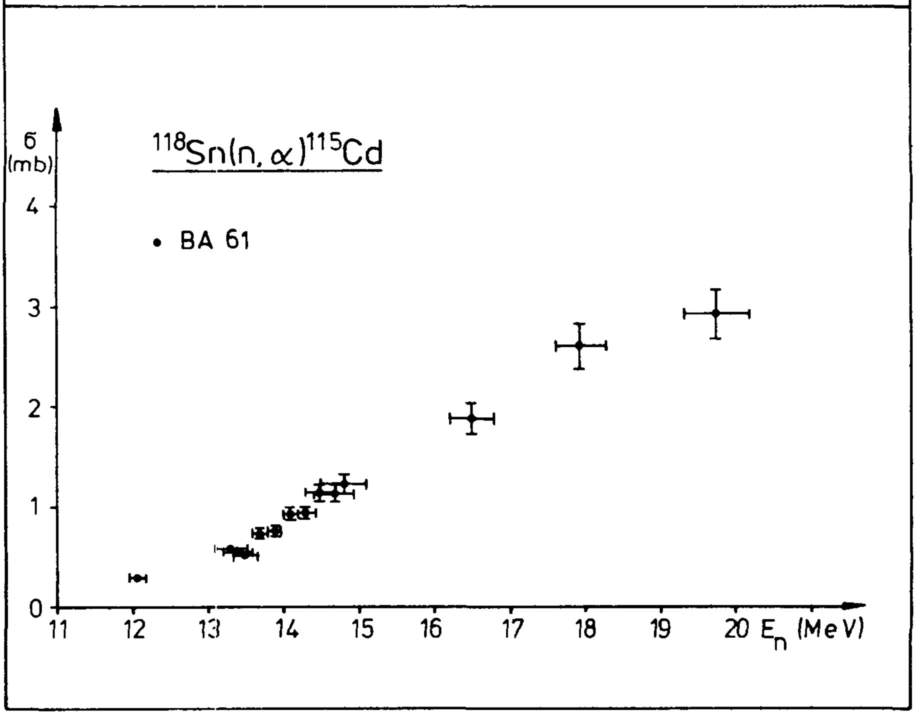

$^{94}Zr(n,\alpha)^{91}Sr$
• BA 61
σ (mb)
0
5
11 12 13 14 15 16 17 18 19 20 E_n(MeV)



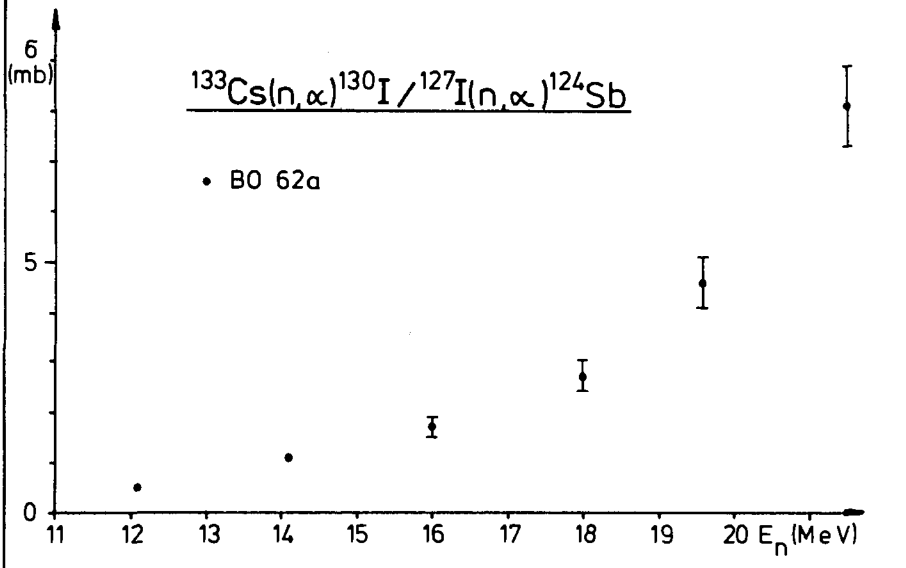
$^{93}Nb(n,\alpha)^{90g}Y^*$
× TE 60
• BA 61
6 (mb)
10
0
1 2 3 4 5 6 7 8 9 10 E_n(MeV)
$^{93}Nb(n,\alpha)^{90g}Y^*$
× TE 60
• BA 61
6 (mb)
10
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

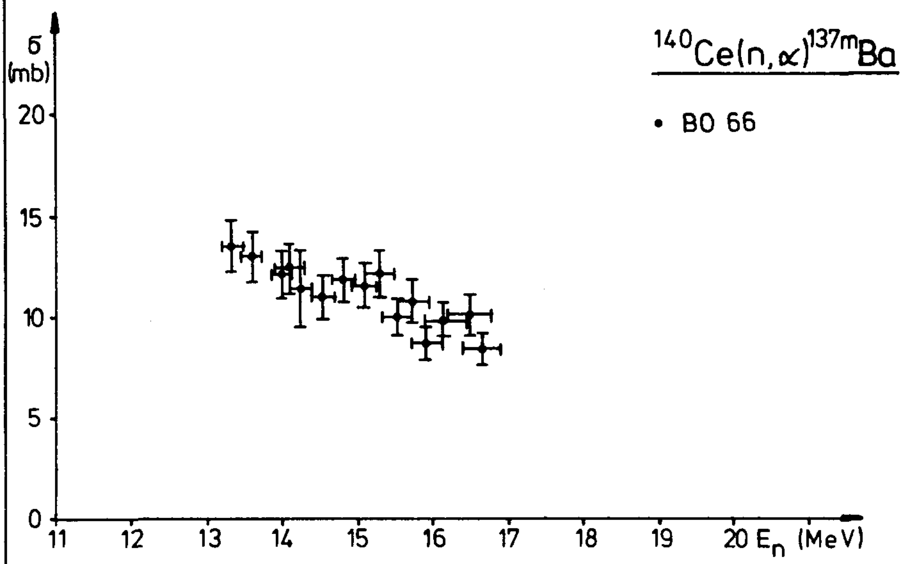


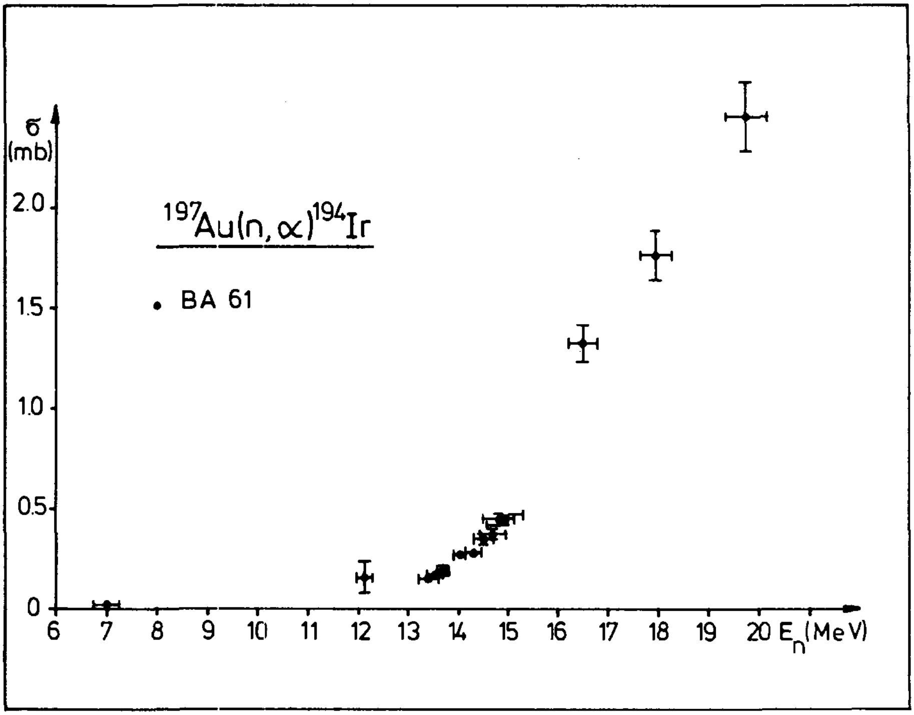
σ (mb)
$^{112}Cd(n,\alpha)^{109}Pd$
• BA 61
5
0
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 E_n (MeV)



σ (mb)
$^{118}Sn(n,\alpha)^{115}Cd$
• BA 61
4
3
2
1
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


σ (mb)
$^{133}Cs(n,\alpha)^{130}I\,/\,^{127}I(n,\alpha)^{124}Sb$
• BO 62a
0
5
11
12
13
14
15
16
17
18
19
20 E_n (MeV)


σ (mb)
$^{140}Ce(n,\alpha)^{137m}Ba$
• BO 66
0
5
10
15
20
11
12
13
14
15
16
17
18
19
20 E_n (MeV)

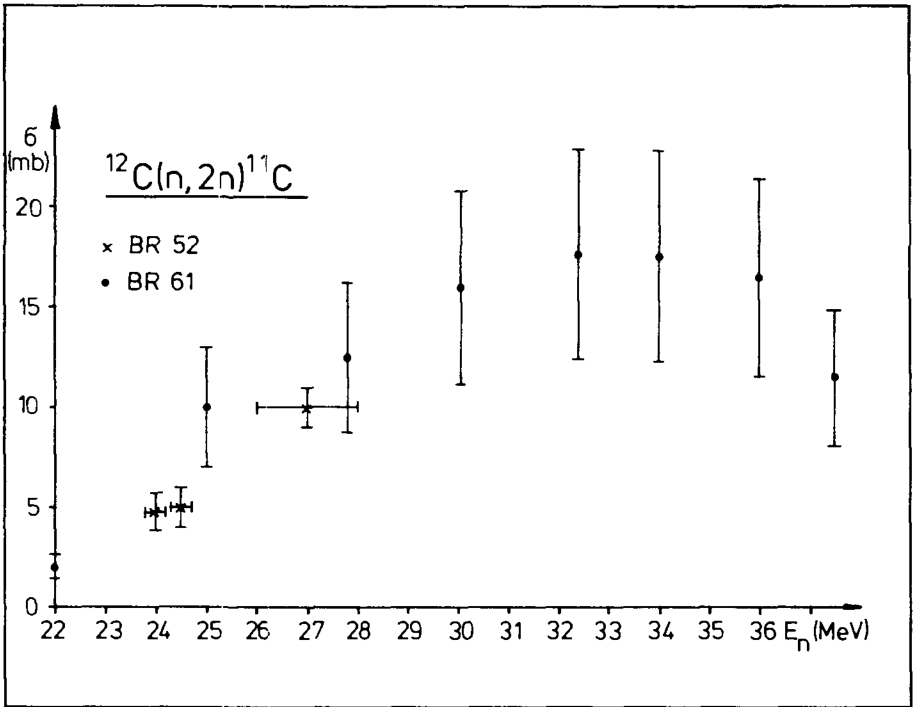

σ (mb)
2.0
1.5
1.0
0.5
0
$^{197}Au(n,\alpha)^{194}Ir$
• BA 61
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 E_n(MeV)

GRAPHS OF (n, 2n) CROSS-SECTIONS

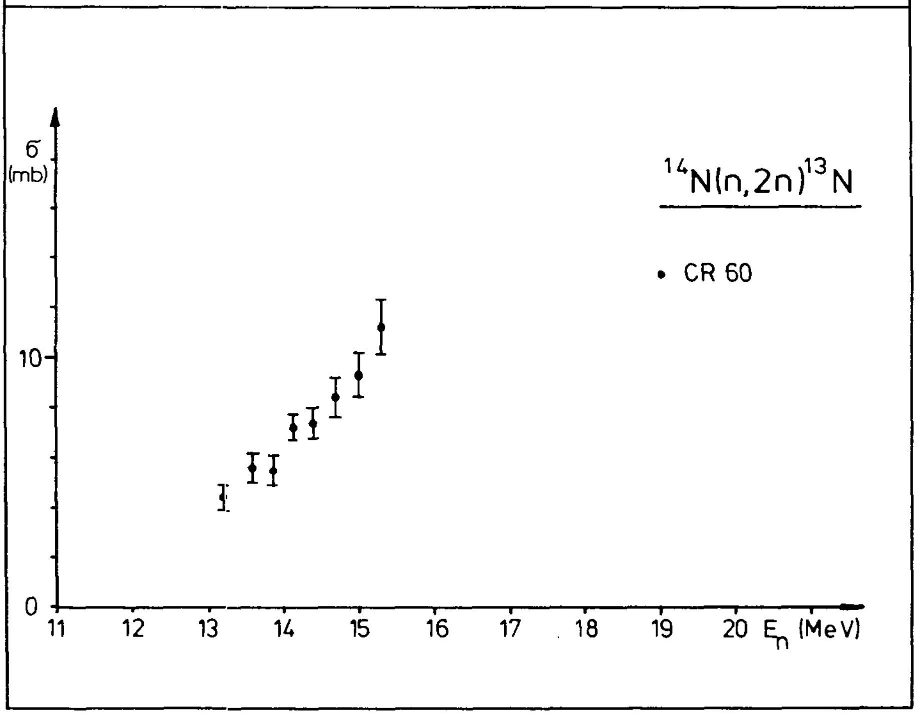
Excitation functions of (n, 2n) reactions for the target nuclei:

^{12}C, ^{14}N, ^{16}O, ^{19}F, ^{23}Na, ^{27}Al, ^{31}P, ^{32}S, ^{35}Cl, ^{39}K, ^{45}Sc, ^{46}Ti,
^{50}Cr, ^{52}Cr, ^{55}Mn, ^{54}Fe, ^{59}Co, ^{58}Ni, ^{63}Cu, ^{65}Cu, ^{64}Zn, ^{66}Zn, ^{69}Ga,
^{70}Ge, ^{76}Ge, ^{75}As, ^{74}Se, ^{78}Se, ^{80}Se, ^{79}Br, ^{81}Br, ^{85}Rb, ^{87}Rb, ^{84}Sr,
^{86}Sr, ^{88}Sr, ^{89}Y, ^{90}Zr, ^{93}Nb, ^{92}Mo, ^{94}Mo, ^{96}Ru, ^{104}Ru, ^{103}Rh,
^{102}Pd, ^{110}Pd, ^{107}Ag, ^{109}Ag, ^{106}Cd, ^{116}Cd, ^{113}In, ^{115}In, ^{112}Sn,
^{121}Sb, ^{123}Sb, ^{128}Te, ^{130}Te, ^{127}I, ^{133}Cs, ^{140}Ce, ^{142}Ce, ^{141}Pr,
^{142}Nd, ^{144}Sm, ^{165}Ho, ^{168}Er, ^{169}Tm, ^{181}Ta, ^{184}W, ^{192}Os, ^{191}Ir,
^{198}Pt, ^{197}Au, ^{203}Tl, ^{204}Hg, ^{204}Pb, ^{208}Pb, ^{232}Th, ^{238}U

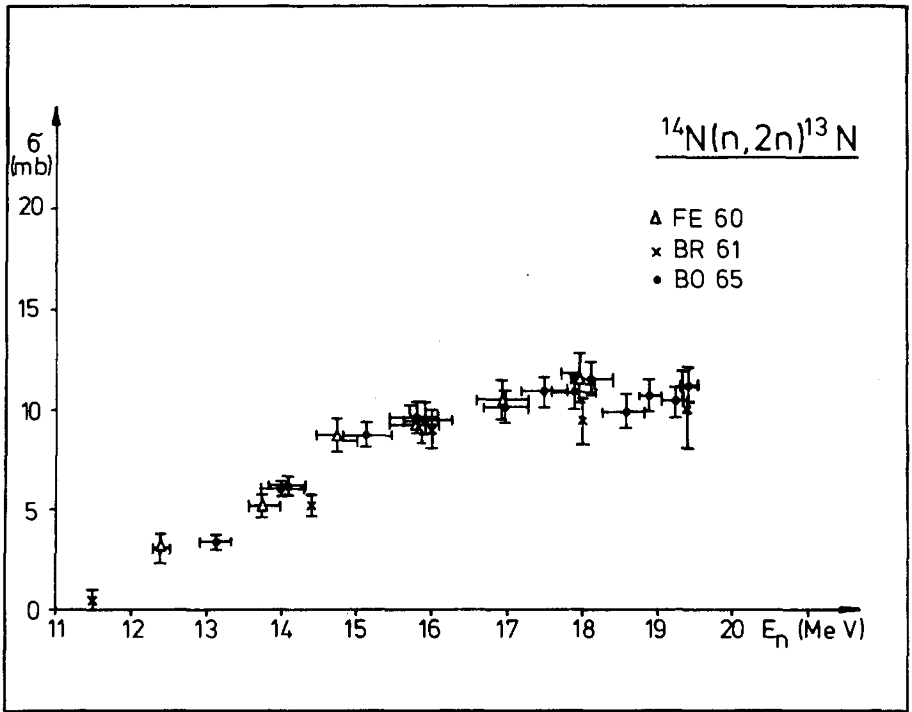
(The abbreviations of references (e.g. BR 52) are constructed from the name of the first author and the year of publication. A list of references is given on pages 270-272.)

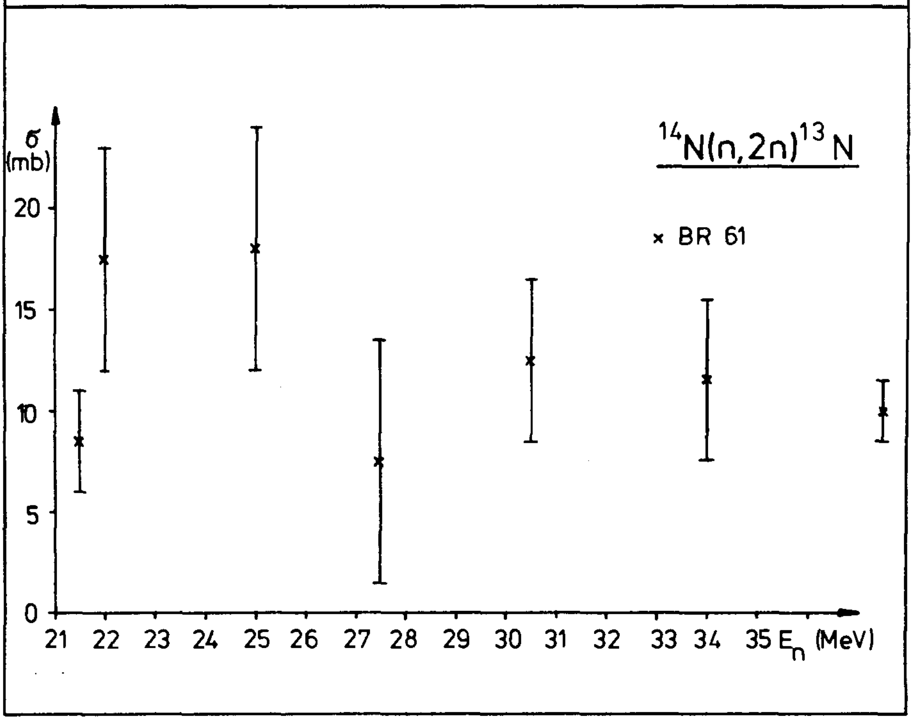


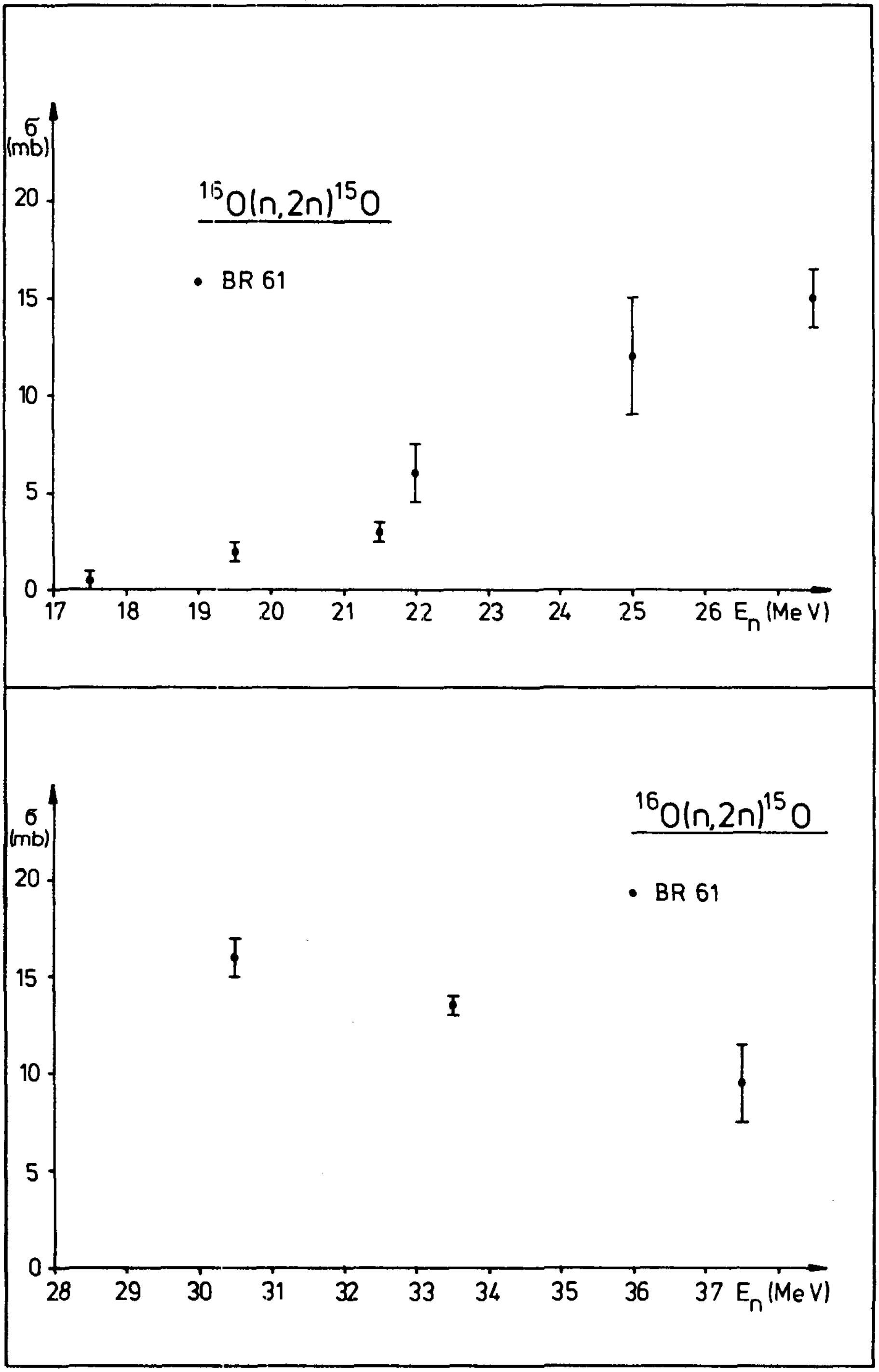
σ (mb)
$^{12}C(n,2n)^{11}C$
× BR 52
• BR 61
20
15
10
5
0
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 E_n (MeV)

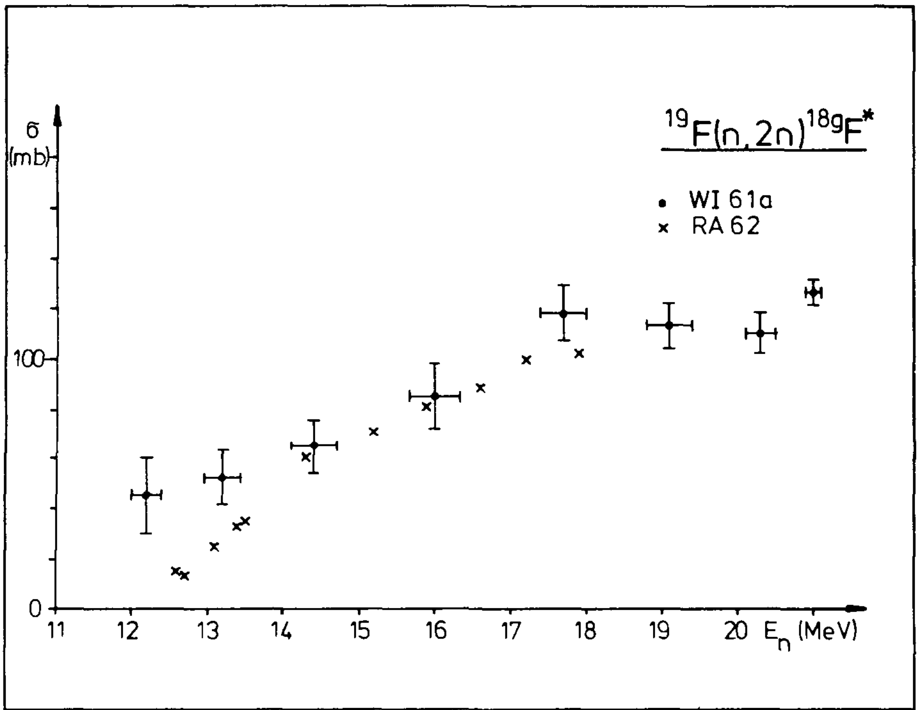


σ (mb)
$^{14}N(n,2n)^{13}N$
• CR 60
10
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

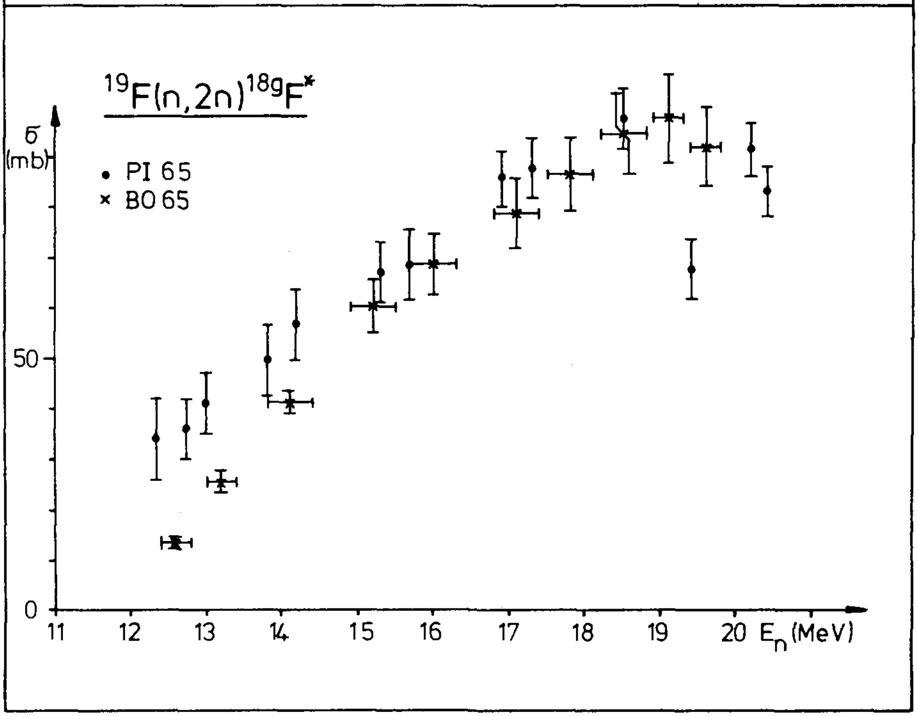

$^{14}N(n,2n)^{13}N$
△ FE 60
× BR 61
• BO 65
σ (mb)
0
5
10
15
20
11 12 13 14 15 16 17 18 19 20
E_n (Me V)


$^{14}N(n,2n)^{13}N$
× BR 61
σ (mb)
0
5
10
15
20
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
E_n (MeV)

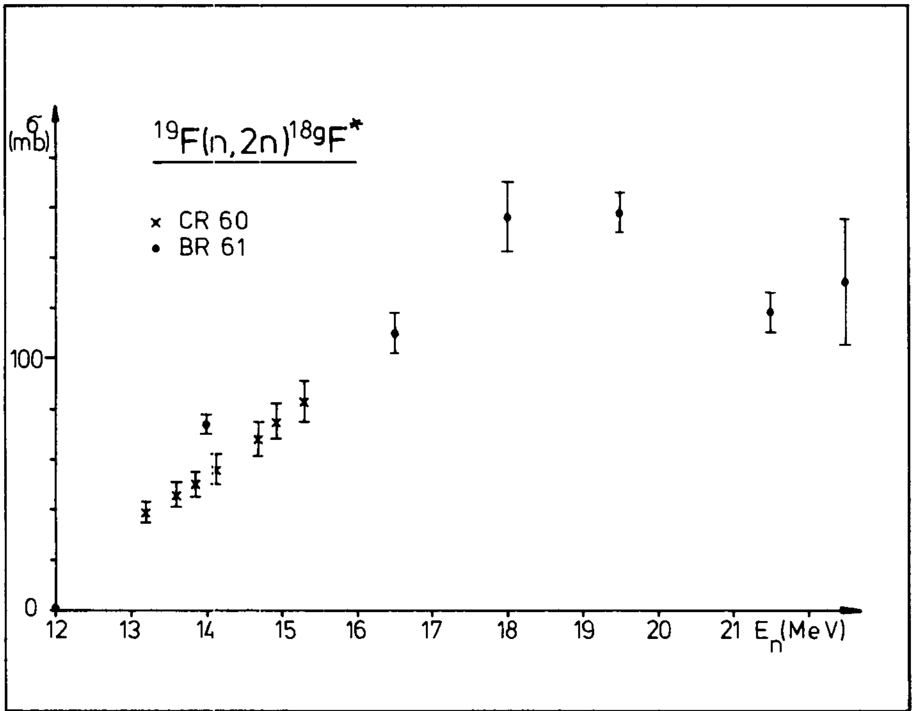

σ (mb)
$^{16}O(n,2n)^{15}O$
• BR 61
0
5
10
15
20
17
18
19
20
21
22
23
24
25
26
E_n (MeV)
σ (mb)
$^{16}O(n,2n)^{15}O$
• BR 61
0
5
10
15
20
28
29
30
31
32
33
34
35
36
37
E_n (MeV)

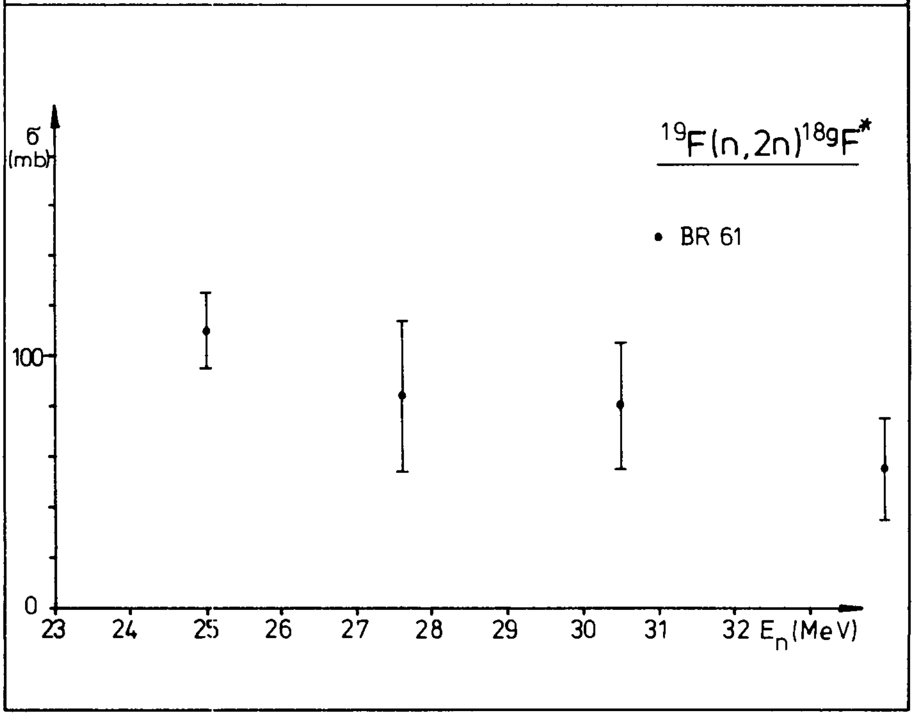


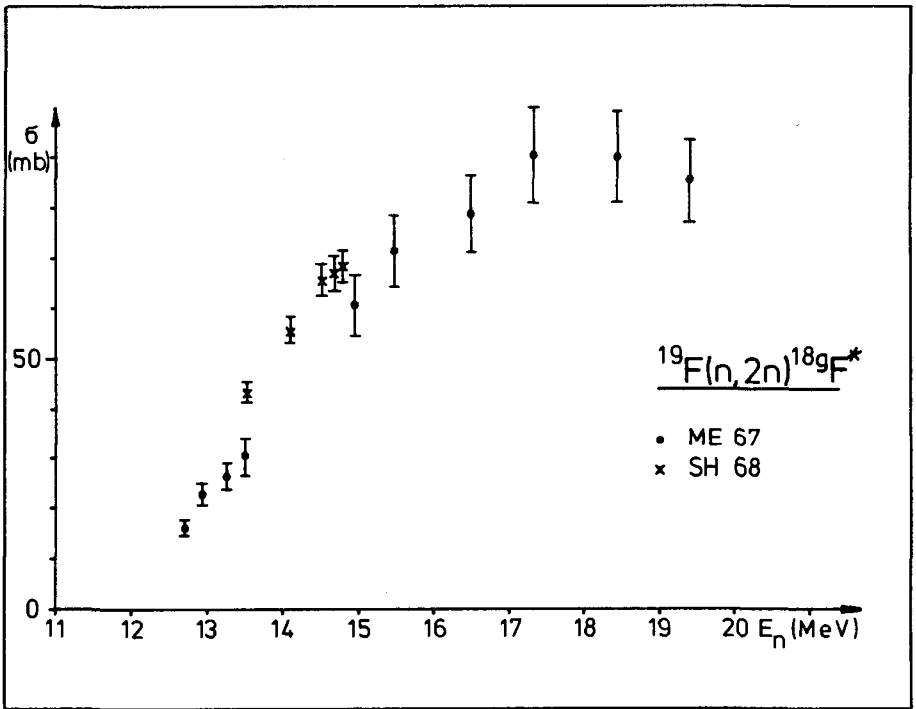
$^{19}F(n,2n)^{18g}F^*$
• WI 61a
× RA 62
σ (mb)
100
0
11 12 13 14 15 16 17 18 19 20
E_n (MeV)



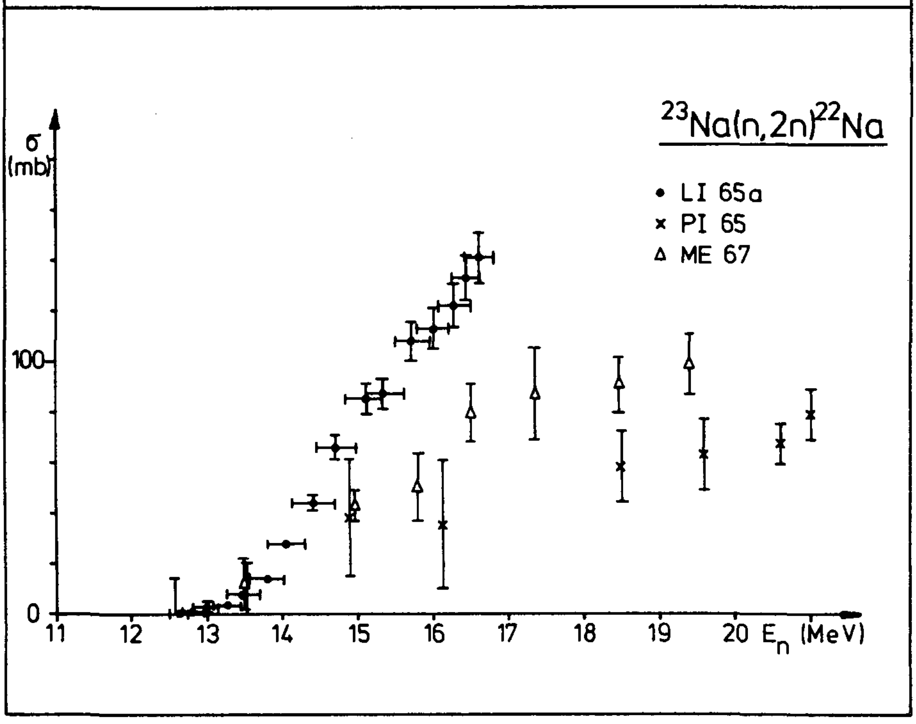
$^{19}F(n,2n)^{18g}F^*$
• PI 65
× BO 65
σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20
E_n (MeV)


$^{19}F(n,2n)^{18g}F^*$
× CR 60
• BR 61
σ (mb)
100
0
12
13
14
15
16
17
18
19
20
21
E_n(MeV)

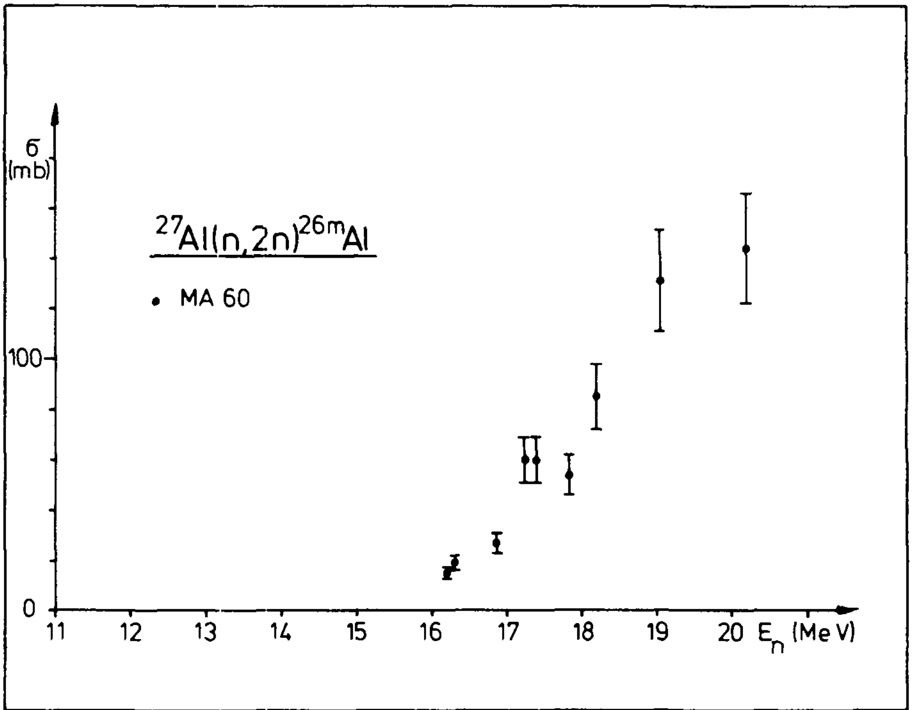

$^{19}F(n,2n)^{18g}F^*$
• BR 61
σ (mb)
100
0
23
24
25
26
27
28
29
30
31
32
E_n(MeV)

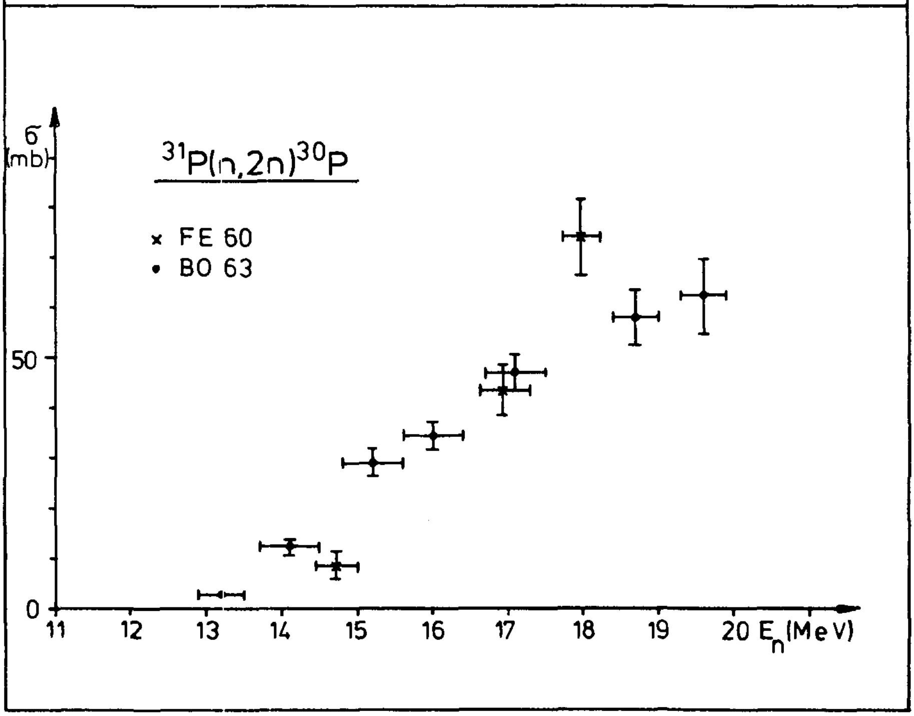


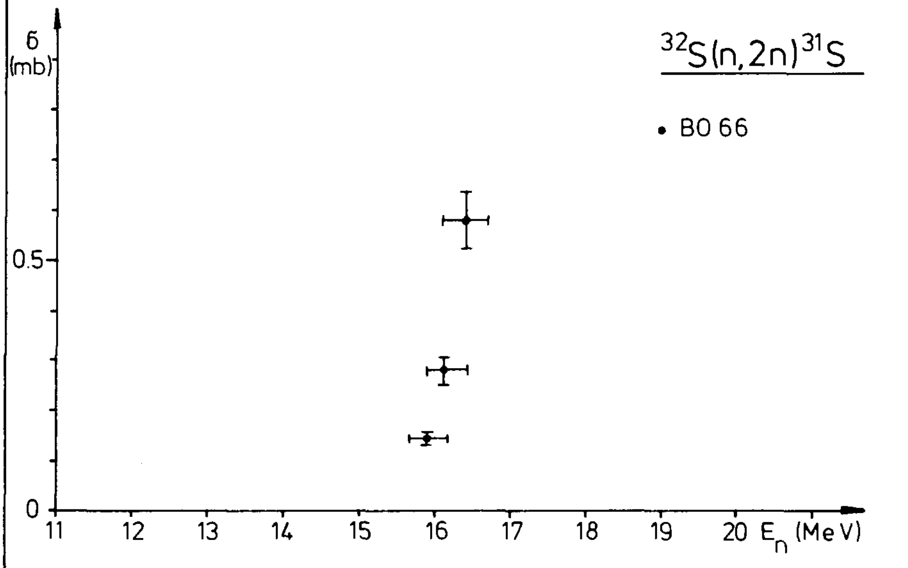
σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{19}F(n,2n)^{18g}F^*$
• ME 67
× SH 68



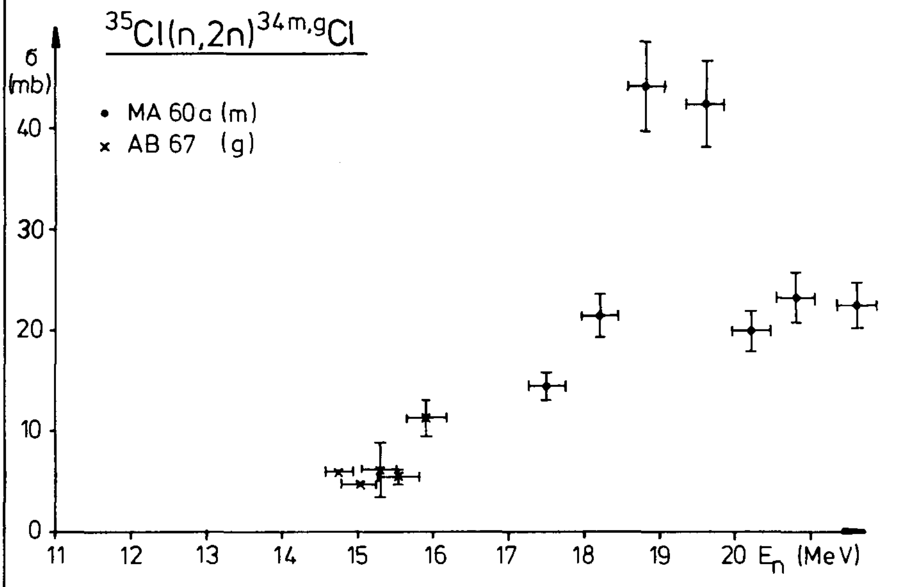
σ (mb)
100
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{23}Na(n,2n)^{22}Na$
• LI 65a
× PI 65
Δ ME 67


σ (mb)
$^{27}Al(n,2n)^{26m}Al$
• MA 60
100
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)

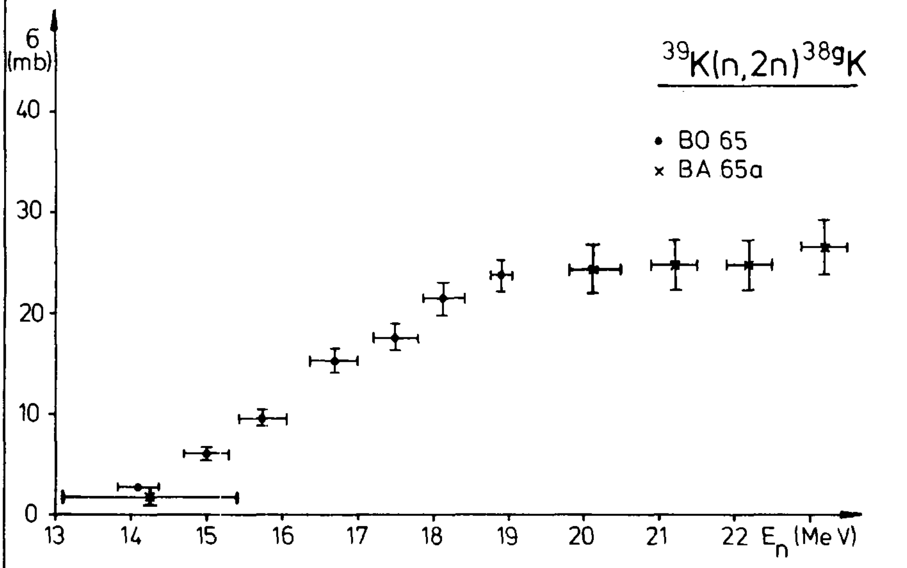

σ (mb)
$^{31}P(n,2n)^{30}P$
× FE 60
• BO 63
50
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)



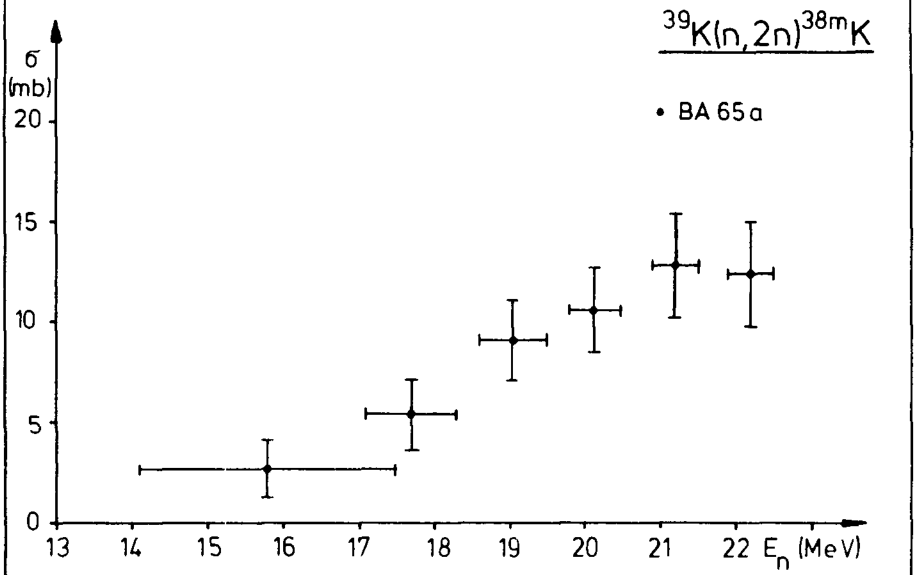
$^{32}S(n,2n)^{31}S$
• BO 66
σ (mb)
0.5
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



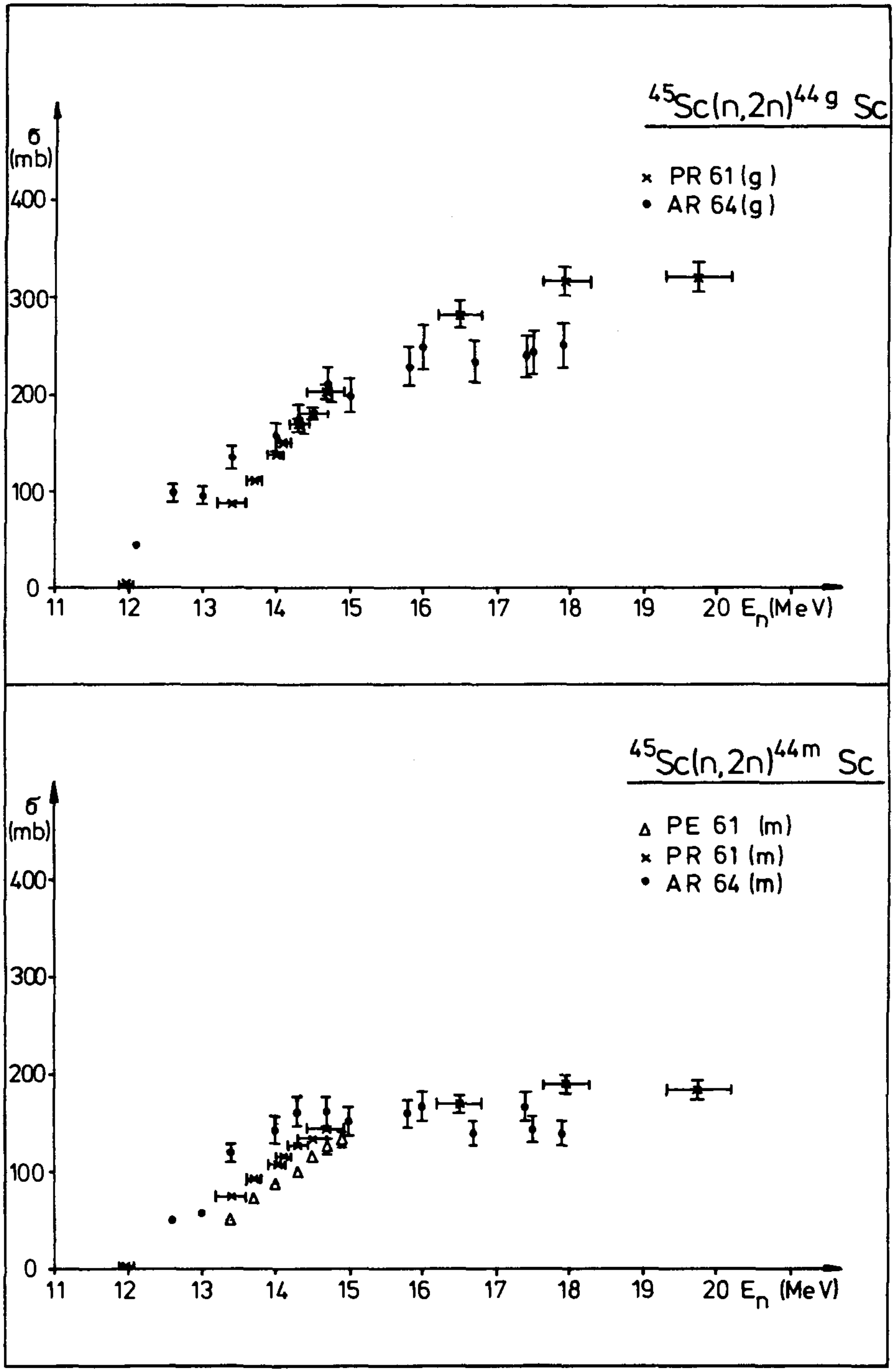
$^{35}Cl(n,2n)^{34m,g}Cl$
• MA 60a (m)
× AB 67 (g)
σ (mb)
40
30
20
10
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

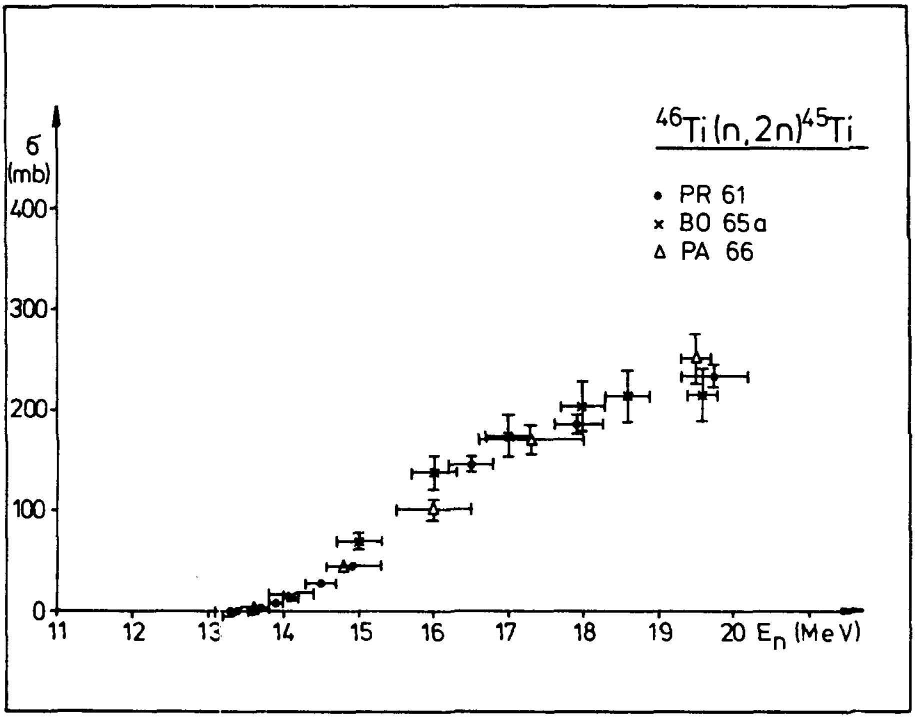


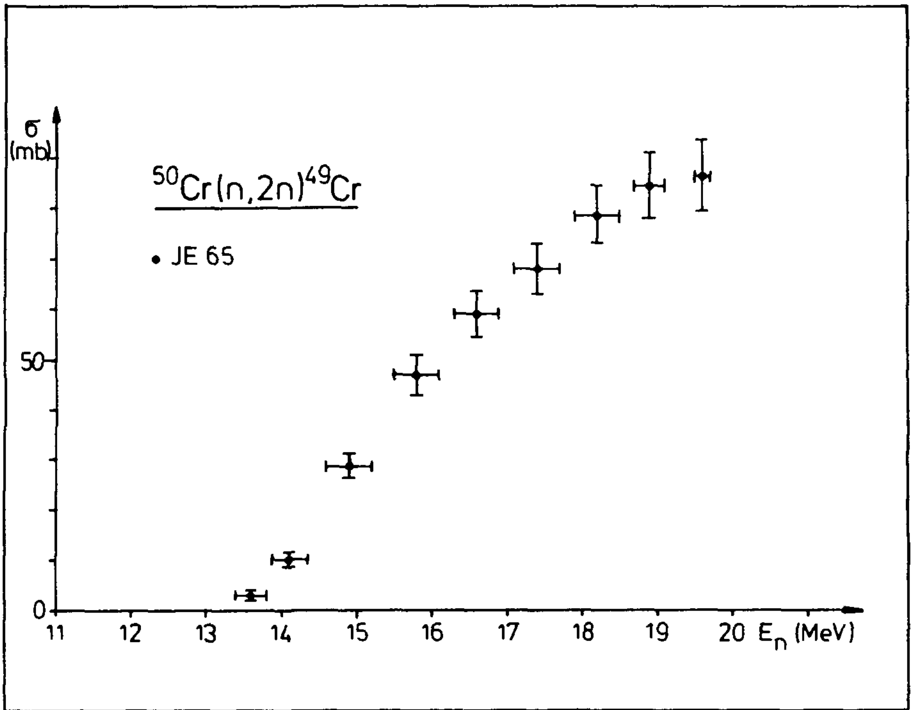
$^{39}K(n,2n)^{38g}K$
• BO 65
× BA 65a
σ (mb)
0
10
20
30
40
13
14
15
16
17
18
19
20
21
22
E_n (MeV)

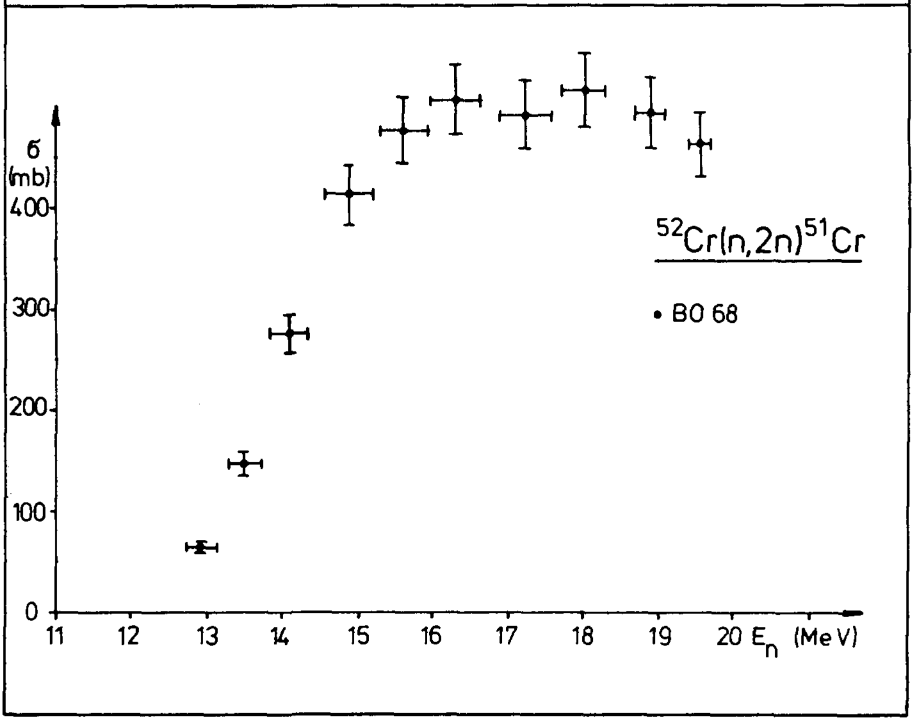


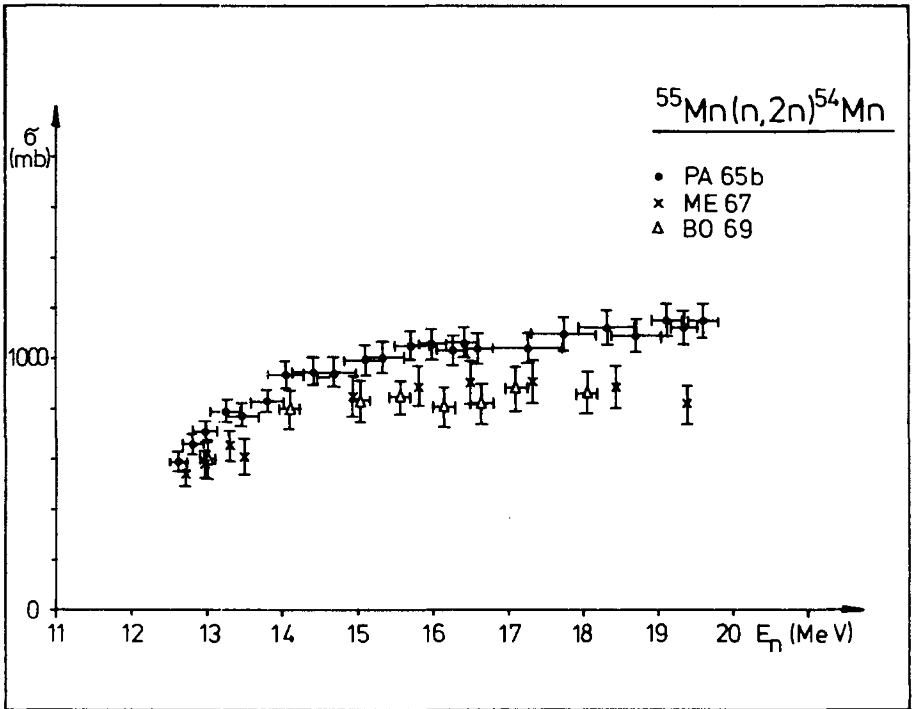
$^{39}K(n,2n)^{38m}K$
• BA 65a
σ (mb)
0
5
10
15
20
13
14
15
16
17
18
19
20
21
22
E_n (MeV)


^{45}Sc(n,2n)^{44g} Sc
× PR 61 (g)
• AR 64 (g)
σ (mb)
400
300
200
100
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)
^{45}Sc(n,2n)^{44m} Sc
Δ PE 61 (m)
× PR 61 (m)
• AR 64 (m)
σ (mb)
400
300
200
100
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

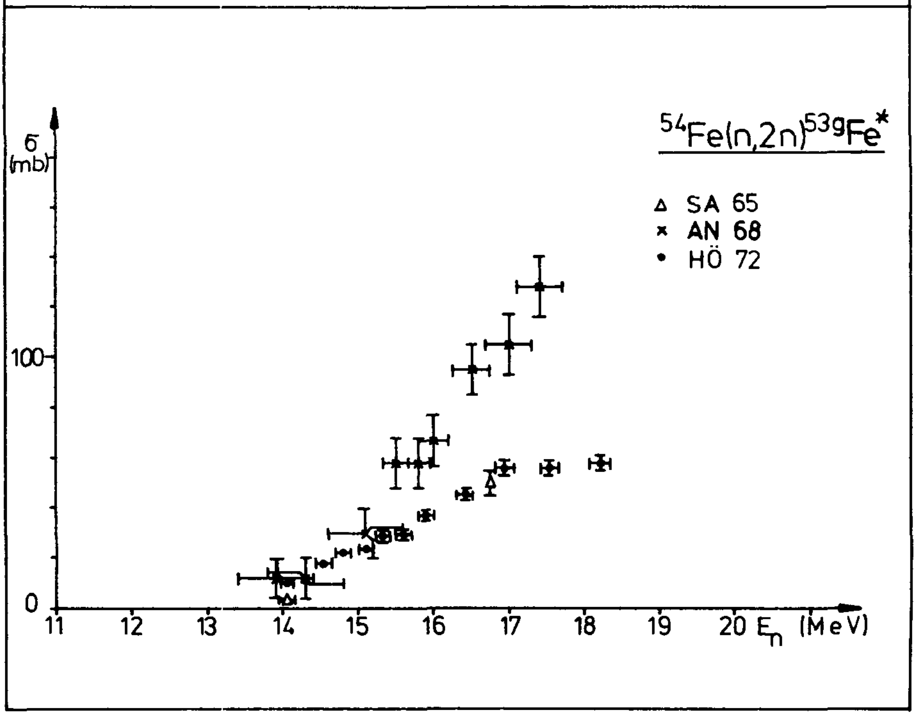

$^{46}Ti(n,2n)^{45}Ti$
• PR 61
× BO 65a
Δ PA 66
σ (mb)
400
300
200
100
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)


σ (mb)
$^{50}Cr(n,2n)^{49}Cr$
• JE 65
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

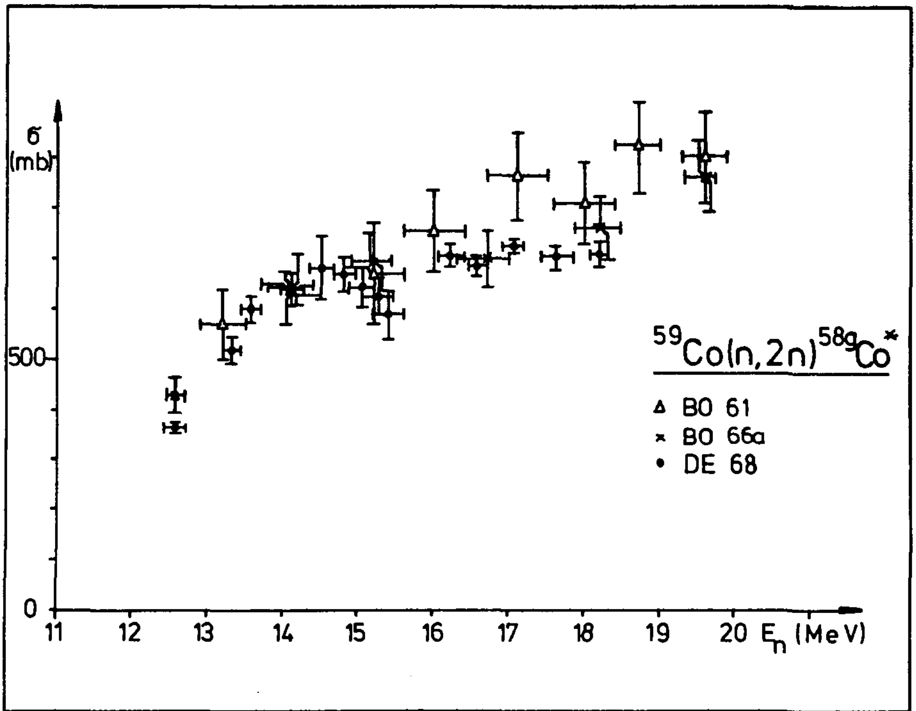

σ (mb)
400
300
200
100
0
$^{52}Cr(n,2n)^{51}Cr$
• BO 68
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

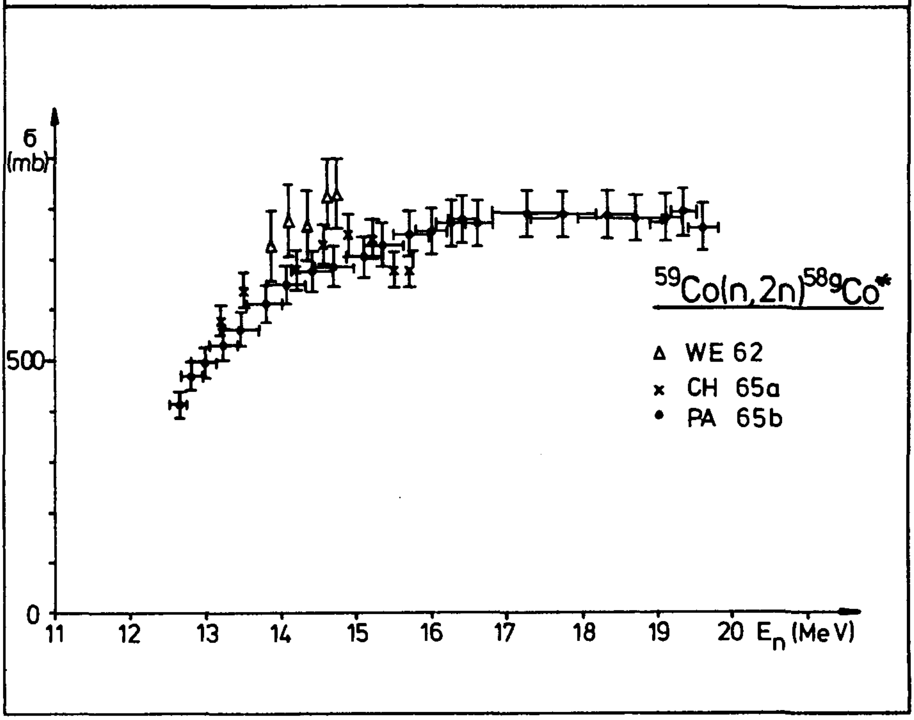


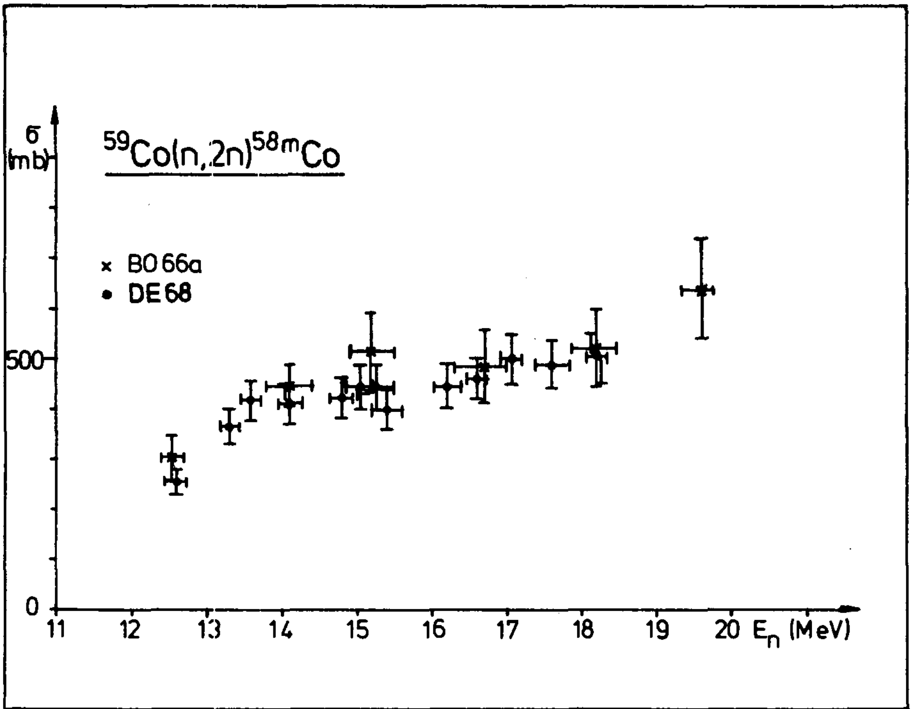
$^{55}Mn(n,2n)^{54}Mn$
• PA 65b
× ME 67
Δ BO 69
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20
E_n (MeV)

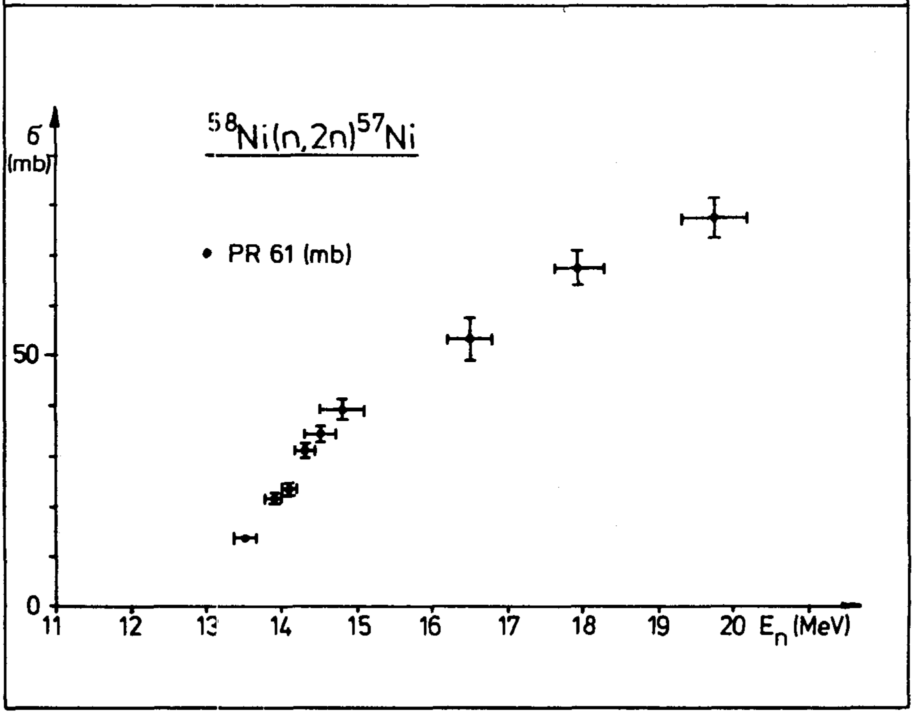


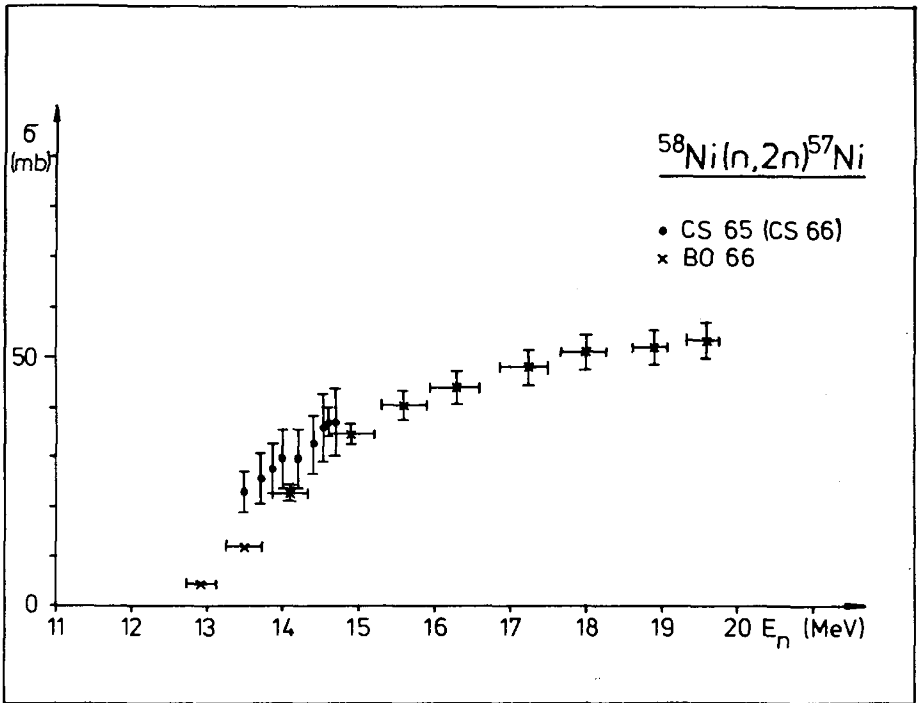
$^{54}Fe(n,2n)^{53g}Fe^*$
Δ SA 65
× AN 68
• HÖ 72
σ (mb)
100
0
11 12 13 14 15 16 17 18 19 20
E_n (MeV)

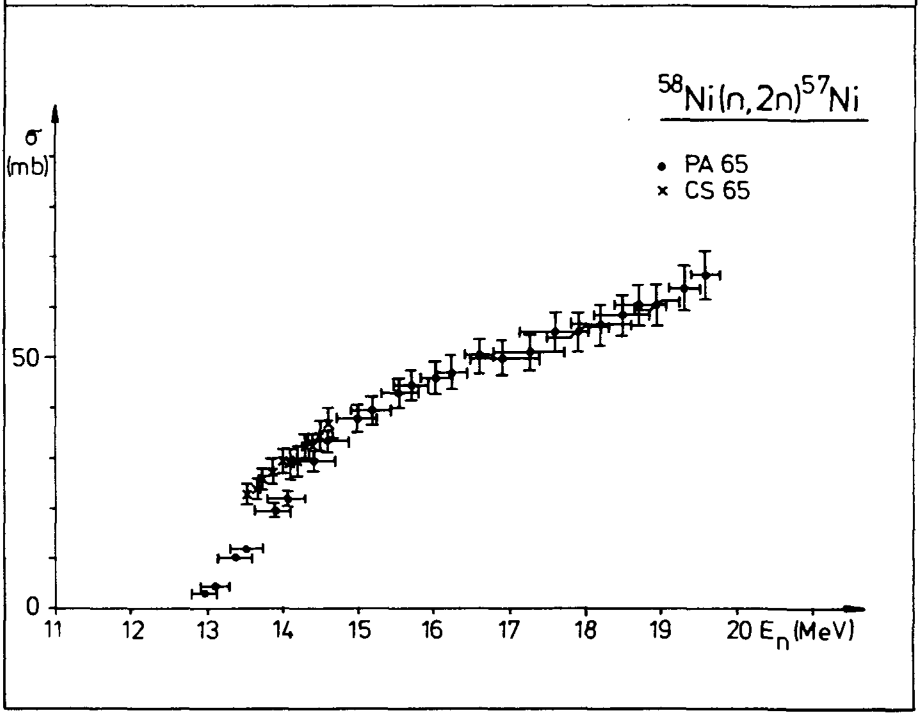

σ
(mb)
500
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)
$^{59}Co(n,2n)^{58g}Co^{*}$
Δ BO 61
× BO 66a
• DE 68

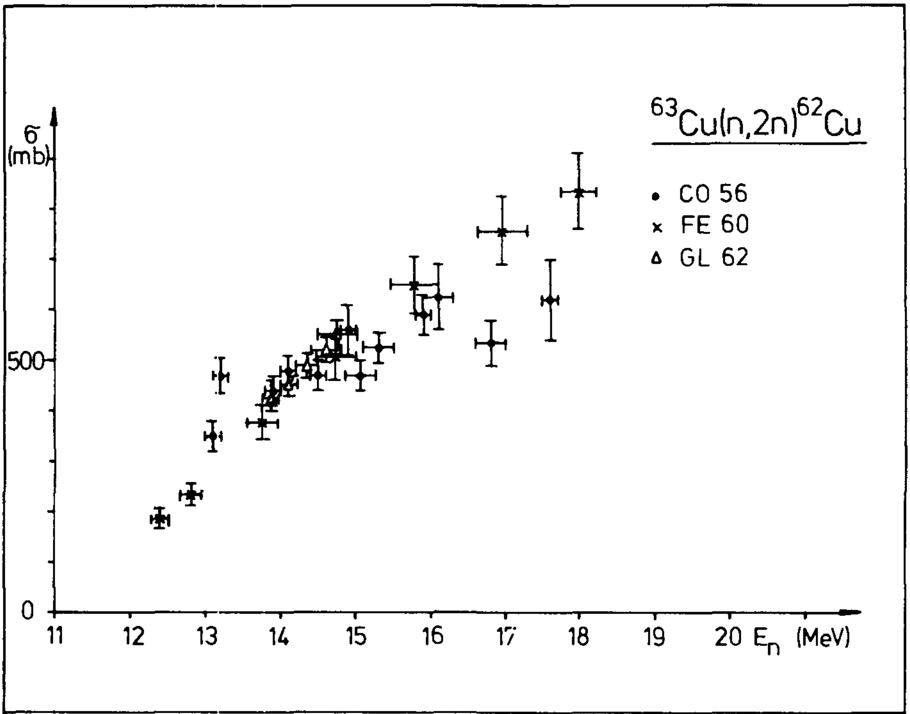

σ
(mb)
500
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)
$^{59}Co(n,2n)^{58g}Co^{*}$
Δ WE 62
× CH 65a
• PA 65b


$^{59}Co(n,2n)^{58m}Co$
σ (mb)
× BO 66a
• DE 68
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

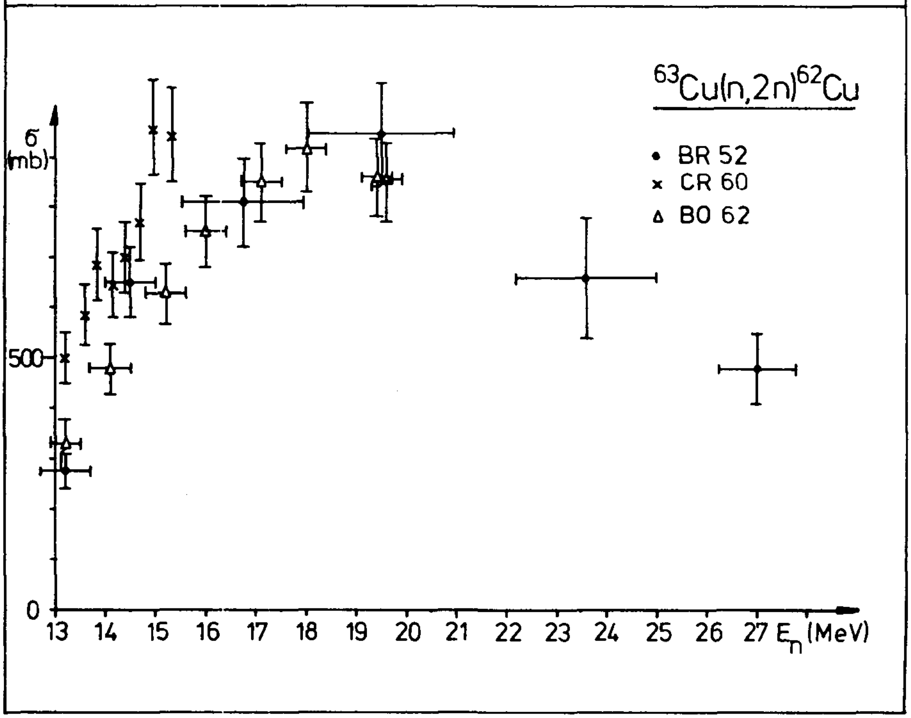

$^{58}Ni(n,2n)^{57}Ni$
σ (mb)
• PR 61 (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


^{58}Ni(n,2n)^{57}Ni
• CS 65 (CS 66)
× BO 66
σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

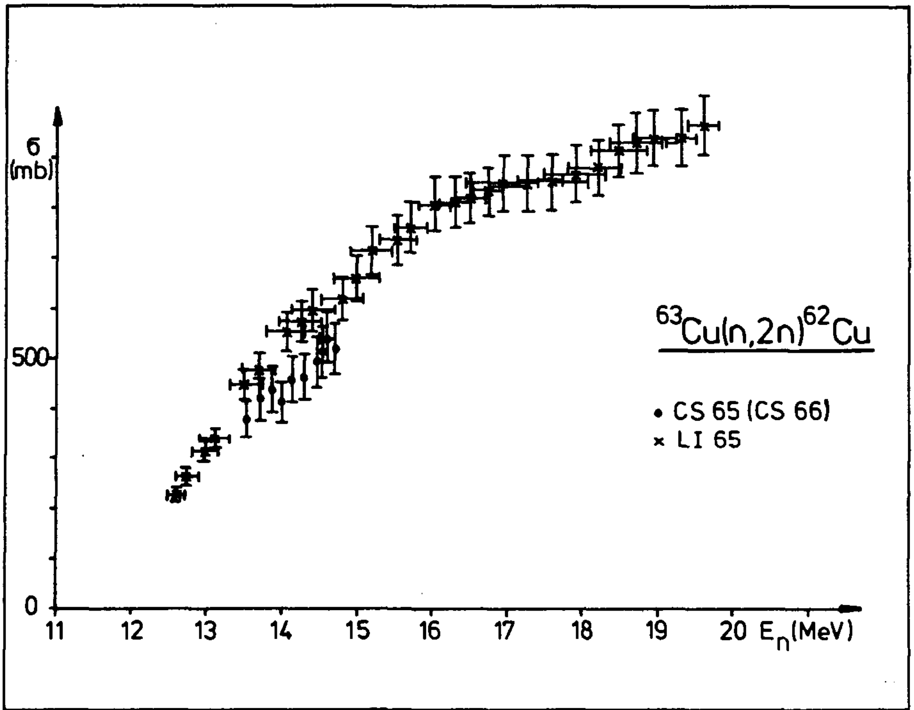

^{58}Ni(n,2n)^{57}Ni
• PA 65
× CS 65
σ (mb)
50
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

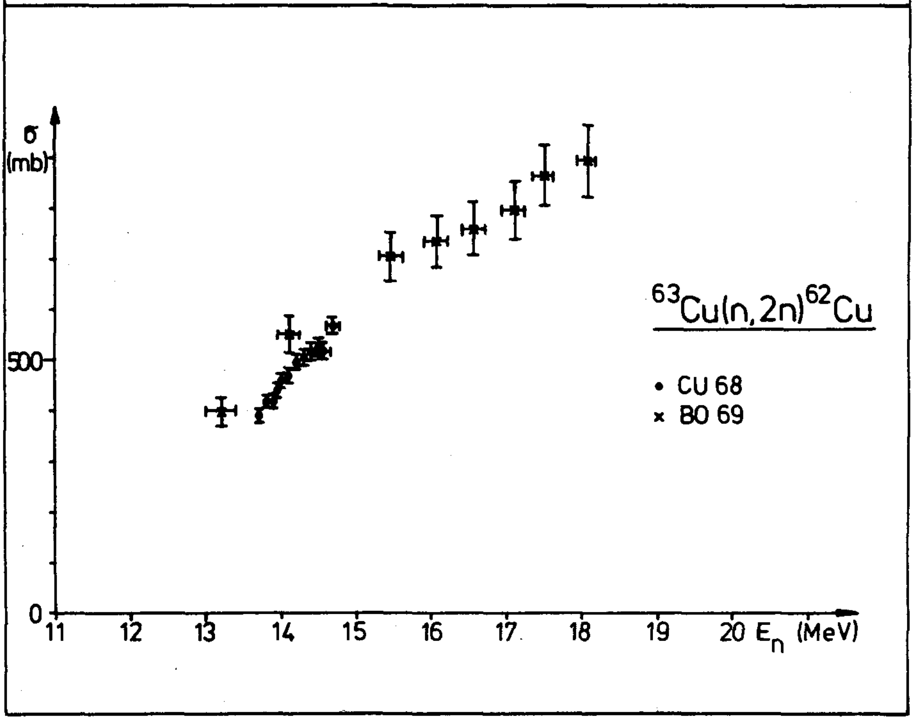


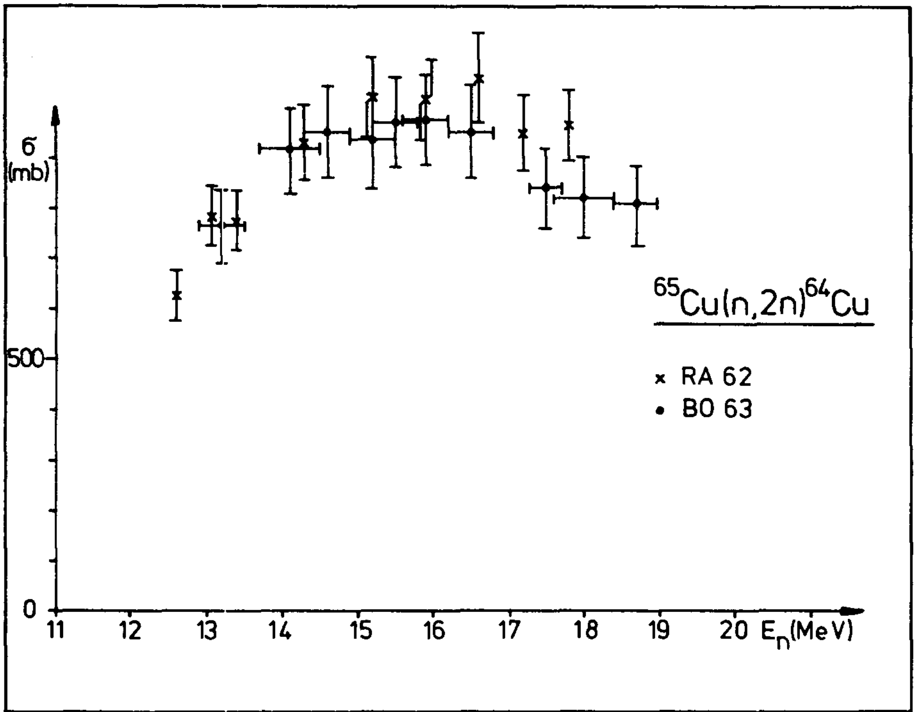
$^{63}Cu(n,2n)^{62}Cu$
• CO 56
× FE 60
Δ GL 62
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

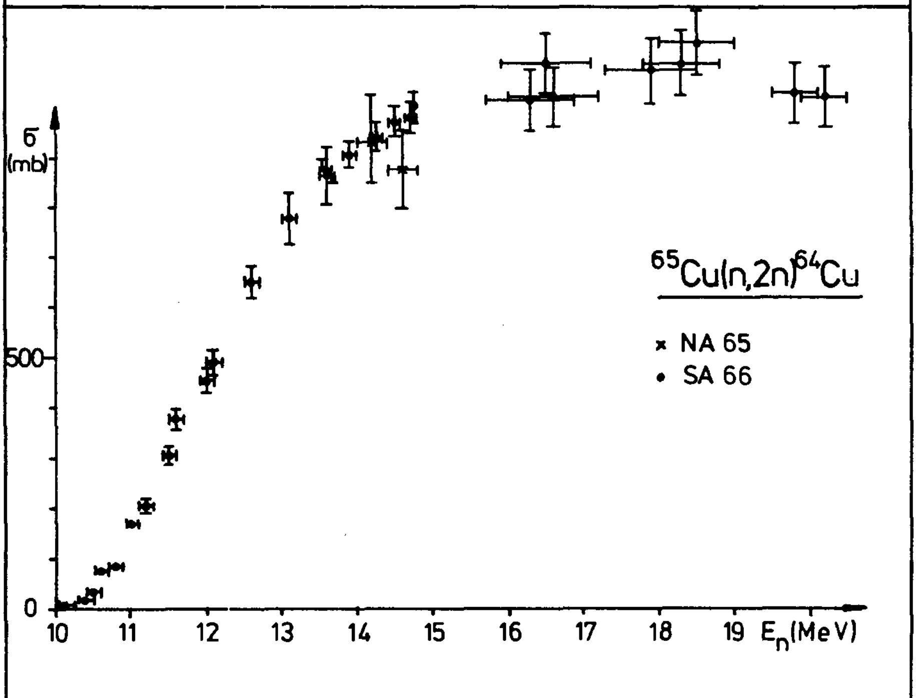


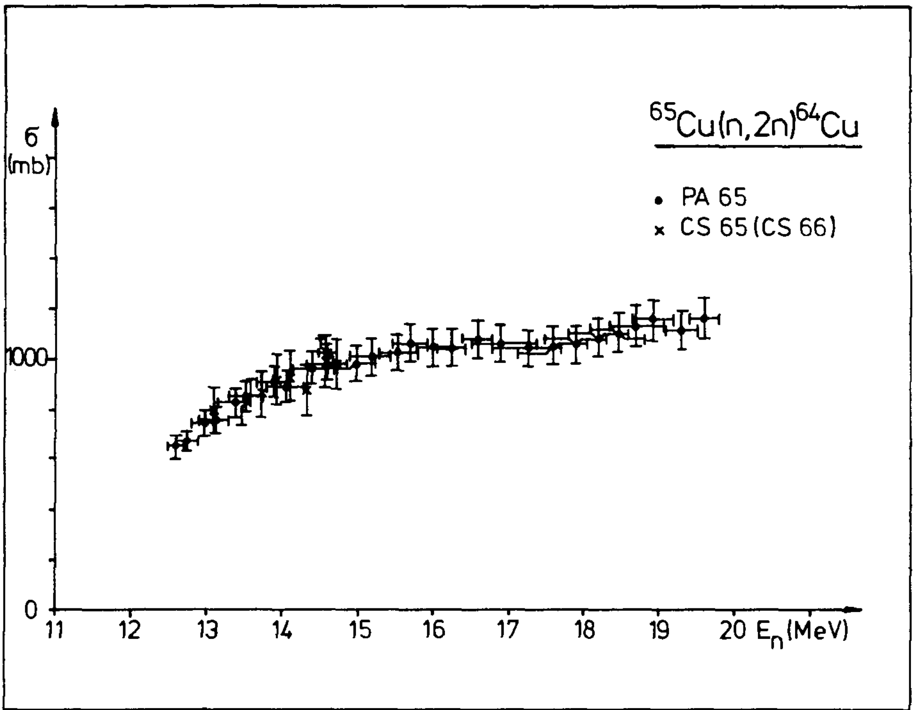
$^{63}Cu(n,2n)^{62}Cu$
• BR 52
× CR 60
Δ BO 62
σ (mb)
500
0
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 E_n (MeV)

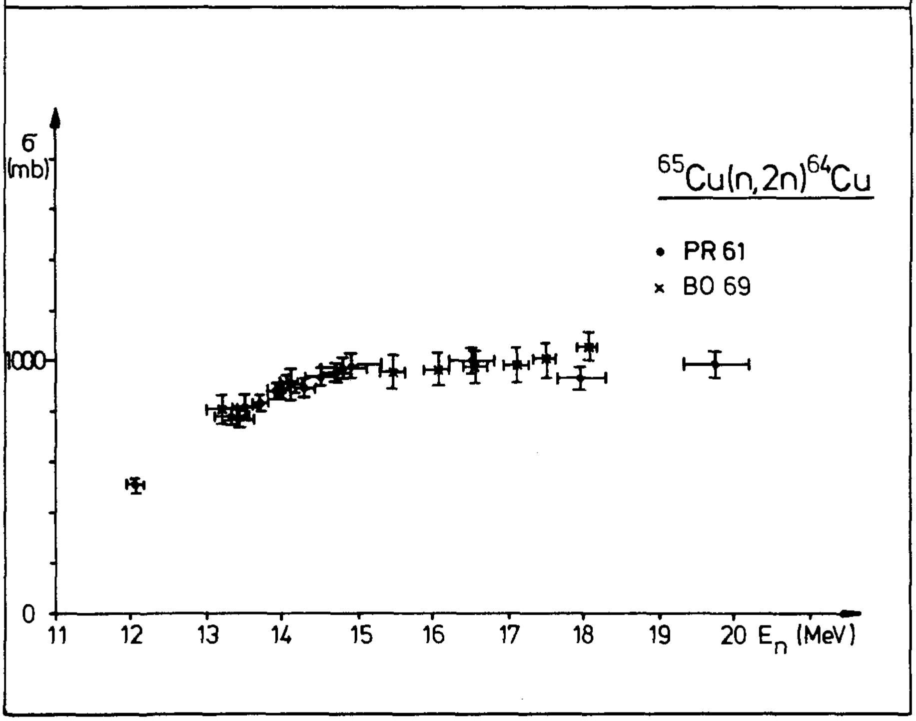

σ (mb)
500
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)
$^{63}Cu(n,2n)^{62}Cu$
• CS 65 (CS 66)
× LI 65

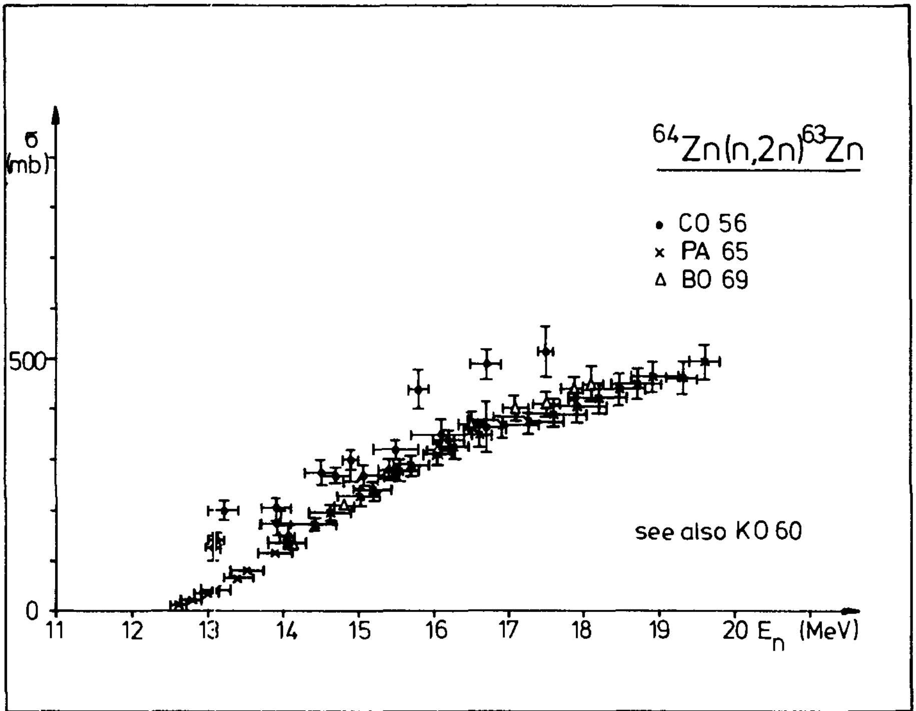

σ (mb)
500
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)
$^{63}Cu(n,2n)^{62}Cu$
• CU 68
× BO 69


σ (mb)
500
0
11
12
13
14
15
16
17
18
19
20
E_n(MeV)
$^{65}Cu(n,2n)^{64}Cu$
× RA 62
• BO 63

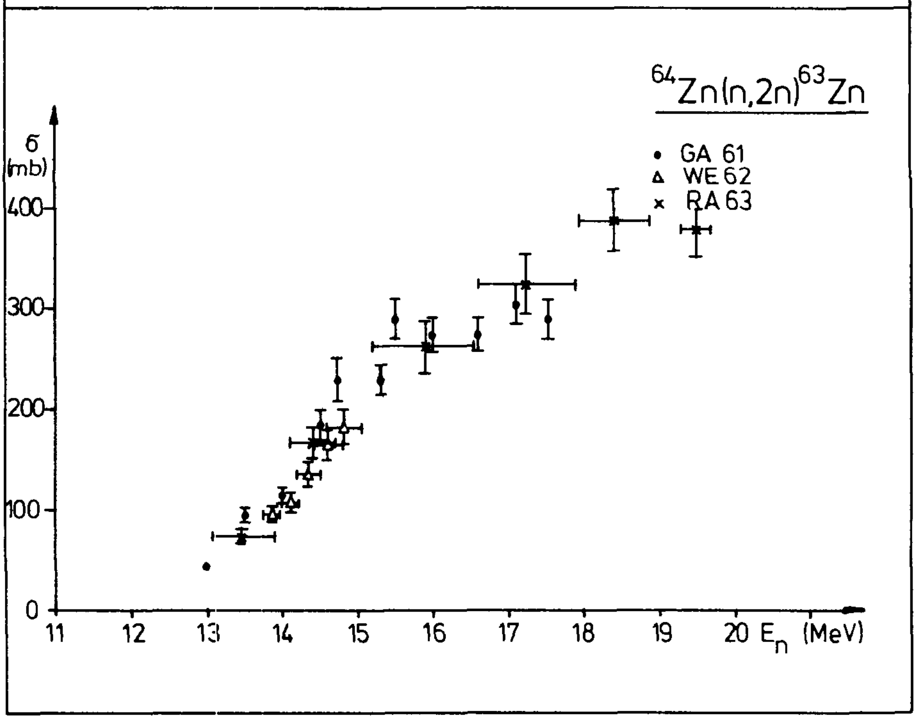

σ (mb)
500
0
10
11
12
13
14
15
16
17
18
19
E_n(MeV)
$^{65}Cu(n,2n)^{64}Cu$
× NA 65
• SA 66


$^{65}Cu(n,2n)^{64}Cu$
• PA 65
× CS 65 (CS 66)
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

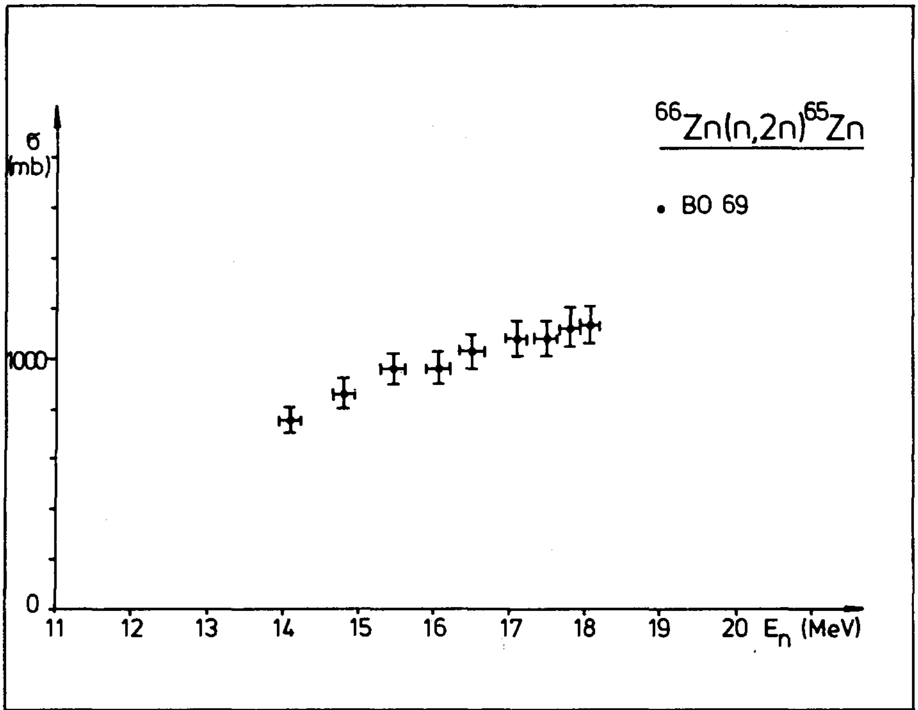

$^{65}Cu(n,2n)^{64}Cu$
• PR 61
× BO 69
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

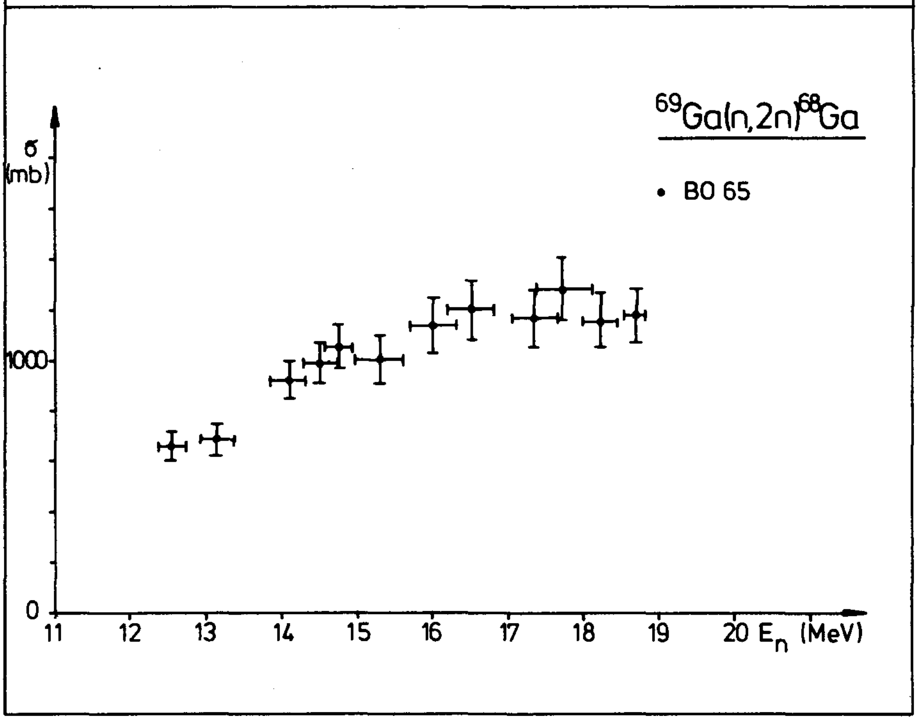


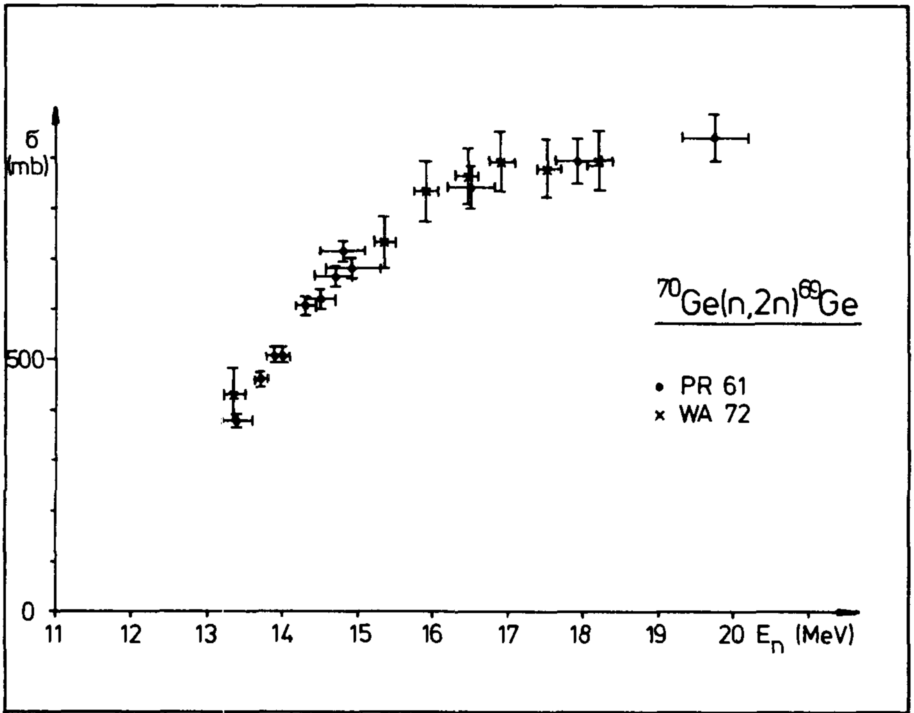
$^{64}Zn(n,2n)^{63}Zn$
• CO 56
× PA 65
Δ BO 69
see also KO 60
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



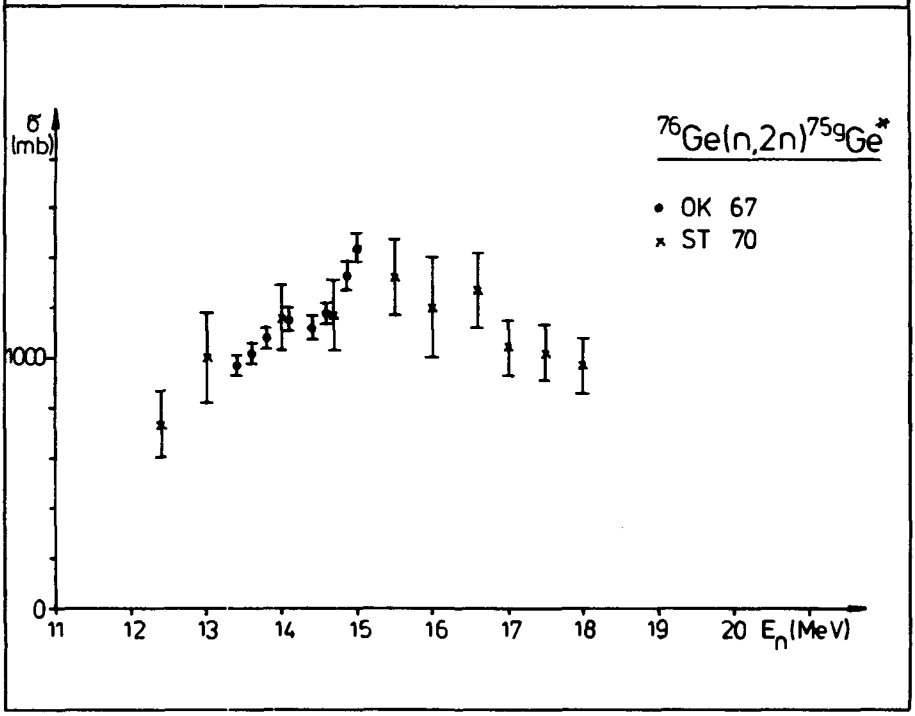
$^{64}Zn(n,2n)^{63}Zn$
• GA 61
Δ WE 62
× RA 63
σ (mb)
400
300
200
100
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


66Zn(n,2n)65Zn
• BO 69
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 En (MeV)

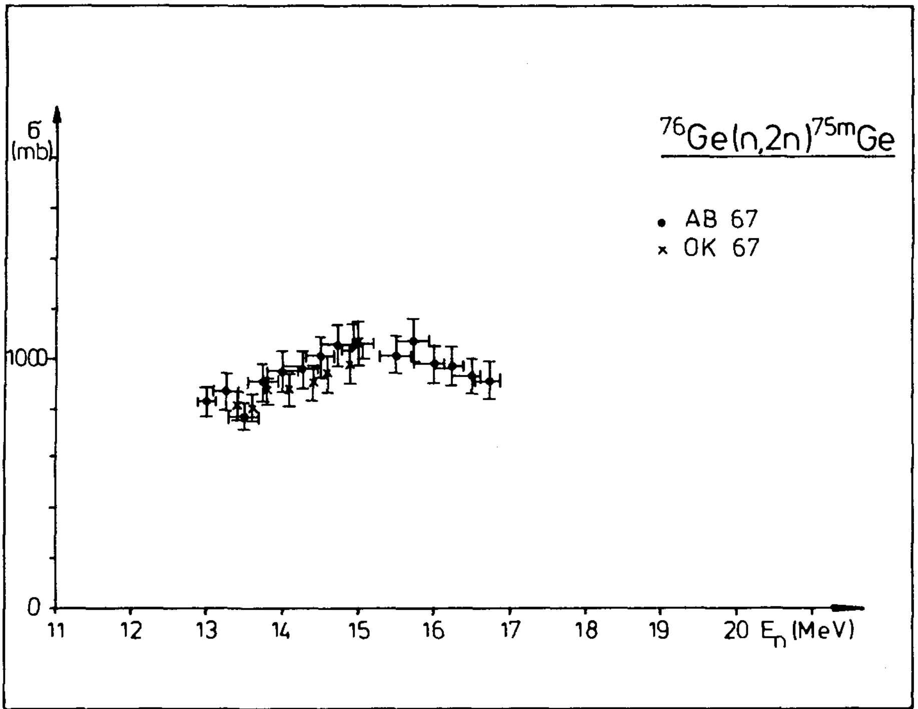

69Ga(n,2n)68Ga
• BO 65
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 En (MeV)



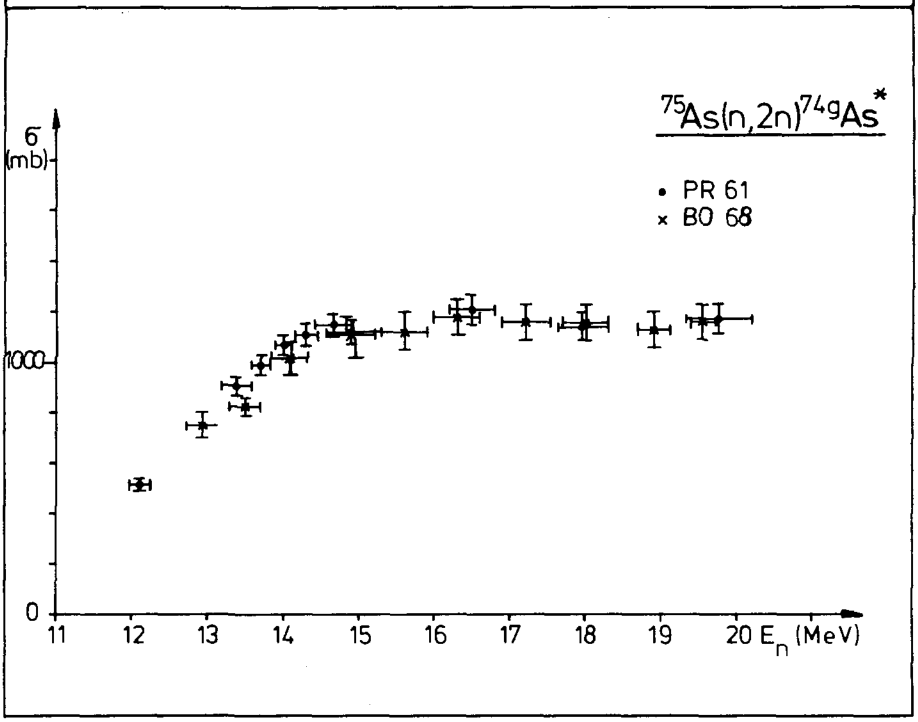
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{70}Ge(n,2n)^{69}Ge$
• PR 61
× WA 72



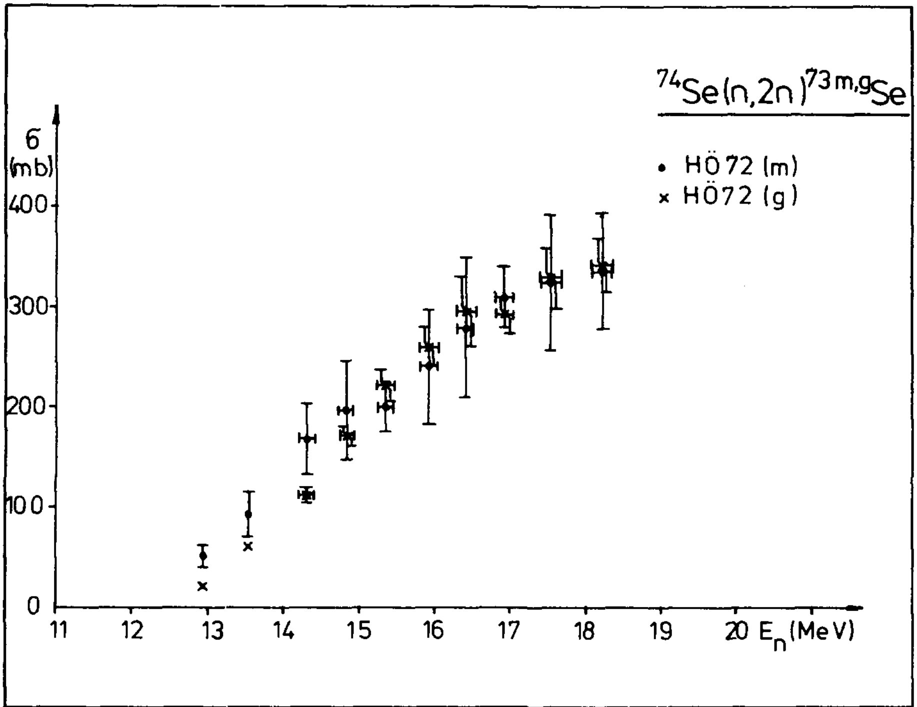
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n(MeV)
$^{76}Ge(n,2n)^{75g}Ge^{*}$
• OK 67
× ST 70

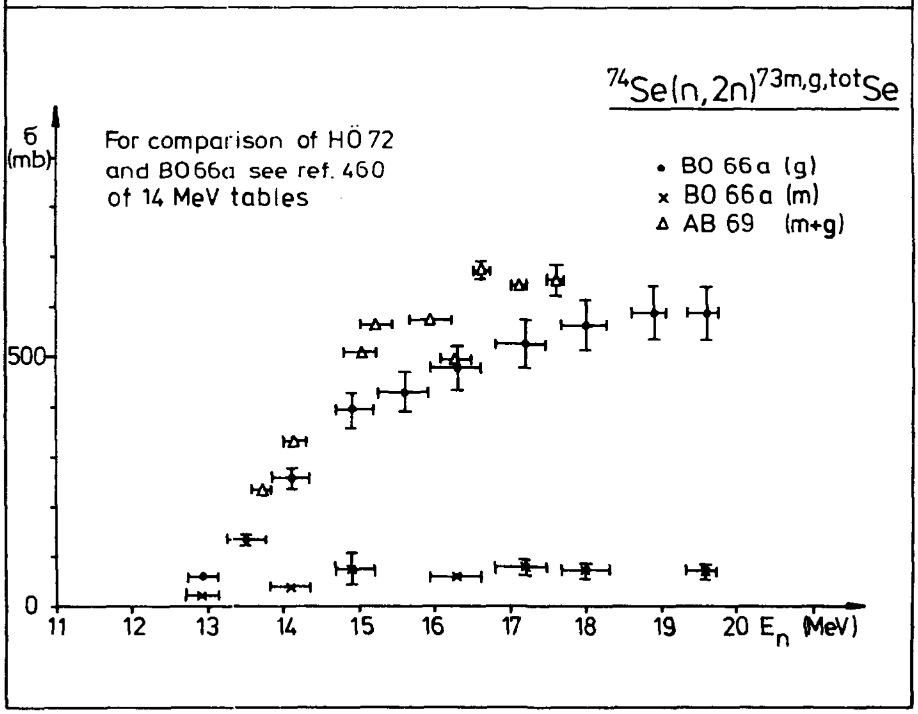


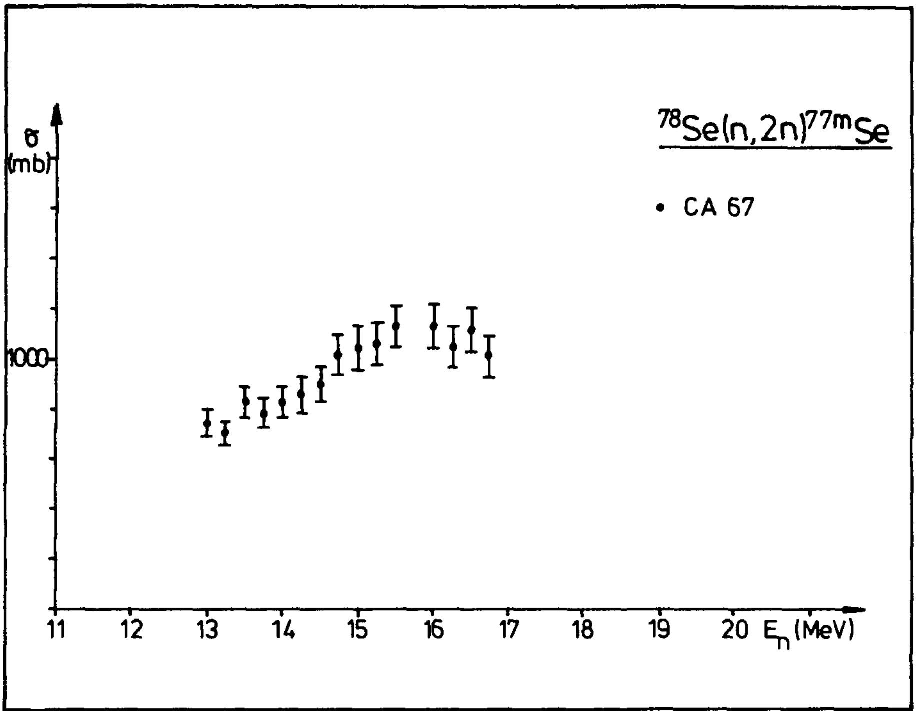
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
76Ge(n,2n)75mGe
• AB 67
× OK 67



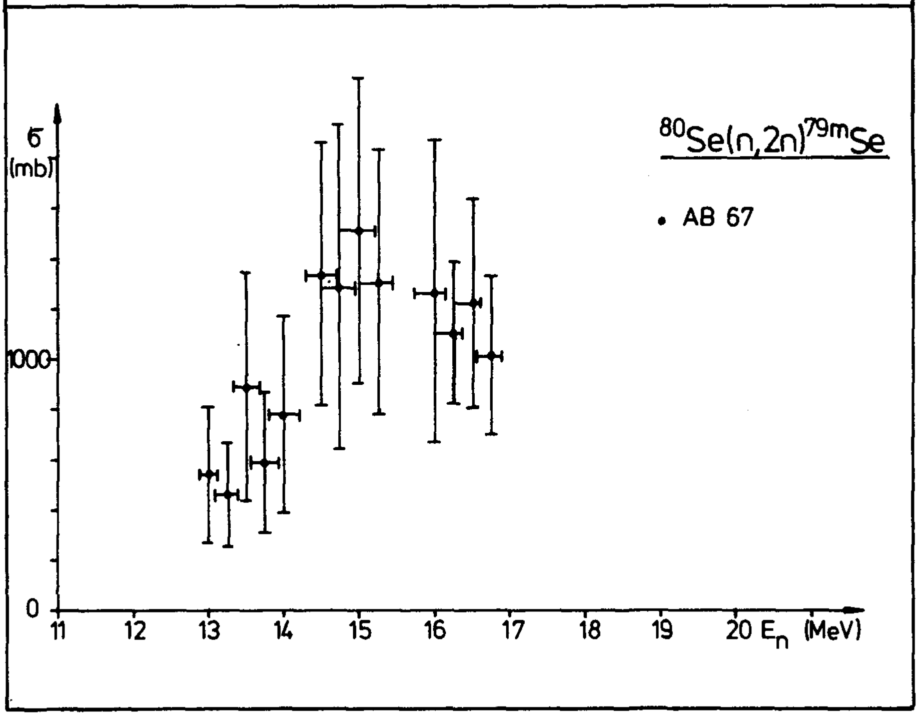
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
75As(n,2n)74gAs*
• PR 61
× BO 68


$^{74}Se(n,2n)^{73m,g}Se$
• HÖ 72 (m)
× HÖ 72 (g)
σ (mb)
0
100
200
300
400
11
12
13
14
15
16
17
18
19
20 E_n (MeV)

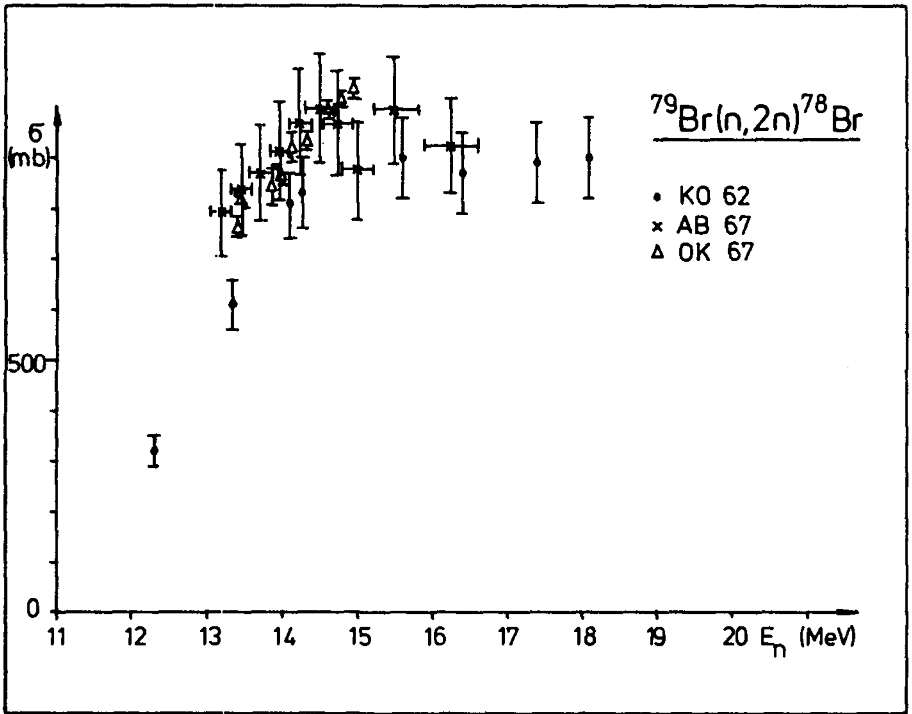

$^{74}Se(n,2n)^{73m,g,tot}Se$
For comparison of HÖ 72 and BO66a see ref. 460 of 14 MeV tables
• BO 66a (g)
× BO 66a (m)
Δ AB 69 (m+g)
σ (mb)
0
500
11
12
13
14
15
16
17
18
19
20 E_n (MeV)



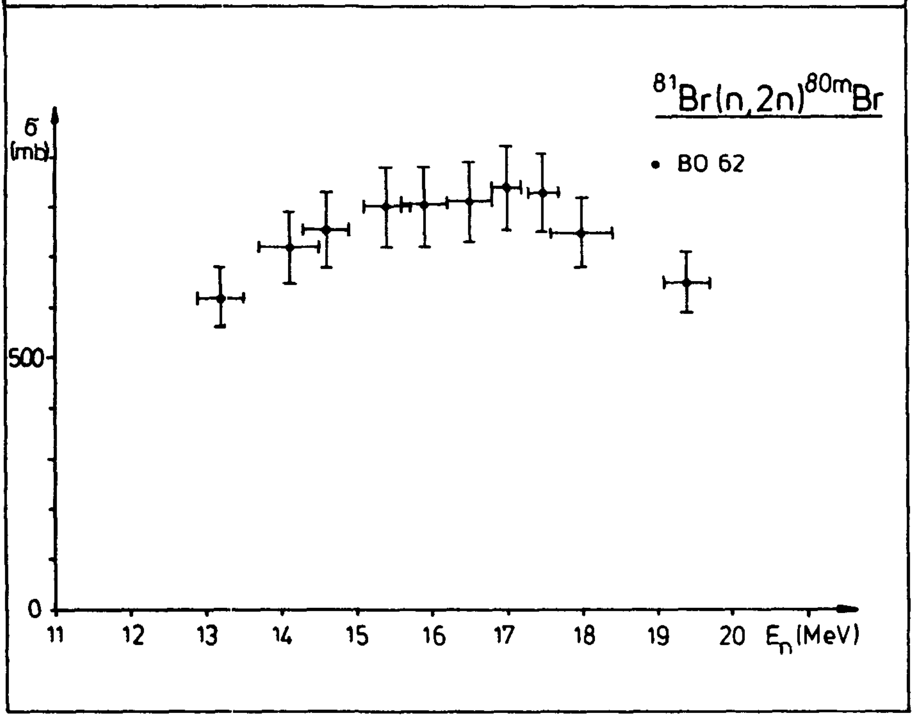
σ (mb)
1000
11
12
13
14
15
16
17
18
19
20 E_n (MeV)
$^{78}Se(n,2n)^{77m}Se$
• CA 67



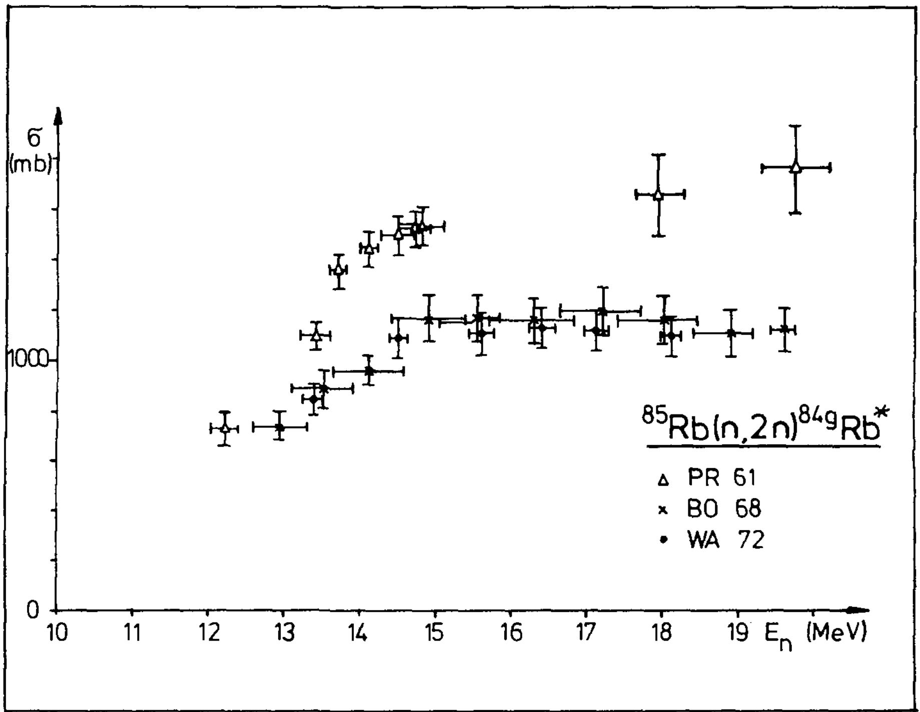
σ (mb)
1000
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)
$^{80}Se(n,2n)^{79m}Se$
• AB 67

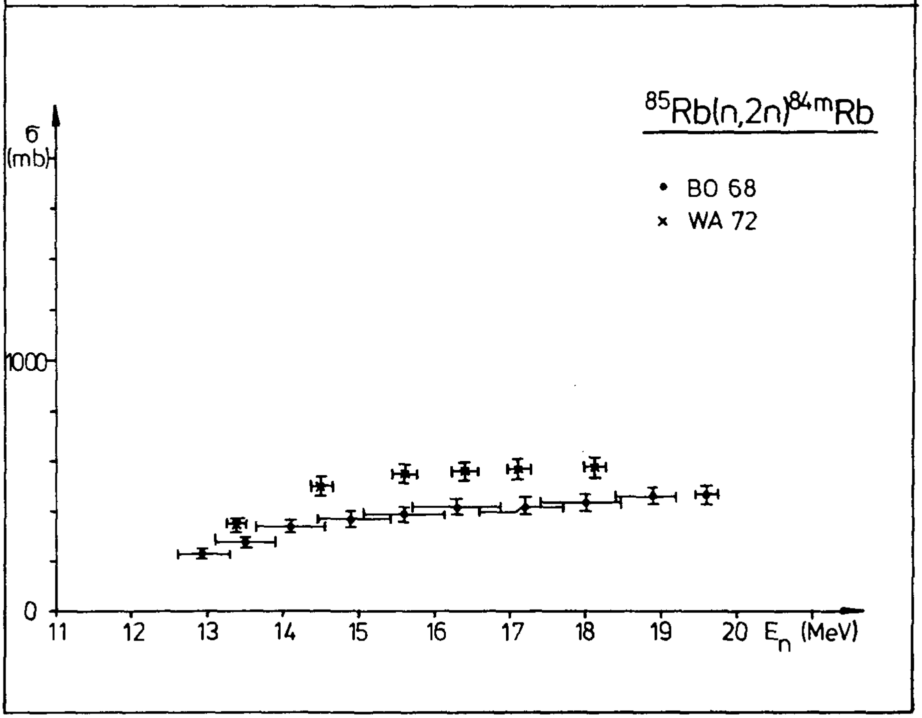


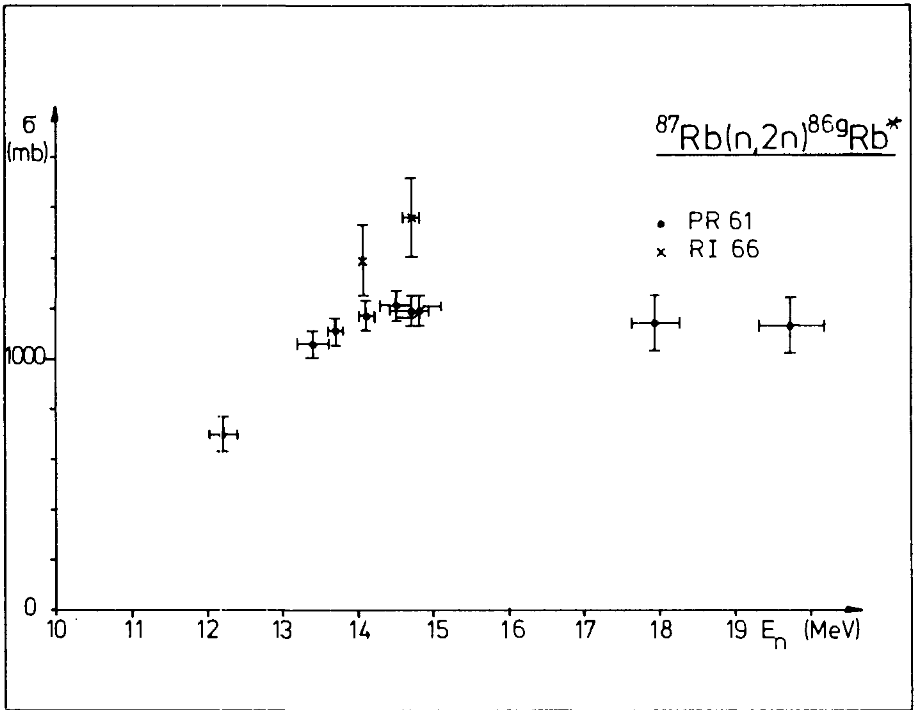
$^{79}Br(n,2n)^{78}Br$
• KO 62
× AB 67
Δ OK 67
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

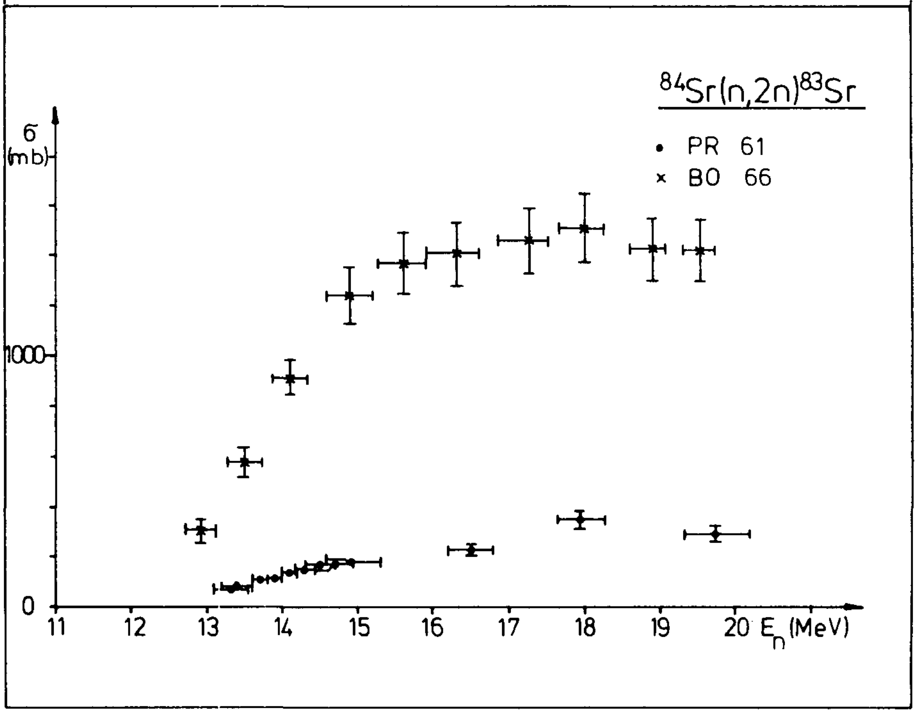


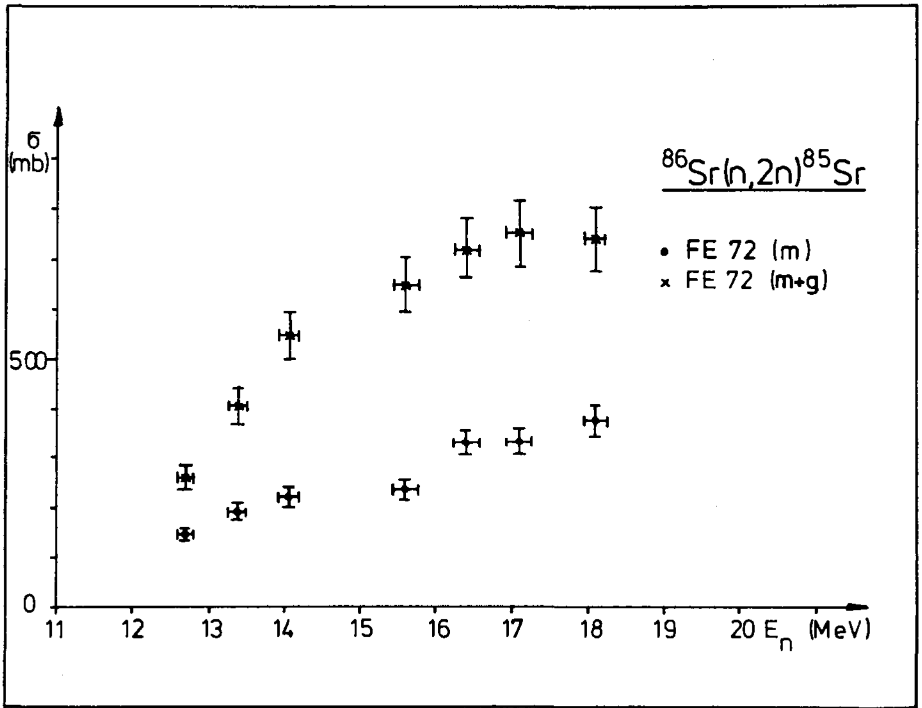
$^{81}Br(n,2n)^{80m}Br$
• BO 62
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


σ (mb)
1000
0
10
11
12
13
14
15
16
17
18
19
E_n (MeV)
$^{85}Rb(n,2n)^{84g}Rb^*$
Δ PR 61
× BO 68
• WA 72

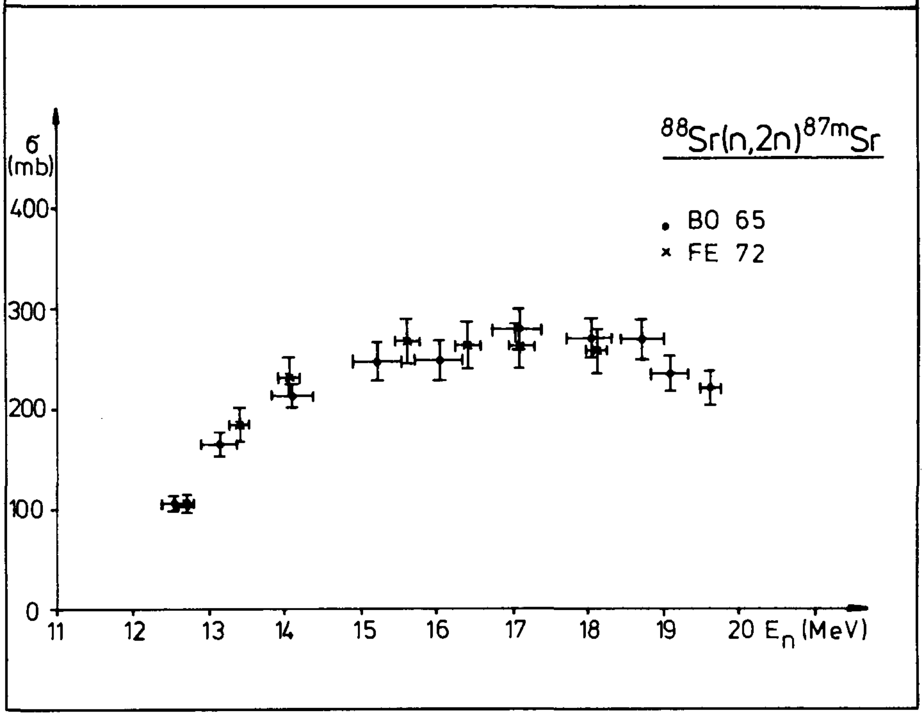

$^{85}Rb(n,2n)^{84m}Rb$
• BO 68
× WA 72
σ (mb)
1000
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)


$^{87}Rb(n,2n)^{86g}Rb^*$
• PR 61
× RI 66
σ (mb)
1000
0
10
11
12
13
14
15
16
17
18
19
E_n (MeV)

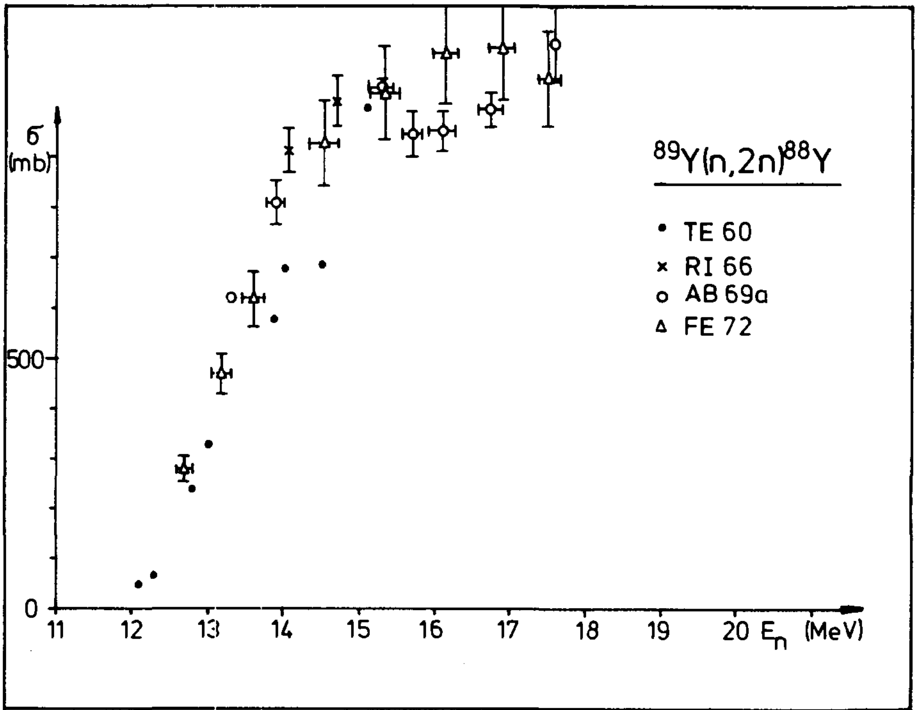

$^{84}Sr(n,2n)^{83}Sr$
• PR 61
× BO 66
σ (mb)
1000
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)

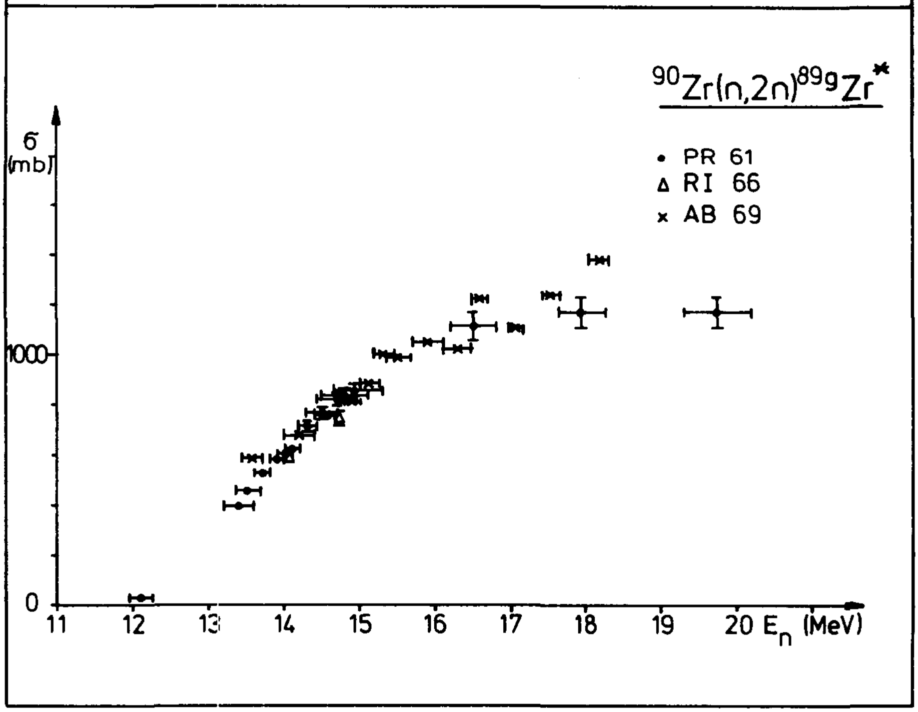


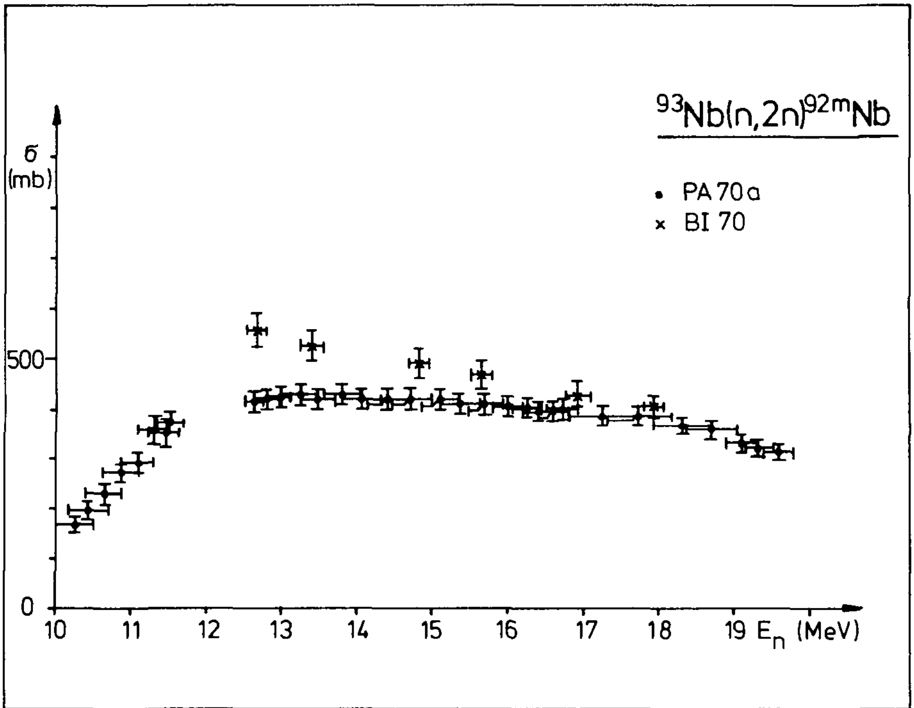
⁸⁶Sr(n,2n)⁸⁵Sr
• FE 72 (m)
× FE 72 (m+g)
σ (mb)
500
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)



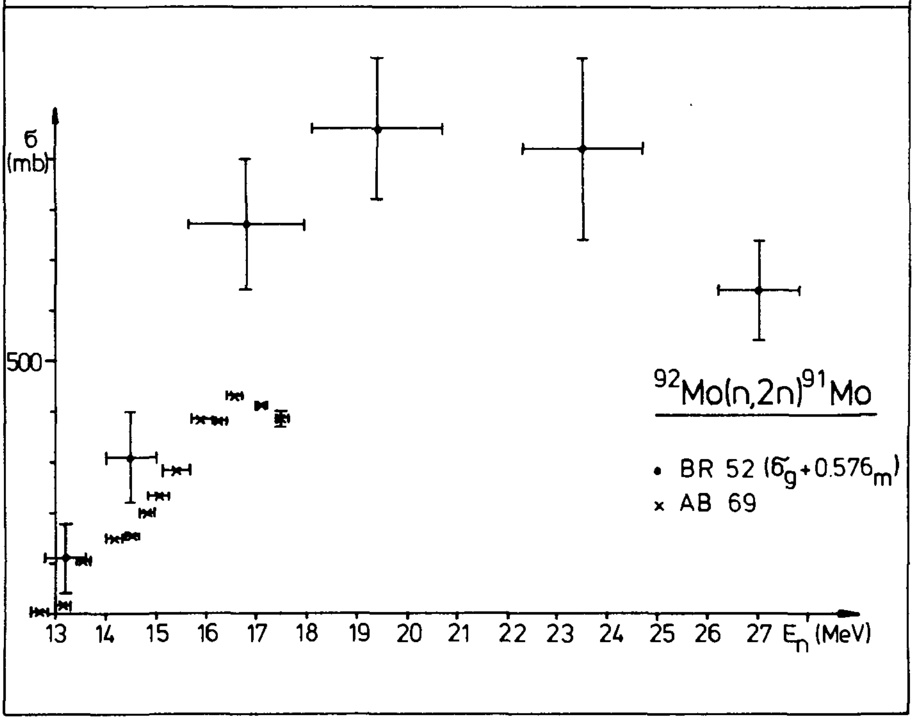
⁸⁸Sr(n,2n)⁸⁷ᵐSr
• BO 65
× FE 72
σ (mb)
400
300
200
100
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)


$^{89}Y(n,2n)^{88}Y$
• TE 60
× RI 66
o AB 69a
Δ FE 72
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

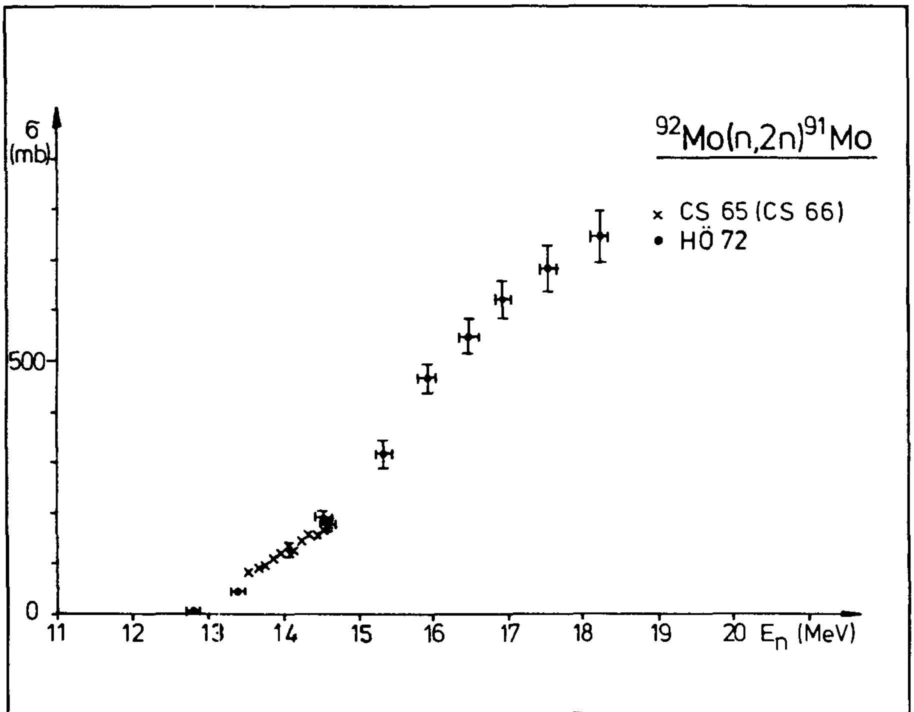

$^{90}Zr(n,2n)^{89g}Zr^{*}$
• PR 61
Δ RI 66
× AB 69
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



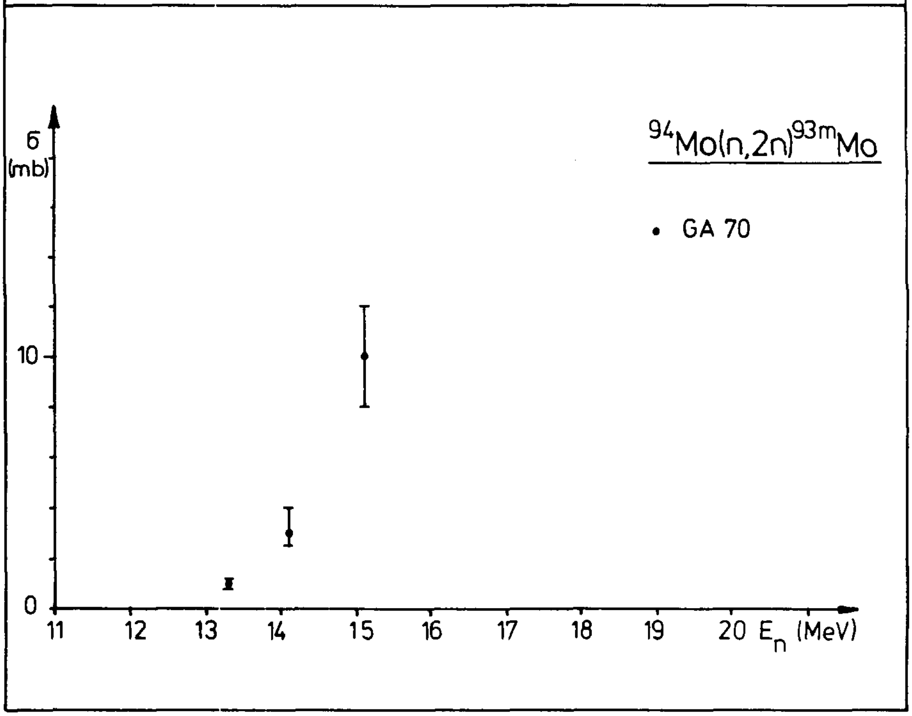
$^{93}Nb(n,2n)^{92m}Nb$
• PA 70a
× BI 70
σ (mb)
500
0
10
11
12
13
14
15
16
17
18
19
E_n (MeV)



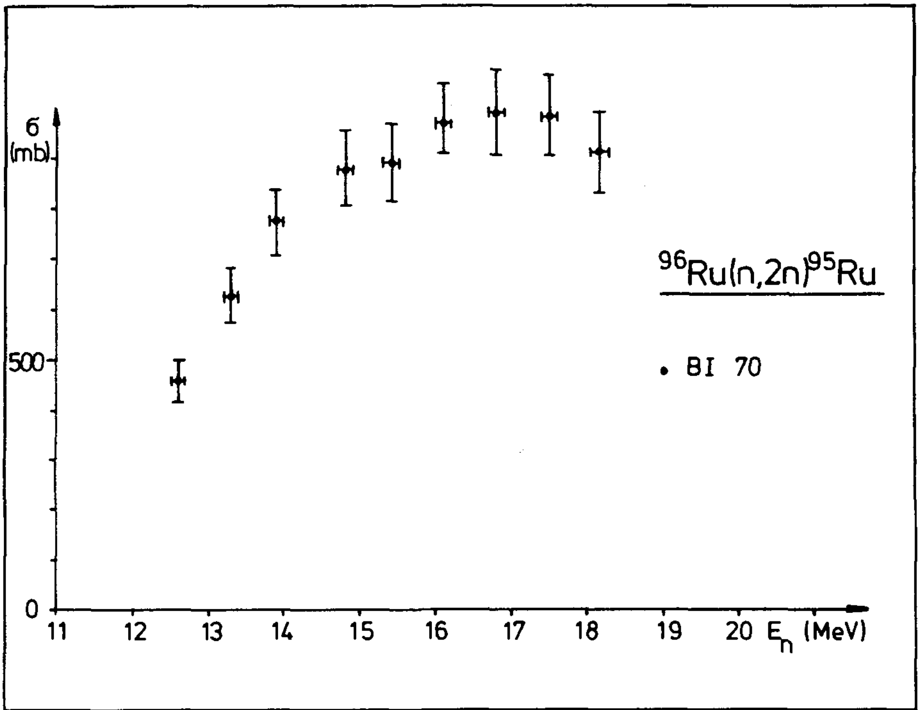
$^{92}Mo(n,2n)^{91}Mo$
• BR 52 (σ_g+0.576σ_m)
× AB 69
σ (mb)
500
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
E_n (MeV)



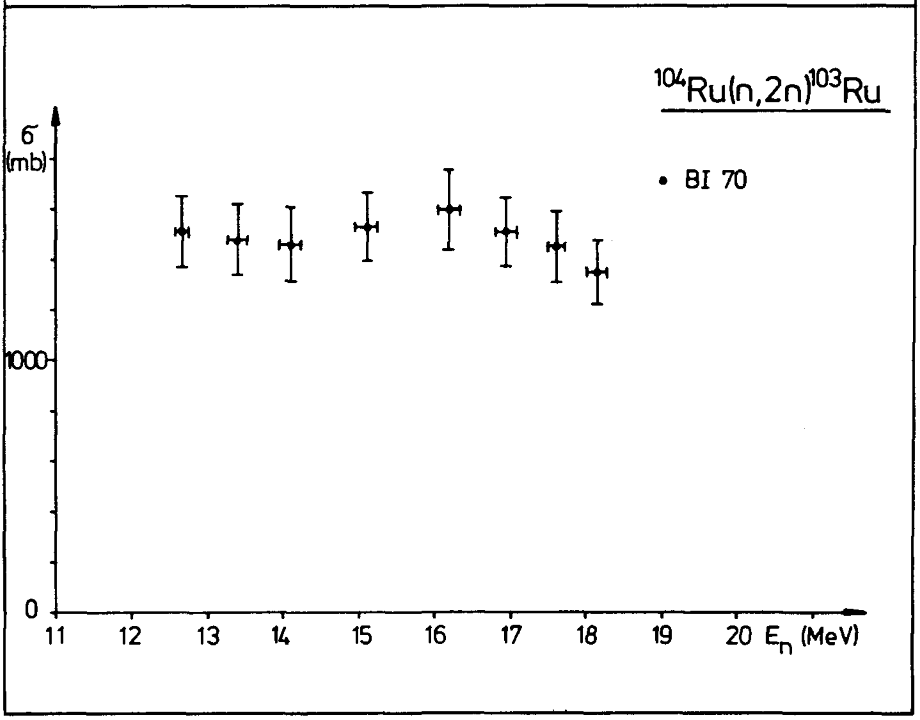
$^{92}Mo(n,2n)^{91}Mo$
× CS 65 (CS 66)
• HÖ 72
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



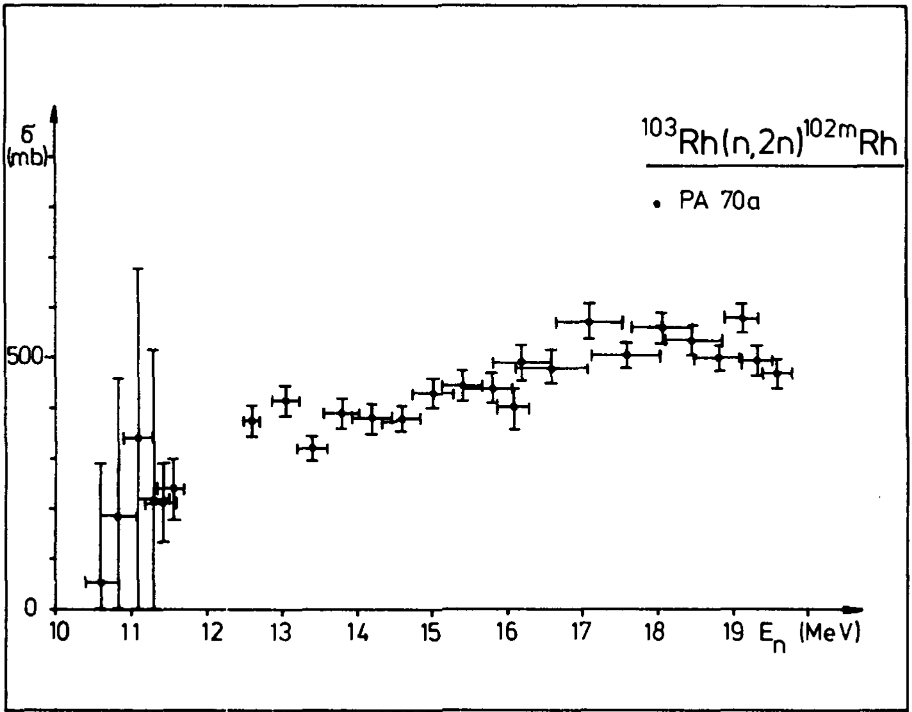
$^{94}Mo(n,2n)^{93m}Mo$
• GA 70
σ (mb)
10
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



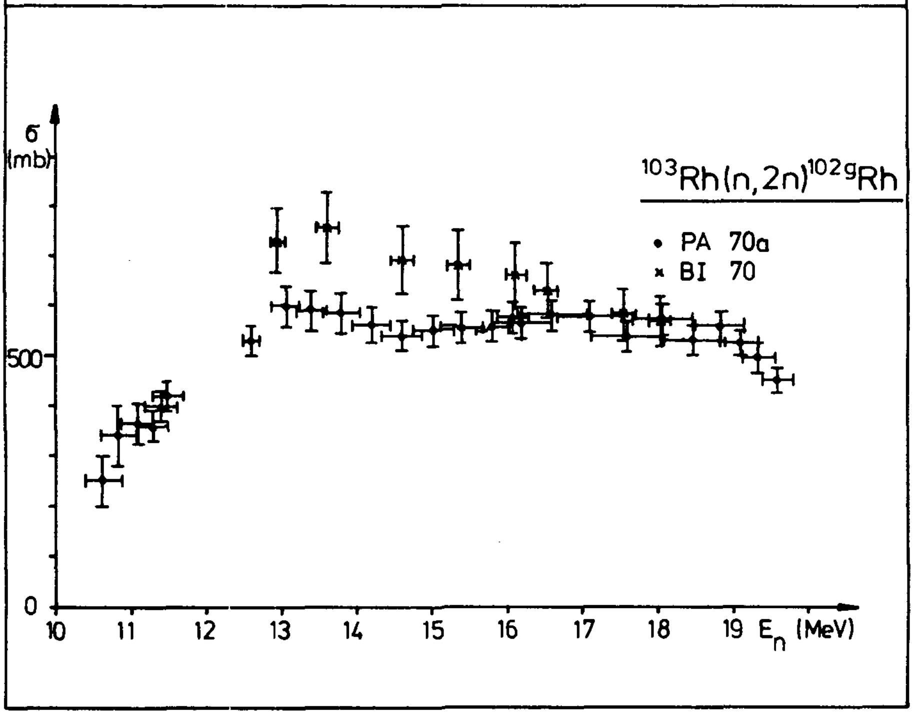
σ (mb)
500
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)
$^{96}Ru(n,2n)^{95}Ru$
• BI 70



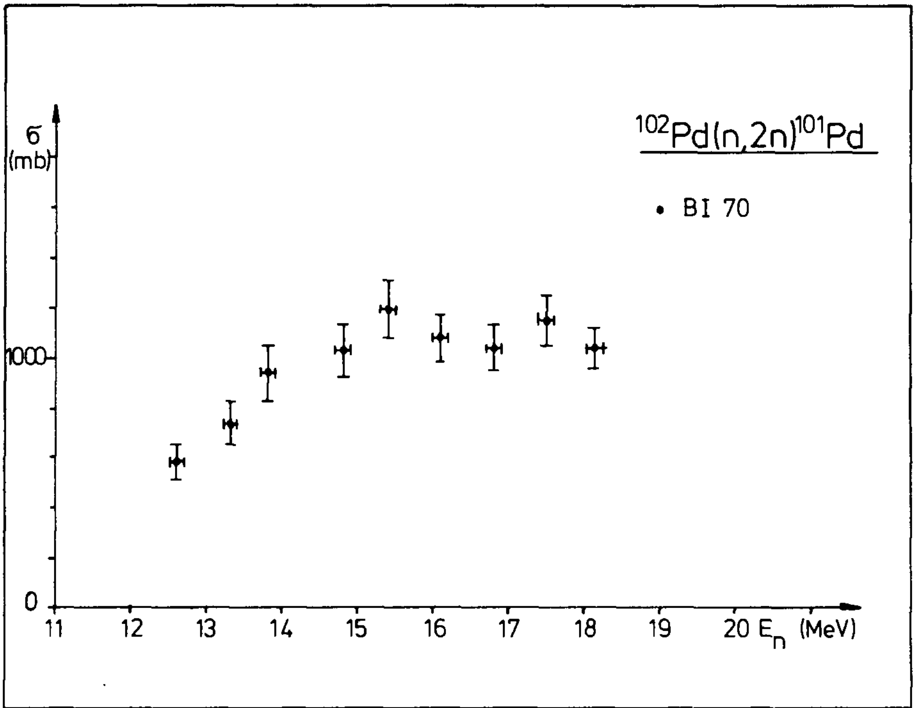
$^{104}Ru(n,2n)^{103}Ru$
σ (mb)
• BI 70
1000
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)



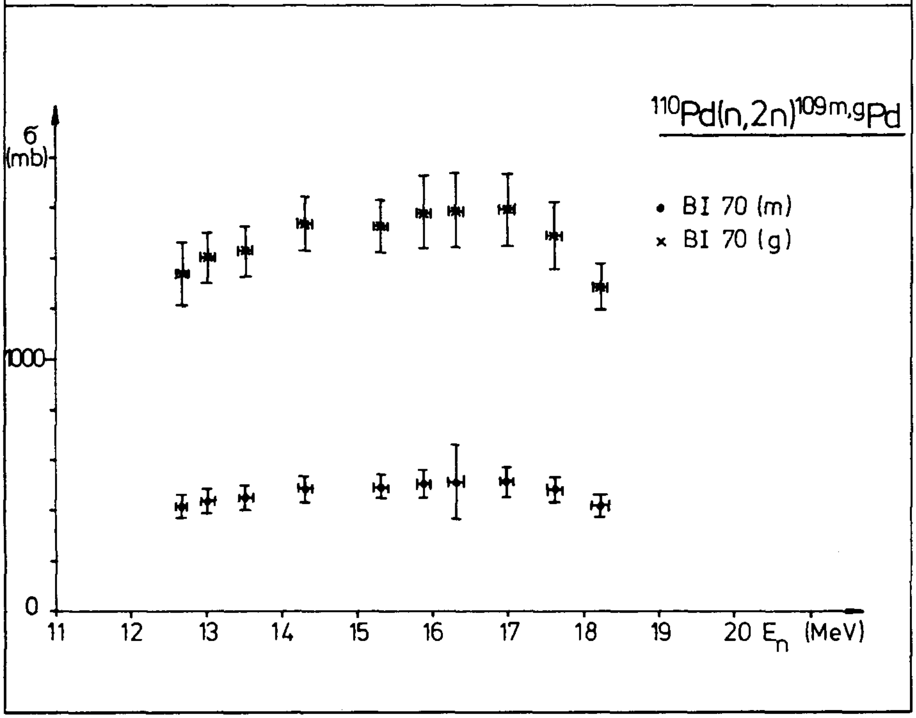
$^{103}Rh(n,2n)^{102m}Rh$
• PA 70a
σ (mb)
500
0
10
11
12
13
14
15
16
17
18
19
E_n (MeV)



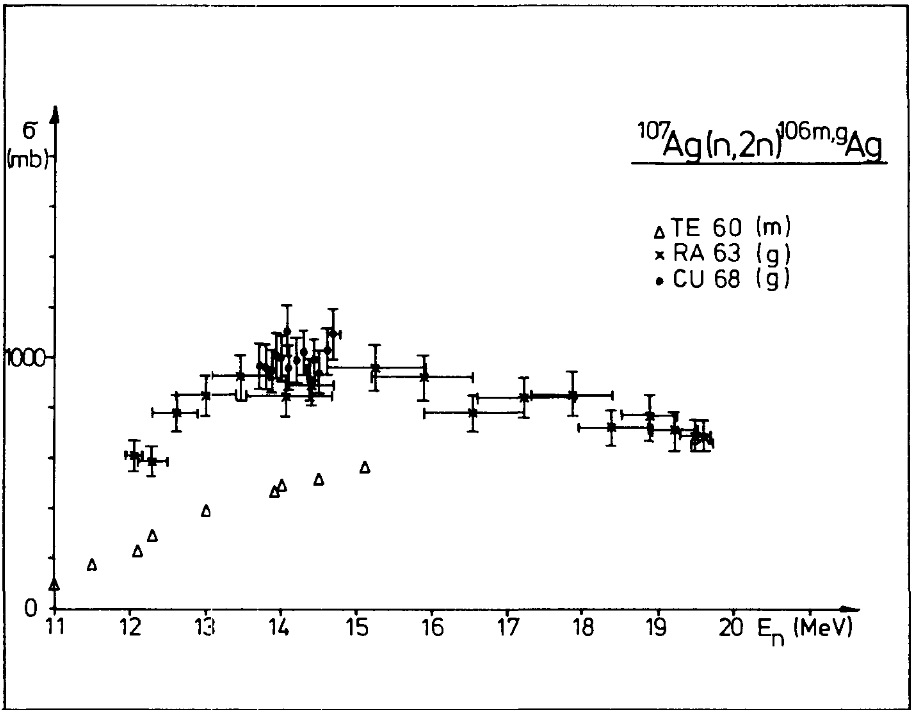
$^{103}Rh(n,2n)^{102g}Rh$
• PA 70a
× BI 70
σ (mb)
500
0
10
11
12
13
14
15
16
17
18
19
E_n (MeV)



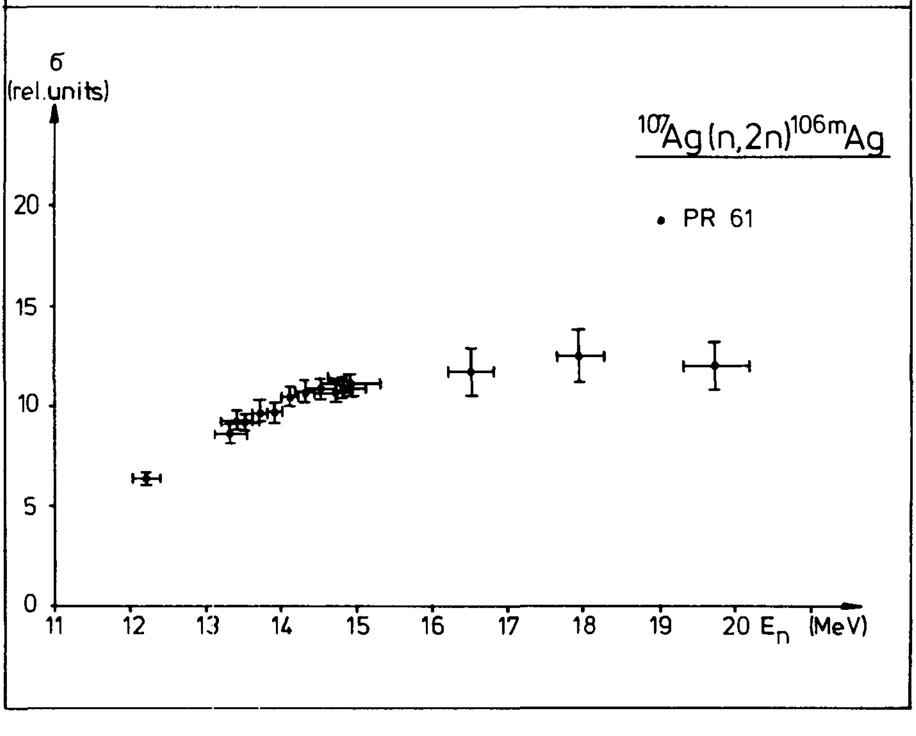
$^{102}Pd(n,2n)^{101}Pd$
• BI 70
σ (mb)
1000
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)



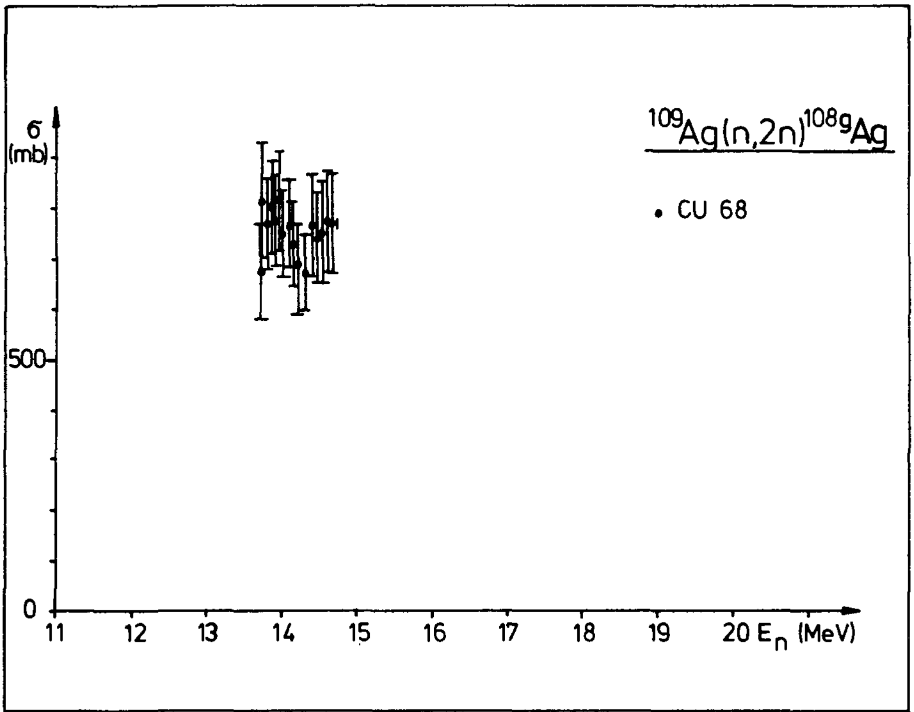
$^{110}Pd(n,2n)^{109m,g}Pd$
• BI 70 (m)
× BI 70 (g)
σ (mb)
1000
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)

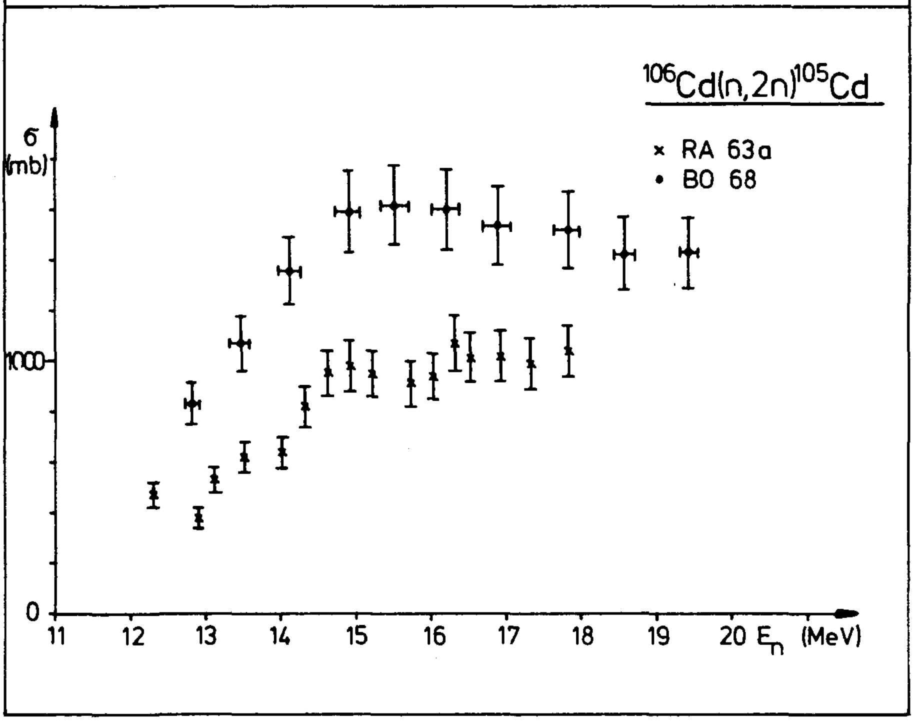


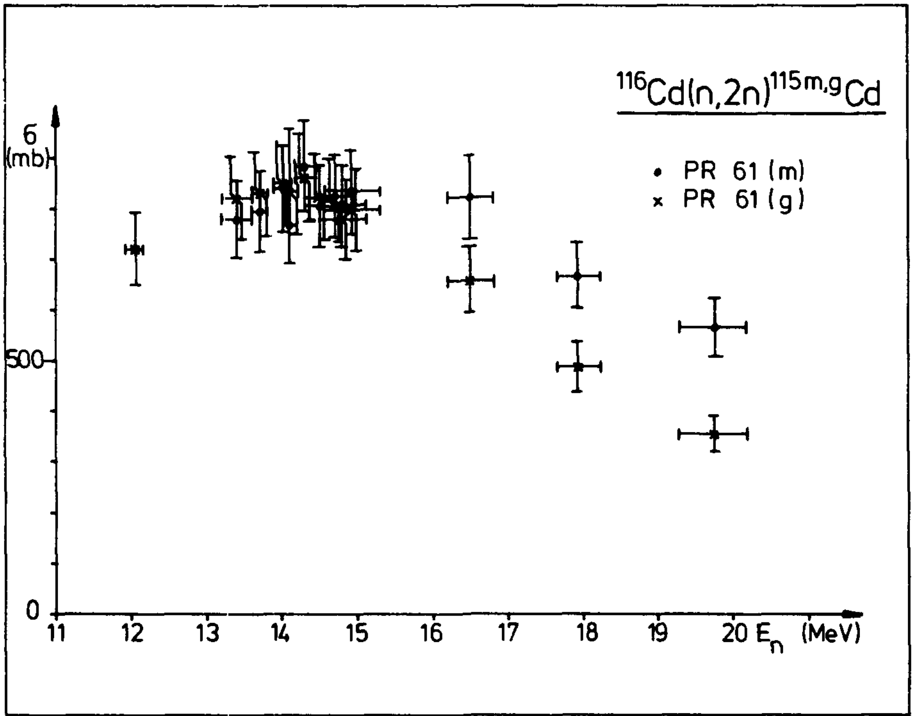
σ (mb)
$^{107}Ag(n,2n)^{106m,g}Ag$
TE 60 (m)
RA 63 (g)
CU 68 (g)
1000
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)



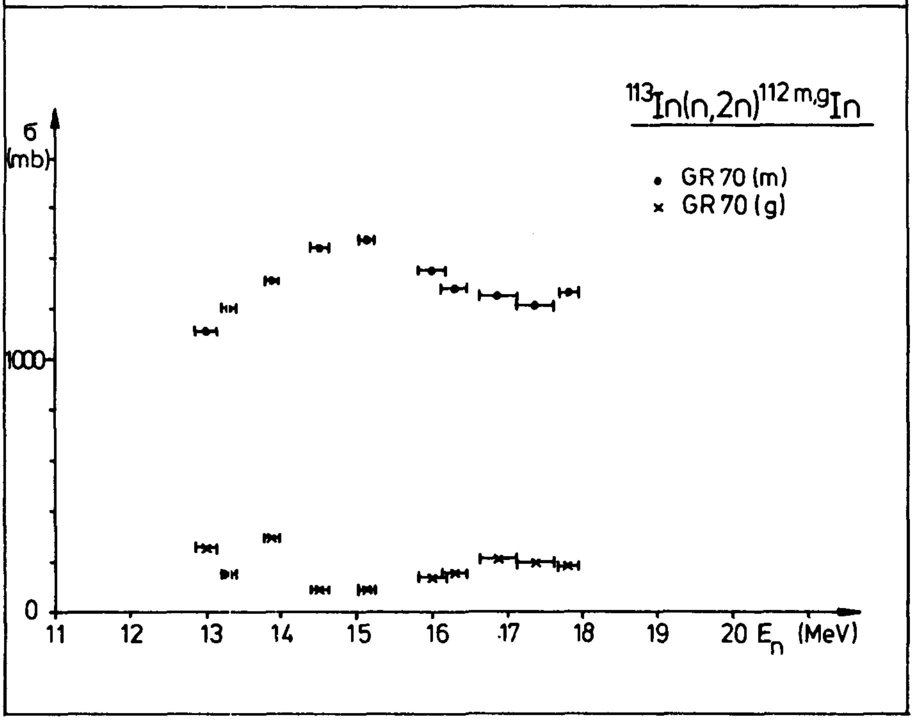
σ (rel.units)
$^{107}Ag(n,2n)^{106m}Ag$
PR 61
20
15
10
5
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)


$^{109}Ag(n,2n)^{108g}Ag$
• CU 68
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

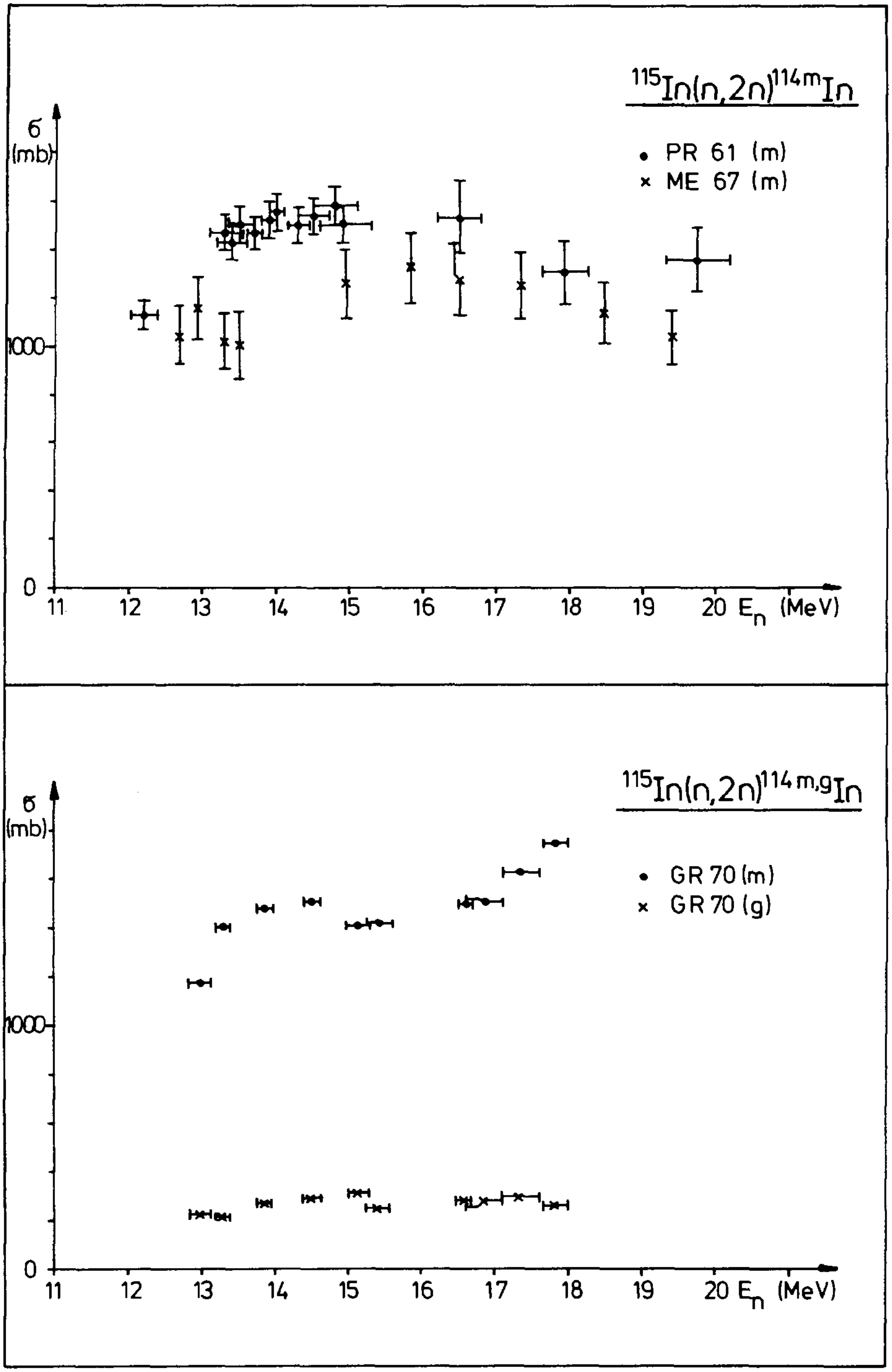

$^{106}Cd(n,2n)^{105}Cd$
× RA 63a
• BO 68
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

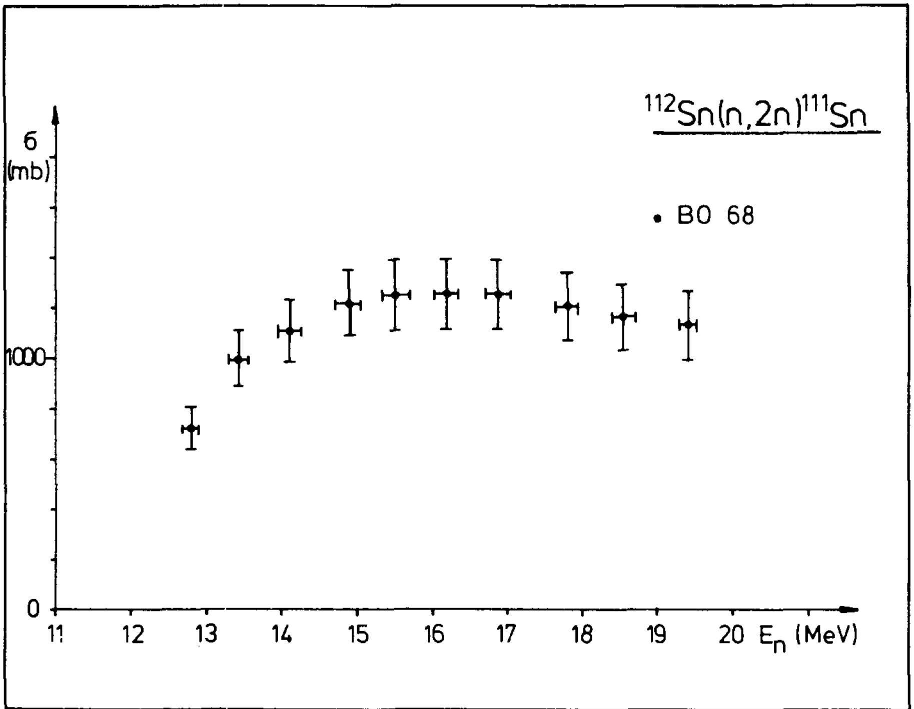


$^{116}Cd(n,2n)^{115m,g}Cd$
• PR 61 (m)
× PR 61 (g)
σ (mb)
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

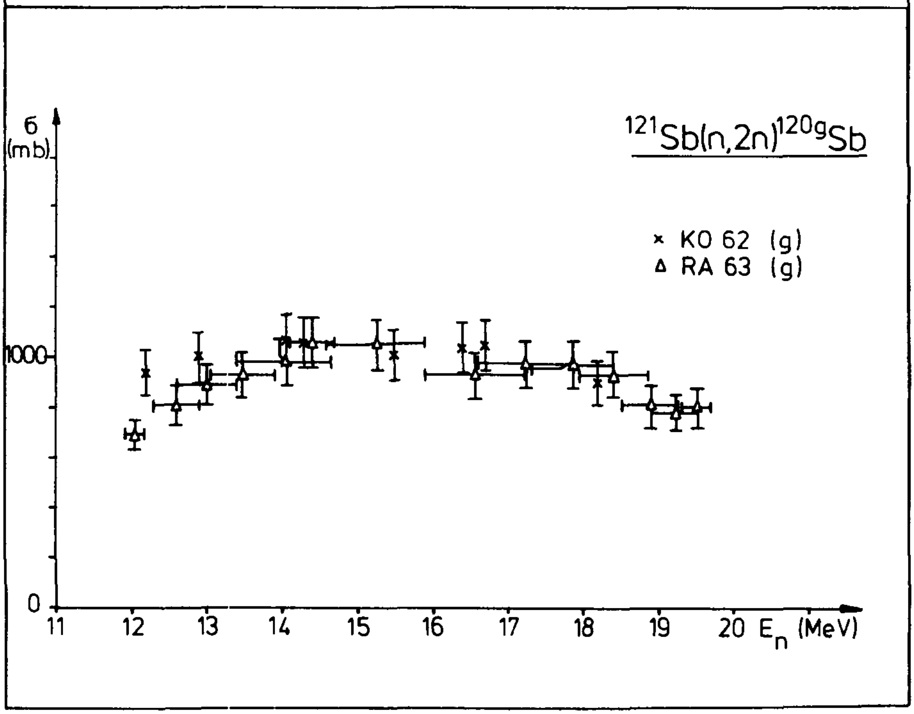


$^{113}In(n,2n)^{112m,g}In$
• GR 70 (m)
× GR 70 (g)
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

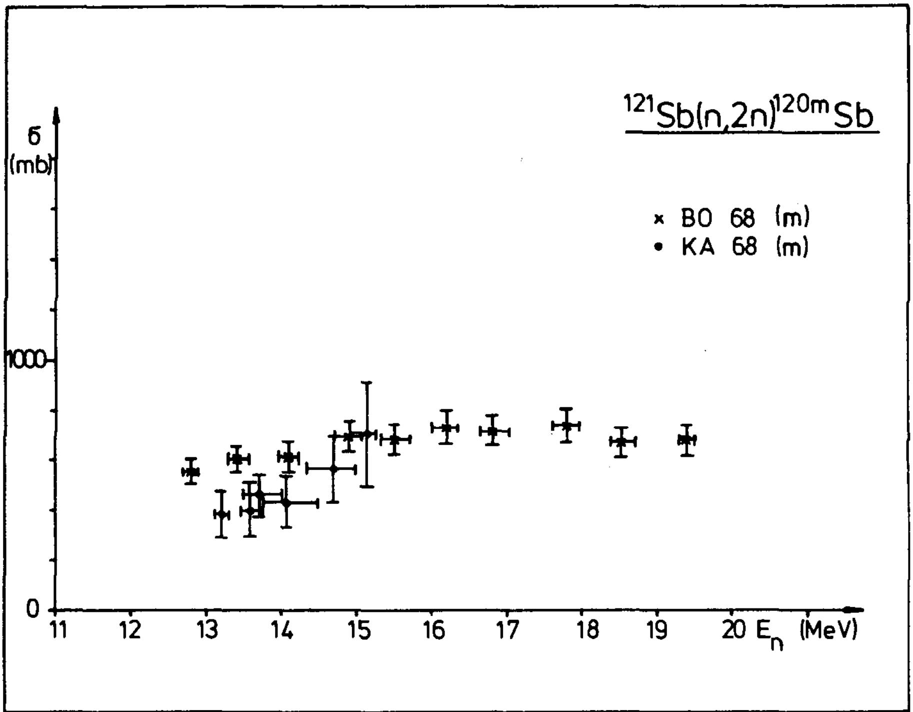

$^{115}In(n,2n)^{114m}In$
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
• PR 61 (m)
× ME 67 (m)
$^{115}In(n,2n)^{114m,g}In$
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
• GR 70 (m)
× GR 70 (g)



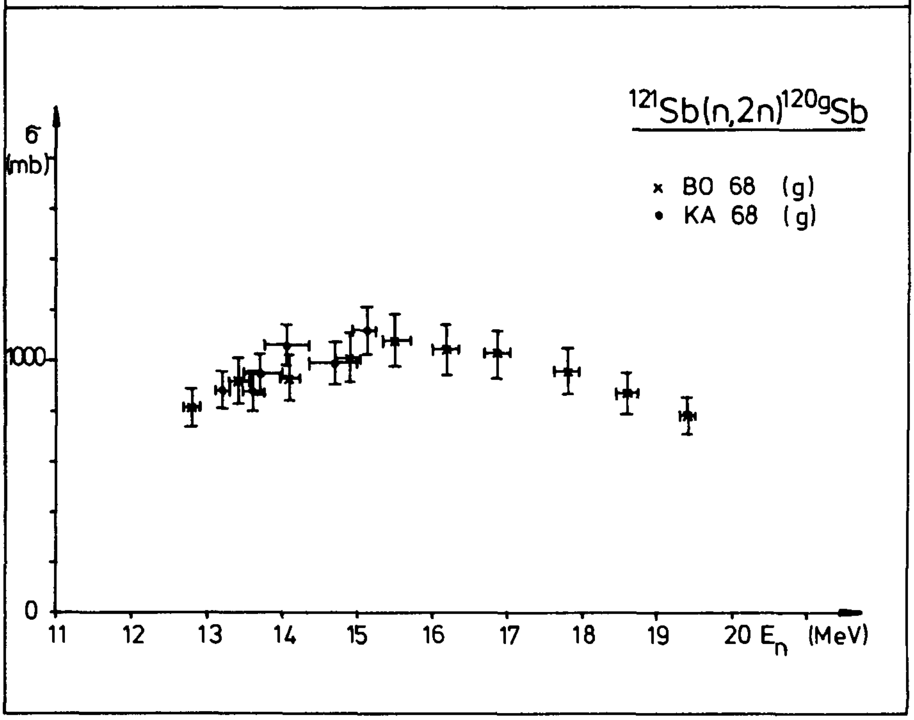
$^{112}Sn(n,2n)^{111}Sn$
σ (mb)
1000
0
• BO 68
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



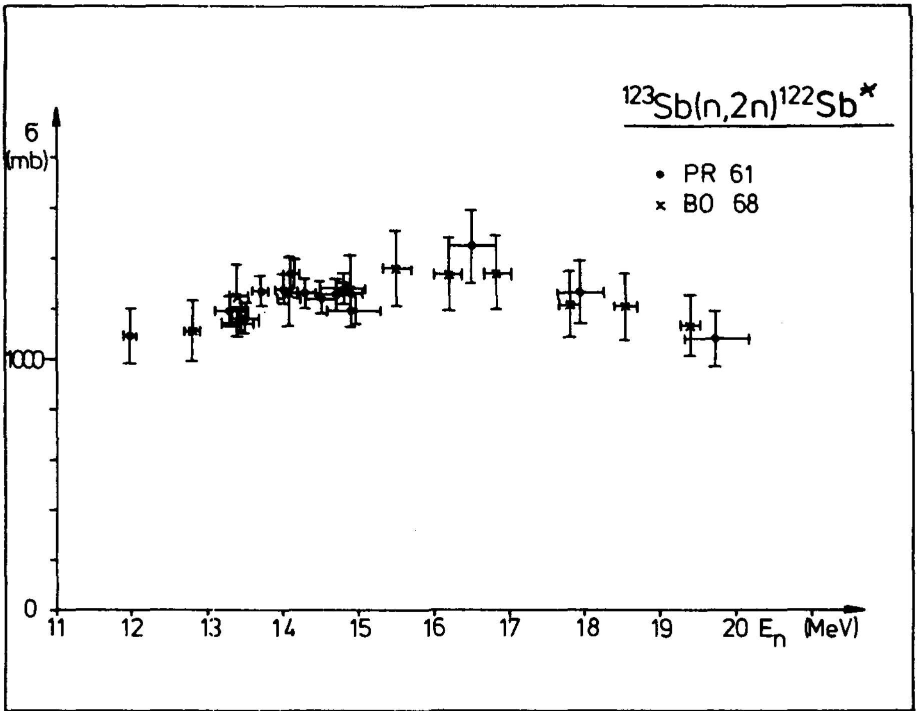
$^{121}Sb(n,2n)^{120g}Sb$
σ (mb)
1000
0
× KO 62 (g)
Δ RA 63 (g)
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

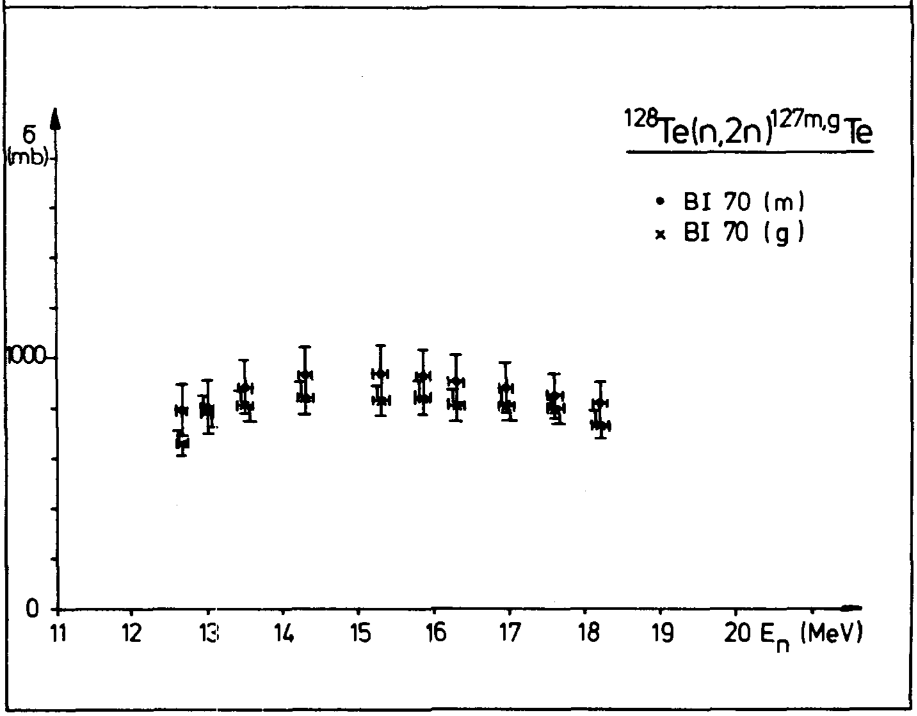


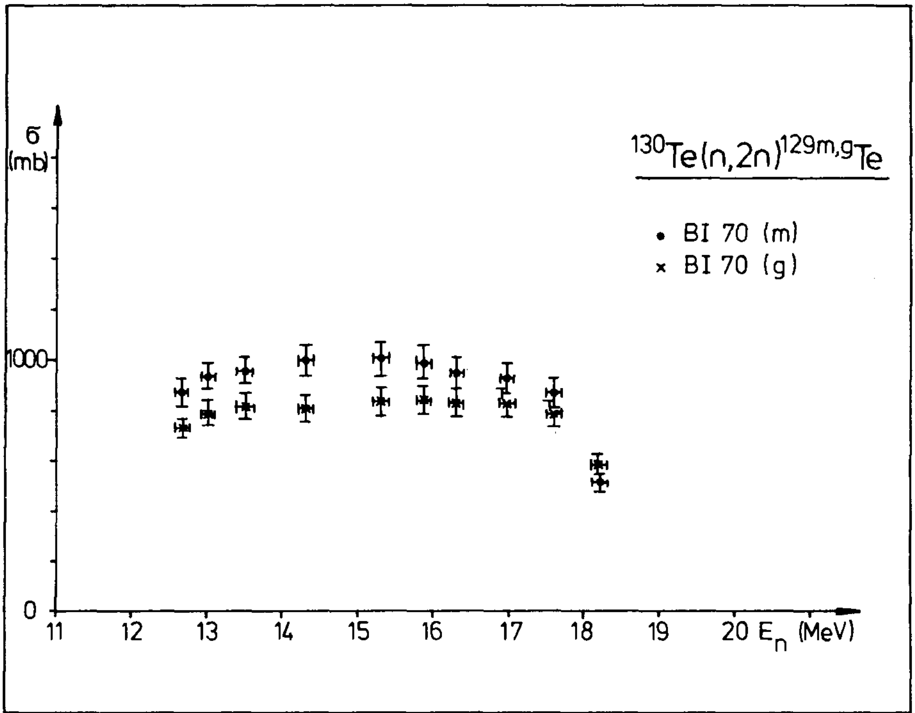
$^{121}Sb(n,2n)^{120m}Sb$
× BO 68 (m)
• KA 68 (m)
σ (mb)
1000
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)



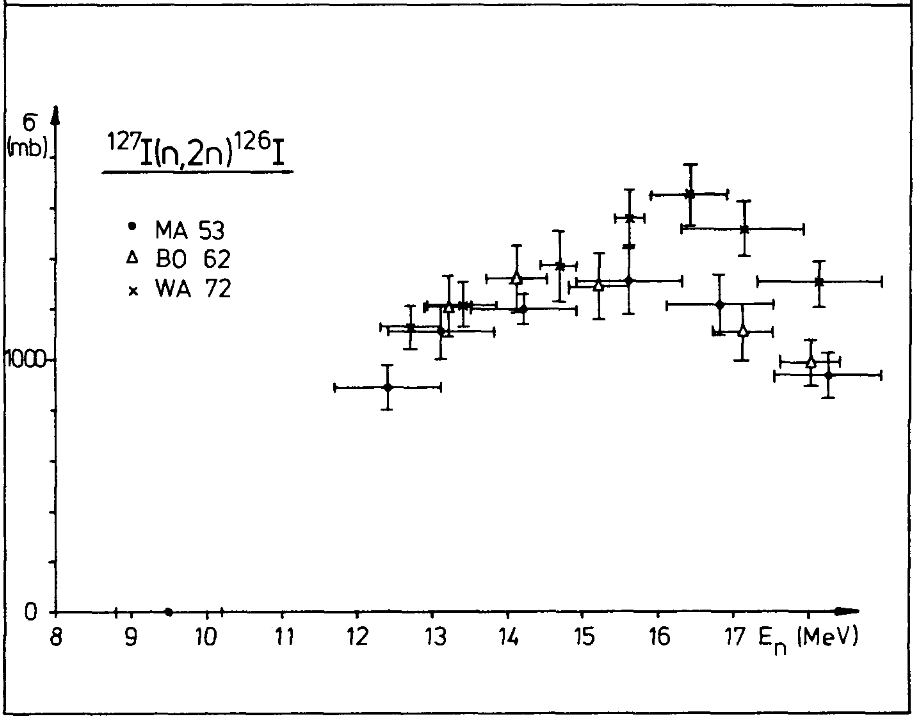
$^{121}Sb(n,2n)^{120g}Sb$
× BO 68 (g)
• KA 68 (g)
σ (mb)
1000
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)


$^{123}Sb(n,2n)^{122}Sb^*$
• PR 61
× BO 68
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

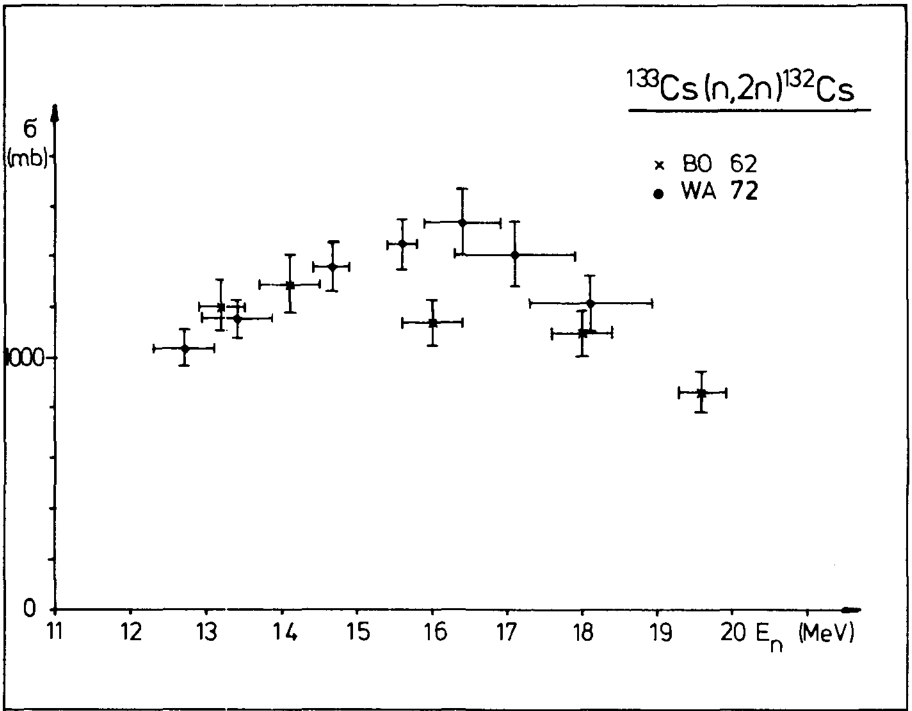

$^{128}Te(n,2n)^{127m,g}Te$
• BI 70 (m)
× BI 70 (g)
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

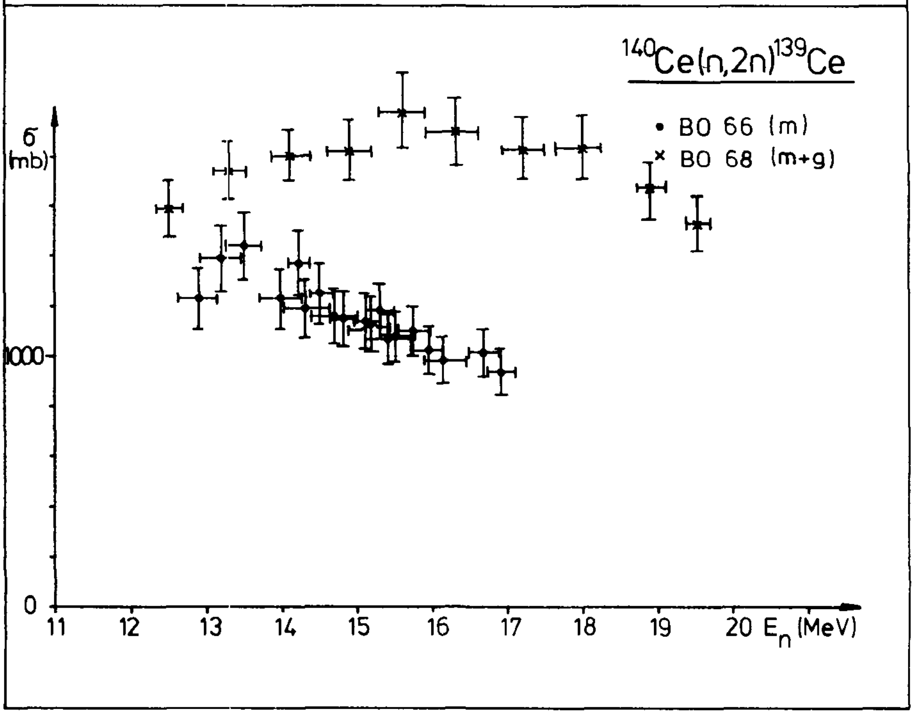


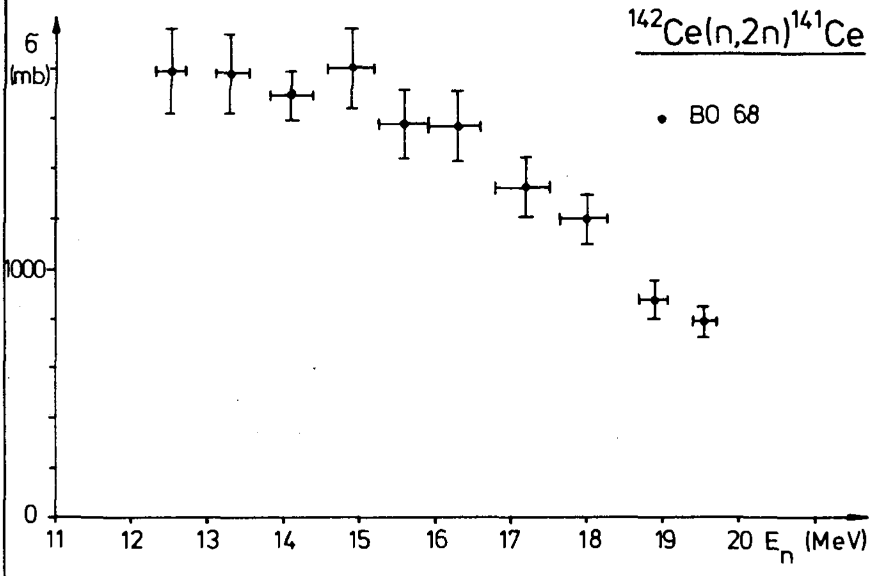
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
130Te(n,2n)129m,gTe
• BI 70 (m)
× BI 70 (g)

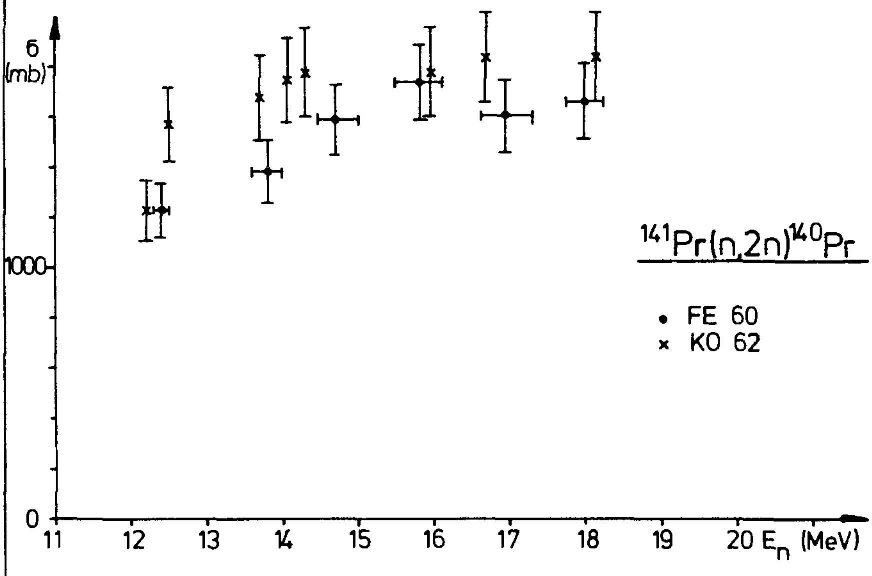


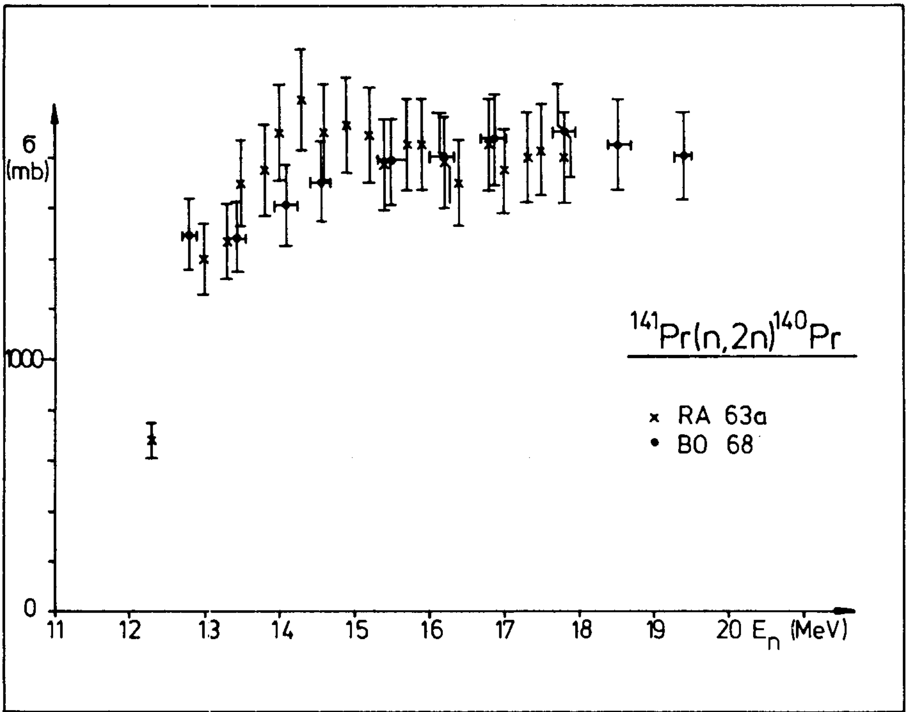
σ (mb)
127I(n,2n)126I
• MA 53
Δ BO 62
× WA 72
1000
0
8 9 10 11 12 13 14 15 16 17 E_n (MeV)


133Cs(n,2n)132Cs
× BO 62
• WA 72
σ (mb)
1000
0
11
12
13
14
15
16
17
18
19
20 En (MeV)

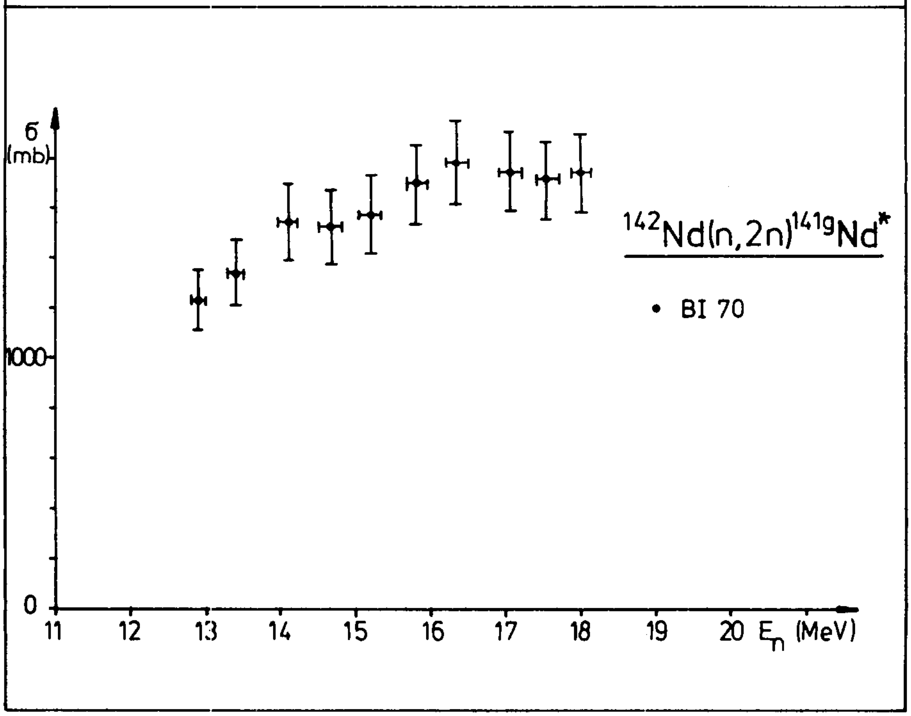

140Ce(n,2n)139Ce
• BO 66 (m)
× BO 68 (m+g)
σ (mb)
1000
0
11
12
13
14
15
16
17
18
19
20 En (MeV)


$^{142}Ce(n,2n)^{141}Ce$
• BO 68
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

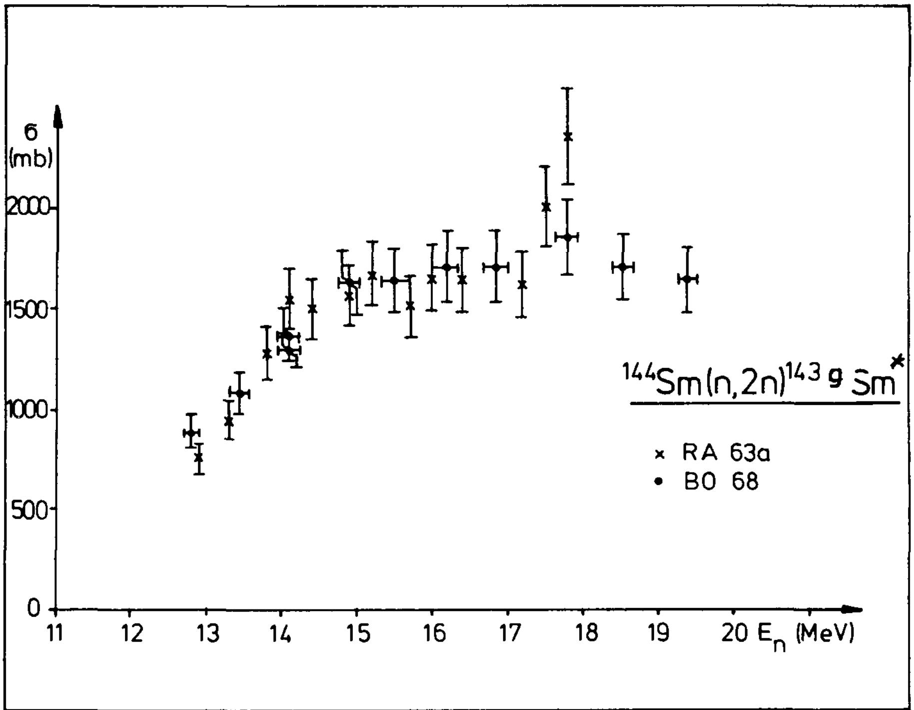

$^{141}Pr(n,2n)^{140}Pr$
• FE 60
× KO 62
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

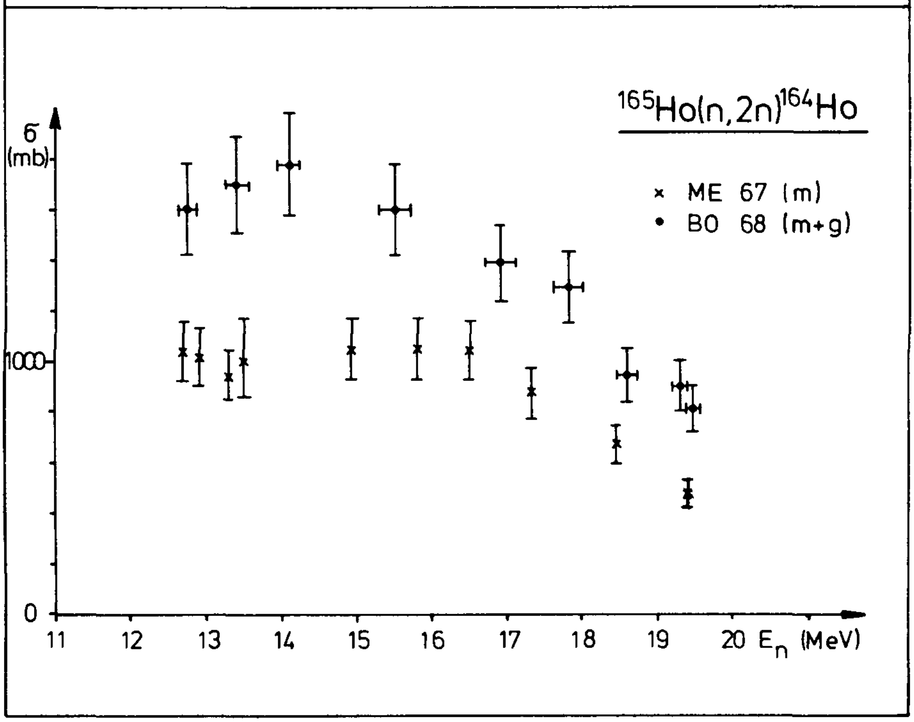


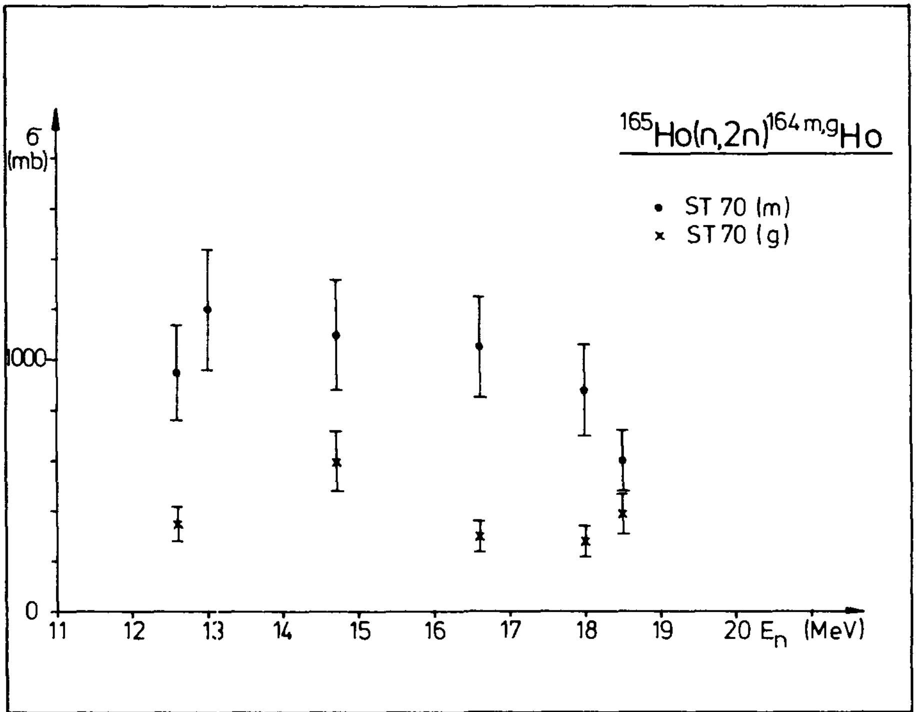
σ
(mb)
1000
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)
^{141}Pr(n,2n)^{140}Pr
× RA 63a
• BO 68

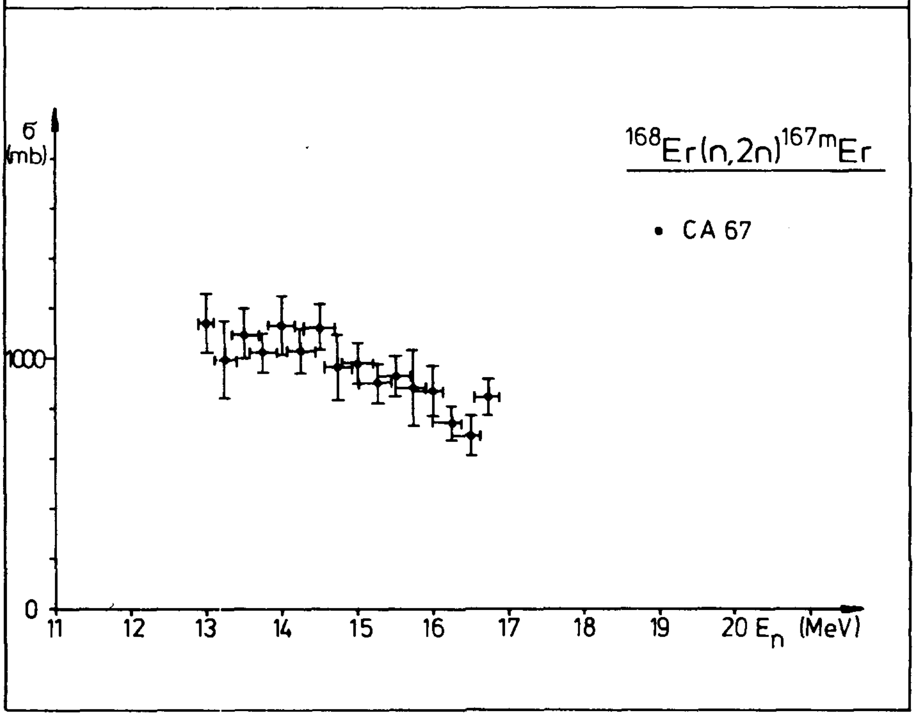


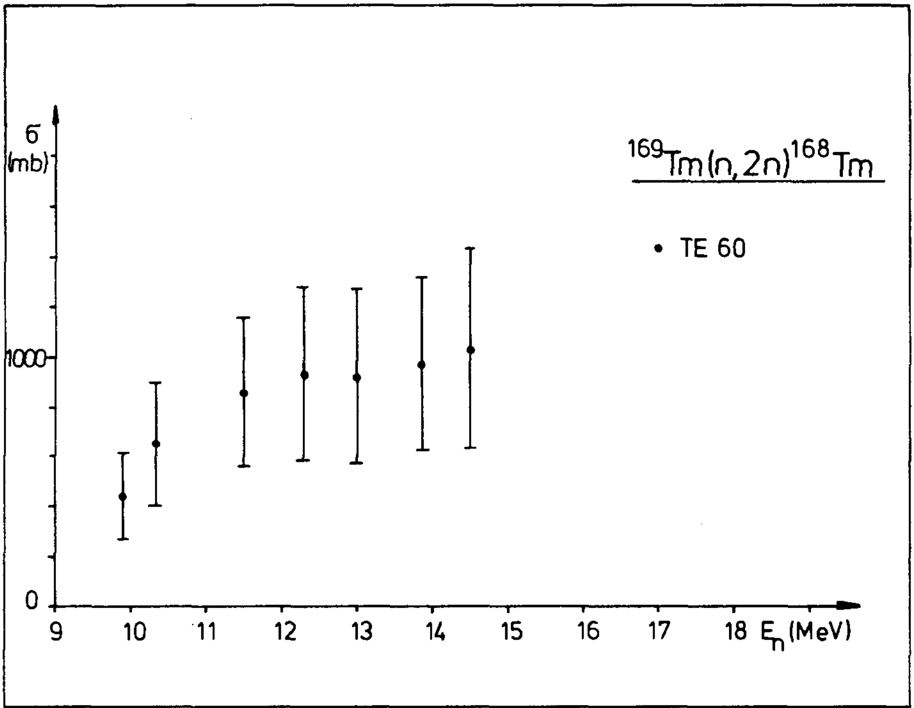
σ
(mb)
1000
0
11
12
13
14
15
16
17
18
19
20 E_n (MeV)
^{142}Nd(n,2n)^{141g}Nd*
• BI 70


σ (mb)
2000
1500
1000
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{144}Sm(n,2n)^{143g}Sm^*$
× RA 63a
• BO 68

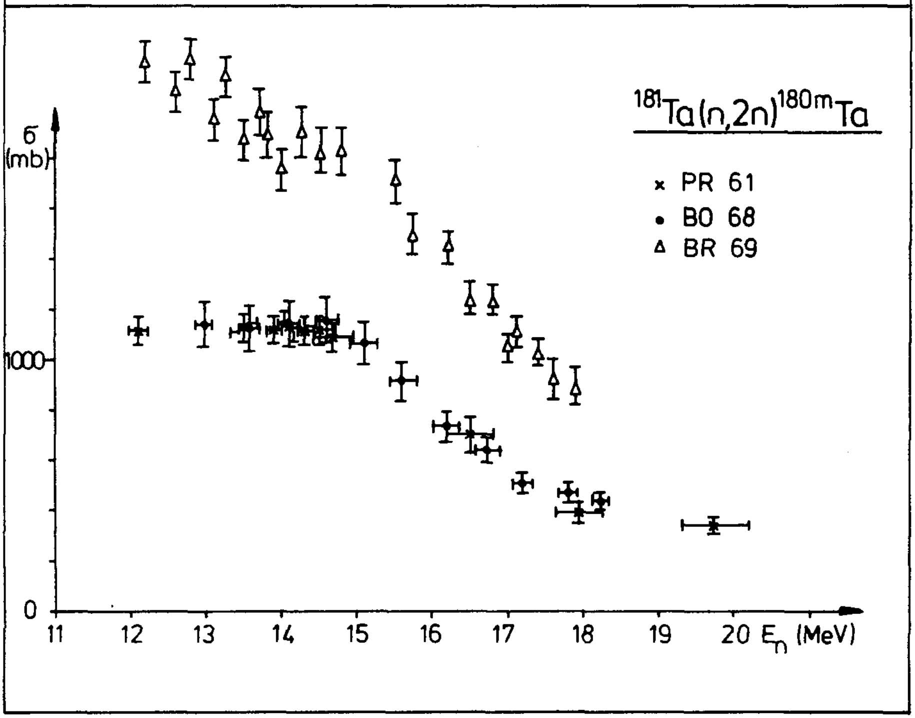

σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{165}Ho(n,2n)^{164}Ho$
× ME 67 (m)
• BO 68 (m+g)


$^{165}Ho(n,2n)^{164m,g}Ho$
• ST 70 (m)
× ST 70 (g)
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

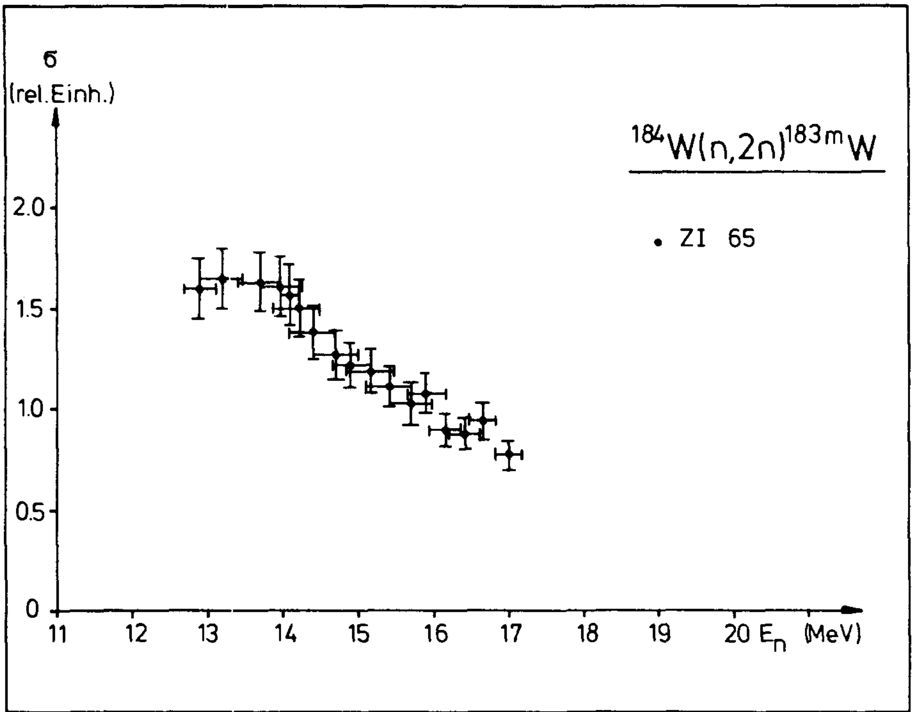

$^{168}Er(n,2n)^{167m}Er$
• CA 67
σ (mb)
1000
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

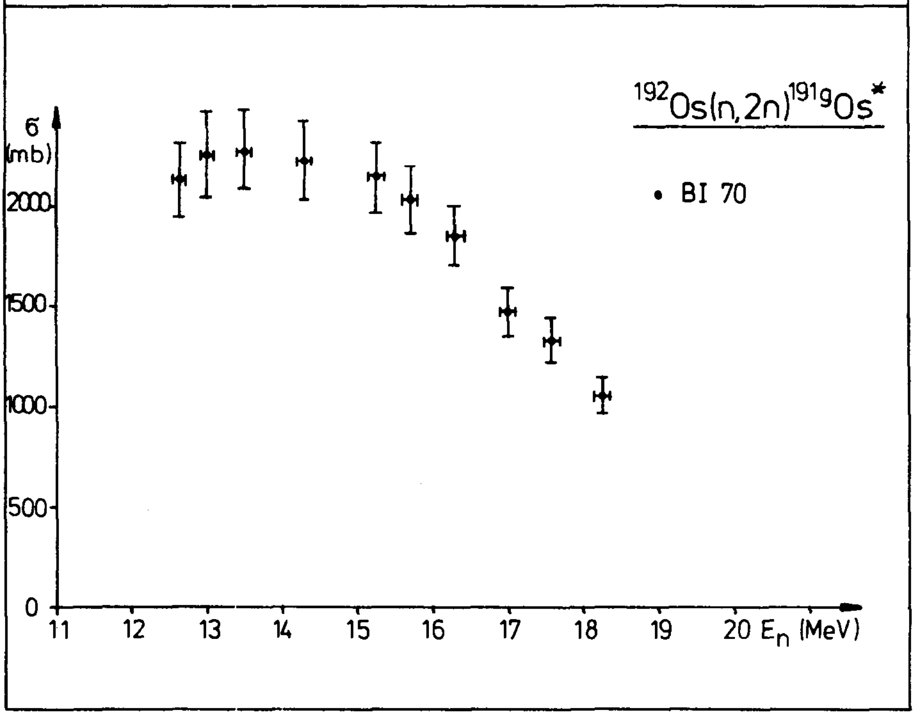


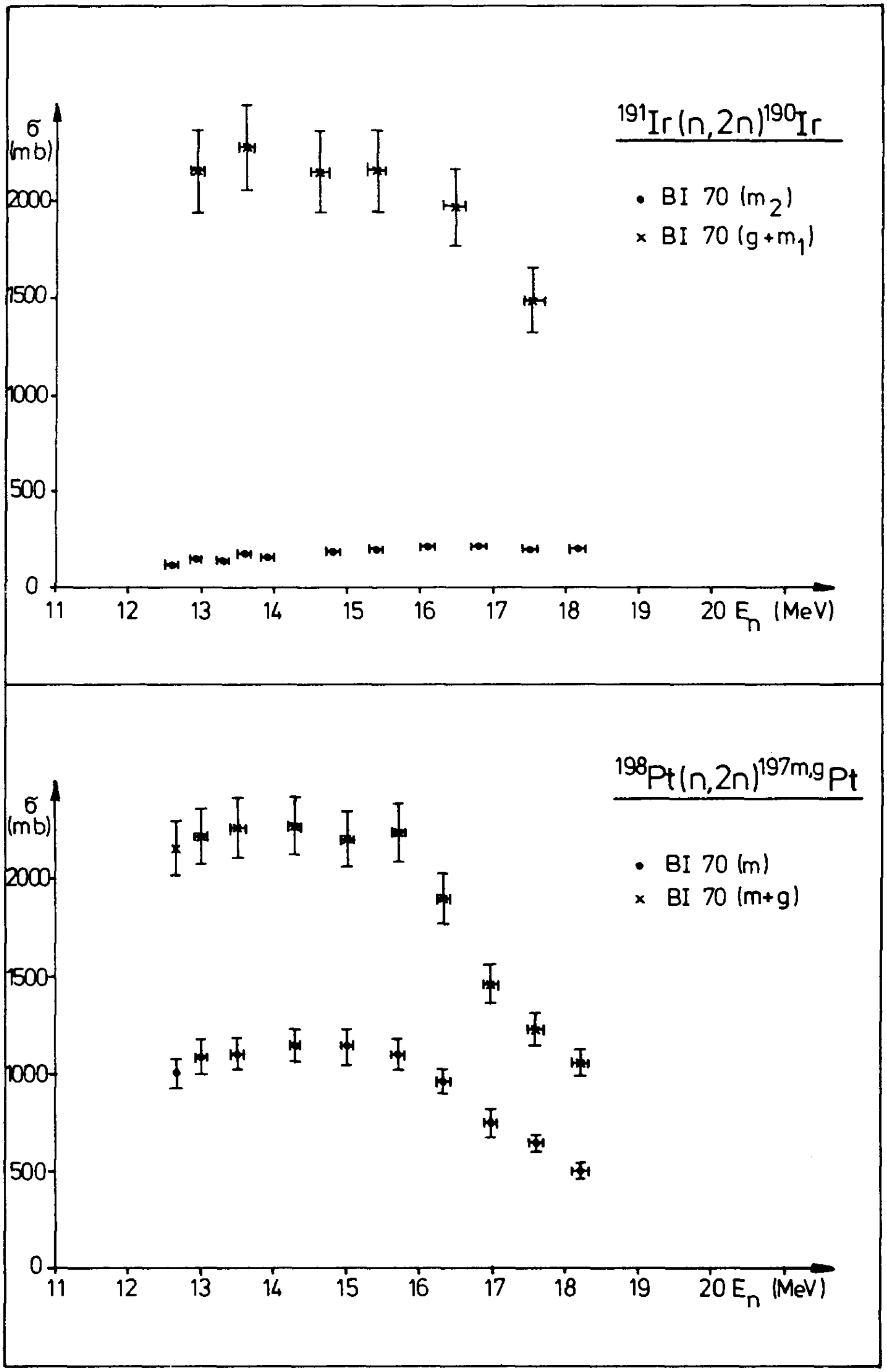
б
(mb)
^{169}Tm(n,2n)^{168}Tm
• TE 60
1000
0
9
10
11
12
13
14
15
16
17
18
E_n (MeV)



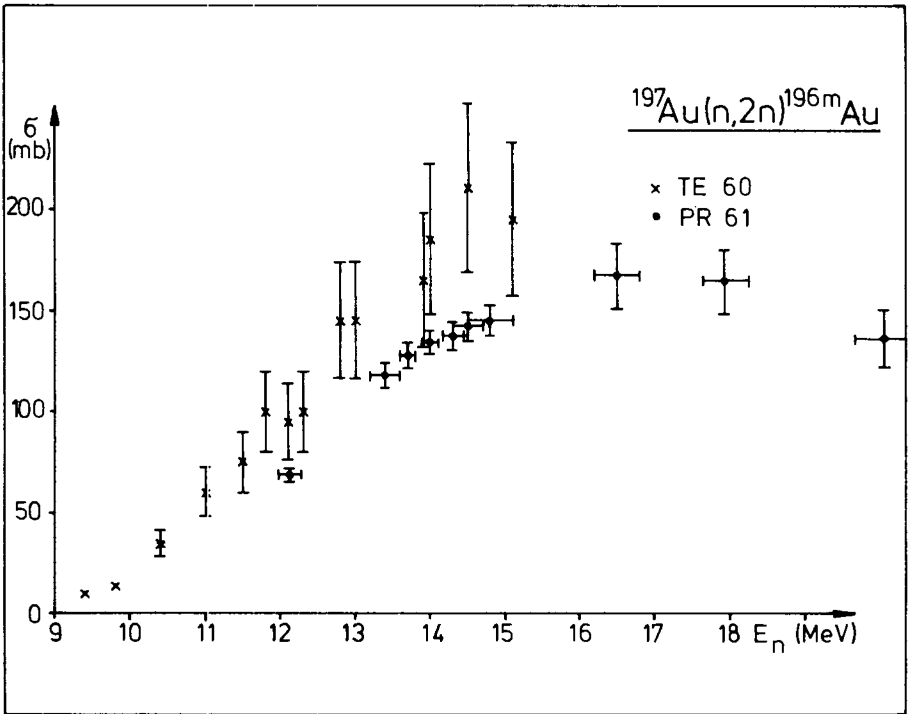
б
(mb)
^{181}Ta(n,2n)^{180m}Ta
× PR 61
• BO 68
Δ BR 69
1000
0
11
12
13
14
15
16
17
18
19
20
E_n (MeV)


σ
(rel.Einh.)
$^{184}W(n,2n)^{183m}W$
• ZI 65
2.0
1.5
1.0
0.5
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)

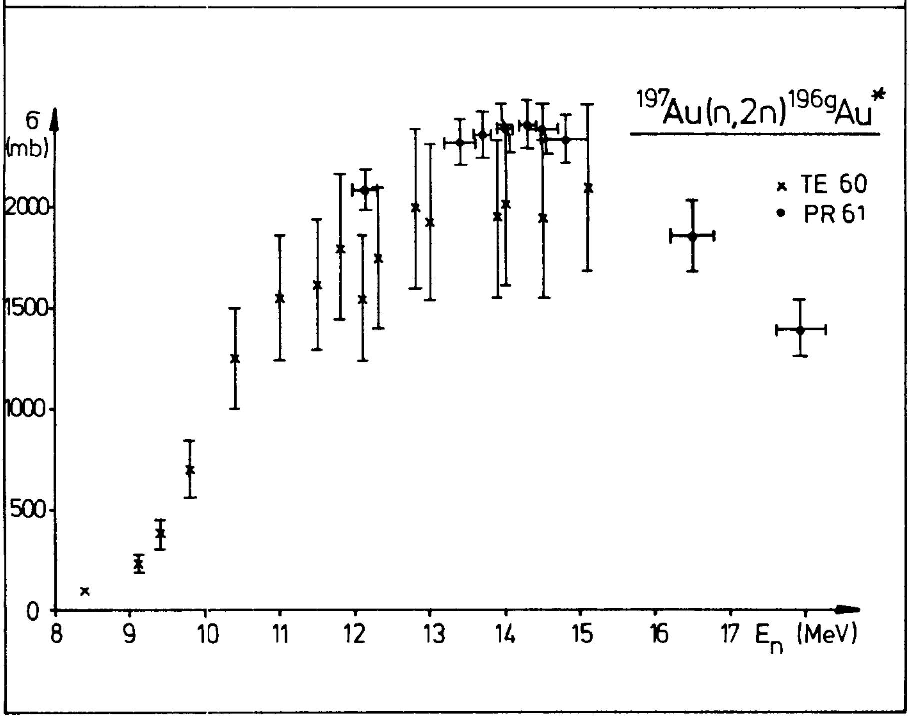

$^{192}Os(n,2n)^{191g}Os^*$
• BI 70
σ
(mb)
2000
1500
1000
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)



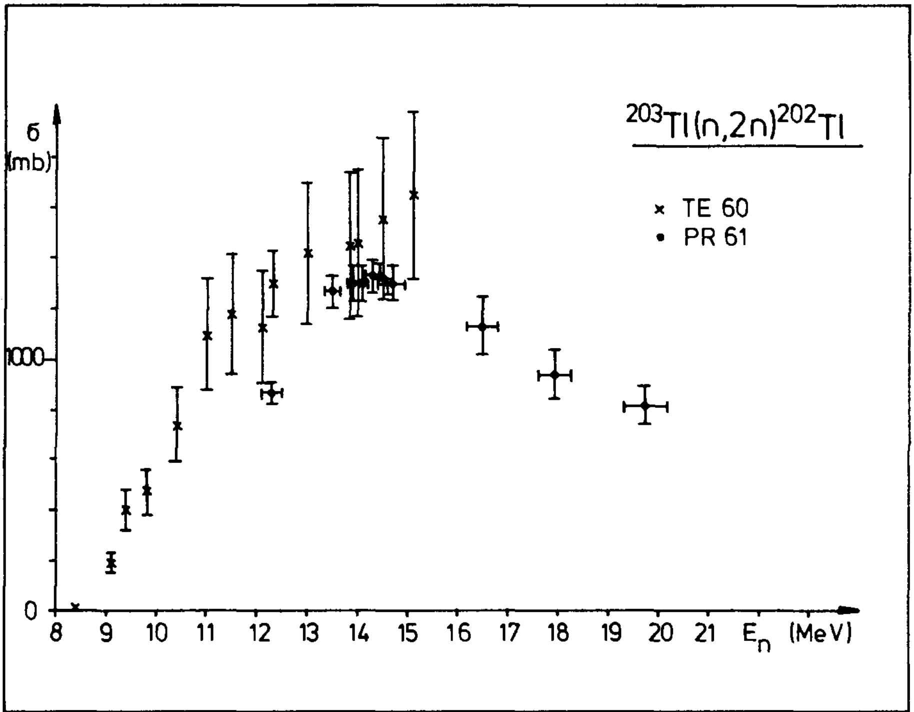
^{191}Ir(n,2n)^{190}Ir
• BI 70 (m$_2$)
× BI 70 (g+m$_1$)
σ (mb)
0
500
1000
1500
2000
11 12 13 14 15 16 17 18 19 20 E$_n$ (MeV)
^{198}Pt(n,2n)^{197m,g}Pt
• BI 70 (m)
× BI 70 (m+g)
σ (mb)
0
500
1000
1500
2000
11 12 13 14 15 16 17 18 19 20 E$_n$ (MeV)



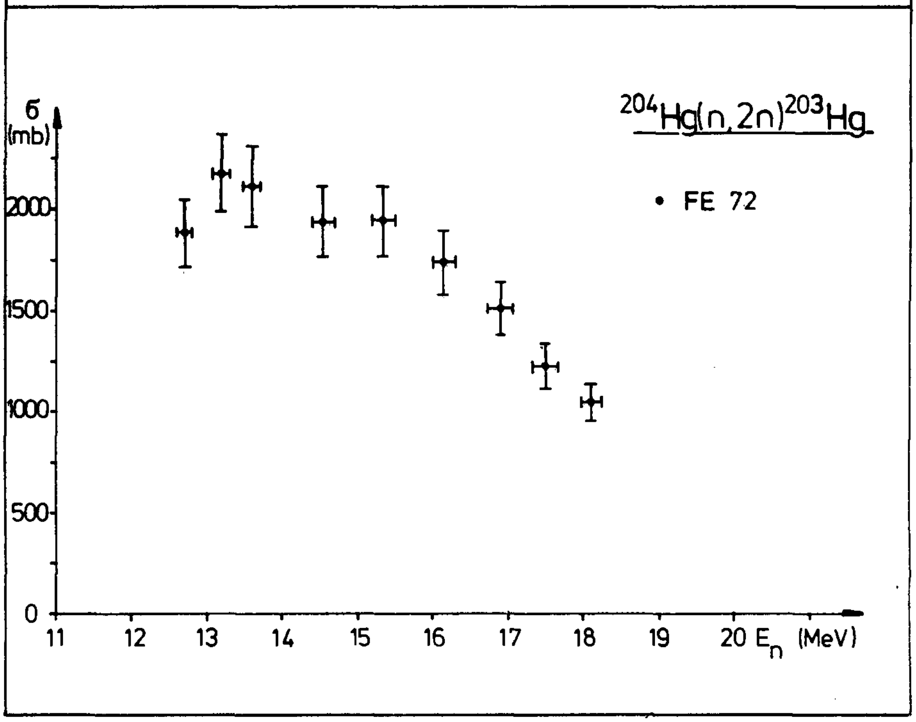
$^{197}Au(n,2n)^{196m}Au$
× TE 60
• PR 61
σ (mb)
0
50
100
150
200
9
10
11
12
13
14
15
16
17
18
E_n (MeV)



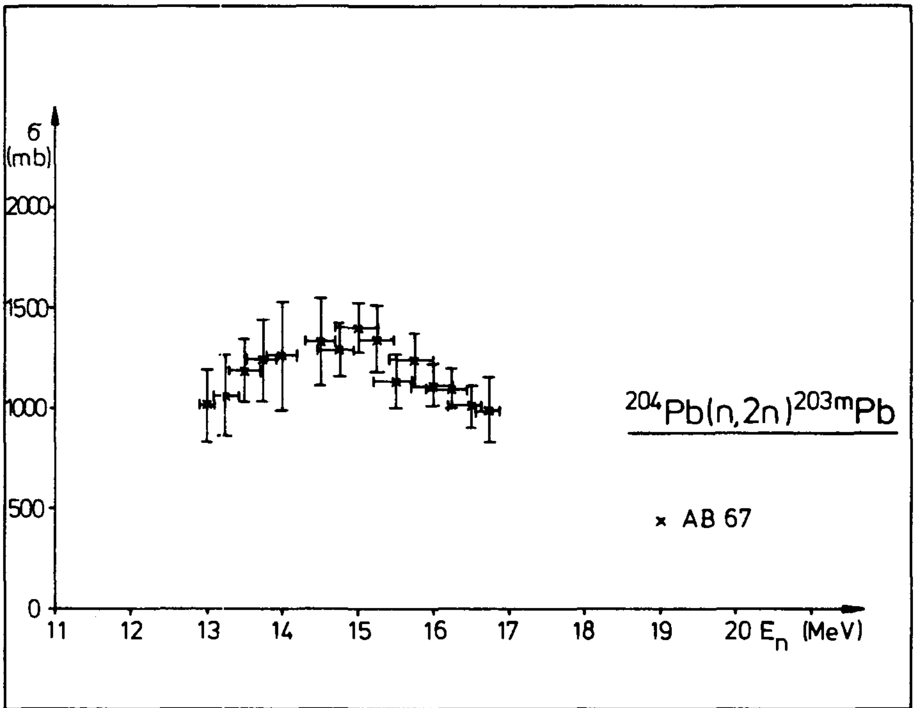
$^{197}Au(n,2n)^{196g}Au^*$
× TE 60
• PR 61
σ (mb)
0
500
1000
1500
2000
8
9
10
11
12
13
14
15
16
17
E_n (MeV)

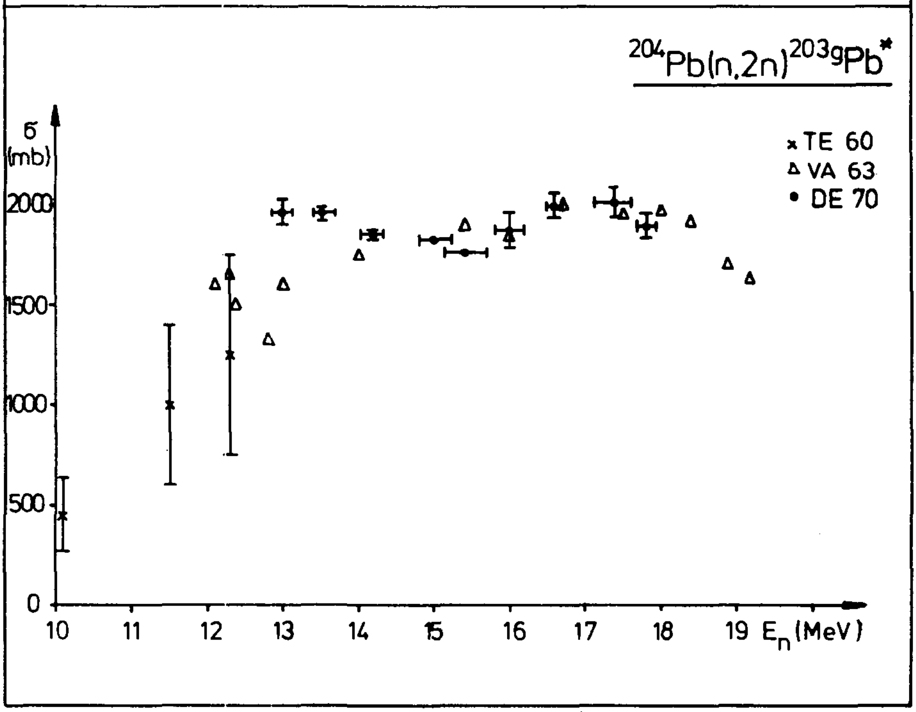


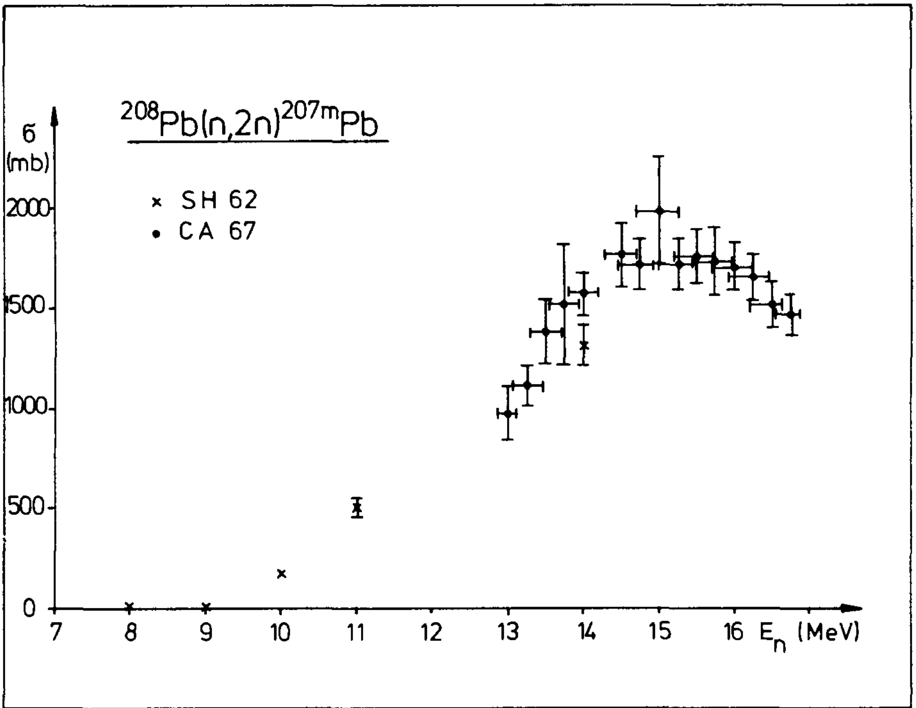
^{203}Tl(n,2n)^{202}Tl
× TE 60
• PR 61
σ (mb)
1000
0
8 9 10 11 12 13 14 15 16 17 18 19 20 21 E_n (MeV)



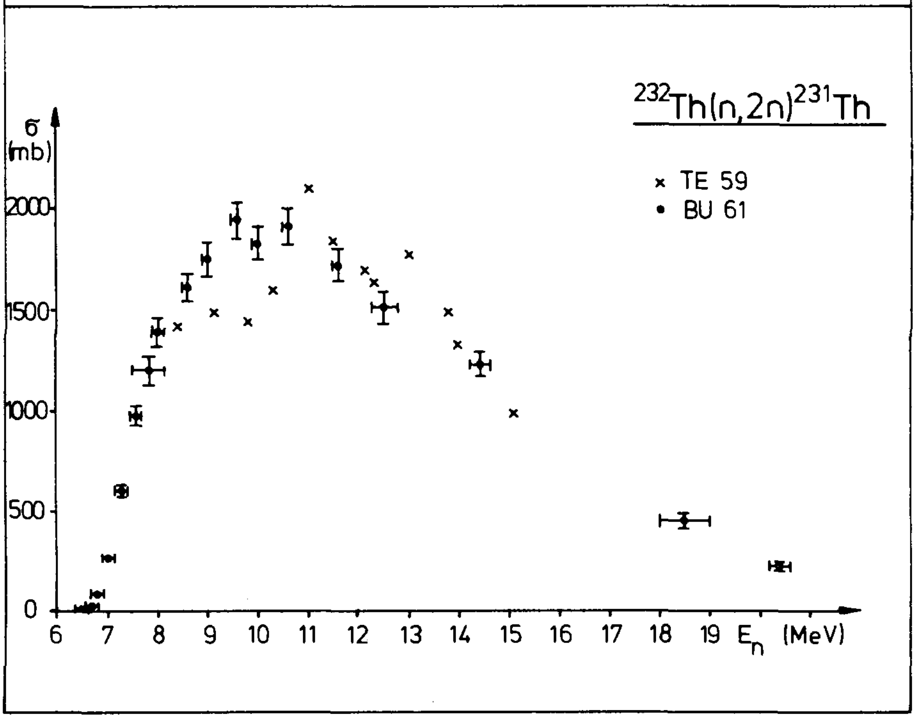
^{204}Hg(n,2n)^{203}Hg
• FE 72
σ (mb)
2000
1500
1000
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


σ (mb)
2000
1500
1000
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)
$^{204}Pb(n,2n)^{203m}Pb$
× AB 67

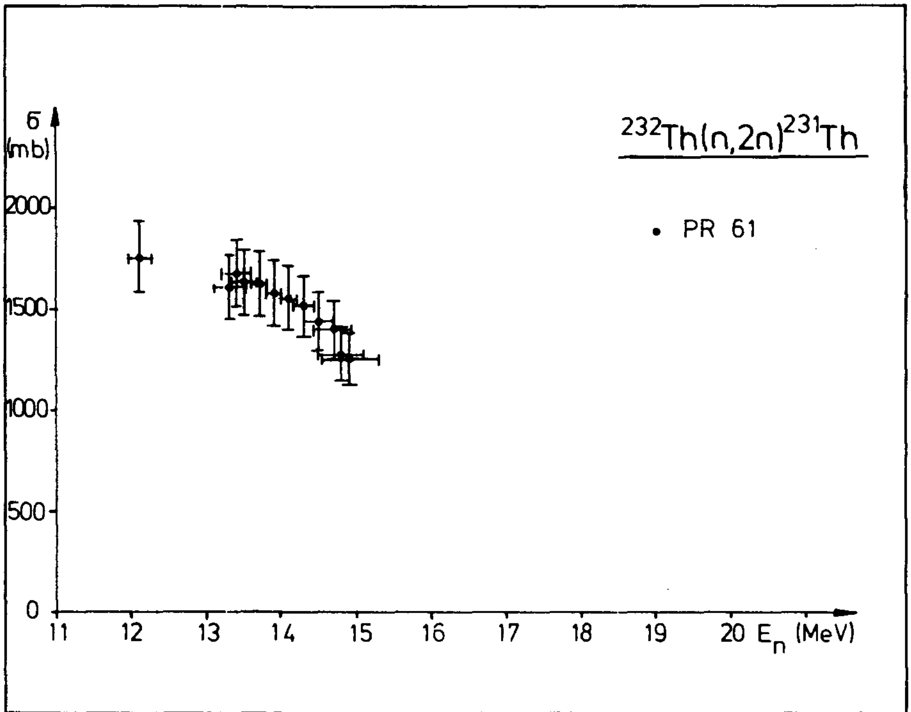

$^{204}Pb(n,2n)^{203g}Pb^*$
σ (mb)
2000
1500
1000
500
0
10 11 12 13 14 15 16 17 18 19 E_n (MeV)
× TE 60
Δ VA 63
• DE 70

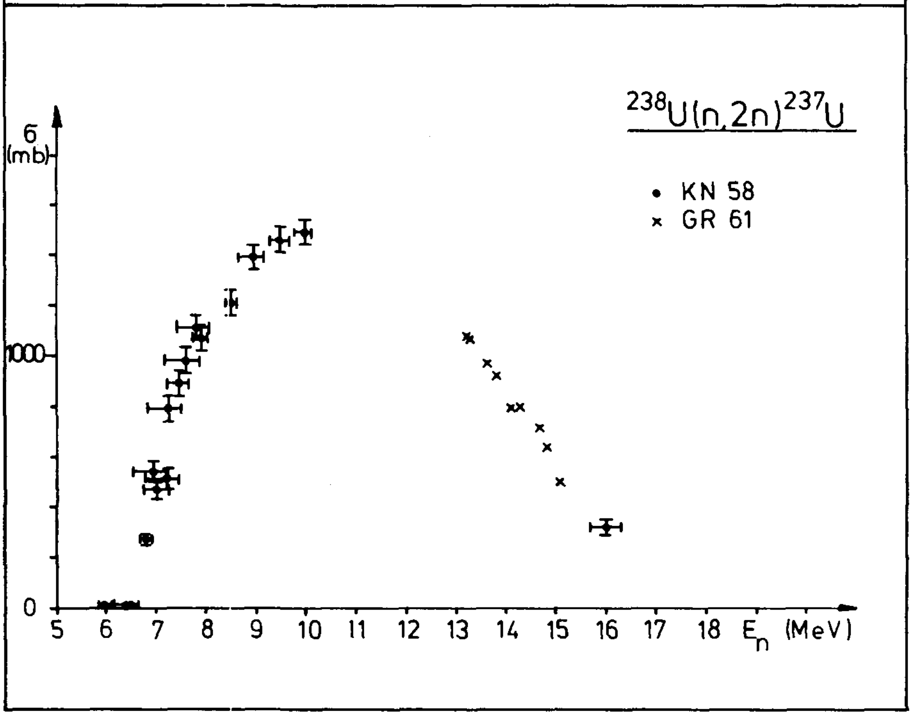


$^{208}Pb(n,2n)^{207m}Pb$
σ (mb)
2000
1500
1000
500
0
7 8 9 10 11 12 13 14 15 16 E_n (MeV)
× SH 62
• CA 67



$^{232}Th(n,2n)^{231}Th$
σ (mb)
2000
1500
1000
500
0
6 7 8 9 10 11 12 13 14 15 16 17 18 19 E_n (MeV)
× TE 59
• BU 61


$^{232}Th(n,2n)^{231}Th$
• PR 61
σ (mb)
2000
1500
1000
500
0
11 12 13 14 15 16 17 18 19 20 E_n (MeV)


$^{238}U(n,2n)^{237}U$
• KN 58
× GR 61
σ (mb)
1000
0
5 6 7 8 9 10 11 12 13 14 15 16 17 18 E_n (MeV)

REFERENCES TO GRAPHS

AB 67 ABELS, C., BORMANN, M., CARSTENS, W., Rep. EANDC(E)76"U", NEA, Paris (1967) 51.

AB 69 ABBOUD, A., DECOWSKI, P., GROCHULSKI, W., MARCINKOWSKI, A., PIOTROWSKI, J., SIWEK, K., WILHELMI, Z., Nucl. Phys. A139 (1969) 42.

AB 69a ABBOUD, A., DECOWSKI, P., GROCHULSKI, W., MARCINKOWSKI, A., SIWEK, K., TURKIEWICZ, I., WILHELMI, Z., Rep. IBJ 1147/I/PL (1969).

AD 53 ADLER, H., HUBER, P., HÄLG, W., Helv. Phys. Acta 26 (1953) 349.

AG 62 AGODI, A., PAPPALARDO, G., RICAMO, R., VINLIGUERRA, D., Nuovo Cim. X23 (1962) 1136.

AL 57 ALLEN, L., Jr., BIGGERS, W.A., PRESTWOOD, R.J., SMITH, R.K., Phys. Rev. 107 (1957) 1363.

AN 68 ANDREEV, M.F., SEROV, V.I., Sov. J. Nucl. Phys. 7 (1968) 454.

AR 56 ARMSTRONG, A.H., FREYE, G.M., Phys. Rev. 103 (1956) 335.

AR 64 ARNOLD, D.M., RAYBURN, L.A., Bull. Am. Phys. Soc. 9 (1964) 352.

BA 55 BATCHELOR, R., AVES, R., SKYRME, T.H.R., Rev. Sci. Instrum. 26 (1955) 1037.

BA 59 BARRY, J., COLEMAN, R., HAWKER, B., PERKIN, J., Proc. Phys. Soc. 74 (1959) 632.

BA 61 BAYHURST, B.P., PRESTWOOD, R.J., J. Inorg. Nucl. Chem. 23 (1961) 173.

BA 61a BASS, R., BONNER, T.W., HAENNI, H.P., Nucl. Phys. 23 (1961) 122.

BA 62 BARRY, J., J. Nucl. Energy AB 16 (1962) 467.

BA 63 BARRY, J., J. Nucl. Energy AB 17 (1963) 273.

BA 64 BASS, R., FANGER, U., SALEH FATMA, M., Nucl. Phys. 56 (1964) 569.

BA 65 BASS, R., KRÜGER, K., STAGINNUS, B., HAUG, P., Rep. EANDC(E)66"U", NEA, Paris (1966) 64.

BA 65a BASS, R., BINDHARDT, C., KRÜGER, K., Rep. EANDC(E)57"U", NEA, Paris (1965) 1.

BI 63 BIRK, M., GOLDRING, G., HILLMAN, P., Nucl. Instrum. Methods 21 (1963) 197.

BI 70 BISSEM, H.H., BORMANN, M., MAGIERA, E., WARNEMÜNDE, R., Nucl. Phys. A157 (1970) 481.

BO 55 BOSTROM, N.A.; HUDSPETH, E.L., MORGAN, I.L., Phys. Rev. 99 (1955) 643 A.

BO 61 BORMANN, M., CIERJACKS, S., LANGKAU, R., NEUERT, H., POLLEHN, H., J. Phys. Rad. 22 (1961) 602.

BO 62 BORMANN, M., CIERJACKS, S., LANGKAU, R., NEUERT, H., Z. Phys. 166 (1962) 477.

BO 62a BORMANN, M., Z. Naturforsch. 17a (1962) 479.

BO 63 BORMANN, M., CIERJACKS, S., FRETWURST, E., GIESECKE, K.-J., NEUERT, H., POLLEHN, H., Z. Phys. 174 (1963) 1.

BO 64 BONAZZOLA, G.C., BROUETTO, P., CHIAVASSA, E., SPINOGLIO, R., PASQUARELLI, A., Nucl. Phys. 51 (1964) 337.

BO 65 BORMANN, M., FRETWURST, E., SCHEHKA, P., WREGE, G., BÜTTNER, H., LINDNER, A., MELDNER, H., Nucl. Phys. 63 (1965) 438.

BO 65a BORMANN, M., SCHEHKA, P., DREYER, F., FRETWURST, E., Rep. EANDC(E)57"U", NEA, Paris (1965) 17.

BO 66 BORMANN, M., DREYER, F., ZIELINSKI, U., Rep. EANDC(E)66"U", NEA, Paris (1966) 42.

BO 66a BORMANN, M., DREYER, F., SEEBECK, U., VOIGTS, W., Z. Naturforsch. 21a (1966) 988.

BO 67 BORMANN, M., DREYER, F., NEUERT, H., RIEHLE, I., ZIELINSKI, U., Nuclear Data for Reactors – 1966 (Proc. Conf. Paris, 1966) 1, IAEA, Vienna (1967) 225.

BO 68 BORMANN, M., BEHREND, A., RIEHLE, I., VOGEL, O., Nucl. Phys. A115 (1968) 309.

BO 69 BORMANN, M., LAMMERS, B., Nucl. Phys. A130 (1969) 195.

BR 52 BROLLEY, J.E., FOWLER, J.L., SCHLACKS, L.K., Phys. Rev. 88 (1952) 618.

BR 61 BRILL, O.D., VLASOV, N.A., KALININ, S.P., SOKOLOV, L.S., Sov. Phys. – Dokl. 6 (1961) 24.

BR 69 BRZOSKO, J., GIERUK, E., SOLTAN, A., WILHELMI, Z., Nucl. Phys. A123 (1969) 603.

BU 61 BUTLER, J.P., SANTRY, D.C., Can. J. Chem. 39 (1961) 689.

BU 63 BUTLER, J.P., SANTRY, D.C., Can. J. Phys. 41 (1963) 372.

CA 62 CALVI, G., POTENZA, R., RICAMO, R., VINCIGUERRA, D., Nucl. Phys. 39 (1962) 621.

CA 64 CARROLL, E.E., Jr., SMITH, G.C., STOOKSBERRY, R.W., Trans. Am. Nucl. Soc. 7 (1964) 268.

CA 65 CARROLL, E.E., Jr., SMITH, G.C., Nucl. Sci. Eng. 22 (1965) 411.

CA 67 CARSTENS, W., Diplomarbeit, Hamburg (1967).

CH 65 CHOJNACKI, S., Int. Conf. Study of Nuclear Structure with Neutrons, Antwerp (1965).

CH 65a CHOJNACKI, S., DECOWSKI, P., GIERUK, E., GROCHULSKI, W., MARCINKOWSKI, A., SIWEK, K., SLEDZINSKA, I., WILHELMI, Z., Int. Conf. Study of Nuclear Structure with Neutrons, Antwerp (1965).

CI 62 CIERJACKS, S., Diplomarbeit, Hamburg (1962).

CO 50 COON, J.H., Phys. Rev. 80 (1950) 488.

CO 56 COHEN, A.V., WHITE, P.H., Nucl. Phys. 1 (1956) 73.

CR 60 McCRARY, J.H., MORGAN, I.L., Bull. Am. Phys. Soc. 5 (1960) 246.
CR 62 CROSS, W.G., CLARKE, R.L., Prog. Rep. AECL-1542 (1962).
CR 69 CRUMPTON, D., COX, A.J., COOPER, P.N., FRANÇOIS, P.E., HUNT, S.E., J. Inorg. Nucl. Chem. 31 (1969) 1.
CS 65 CSIKAI, J., Int. Conf. Study of Nuclear Structure with Neutrons, Antwerp (1965) 102.
CS 66 CSIKAI, J., ATOMKI (At. Kut. Intez.) Kozl. 8 (1966) 79.
CU 60 CUZZOCREA, P., Nuovo Cim. 16 (1960) 450.
CU 63 CUZZOCREA, P., PAPPALARDO, G., Nucl. Phys. 48 (1963) 686.
CU 68 CUZZOCREA, P., PERILLO, E., NOTARRIGO, S., Nuovo Cim. 54B (1968) 53.
DE 65 DEBERTIN, K., RÖSSLE, E., Nucl. Phys. 70 (1965) 89.
DE 68 DECOWSKI, P., GROCHULSKI, W., MARCINKOWSKI, A., SIWEK, K., SLEDZINSKA, I., WILHELMI, Z., Nucl. Phys. A112 (1968) 513.
DE 70 DECOWSKI, P., GROCHULSKI, W., MARCINKOWSKI, A., KAROLYI, J., PIOTROWSKI, J., SAAD, E., SIWEK-WILCZYNSKA, K., TURKIEWICZ, I.M., WILHELMI, Z., Rep. IBJ 1197/I/PL (1970).
FE 60 FERGUSON, J.M., THOMPSON, W.E., Phys. Rev. 118 (1960) 228.
FE 72 FEDDERSEN, K.H., Diplomarbeit, Hamburg (1972).
GA 61 GABBARD, F., private communication, quoted in Rep. BNL-325 (1965).
GA 61a GABBARD, F. private communication, quoted in J. Nucl. Energy AB 19 (1965) 907.
GA 62 GABBARD, F., KERN, B.D., Phys. Rev. 128 (1962) 1276.
GA 70 GANGRSKIJ, Y.P., KHARISOV, I.F., Sov. J. Nucl. Phys. 12 (1971) 611.
GL 62 GLOVER, R.N., WEIGOLD, E., Nucl. Phys. 29 (1962) 309.
GO 60 GONZÁLEZ, L., RAPAPORT, J., LOEF, J.J. van, Phys. Rev. 120 (1960) 1319.
GO 61 GONZÁLEZ, L., TRIER, A., LOEF, J.J. van, Phys. Rev. 126 (1961) 271.
GR 58 GRUNDL, J.A., HENKEL, R.L., PERKINS, B.L., Phys. Rev. 109 (1958) 425.
GR 61 GRAVES, CONNOR, FORD, WARREN, cited in VANDENBOSCH, R., HUIZENGA, J.R., MILLER, W.F., KEBERLE, E.M., Nucl. Phys. 25 (1961) 511.
GR 70 GROCHULSKI, W., KAROLYI, J., MARCINKOWSKI, A., PIOTROWSKI, J., SAAD, E., SIWEK, K., WILHELMI, Z., Rep. INR 1197/I/PL (1970).
HE 54 HENKEL, R.L., private communication, cited in Rep. BNL-325, Suppl. 2 (1964).
HI 66 HILLE, P., MÜNZER, H., Acta Phys. Austriaca 23 (1965) 44.
HÖ 72 HÖLSCHER, H.H., Diplomarbeit, Hamburg (1972).
HU 58 HUGHES, D., SCHWARTZ, R., private communication, cited in LISKIEN, H., PAULSEN, A., Rep. EUR 119e (1968).
HU 59 HUDSON, O.M., MORGAN, I.L., Bull. Am. Phys. Soc. II 4 (1959) 97.
HÜ 55 HÜRLIMANN, T., HUBER, P., Helv. Phys. Acta 28 (1955) 33.
IM 60 IMHOF, W.L., private communication (1960), cited in Rep. BNL-325 (1965).
IM 61 IMHOF, W.L., private communication (1961), cited in Rep. BNL-325 (1965).
JE 63 JERONYMO, J.M.F., MANI, G.S., OLKOWSKY, J., SADEGHI, A., WILLIAMSON, C.F., Nucl. Phys. 47 (1963) 157.
JE 63a JERONYMO, J.M.F., MANI, G.S., OLKOWSKY, J., SADEGHI, A., WILLIAMSON, C.F., J. Phys. (Paris) 24 (1963) 816.
JE 65 JESSEN, P., BORMANN, M., DREYER, F., NEUERT, H., Nucl. Data 1A (1965) 103.
JO 65 JOHNSON, R.G., SALISBURY, S., VAUGHN, F.J., Rep. LMSC-4-50-62-1 (Oct.1962).
JU 62 DeJUREN, J.A., STOOKSBERRY, R.W., WALLIS, M., Phys. Rev. 127 (1962) 1229.
KA 68 KANDA, Y., J. Phys. Soc. Jap. 24 (1968) 17.
KE 59 KERN, B.D., THOMPSON, W.E., FERGUSON, J.M., Nucl. Phys. 10 (1959) 226.
KL 48 KLEMA, E., HANSON, A., Phys. Rev. 73 (1948) 106.
KN 58 KNIGHT, J.D., SMITH, R.K., WARREN, B., Phys. Rev. 112 (1958) 259.
KO 60 KOEHLER, D.R., ALFORD, W.L., Phys. Rev. 119 (1960) 311.
KO 62 KOEHLER, D.R., ALFORD, W.L., Bull. Am. Phys. Soc. 5 (1960) 443 C11.
KO 63 KONIJN, J., LAUBER, A., Nucl. Phys. 48 (1963) 191.
KR 59 KREGER, W., KERN, B.D., Phys. Rev. 113 (1959) 890.
LA 63 LANGKAU, R., Z. Naturforsch. 18a (1963) 914.
LA 65 LAUBER, A., MALMSKOG, S., Nucl. Phys. 73 (1965) 234.
LI 65 LISKIEN, H., PAULSEN, A., J. Nucl. Energy AB 19 (1965) 73.
LI 65a LISKIEN, H., PAULSEN, A., Nucl. Phys. 63 (1965) 393.
LI 66 LISKIEN, H., PAULSEN, A., Nukleonik 8 (1966) 315.
LÜ 50 LÜSCHER, E., RICAMO, R., SCHERRER, P., ZÜNTI, W., Helv. Phys. Acta 23 (1950) 561.
MA 53 MARTIN, H.C., TASCHEK, R.F., Phys. Rev. 89 (1953) 1302.

MA 55 MARION, J.B., BRUGGER, R.M., Phys. Rev. 100 (1955) 69.
MA 56 MARION, J.B., BRUGGER, R.M., CHAPMAN, R.A., Phys. Rev. 101 (1956) 247.
MA 60 MANI, G.S., McCALLUM, G.J., FERGUSON, A.T.G., Nucl. Phys. 19 (1960) 535.
MA 60a MANI, G.S., TOMBRELLO, T.A., RAO, D.A.A.S.N., Nucl. Phys. 21 (1960) 344.
MA 66 MATHUR, S.C., MORGAN, I.L., Nucl. Phys. 75 (1966) 561.
ME 48 METZGER, J., ALDER, F., HUBER, P., Helv. Phys. Acta 21 (1948) 278.
ME 63 MEADOWS, J.W., WHALEN, J.F., Phys. Rev. 130 (1963) 2022.
ME 67 MENLOVE, H.O., COOP, K.L., GRENCH, H.A., Phys. Rev. 163 (1967) 1308.
MO 58 MORITA, S., J. Phys. Soc. Jap. 13 (1958) 431.
NA 62 NAKAI, K., GOTOH, H., AMANO, H., J. Phys. Soc. Jap. 17 (1962) 1215.
NA 65 NAGEL, W., ATEN, A.H.W., Jr., Physica 31 (1965) 1091.
OK 67 OKUMURA, S., Nucl. Phys. A93 (1967) 74.
PA 65 PAULSEN, A., LISKIEN, H., Nukleonik 7 (1965) 117.
PA 65b PAULSEN, A., LISKIEN, H., J. Nucl. Energy AB 19 (1965) 907.
PA 66 PAI, H.L., Can. J. Phys. 44 (1966) 2337.
PA 67 PAULSEN, A., Nukleonik 10 (1967) 91.
PA 70a PAULSEN, A., WIDERA, R., Z. Phys. 238 (1970) 23.
PE 61 PERKIN, J.L., private communication, quoted in Rep. BNL-325, Suppl. 2 (1966).
PI 63 PICARD, J., WILLIAMSON, C.F., J. Phys. (London) 24 (1963) 813.
PI 65 PICARD, J., WILLIAMSON, C.F., Nucl. Phys. 63 (1965) 673.
PR 61 PRESTWOOD, R.J., BAYHURST, B.P., Phys. Rev. 121 (1961) 1438.
PR 69 PRESSER, G., BASS, R., KRÜGER, K., Nucl. Phys. A131 (1969) 679.
RA 58 RAPAPORT, J., LOEF, J.J. van, Phys. Rev. 114 (1958) 565.
RA 62 RAYBURN, L.A., Bull. Am. Phys. Soc. 7 (1962) 335.
RA 63 RAYBURN, L.A., Phys. Rev. 130 (1963) 731.
RA 63a RAYBURN, L.A., Bull. Am. Phys. Soc. 8 (1963) 121.
RI 51 RICAMO, R., Nuovo Cim. 8 (1951) 383.
RI 66 RIEDER, R., MÜNZER, H., Acta Phys. Austriaca 23 (1966) 42.
RI 68 RIMMER, E., FISHER, P., Nucl. Phys. A108 (1968) 567.
SA 61 SAYRES, A.R., JONES, K.W., WU, C.S., Phys. Rev. 122 (1961) 1853.
SA 63 SANTRY, D.C., BUTLER, J.P., Can. J. Chem. 41 (1963) 123.
SA 64 SANTRY, D.C., BUTLER, J.P., Can. J. Phys. 42 (1964) 1030.
SA 65 SALISBURY, S.R., CHALMERS, R.A., Phys. Rev. 140 (1965) B 305.
SA 66 SANTRY, D.C., BUTLER, J.P., Can. J. Phys. 44 (1966) 1183.
SC 61 SCHMITT, H.W., HALPERIN, J., Phys. Rev. 121 (1961) 827.
SC 70 SCOBEL, W., BORMANN, M., Z. Naturforsch. 25a (1970) 1406.
SE 61 SEEMANN, K.W., MOORE, W.E., Bull. Am. Phys. Soc. 6 (1961) 237.
SH 62 SHUNK, E.R., WAGNER, R.T., HEMMENDINGER, A., Bull. Am. Phys. Soc. 7 (1962) 334.
SH 68 SHIOKAWA, T., YAGI, M., KAJI, H., SASAKI, T., J. Inorg. Nucl. Chem. 30 (1968) 1.
SM 60 SMITH, D.M., BOSTROM, N.A., HUDSPETH, E.L., Phys. Rev. 117 (1960) 514.
ST 57 STELSON, P.H., CAMPBELL, E.C., Phys. Rev. 106 (1957) 1252.
ST 70 STEINER, E., HUBER, P., SALATHE, W., WAGNER, R., Helv. Phys. Acta 43 (1970) 17.
SU 66 SURESH, C., MATHUR, S.C., MORGAN, I.L., Nucl. Phys. 75 (1966) 561.
TE 58 TERRELL, J., HOLM, D.M., Phys. Rev. 109 (1958) 2031.
TE 59 TEWES, H.A., CARETTO, A.A., MILLER, A.E., Bull. Am. Phys. Soc. 4 (1959) 445.
TE 60 TEWES, H.A., CARETTO, A.A., MILLER, A.E., NETHAWAY, D.R., Rep. UCRL-6028T (1960).
TR 62 TRIER, A., Z. Naturforsch. 17a (1962) 275.
UR 61 URECH, S., JEANUET, E., ROSSEL, J., Helv. Phys. Acta 34 (1961) 954.
VA 61 LOEF, J.J. van, Nucl. Phys. 24 (1961) 340.
VA 63 VAUGHN, F.J., private communication (1963), cited in Rep. BNL-325 (1965).
WA 72 WAGENER, H.H., Diplomarbeit, Hamburg (1972).
WE 62 WEIGOLD, E., GLOVER, R.N., Nucl. Phys. 32 (1962) 106.
WI 61 WILLIAMSON, C.F., Phys. Rev. 122 (1961) 1877.
WI 61a WILLIAMSON, C.F., PICARD, J., J. Phys. Rad. 22 (1961) 651.
WÖ 66 WÖLFER, G., BORMANN, M., Z. Phys. 194 (1966) 75.
ZI 65 ZIELINSKI, U., Diplomarbeit, Hamburg (1965).

CROSS-SECTIONS FOR FISSION NEUTRON SPECTRUM INDUCED REACTIONS

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ABSTRACT. A review is given of cross-sections averaged in a uranium-235 fission neutron spectrum. The review extends to all integral measurements available in the literature up to April 1973 for (n, p), (n, α), (n, 2n) and (n, n') reactions. Whenever possible, the cross-sections have been renormalized to a standard value of 1250 ± 70 mb for the uranium-235 fission cross-section averaged in the thermal fission neutron spectrum of uranium-235. Recommended values have been attributed. Furthermore, averaged (n, p), (n, α) and (n, 2n) cross-sections have been estimated for all stable and a few long-lived isotopes and are compiled in a separate table.

INTRODUCTION

The fast component of a reactor neutron flux induces activity which can be used for neutron activation analysis, but which can also interfere with activity induced by thermal neutrons.

In both cases, a knowledge of the cross-sections averaged in the fast neutron spectrum is required. Since the shape of this fast neutron spectrum changes from one reactor to another, and even from one position in the reactor to another, one must refer to a precisely defined averaged cross-section. For this the cross-section averaged in the uranium-235 thermal fission neutron spectrum is used:

$$\bar{\sigma} = \int_0^\infty \sigma(E)\ \chi(E)\ dE$$

where $\sigma(E)$ is the activation cross-section and $\chi(E)$ the normalized flux density distribution of the fission neutron spectrum ($\int_0^\infty \chi(E)\ dE = 1$).

Estimates of $\bar{\sigma}$ are made either by integral or differential measurements. In integral measurements, the samples are exposed to fission neutrons, and $\bar{\sigma}$ is deduced from the measured induced activity and the determined fission neutron flux. In differential measurements, $\sigma(E)$ is measured and $\bar{\sigma}$ is computed using various representations of $\chi(E)$.

In the following, a review of integral measurements for (n, p), (n, α), (n, 2n) and (n, n') reactions, and an estimation of (n, p), (n, α) and (n, 2n) averaged cross-sections for the stable and long-lived isotopes of the elements from lithium to bismuth are given.

REVIEW OF INTEGRAL MEASUREMENTS FOR (n, p), (n, α), (n, 2n) AND (n, n') REACTIONS

In this review, we are interested in the compilation of all available data rather than in a very precise assessment of a few reactions important for neutron dosimetry and/or fast reactor technology. This means that we shall not discuss or analyse the discrepancies between differential and integral measurements. For most reactions, the agreement between the results of each method is adequate for our purpose.

We have chosen to review only the integral measurements, simply because they are more numerous than the differential ones while at the same time including practically all of them. Therefore, if not otherwise indicated, the original values quoted in the tables are derived from integral measurements. In some rare cases, where integral measurements are not available or are too discrepant, we have used differential or calculated data.

In some integral measurements, great care was exercised in exposing the samples to a neutron flux that was as close as possible to a thermal neutron induced uranium-235 fission neutron spectrum. This was achieved using fission plate or converter techniques. In most other cases, it was simply checked that the reactor spectrum did not deviate "significantly" from a pure fission spectrum. This spectrum equivalence is true in general for the energy range above about 1.5 MeV. Therefore, for threshold reactions, the fission neutron spectrum is used as zero-order approximation to the true spectrum, independent of reactor type and irradiation position.

Most of the integral measurements were made relative to a standard reaction and have therefore to be renormalized for intercomparison. Table I gives the most commonly used standard reactions and the values adopted in this review. These values are taken from a report by A. Fabry (Ref. FA72), which is an evaluation of experimental microscopic integral cross-sections measured in the thermal fission neutron spectrum of uranium-235 for 29 nuclear reactions relevant to neutron dosimetry and fast reactor technology.

Renormalization

Whenever possible and if not already renormalized by Fabry, the original data have been renormalized according to the standard values given in Table I. For some less common standards, recommended values from Tables II, III and IV have been used.

The renormalization is done by multiplying, for each reaction, the original data by the ratio of the new standard value to the old one. Branching ratios have not been taken into account in this renormalization. Errors have been considered as standard deviations. Renormalized errors always include the uncertainty in the standard cross-section used for renormalization.

In Fabry's evaluation a least-squares method is used to produce a recommended set of fission spectrum integral data scaled to a unique standard, which has been chosen to be the uranium-235 fission cross-section averaged in the uranium-235 thermal fission neutron spectrum and for which a value of 1250 mb has been accepted.

Fabry first renormalized experimental data sets of various authors to his own experimental data set, for which a uranium-235 standard value of 1335 mb had been accepted. All the renormalized data sets, together with Fabry's data set, were then scaled to a value of 1250 mb for the fission spectrum averaged uranium-235 fission cross-section.

Consequently, all renormalized values appearing in the tables are linked to the uranium-235 standard value. Except for the values renormalized by Fabry, the absolute errors on renormalized values include an absolute error of 70 mb on the uranium-235 standard value.

Determination of recommended values

Keeping in mind the practical use of these tables, we have decided to give a "recommended" value for each single reaction appearing in the tables, even if some values are of doubtful quality.

For the reactions which he has evaluated, Fabry recommends values that are a weighted average of his renormalized and then scaled values. In most cases, Fabry's recommended values are also ours, except for the errors which, in our case, always include the error in the uranium-235 standard. These values are strongly recommended.

For the cross-sections not evaluated by Fabry a selection has been made among the available renormalized values. A weighted average of the selected values was then performed using the inverse of the squared errors as weight. Averaged values of at least three renormalized values agreeing within 15% are also strongly recommended. Both these values and Fabry's recommended values appear underlined in the tables.

Other "recommended" values are: either the average of discrepant values, or the average of only two agreeing values, or no average at all for single measurements.

Structure of Tables II, III, IV and V

Tables II, III, IV and V summarize the status of integral measurements. For each reaction all data available in the common literature up to April 1973 are given, together with the standard used, if this is known or relevant. The first column gives the reactions. In the second column appear the references to the original values, which are given in the third column. The fourth column gives the standard used by the author. The numbers in parentheses refer to notes, a list of which is given following Table V. Renormalized values are given in the fifth column and recommended values in the sixth.

The boxes drawn within the tables for some reactions contain the original data and their renormalized values used by Fabry in his evaluation. The result of the evaluation, Fabry's recommended value, given in the third column, appears in the last line of the box, attached to the underlined reference FA72. Our recommended value, which is identical to Fabry's value except for the error as explained previously, is given in the last column. The dotted line within the box separates the measurements performed with fission plates or converter (upper part) from the ones done by exposure to pile neutrons (lower part).

The renormalized values selected for averaging are marked with a short line on the right-hand side. The brace } collects the renormalized values in an average recommended value. Absolute errors given in parentheses are those that have been arbitrarily chosen when no error had been given by the author.

ESTIMATED AVERAGE FISSION NEUTRON CROSS-SECTIONS FOR (n, p), (n, α) AND (n, 2n) REACTIONS

Tables II to V are far from being complete and numerous cross-sections required by the experimentalist are unknown, hence the need for a complete estimation. Some publications give cross-sections which have been theoretically calculated (see, for example, Pearlstein's calculations (Ref. PL73) using an empirical model based on statistical theory for nuclides having 21 to 41 protons) or evaluated (see, for example, the evaluation by Pope and Story (Ref. PO73) using the United Kingdom Nuclear Data Library for 64 data files). But, so far, only Roy and Hawton (Ref. RO60) have attempted an estimation covering all stable isotopes and a few long-lived radionuclides from lithium to bismuth. Since the number of available measurements on which the estimation is based has nearly doubled since 1960, we thought it to be useful to review the values estimated by Roy and Hawton.

Basis of the estimation

Hughes (Ref. HU53) has defined a useful quantity E_{eff}, called the effective energy, assuming that the cross-section $\sigma(E)$ is proportional to the penetrability P(E) of the Coulomb barrier which confronts the charged particle leaving the compound nucleus. In this case, the reaction rate, as a function of the energy E of the incoming neutrons, is proportional to the product of P(E) and $\chi(E)$. Thus the spectrum-averaged cross-section is proportional to the area under the curve $\chi(E)$ P(E) in Fig. 1.

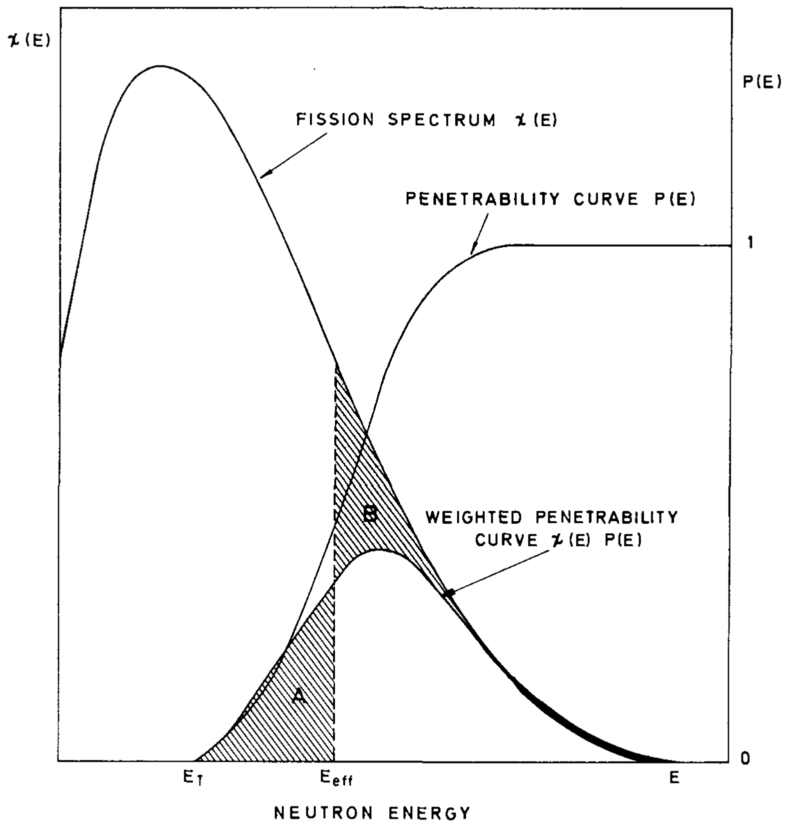

FIG. 1. E_{eff} is defined in such a way that area A is equal to area B.

As shown in Fig. 1, E_{eff} is defined as the energy for which the area marked A is equal to the area marked B, so that the area under the curve $\chi(E)\,P(E)$ is the same as the one delimited by $\chi(E)$ and a vertical dotted line drawn at E_{eff}. At unit penetrability, the cross-section $\sigma(E)$ becomes constant and equals σ_0, which Hughes' measurements have shown to be roughly proportional to the surface of the nucleus. The cross-section $\sigma(E)$ can then be written $\sigma(E) = a\,P(E)\,A^{2/3}$, where A is the mass number and a is a constant. The spectrum-averaged cross-section can then be written:

$$\bar{\sigma} = \int_0^\infty \sigma(E)\,\chi(E)\,dE = a\,A^{2/3}\int_0^\infty P(E)\,\chi(E)\,dE$$

$$= a\,A^{2/3}\int_{E_{eff}}^\infty \chi(E)\,dE$$

The quantity $\bar{\sigma}/A^{2/3}$ is proportional to the integral of the fission neutron spectrum from E_{eff} to infinity, and it is then possible to predict an average cross-section if the effective energy of a given reaction is known. The

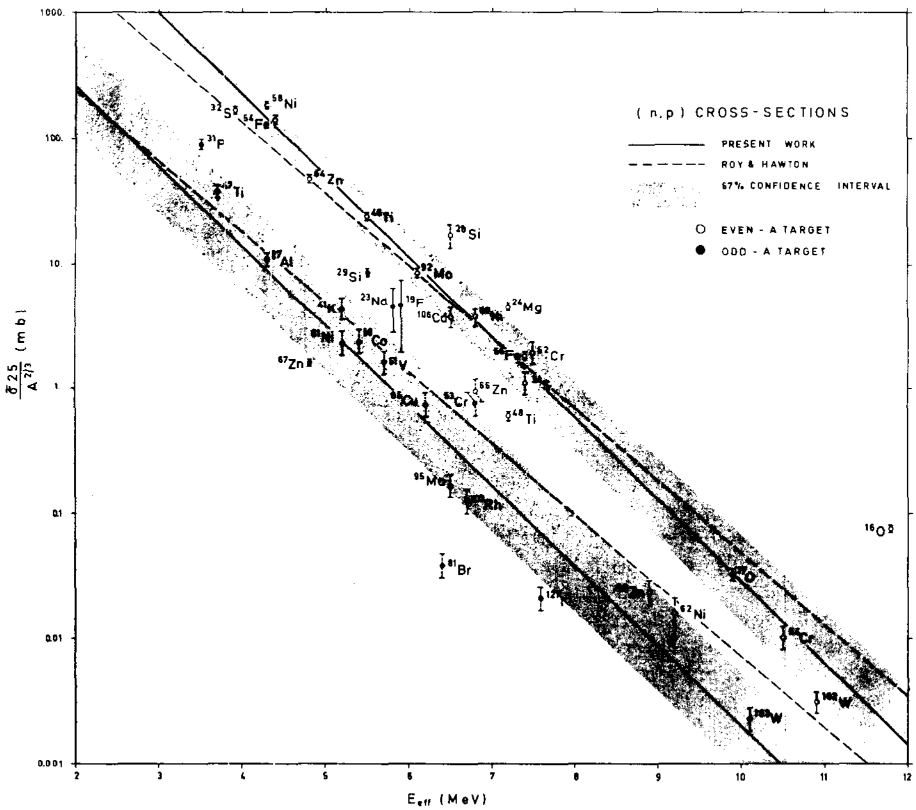

FIG.2. (n, p) cross-sections averaged in a fission neutron spectrum.

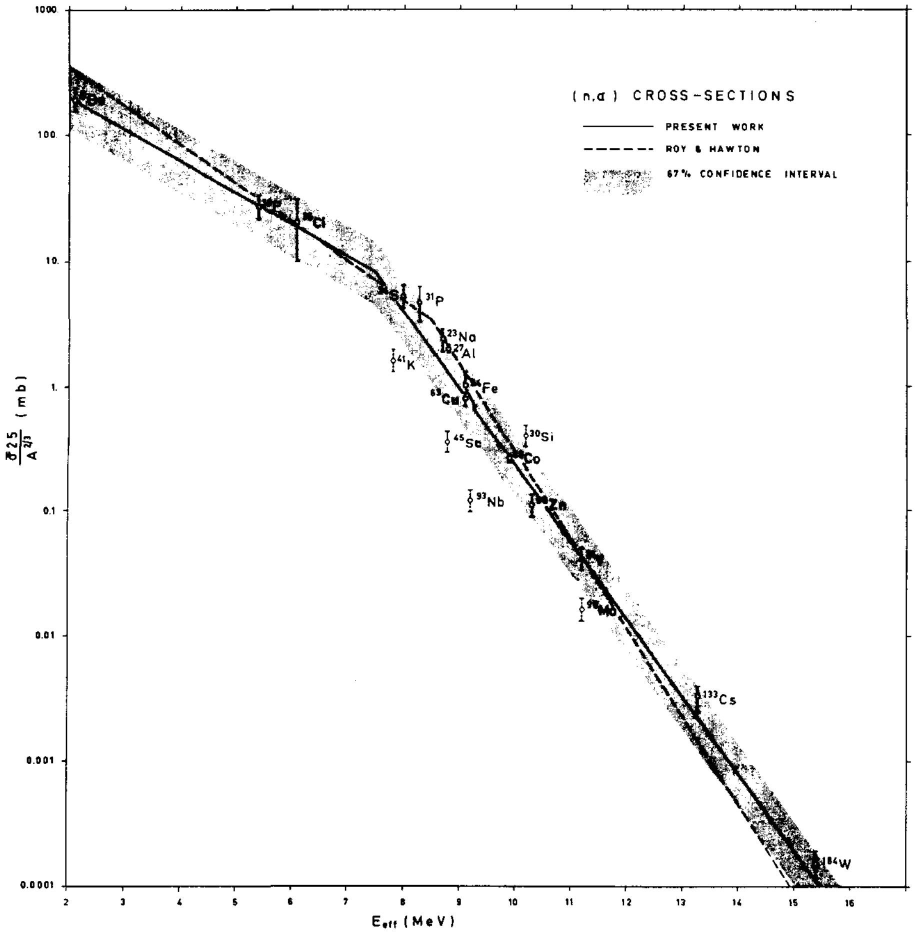

FIG.3. (n,α) cross-sections averaged in a fission neutron spectrum.

validity of this very simple model was tested by Hughes' old measurements. Later on, large discrepancies with more recent measurements have shown the inadequacy of Hughes' model to predict average cross-sections.

Rather than trying to refine the previous theory, Roy and Hawton (Ref. RO60) have looked for an empirical correlation between $\bar{\sigma}$ and E_{eff}. For each measurement, they have plotted the quantity $\bar{\sigma} \cdot 25/A^{2/3}$ versus E_{eff} (E_{eff} being obtained from Hughes' plots (Ref. HU53, Fig. 4-3)). The number 25 means that the cross-sections have been renormalized arbitrarily to a nucleus of mass A = 125, for which $A^{2/3} = 25$. The (n, 2n) cross-sections have been plotted versus the threshold energy E_T. From the line giving the best fit of the experimental points, Roy and Hawton have then tabulated the estimated cross-sections. The lines fitted by Roy and Hawton have a steeper slope than the ones given by the integral of the fission neutron spectrum from

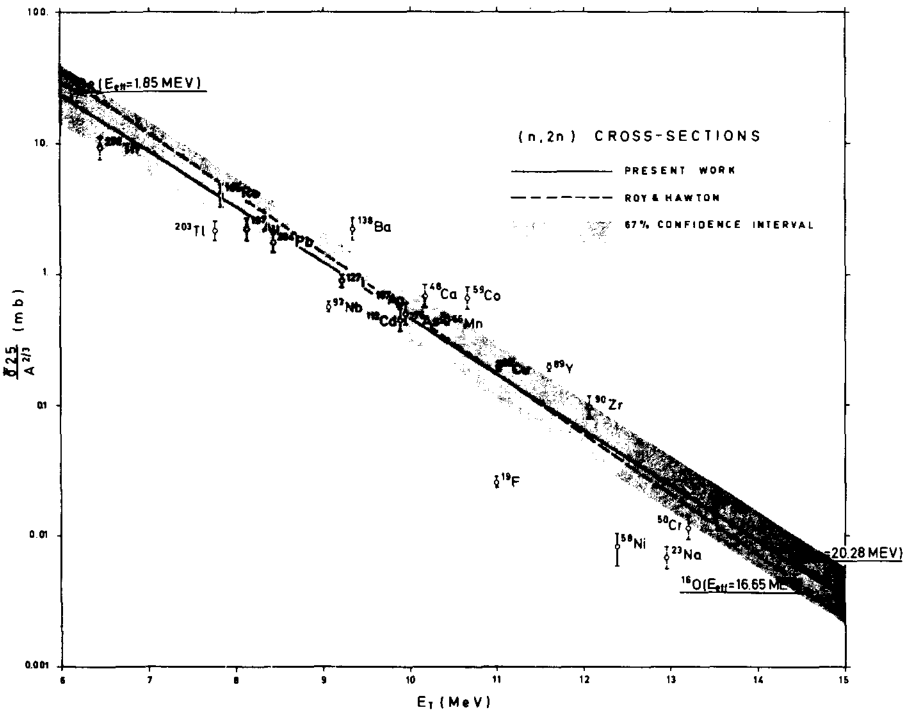

FIG.4. (n,2n) cross-sections averaged in a fission neutron spectrum.

Hughes' model. Moreover, for (n, p) cross-sections, the data split along two parallel lines, the odd-A nuclei having much lower cross-sections than the even-A nuclides.

This compilation assumes the approach by Roy and Hawton to the measurements presently available. All recommended values of Tables II, III and IV have been used for the fit, except for the data marked with +. Relative errors on data from a single measurement or on data averaged over two measurements have been increased arbitrarily up to 20% whenever they were lower than this value. This was done in order to give lower weight to the unsupported measurements. The 20% arbitrary errors appear in Figs 2, 3 and 4 as dotted error bars.

Threshold energies E_T have also been recalculated using the latest Q-value evaluation (Ref. GV72); for exoergic reactions $E_T = -Q$, for endoergic reactions $E_T = -Q(A+1)/A$, where A is the mass number of the target nuclide. Several threshold values, for which Q was not evaluated, have been taken from Ref. HW70. These changes in the threshold values resulted in corrected effective energies.

Figures 2, 3 and 4 show the results. The shaded areas define a 67% confidence interval. It can be seen that our best fits have consistently greater slopes than the ones of Roy and Hawton. Except for (n, p) cross-sections of odd-A nuclei, the dispersion of which is large anyway, our fit is not very much different from that of Roy and Hawton.

Table of estimated values (Tab.VI)

The fission neutron spectrum averaged cross-sections are estimated from the solid lines in Figs 2, 3 and 4, giving the best fits to the experimental data, and are compiled in Table VI, together with their estimated relative errors (one standard deviation). For those reactions where $\bar{\sigma}$ is less than 0.1 μb, $\bar{\sigma}$ is simply given as < 0.0001 mb. No value is given for the few reactions for which E_{eff} is less than 2 MeV, the validity of the estimation being doubtful in this case. The recommended values of $\bar{\sigma}$ given in Tables II, III and IV should of course be preferred to the estimated ones.

ACKNOWLEDGEMENTS

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TABLE I. ADOPTED STANDARDS

Reactions	$\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{24}Mg(n,p)^{24}Na$	1.53 ± 0.09
$^{27}Al(n,\alpha)^{24}Na$	0.725 ± 0.045
$^{32}S(n,p)^{32}P$	69 ± 4
$^{46}Ti(n,p)^{46}Sc$	12.5 ± 0.9
$^{54}Fe(n,p)^{54}Mn$	82.5 ± 5
$^{58}Ni(n,p)^{58}Co$	113 ± 7
$^{235}U(n,f)FP$	1250 ± 70
$^{238}U(n,f)FP$	328 ± 10

Explanation of symbols used in Tables II, III, IV and V

( )*	The reaction has been used as standard with the numerical value given in parentheses.
(±0.05)	The error given in parentheses has been arbitrarily chosen.
-	Marks the data selected for use in the averaging process.
}	Collects renormalized values in an averaged recommended value.
+	Marks the data not accepted for the fit of the estimated values.
1.53±0.09	Underlined data are strongly recommended.
FA72	Refers to Fabry's recommended values (reported in the "original values" column of the tables).

The boxes drawn within the tables for some reactions include the original data and their renormalized values used by Fabry (FA72) in his evaluation.

-----	Separates within the box the measurements performed with fission plates or converter (upper part) from the ones done by exposure to pile neutrons (lower part).
(1), (2)...(29)	Refer to Notes to Tables II-V, a list of which follows Table V.

TABLE II. INTEGRAL (n, p) CROSS-SECTIONS AVERAGED IN THE URANIUM-235 THERMAL FISSION NEUTRON SPECTRUM

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards[a] (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{16}O(n,p)^{16}N$	HU53	0.014	(1)	0.022	
	RY58	0.019±25%	$^{27}Al(n,\alpha)$=0.6±20%	0.023±0.003	0.019±0.001 +
	HE58	(1.85±0.11)10^{-2}	(2)	0.018±0.0011	
$^{17}O(n,p)^{17}N$	RY58	0.0052±30%	$^{27}Al(n,\alpha)$=0.6±20%	0.0063±0.0013	
	HE58	(9.3±0.9) 10^{-3}	(2)	0.0093±0.0009	0.0086±0.0008 +
	AM64	(7.4±0.6)10^{-3}	$^{27}Al(n,\alpha)$=0.6	0.0089±0.0009	
$^{19}F(n,p)^{19}O$	HU53	0.5	(1)	0.8	1.35±0.8
	SA59	0.99	$^{31}P(n,p)$=19	1.9	
$^{23}Na(n,p)^{23}Ne$	HU53	0.7	(1)	1.1	1.5±0.6
	SA59	1.0	$^{31}P(n,p)$=19	1.9	
$^{24}Mg(n,p)^{24}Na$	HU53	1.0	(1)	1.6	
	WA62	1.05±0.25	unknown		
	BO64	1.31±0.06	$^{32}S(n,p)$=60	1.53±0.07	
	BR67,70	1.44±0.05	(3)	1.53±0.053	
	NJ70	1.31±0.05	$^{27}Al(n,\alpha)$= 0.61	1.58±0.06	
	KI71	(1.4)*	(4)	1.56	
	FA72	1.62±0.07	$^{235}U(n,f)$=1335 (7)	1.52±0.045	
	RI57	1.29	$^{238}U(n,f)$=304	1.53	
	PA61	1.2	$^{27}Al(n,\alpha)$=0.60	1.51	
	HO62	1.1	$^{27}Al(n,\alpha)$=0.57	1.41	
	NS68	1.30±0.17	(5)	1.53±0.20	
	KI71	(1.4)*	(4)	1.56	
	MC72	(6)		1.51±0.12	
	FA72	1.53±0.03	$^{235}U(n,f)$=1250	1.53±0.09	1.53±0.09

[a] Numbers in parentheses refer to notes, a list of which follows Table V.

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{25}Mg(n,p)^{25}Na$	HU53	2.0	(1)	3.2	3.2(±1.6) +
$^{27}Al(n,p)^{27}Mg$	HU53	2.8	(1)	4.5	
	BO64	2.9±0.5	$^{32}S(n,p)$=60	3.4±0.6	
	GR68	(8)		4.7±0.3	
	NJ70	2.9±0.3	$^{27}Al(n,\alpha)$=0.61	3.5±0.35	
	FA72	4.35±0.20	$^{235}U(n,f)$=1335 (7)	4.07±0.15	
	RI57	3.43	$^{238}U(n,f)$=304	4.01	
	MC72	(6)		4.17±0.33	
	FA72	4.0 ±0.4	$^{235}U(n,f)$=1250	4.0±0.45 -	4.0±0.45
	FH64	3.40±0.38	unknown		
$^{28}Si(n,p)^{28}Al$	HU53	4	(1)	6.4	
	BU70	6.68±0.08	$^{32}S(n,p)$=65	7.1±0.4 -	6.4±0.8
	KI71	4.90±0.32	(4)	5.4±0.5 -	
$^{29}Si(n,p)^{29}Al$	HU53	2.7	(1)	4.3	
	NS68	2.40±0.18	(5)	2.8±0.3 -	3.3±0.2
	BU70	3.41±0.04	$^{32}S(n,p)$=65	3.6±0.2 -	
	KI71	2.98±0.17	(4)	3.3±0.3 -	
$^{31}P(n,p)^{31}Si$	HU53	19	(1)	30	
	HR60	(23)	$^{32}S(n,p)$=69±4	35±3	
	BO64	30.5±1.2	$^{32}S(n,p)$=60	35.5±1.4	
	GR68	(8)		38.6±2.5	
	RI57	31.2	$^{238}U(n,f)$=304	36.5	
	FA72	36±2	$^{235}U(n,f)$=1250	36±3 -	36±3

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{32}S(n,p)^{32}P$	HU53	30	(1)	48	
	SA59	21	$^{31}P(n,p)$=19	40	
	DU62	58±15%	$^{238}U(n,f)$=310	61±9	
	DE62	65±3	(9)		
	FH64	61±5	unknown		
	LW66,68	41	$^{54}Fe(n,p)$=60	56	
	BO64	(60)*±1.2	$^{32}S(n,p)$=60	70±1.4	
	FA72	73±3	$^{235}U(n,f)$=1335 (7)	68.5±2	
	RI57	60.3	$^{238}U(n,f)$=304	71.2	
	PA61	58 (16)	$^{27}Al(n,\alpha)$=0.6	73±7	
	MA64/1	65 (17)	$^{32}S(n,p)$=65	68.5	
	MC72	(6)		70.5±5.6	
	FA72	69±2	$^{235}U(n,f)$=1250	69±4	69±4
$^{33}S(n,p)^{33}P$	KO66/2	376±20	$^{32}S(n,p)$=66	383±31	
	LW66,68	55	$^{54}Fe(n,p)$=60	76	76(±15) +
$^{34}S(n,p)^{34}P$	RA67/1	0.36±0.032	$^{58}Ni(n,p)$=95	0.43±0.05	0.43±0.05
$^{35}Cl(n,p)^{35}S$	HU53	16	(1)	26	
	GI66	~810±40	unknown		
	RA67/1	78.3(calc.)	(24)		78 (±23) +
$^{37}Cl(n,p)^{37}S$	HU53	0.24	(1)	0.38	0.38(±0.19) +
$^{41}K(n,p)^{41}Ar$	LA65	2.73±0.41	unknown		
	RA67/1	1.78±0.14	$^{58}Ni(n,p)$=95	2.1±0.2	2.1±0.2

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
^{43}Ca(n,p)^{43}K	GI66	0.3	unknown		0.3(±0.15) +
^{45}Sc(n,p)^{45}Ca	MU61	9±1	^{32}S(n,p)=66	9.4±1.2	15±12 +
	RG68/2	34.6±0.5	^{32}S(n,p)=60	39.8±2.4	
^{46}Ti(n,p)^{46}Sc	ME58	4.1	^{32}S(n,p)=30	9.4	
	DU62	10±15%	^{238}U(n,f)=310	10.6±1.6	
	NL63	15±2	^{58}Ni(n,p)=101	17±2	
	NI63	17±3	^{58}Ni(n,p)=92	21±4	
	ZJ	12.8	^{27}Al(n,α)=0.608	15±3	
	KO66/1	12.6±0.4	^{32}S(n,p)=66	13.2±0.9	
	DS67	8.6±1.4	unknown		
	BO64	12.8±0.6	^{32}S(n,p)=60	15	
	BR67,70	11.6±0.5	(3)	12.3±0.5	
	KI71	10.8±0.61	(4)	12.0±0.7	
	FA72	13.0±0.6	^{235}U(n,f)=1335 (7)	12.2±0.4	
	HO62	9.0	^{27}Al(n,α)=0.57	11.4	
	BO64	8.0±0.6	^{58}Ni(n,p)=90	9.3	
	MA64/2	8.±0.8	^{58}Ni(n,p)=107	8.45±0.85	
	RA67/1	(12.6)*	^{46}Ti(n,p)=12.6	12.3	
	NS68	9.30±0.73	(5)	10.9±0.9	
	SC69	10.9±0.7	^{27}Al(n,α)=0.767	10.6±0.7	
	KI71	11.2±0.63	(4)	12.5±0.7	
	MC72	(6)		13.0±1	
	FA72	12.5±0.5	^{235}U(n,f)=1250	12.5±0.9	12.5±0.9

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{47}Ti(n,p)^{47}Sc$	ME58	0.21	$^{32}S(n,p)=30$	0.48	
	DU62	18±15%	$^{238}U(n,f)=310$	19±3	
	NI63	18±3	$^{58}Ni(n,p)=92$	22±4	
	KO66/1	13.2±1	$^{32}S(n,p)=66$	13.8±1.3	
	DS67	18.2±2.6	unknown		
	BO64	22±1.5	$^{32}S(n,p)=60$	25.6±1.7	
	KI71	17.3±0.90	(4)	19.3±1	
	HO62	15	$^{27}Al(n,\alpha)=0.57$	19.2	
	NS68	26±3.1	(5)	30.5±3.6	
	SC69	19.8±1.2	$^{27}Al(n,\alpha)=0.767$	19.2±1.1	
	KI71	19.0±1.2	(4)	21.2±1.3	
	FA72	20±2	$^{235}U(n,f)=1250$	20±2.3	20±2.3
$^{48}Ti(n,p)^{48}Sc$	ME58	0.077	$^{32}S(n,p)=30$	0.18	
	DU62	0.53±15%	$^{238}U(n,f)=310$	0.56±0.09	
	NI63	0.44±0.08	$^{58}Ni(n,p)=92$	0.54±0.10	
	KO66/1	3.3±0.2	$^{32}S(n,p)=66$	3.45±0.3	
	DS67	0.11±0.01	unknown		
	BO64	0.21±0.016	$^{32}S(n,p)=60$	0.245±0.002	
	KI71	0.272±0.052	(4)	0.303±0.058	
	HO62	0.25	$^{27}Al(n,\alpha)=0.57$	0.32	
	NS68	0.240±0.054	(5)	0.282±0.063	
	SC69	0.334±0.02	$^{27}Al(n,\alpha)=0.767$	0.324±0.02	
	KI71	0.294±0.025	(4)	0.328±0.028	
	FA72	0.315±0.02	$^{235}U(n,f)=1250$	0.315±0.027	0.315 ± 0.027
$^{51}V(n,p)^{51}Ti$	NS68	0.74±0.08	(5)	0.87±0.11	0.87±0.11
$^{52}Cr(n,p)^{52}V$	RA67/1	0.92±0.037	$^{58}Ni(n,p)=95$	1.09±0.08	1.09±0.08

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{53}Cr(n,p)^{53}V$	RA67/1	0.37±0.026	$^{58}Ni(n,p)$=95	0.44±0.04	0.44±0.04
$^{54}Cr(n,p)^{54}V$	RA67/1	(4.9±0.8)10^{-3}	$^{58}Ni(n,p)$=95	(5.8±1.0)10^{-3}	0.0058±0.001
$^{54}Fe(n,p)^{54}Mn$	SC57	15	(10)	46	
	ME58	23	$^{32}S(n,p)$=30	53	
	RO59	56	$^{27}Al(n,\alpha)$=0.6	68	
	DU62	59±15%	$^{238}U(n,f)$=310	62±10	
	BA68	59.8±14%	unknown		
	ST70	63±1	$^{58}Ni(n,p)$=105	68±4	
	BO64	66±3.5	$^{32}S(n,p)$=60	77±4	
	BR67,70	76.5±3.0	(3)	81.5±3.2	
	FA72	89±5	$^{235}U(n,f)$=1335 (7)	83.5±2.5	
	PA61	54	$^{27}Al(n,\alpha)$=0.60	73	
	HO62	65	$^{27}Al(n,\alpha)$=0.57	83	
	MA64/3	76±3	$^{58}Ni(n,p)$=107	83.3± 3.3	
	NS68	67±9	(5)	84.7±10.5	
	MC72	(6)		81.5±4.5	
	FA72	82.5±2	$^{235}U(n,f)$=1250	82.5±5	82.5±5
$^{56}Fe(n,p)^{56}Mn$	ME58	0.44	$^{32}S(n,p)$=30	1.0	
(see also next page)	DU62	1.2±15%	$^{238}U(n,f)$=310	1.3±0.2	
	BO64	0.90±0.05	$^{32}S(n,p)$=60	1.05±0.06	
	GR68	(a)	(8)	1.07±0.07	
	BR67,70	1.06±0.04	(3)	1.13±0.043	
	NJ70	0.85±0.05	$^{27}Al(n,\alpha)$=0.61	1.025±0.06	
	FA72	1.15±0.04	$^{235}U(n,f)$=1335 (7)	1.08±0.035	

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{56}Fe(n,p)^{56}Mn$ (cont'd)	PA61	0.82	$^{27}Al(n,\alpha)$=0.60	1.03	
	HO62	0.71	$^{27}Al(n,\alpha)$=0.57	0.91	
	NS68	0.96±0.09	(5)	1.13±0.11	
	MC72	(6)		1.29±0.10	
	FA72	1.07±0.06	$^{235}U(n,f)$=1250	1.07±0.08	1.07±0.08
$^{59}Co(n,p)^{59}Fe$	SC57	0.25	(10)	0.77	
	ME58	5.7	$^{32}S(n,p)$=30	13	
	RC59	~0.3	$^{27}Al(n,\alpha)$=0.6		
	DU62	1.4±15%	$^{238}U(n,f)$=310	1.5±0.2	1.42±0.14
	WA63	0.5	unknown		
	BA68	1.46±23%	unknown		
	NS68	1.15±0.15	(5)	1.35±0.2	
$^{58}Ni(n,p)^{58}Co$ (see also next page)	ME58	45	$^{32}S(n,p)$=30	103.5	
	RB59	225	$^{32}S(n,p)$=30	517.5	
	RC59	140	$^{27}Al(n,\alpha)$=0.60	169	
	DU62	97±15%	$^{238}U(n,f)$=310	103±16	
	ZJ63	120	$^{27}Al(n,\alpha)$=0.608	143	
	BA68	75.7±12%	unknown		
	BO64	105±5	$^{32}S(n,p)$=60	122.5±6	
	BR67,70	104.5±4.0	(3)	113.3±4.3	
	KI71	(104)*	(4)	116	
	FA72	120±6	$^{235}U(n,f)$=1335 (7)	112.5±3.5	
	PA51	92	$^{27}Al(n,\alpha)$=0.60	115.5	
	HO62	90	$^{27}Al(n,\alpha)$=0.57	115	
	MA64/1	107 (17)	$^{32}S(n,p)$=65	113	
	RA67/1	(95)*	$^{58}Ni(n,p)$=95	111	

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{58}Ni(n,p)^{58}Co$ (cont'd)	NS68	96±13	(5)	113±15	
	SC69	114±7	$^{27}Al(n,\alpha)$=0.767	110.5±7	
	KI71	(104)*	(4)	116	
	MC72	(6)		110±5.7	
	FA72	113±2.5	$^{235}U(n,f)$=1250	113±7	113±7
$^{58}Ni(n,p)^{58m}Co$	ME58	13	$^{32}S(n,p)$=30	30	
	BO64	30±7	$^{32}S(n,p)$=60	35±8	
	BR67,70	33.7±1.1	(3)	35.8±1.2	
	FA72	37.5±5	$^{235}U(n,f)$=1335 (7)	35.1±1.1	
	PA61	28	$^{27}Al(n,\alpha)$=0.60	35	
	HO62	30.5	$^{27}Al(n,\alpha)$=0.57	39	
	FA72	35.4±1.0	$^{235}U(n,f)$=1250	35.4±2.2	35.4±2.2
$^{60}Ni(n,p)^{60}Co$	RB59	<4.5	$^{32}S(n,p)$=30		
	SC57	0.56	(10)	1.72	
	ME58	3-7	$^{32}S(n,p)$=30		
	RC59	<2	$^{27}Al(n,\alpha)$=0.60		
	DU62	3.2±15%	$^{238}U(n,f)$=310	3.4±0.5	2.3±0.4
	HO62	<0.5	$^{27}Al(n,\alpha)$=0.57		
	NS68	1.69±0.18	(5)	2.0±0.2	
	HA72	4.4±1.0	$^{58}Ni(n,p)$=105	4.7±1.1	
$^{60}Ni(n,p)^{60m}Co$	HA72	1.98±0.20	$^{58}Ni(n,p)$=105	2.1±0.3	2.1±0.3
$^{61}Ni(n,p)^{61}Co$	SC69	1.3±0.1	$^{27}Al(n,\alpha)$=0.767	1.23±0.12	1.4±0.2
	HA72	1.63±0.12	$^{58}Ni(n,p)$=105	1.75±0.17	

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{62}Ni(n,p)^{62}Co$	HA72	$(9\pm3)10^{-3}$	$^{58}Ni(n,p)$=105	$(9.7\pm3.4)10^{-3}$	0.0097±0.0034
$^{65}Cu(n,p)^{65}Ni$	PA61	0.36	Al(n,α)=0.6	0.435(±10%)	0.48±0.08
	NS68	0.52±0.05	(5)	0.61±0.07	
$^{64}Zn(n,p)^{64}Cu$	ME58	22	$^{32}S(n,p)$=30	51	
	RC59	35	$^{27}Al(n,\alpha)$=0.60	42	
	DU62	31±15%	$^{238}U(n,f)$=310	33±5	
	BO64	27±1.6	$^{32}S(n,p)$=60	31.5±1.9	
	NJ70	25.2±1.3	$^{27}Al(n,\alpha)$=0.61	30.4±1.6	
	KI71	37.4±3.0	(4)	41.7±3.3	
	FA72	32±1.7	$^{235}U(n,f)$=1335 (7)	30±1.2	
	PA61	28	$^{27}Al(n,\alpha)$=0.60	35	
	HO62	25	$^{27}Al(n,\alpha)$=0.57	32	
	RA67/1	26.9±1.2	$^{58}Ni(n,p)$=95	31.4±1.3	
	NS68	27.0±4.1	(5)	31.7±4.8	
	SC69	32±2	$^{27}Al(n,\alpha)$=0.767	31±2	
	KI71	35.5±2.8	(4)	39.6±3.1	
	FA72	31±1.5	$^{235}U(n,f)$=1250	31±2.3	31±2.3
$^{66}Zn(n,p)^{66}Cu$	RA67/1	0.56±0.034	$^{58}Ni(n,p)$=95	0.67±0.06	0.62±0.11
	NS68	0.32±0.11	(5)	0.38±0.13	
$^{67}Zn(n,p)^{67}Cu$ (see also next page)	ME58	0.27	$^{32}S(n,p)$=30	0.62	
	PA61	0.57	$^{27}Al(n,\alpha)$=0.60	0.69	
	DU62	0.88±15%	$^{238}U(n,f)$=310	0.93±0.14	
	BO64	0.9±0.1	$^{32}S(n,p)$=60	1.04±0.13	

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{67}Zn(n,p)^{67}Cu$ (cont'd)	NI65/2	0.88±0.11	$^{58}Ni(n,p)$=92	1.08±0.15	1.07±0.04
	RA67/1	0.96±0.067	$^{58}Ni(n,p)$=95	1.14±0.11	
	OB69	0.82±0.04	$^{54}Fe(n,p)$=61	1.11±0.09	
	HP69	0.8	unknown		
	SC69	1.11±0.08	$^{27}Al(n,\alpha)$=0.767	1.05±0.10	
$^{68}Zn(n,p)^{68}Cu$	RA67/1	(13.1±1.9)10-3	$^{58}Ni(n,p)$=95	0.0156±0.0025	0.0156±0.0025
$^{69}Ga(n,p)^{69m}Zn$	HP69	0.496±0.073	unknown		0.496±0.073 +
$^{72}Ge(n,p)^{72}Ga$	RC59	<0.01	$^{27}Al(n,\alpha)$=0.6		
	RA67/1	0.0218	(24)		0.022(±0.006)+
$^{75}As(n,p)^{75}Ge$	NS68	0.45 (cal.val.)	(19)		0.45(±0.15) +
$^{74}Se(n,p)^{74}As$	GI66	6.6	unknown		6.6(±3.3) +
$^{81}Br(n,p)^{81g}Se$	ST67	0.020±0.004	$^{27}Al(n,\alpha)$=0.6	0.024±0.005	0.024±0.005
$^{81}Br(n,p)^{81m}Se$	ST67	0.012±0.003	$^{27}Al(n,\alpha)$=0.6	0.0145±0.004	0.0145±0.004
$^{88}Sr(n,p)^{88}Rb$	NS68	0.01 (cal. val.)	(19)		0.01(±0.003) +
$^{89}Y(n,p)^{89}Sr$	BA68	0.31±19%	unknown		0.31±0.06 +
$^{90}Zr(n,p)^{90}Y$	NS68	0.18 (cal.val.)	(19)		0.18(±0.06) +
$^{92}Mo(n,p)^{92m}Nb$ (see also next page)	ME58	1.3	$^{32}S(n,p)$=30	3	
	CO62	7.43±10%	$^{58}Ni(n,p)$=105	8.0±0.9	

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{92}Mo(n,p)^{92m}Nb$	BO64	6.2±0.4	$^{32}S(n,p)$=60	7.23±0.5	
(cont'd)	BR67,70	6.57±0.28	(3)	7.00±0.30	
	KI71	6.04±0.45	(4)	6.73±0.05	
	FA72	7.7±0.5	$^{235}U(n,f)$=1335 (7)	7.2±0.3	
	HO62	6.0	$^{27}Al(n,\alpha)$=0.57	7.65	
	RA67/1	6.74±0.27	$^{46}Ti(n,p)$=12.6	6.58±0.26	
	NS68	6.70±0.63	(5)	7.87±0.74	
	KI71	6.00±0.43	(4)	6.70±0.47	
	FA72	7.0±0.4	$^{235}U(n,f)$=1250	7.0±0.6	7.0±0.6
$^{95}Mo(n,p)^{95}Nb$	ME58	<0.1	$^{32}S(n,p)$=30		
	GO62	0.78±10%	$^{92}Mo(n,p)$= 7.43	0.73±0.08	
	HO62	<0.1	$^{27}Al(n,\alpha)$=0.57		
	BO64	0.13±0.02	$^{32}S(n,p)$=60	0.150±0.02	0.14±0.01
	RA67/1	0.138±0.006	$^{46}Ti(n,p)$=12.6	0.137±0.012	
$^{96}Mo(n,p)^{96}Nb$	GO62	0.24±10%	$^{92}Mo(n,p)$=7.43	0.23±0.03	0.23±0.03 +
$^{103}Rh(n,p)^{103}Ru$	FR67	0.093±0.001	$^{32}S(n,p)$=60	0.107±0.006	0.107±0.006
$^{109}Ag(n,p)^{109}Pd$	NS68	0.06 (cal.val.)	(19)		0.06(±0.02) +
$^{106}Cd(n,p)^{106}Ag$	ST67	2.7±0.2	$^{27}Al(n,\alpha)$=0.6	3.3±0.3	3.3±0.3
$^{110}Cd(n,p)^{110}Ag$	RC59	∼0.1	$^{27}Al(n,\alpha)$=0.6		0.1(±0.05) +
$^{127}I(n,p)^{127m}Te$	RG68/1	(11.1±0.2)10^{-3}	$^{32}S(n,p)$=60	(12.8±0.8)10^{-3}	0.0128±0.0008

TABLE II (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{127}I(n,p)^{127g}Te$	RG68/1	$(7.62 \pm 0.11)10^{-3}$	$^{32}S(n,p)=60$	$(8.8 \pm 0.5)10^{-3}$	0.0088 ± 0.0005
$^{132}Ba(n,p)^{132}Cs$	RB59	5.3	$^{32}S(n,p)=30$	12	12(±6) +
$^{136}Ba(n,p)^{136}Cs$	RB59	0.0015	$^{32}S(n,p)=30$	0.0035	0.0035(±0.0017) +
$^{140}Ce(n,p)^{140}La$	DS68	3.5 ± 0.9	$^{58}Ni(n,2n)=0.004$	4.3 ± 1.6	4.3 ± 1.6 +
$^{141}Pr(n,p)^{141}Ce$	OB67	0.12	unknown		0.12(±0.06) +
$^{182}W(n,p)^{182}Ta$	RV67	$(3.8 \pm 0.6)10^{-3}$	(11)	$(4.0 \pm 0.7)10^{-3}$	0.004 ± 0.0007
$^{183}W(n,p)^{183}Ta$	RV67	$(2.8 \pm 0.5)10^{-3}$	(11)	$(3.0 \pm 0.6)10^{-3}$	0.003 ± 0.0006
$^{203}Tl(n,p)^{203}Hg$	ME58	0.004	$^{32}S(n,p)=30$	0.009	0.009(±0.004)+

TABLE III. INTEGRAL (n, α) CROSS-SECTIONS AVERAGED IN THE URANIUM-235 THERMAL FISSION NEUTRON SPECTRUM

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards[a] (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{9}Be(n,\alpha)^{6}He$	HU53	10	(1)	16	
	GN68	38.2±3.8	(15)		32.8±3.8
$^{11}B(n,\alpha)^{8}Li$	HU53	0.085	(1)	0.14	0.14(±0.07) +
$^{19}F(n,\alpha)^{16}N$	HU53	4.5	(1)	7.2	7.85±0.9
	SA59	4.5	$^{31}P(n,p)$=19	8.5	
$^{23}Na(n,\alpha)^{20}F$	HU53	0.4	(1)	0.64	0.765±0.17
	SA59	0.47	$^{31}P(n,p)$=19	0.89	
$^{27}Al(n,\alpha)^{24}Na$ (see also next page)	HU53	0.6	(1)	0.96	
	SA59	0.44	$^{31}P(n,p)$=19	0.83	
	ME60	0.48	$^{32}S(n,p)$=60	0.55	
	DE62	0.63±0.03	(9)		
	DU62	0.85±15%	$^{238}U(n,f)$=310	0.90±0.14	
	FH64	0.62±0.03	unknown		
	BO64	0.60±0.03	$^{32}S(n,p)$=60	0.70±0.035	
	GR68		(8)	0.75±0.0045	
	BR67,70	0.695±0.02	(3)	0.74±0.02	
	NJ70	(0.61)*	$^{27}Al(n,\alpha)$=0.61	0.735	
	KI71	(0.63)*	(4)	0.70	
	FA72	0.78±0.03	$^{235}U(n,f)$=1335 (7)	0.73±0.02	
	RI57	0.60	$^{238}U(n,f)$=304	0.71	
	PA61	(0.60)*	$^{27}Al(n,\alpha)$=0.60	0.755	
	HO62	(0.57)*	$^{27}Al(n,\alpha)$=57	0.73	
	RA67/1	0.61±0.028	$^{58}Ni(n,p)$=95	0.71±0.03	
	NS68	0.58±0.07	(5)	0.68±0.08	

[a] Numbers in parentheses refer to notes, a list of which follows Table V.

TABLE III (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{27}Al(n,\alpha)^{24}Na$ (cont'd)	SC69	(0.767)*	$^{27}Al(n,\alpha)$=767	0.744±0.045	
	KI71	(0.63)*	(4)	0.70	
	MC72	(6)		0.73±0.015	
	FA72	0.725±0.02	$^{235}U(n,f)$=1250	0.725±0.045	0.725±0.045
$^{30}Si(n,\alpha)^{27}Mg$	NI64	0.15±0.02	$^{27}Al(n,p)$=3.43	0.175±0.03	0.155±0.02
	KI71	0.130±0.020	(4)	0.144±0.023	
$^{31}P(n,\alpha)^{28}Al$	HU53	1.43	(1)	2.29	1.9±0.6
	SA59	0.75	$^{31}P(n,p)$=19	1.44	
$^{34}S(n,\alpha)^{31}Si$	HU53	3.0	(1)	4.8	
	SA59	1.2	$^{31}P(n,p)$=19	2.3	
	BL65	2.23 (calc.)	(18)		2.2(±0.2)
$^{35}Cl(n,\alpha)^{32}P$	HU53	3.0	(1)	4.8	8.8±4.6
	SA59	4.1	$^{31}P(n,p)$=19	7.8	
	DU59	15	unknown		
	NI65/1	12.4	$^{32}S(n,p)$=62	13.8	
	LW66,68	32	$^{54}Fe(n,p)$=60	44	
$^{36}Cl(n,\alpha)^{33}P$	LW66,68	52	$^{54}Fe(n,p)$=60	72	72(±36) +
$^{39}K(n,\alpha)^{36}Cl$	NS68	8.0 (calc.)	(19)		8.0(±0.3) +
$^{41}K(n,\alpha)^{38}Cl$	RA67/1	0.61±0.032	$^{58}Ni(n,p)$=95	0.73±0.06	0.76±0.05
	JO68	0.68±0.05	$^{27}Al(n,\alpha)$=0.6	0.82±0.08	

TABLE III (cont.)

Reactions	References	Original values $\sigma \pm \Delta\sigma$ (mb)	Standards (mb)	Renormalized values $\sigma \pm \Delta\sigma$ (mb)	Recommended values $\sigma \pm \Delta\sigma$ (mb)
$^{40}Ca(n,\alpha)^{42}K$	GI66	13.2	unknown		13(±6) +
$^{44}Ca(n,\alpha)^{41}Ar$	LA65	(61.1±9.2)10^{-3}	unknown		0.0611±0.0092+
$^{45}Sc(n,\alpha)^{42}K$	RC59	<5	$^{27}Al(n,\alpha)$=0.6		
	RG68/2	0.158±0.004	$^{32}S(n,p)$=60	0.182±0.012 –	0.182±0.012
$^{48}Ti(n,\alpha)^{45}Ca$	ME58	0.0055	$^{32}S(n,p)$=30	0.013	0.013(±0.006)+
$^{50}Ti(n,\alpha)^{47}Ca$	ME58	0.0002	$^{32}S(n,p)$=30	0.00046	(4.6(±2.3))10^{-4}+
$^{51}V(n,\alpha)^{48}Sc$	HU53	0.08	(1)	0.13	
	SA59	0.0099	$^{31}P(n,p)$=19	0.0187	
	NS68	(15.3±2.7)10^{-3}	(5)	0.018±0.003 –	} 0.022±0.003
	KI71	0.0217±0.0015	(4)	0.024±0.002 –	
$^{55}Mn(n,\alpha)^{52}V$	NS68	0.11 (calc.)	(19)		0.11(±0.03) +
$^{54}Fe(n,\alpha)^{51}Cr$	ME58	0.37	$^{32}S(n,p)$=30	0.85	
	BA68	0.79±15%	unknown		
	NS68	0.50±0.15	(5)	0.6±0.2 –	0.6±0.2
$^{56}Fe(n,\alpha)^{53}Cr$	BY65	0.397±0.12	unknown		0.397±0.12 +
$^{59}Co(n,\alpha)^{56}Mn$ (see also next page)	SA59	0.14	$^{31}P(n,p)$	0.265	
	BA68	0.32±18%	unknown		
	NS68	0.131±0.011	(5)	0.154±0.016 –	}

TABLE III (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{59}Co(n,\alpha)^{56}Mn$ (cont'd)	BR70	0.147±0.005	(3)	0.156±0.006	0.156±0.009
	FA72	0.156±0.006	$^{235}U(n,f)$=1250	0.156±0.011	
$^{58}Ni(n,\alpha)^{55}Fe$	Sc57	0.17	(10)	0.52	
	BA68	2.95±32%	unknown		3±0.9 +
$^{62}Ni(n,\alpha)^{59}Fe$	SC57	0.013	(10)	0.04	0.09±0.07 +
	ME58	0.025	$^{32}S(n,p)$=30	0.0575	
	RC59	0.14	$^{27}Al(n,\alpha)$=0.6	0.17	
$^{63}Cu(n,\alpha)^{60}Co$	RC59	0.72	$^{27}Al(n,\alpha)$=0.6	0.87	
	NL63	0.54±0.07	$^{58}Ni(n,p)$=101	0.60±0.09	
	LL65	0.44	unknown		
	FA72	0.66±0.06	$^{235}U(n,f)$=1335 (7)	0.62±0.04	
	HO62	0.42	$^{27}Al(n,\alpha)$=0.57	0.535	
	MA64/4	0.45±0.05	$^{54}Fe(n,p)$=76	0.475±0.05	
	NS68	0.382±0.036	(5)	0.449±0.042	
	MC72	(6)		0.495±0.05	
	FA72	0.50±0.05	$^{235}U(n,f)$=1250	0.50±0.06	0.50±0.06
$^{68}Zn(n,\alpha)^{65}Ni$	SA59	0.020	$^{31}P(n,p)$=19	0.038	
	RA67/1	$(6.3\pm0.4)10^{-2}$	$^{58}Ni(n,p)$=95	0.075±0.007	0.074±0.006
	SC69	0.077±0.01	$^{27}Al(n,\alpha)$=0.767	0.073±0.011	

TABLE III (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{72}Ge(n,\alpha)^{69m}Zn$	RC59	<1	$^{31}P(n,p)$=19		
	NI63	0.020±0.005	$^{58}Ni(n,p)$=92	0.025±0.006 —	0.025±0.006 +
$^{74}Ge(n,\alpha)^{71m}Zn$	NI63	0.002±0.001	$^{58}Ni(n,p)$=92	0.0025±0.0013	0.0025±0.0013+
$^{79}Br(n,\alpha)^{76}As$	NS68	0.02 (cal.)	(19)		0.02(±0.006) +
$^{89}Y(n,\alpha)^{89}Sr$	BA68	0.002±27%	unknown		0.002±0.0006 +
$^{92}Zr(n,\alpha)^{89}Sk$	NS68	0.014 (calc.)	(19)		0.014(±0.004)+
$^{93}Nb(n,\alpha)^{90g}Y$	RG72	0.0585±0.0022	$^{27}Al(n,\alpha)$=0.6	0.0707±0.0051	0.0707±0.0051
$^{93}Nb(n,\alpha)^{90m}Y$	RG72	0.0221±0.0003	$^{27}Al(n,\alpha)$=0.6	0.0267±0.0017	0.0267±0.0017
$^{92}Mo(n,\alpha)^{89}Zr$	ME58	0.017	$^{32}S(n,p)$=30	0.04	0.04(±0.02) +
$^{98}Mo(n,\alpha)^{95}Zr$	RA67/1	$(14.0\pm1.3)10^{-3}$	$^{46}Ti(n,p)$=12.6	0.0139±0.0016	0.0139±0.0016
$^{133}Cs(n,\alpha)^{130}I$	SA59	$2.4x10^{-4}$	$^{31}P(n,p)$=19	0.00045	
	ME58	0.0005	$^{32}S(n,p)$=30	0.0012	
	ST67	0.0027±0.0006	$^{27}Al(n,\alpha)$=0.6	0.0033±0.0008 —	0.0033±0.0008
$^{138}Ba(n,\alpha)^{135}Xe$	LA65	$(1.9\pm0.3)10^{-3}$	unknown		0.0019±0.0003 +
$^{181}Ta(n,\alpha)^{178}Lu$	SA59	$8.5x10^{-5}$	$^{31}P(n,p)$=19	$1.6x10^{-4}$	$(1.6(\pm0.8))10^{-4}$ +
$^{184}W(n,\alpha)^{181}Hf$	RV67	$(0.19\pm0.04)10^{-3}$	(11)	$(0.20\pm0.05)10^{-3}$	$(2\pm0.5)10^{-4}$

TABLE IV. INTEGRAL (n, 2n) CROSS-SECTIONS AVERAGED IN THE URANIUM-235 THERMAL FISSION NEUTRON SPECTRUM

Reactions	References	Original values $\sigma \pm \Delta\sigma$ (mb)	Standards[a] (mb)	Renormalized values $\sigma \pm \Delta\sigma$ (mb)	Recommended values $\sigma \pm \Delta\sigma$ (mb)
$^{9}Be(n,2n)^{8}Be$	DB57	73±20	(12)		
	ZH63	70–140	(13)		
	FE66	116.2±13%	(14)	148±19	144±6
	GN68	144±6	(15)		
$^{12}C(n,2n)^{11}C$	RO60	$3x10^{-6}$	$^{32}S(n,p)$=60	$3.5x10^{-6}$	
	NS68	$(3.6±1.2)10^{-7}$	(5)	$(4.2±1.4)10^{-7}$	$(4.2±1.4)10^{-7}$
$^{16}O(n,2n)^{15}O$	NS68	$(4.5±2.0)10^{-6}$	(5)	$(5.3±2.4)10^{-6}$	$(5.3±2.4)10^{-6}$
$^{19}F(n,2n)^{18}F$	LE63	$(8.6±1.3)10^{-3}$	$^{32}S(n,p)$=69	$(8.6±1.4)10^{-3}$	
	RE67	$7.10x10^{-3}$±20%	$^{58}Ni(n,p)$=85	$(9.4±2.0)10^{-3}$	
	NS68	$(7.2±1.0)10^{-3}$	(5)	$(8.5±1.3)10^{-3}$	$(7.3±0.7)10^{-3}$
	NJ70	$(5.3±0.5)10^{-3}$	$^{27}Al(n,\alpha)$=0.61	$(6.3±0.7)10^{-3}$	
$^{23}Na(n,2n)^{22}Na$	BE57	6.10^{-3}	unknown		
	WA62	0.0012	unknown		
	NS68	$(2.7±0.7)10^{-3}$	(5)	$(3.2±0.8)10^{-3}$	$(2.2±0.2)10^{-3}$
	ST70	$(2.0±0.1)10^{-3}$	$^{58}Ni(n,p)$=105	$(2.15±0.2)10^{-3}$	
$^{48}Ca(n,2n)^{47}Ca$	KU65	0.3±0.03	$^{27}Al(n,\alpha)$=0.6	0.36±0.04	0.36±0.04
$^{46}Ti(n,2n)^{45}Ti$	RO60	0.0063	$^{32}S(n,p)$=60	0.0072(±20%)	0.0078±0.0009
	SC69	0.0087±0.001	$^{27}Al(n,\alpha)$=0.767	0.0082±0.0011	
$^{50}Cr(n,2n)^{49}Cr$	QA71	0.0054±0.0008	(20)	0.006±0.001	0.006±0.001

[a] Numbers in parentheses refer to notes, a list of which follows Table V.

TABLE IV (cont.)

Reactions	References	Original values $\sigma \pm \Delta\sigma$ (mb)	Standards (mb)	Renormalized values $\sigma \pm \Delta\sigma$ (mb)	Recommended values $\sigma \pm \Delta\sigma$ (mb)
$^{55}Mn(n,2n)^{54}Mn$	SC57	0.05	(10)	0.15	
	RO60	0.19	$^{32}S(n,p)=60$	0.22	
	HO62	0.18	$^{27}Al(n,\alpha)=0.57$	0.23	
	NS68	0.202±0.018	(5)	0.24±0.025	
	ST70	0.26±0.02	$^{58}Ni(n,p)=105$	0.28±0.03	
	QA71	0.258±0.03	(20)	0.285±0.04	0.258±0.013
	FA72	0.27±0.015	$^{235}U(n,f)=1335(?)$	0.253±0.01	
	FA72	0.253±0.01	$^{235}U(n,f)=1250$	0.253±0.02	
$^{54}Fe(n,2n)^{53}Fe$	HU53	0.0032	(1)	0.005	0.005(±0.0025) +
	BE57	0.1±0.02	unknown		
$^{59}Co(n,2n)^{58}Co$	NS68	0.340±0.0030	(5)	0.40±0.04	0.40±0.04
$^{58}Ni(n,2n)^{57}Ni$	SC57	0.0012	(10)	0.0037	
	RO60	0.006	$^{32}S(n,p)=60$	0.007(±20%)	0.0049±0.0014
	BA68	0.004±0.0009	unknown		
$^{63}Cu(n,2n)^{62}Cu$	GR68		(8)	0.124±0.009	
	FA72	0.124±0.009	$^{235}U(n,f)=1250$	0.124±0.011	0.124±0.011
$^{66}Zn(n,2n)^{65}Zn$	HO62	< 4	$^{27}Al(n,\alpha)=0.57$	< 5	< 5 +
$^{70}Ge(n,2n)^{69}Ge$	RC59	1.5	$^{27}Al(n,\alpha)=0.6$	1.8	1.8(±0.9) +
$^{75}As(n,2n)^{74}As$	RO60	0.29	$^{32}S(n,p)=60$	0.33(±20%)	
	NS68	0.304±0.036	(5)	0.36±0.05	0.33±0.02
	ST70	0.30±0.01	$^{58}Ni(n,p)=105$	0.32±0.02	
$^{78}Se(n,2n)^{77m}Se$	KR65	< 1	(21)	< 1	< 1 +

TABLE IV (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{80}Se(n,2n)^{79m}Se$	KR65	<10	(21)	<10	<10 +
$^{85}Rb(n,2n)^{84}Rb$	RN66	0.2	unknown		0.2(±0.1) +
$^{88}Sr(n,2n)^{87m}Sr$	KR65	<10	(21)	<10	<10 +
$^{89}Y(n,2n)^{88}Y$	RO6C	0.12	$^{32}S(n,p)$=60	0.14±(20%)	0.156±0.011
	BA68	0.22±23%	unknown		
	RA67/2	0.2±0.01	$^{46}Ti(n,p)$=12.6	0.20±0.02	
	ST7C	0.137±0.005	$^{58}Ni(n,p)$=105	0.147±0.010	
	QA71	0.144±0.02	(20)	0.16±0.024	
$^{90}Zr(n,2n)^{89}Zr$	QA71	0.0687±0.01	(20)	0.076±0.01	0.076±0.01
$^{93}Nb(n,2n)^{92m}Nb$	HG66	~0.4	unknown		0.48±0.04
	KI71	0.402±0.034	(4)	0.448±0.038	
	FA72	0.52±0.03	$^{235}U(n,f)$=1335 (7)	0.487±0.02	
	NS68	0.370±0.030	(5)	0.435±0.035	
	KI71	0.432±0.033	(4)	0.482±0.037	
	FA72	0.47±0.03	$^{235}U(n,f)$=1250	0.47±0.04	
	RG72	0.420±0.007	$^{27}Al(n,\alpha)$=0.6	0.51±0.03	
$^{107}Ag(n,2n)^{106m}Ag$	NS68	0.39±0.07	(5)	0.46±0.09	0.46±0.09
$^{112}Cd(n,2n)^{111m}Cd$	KR65	0.35±0.4	(21)	0.42±0.06	0.42±0.06

TABLE IV (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{127}I(n,2n)^{126}I$	RO60	1.7	$^{32}S(n,p)$=60	2.0(±20%)	0.9±0.1
	MC72	(6)		1.09±0.05	
	FA72	1.09±0.05	$^{235}U(n,f)$=1250	1.09±0.08	
	NS68	1.62±0.24	(5)	1.9±0.3	
	RG68/1	0.647±0.010	$^{32}S(n,p)$=60	0.744±0.044	
	ST70	1.02±0.01	$^{58}Ni(n,p)$=105	1.10±0.07	
$^{138}Ba(n,2n)^{137m}Ba$	KR65	2.0±10%	(21)	2.4±0.3	2.4±0.3
$^{186}W(n,2n)^{185}W$	DR66	10.0±0.7	$^{197}Au(n,\gamma)$=133±10 (22)		10.0±0.7 +
$^{185}Re(n,2n)^{184}Re$	ST70	4.3±0.3	$^{58}Ni(n,p)$=105	4.6±0.4	4.6±0.4
$^{185}Re(n,2n)^{184m}Re$	ST70	0.58±0.03	$^{58}Ni(n,p)$=105	0.62±0.05	0.62±0.05
$^{187}Re(n,2n)^{186}Re$	DR67	10±6	$^{197}Au(n,\gamma)$=190±19 (22)		10±6 +
$^{197}Au(n,2n)^{196}Au$	SC69	3.14±0.2	$^{27}Al(n,\alpha)$=0.767	2.97±0.26	3.0±3
$^{203}Tl(n,2n)^{202}Tl$	RO60	4.0	$^{32}S(n,p)$=60	4.6±(20%)	3.0±0.5
	NS68	2.75±0.55	(5)	3.23±0.67	
	QA71	2.41±0.35	(20)	2.64±0.42	

TABLE IV (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{204}Pb(n,2n)^{203}Pb$	RO60	3.3	$^{32}S(n,p)=60$	3.8±(20%)	2.45±0.4
	JU62	5.0±15%	$^{238}U(n,f)=310$	5.3±0.8	
	KI71	1.90±0.18	(4)	2.11±0.23	
	QA71	2.19±0.30	(20)	2.41±0.36	
$^{232}Th(n,2n)^{231}Th$	PH58	12.4±0.6	$^{32}S(n,p)=60.3$	14.2±1.1	14.2±1.1
	SC69	~10	$^{27}Al(n,\alpha)=0.767$		

TABLE V. INTEGRAL (n, n') CROSS-SECTIONS AVERAGED IN THE URANIUM-235 THERMAL FISSION NEUTRON SPECTRUM

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards[a] (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{77}Se(n,n')^{77m}Se$	KR65	600±60	(21)	725±86	733±46
	KO67	652±30	Ni(n,p)=100	737±57	
$^{87}Sr(n,n')^{87m}Sr$	KR65	120±12	(21)	145±17	112±17
	KO67	91±5	^{58}Ni(n,p)=100	103±9	
$^{89}Y(n,n')^{89m}Y$	DI68	128.4±25%	(25)		128±32
$^{93}Nb(n,n')^{93m}Nb$	HG71	97±35 (calc.)	^{103}Rh(n,n')=595±150(26)	87±14	87±14
$^{103}Rh(n,n')^{103m}Rh$	RO64	535.8 (calc.)	(27)		
	KO67	403±40	^{58}Ni(n,p)=100	455±53	533±33
	BT68	716±40 (calc.)	(28)		
	KI69	558±32 (calc.)	(29)		
	HG71	595±150(calc.)	(26)		
$^{111}Cd(n,n')^{111m}Cd$	KR65	140±14	(21)	169±20	228±76
	KO67	289±15	^{58}Ni(n,p)=100	327±26	
$^{115}In(n,n')^{115m}In$	KO67	181±10	^{58}Ni(n,p)=100	205±15	
	BR67,70	177±6.0	(3)	188.5±6.4	
	NJ70	156±5	^{27}Al(n,α)=61	188±6	
	FA72	200±8	^{235}U(n,f)=1335 (7)	187.5±6	
	FA72	188±4	^{235}U(n,f)=1250	188±11	188±11
$^{137}Ba(n,n')^{137m}Ba$	KR65	220±22	(21)	266±32	225±22
	KO67	189±10	^{58}Ni(n,p)=100	214±17	

[a] Numbers in parentheses refer to notes, a list of which follows this table.

TABLE V (cont.)

Reactions	References	Original values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Standards (mb)	Renormalized values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)	Recommended values $\bar{\sigma} \pm \Delta\bar{\sigma}$ (mb)
$^{197}Au(n,n')^{197m}Au$	DI68	379.8±25%	(25)		380±95
$^{204}Pb(n,n')^{204m}Pb$	DU62	22±15%	$^{238}U(n,f)$=310	23.3±3.5 -	18.6±1.5
	KO67	15.3±0.7	$^{58}Ni(n,p)$=100	17.3±1.3 -	
	KI71	18.9±2.0	(4)	21.0±2.5 -	

NOTES TO TABLES II-V

(1) The fission flux was determined by comparison with another fission flux produced in a simpler geometry such as a converter. Hughes' old data set could not be ignored since some of his measurements are still unique or among the few. It was then necessary to perform an empirical renormalization. This was done by comparing Hughes' values with well established ones whenever possible. Hughes' data were found to be consistently too low by an average factor of 1.6.

(2) The fission flux was deduced from the power generated in the uranium rod. This power was calculated from the flow and temperature rise of the cooling water. No renormalization was performed.

(3) Bresesti's data were first reported relative to a value of 0.61 mb for $^{27}Al(n,\alpha)^{24}Na$ (Ref. BR67). After comparison with data obtained by integration of excitation functions over various spectral representations for the fission spectrum, these data were rescaled by a factor of 1.14. The values for $^{46}Ti(n,p)^{46}Sc$, $^{58}Ni(n,p)^{58m}Co$ and $^{92}Mo(n,p)^{92}Nb$ which do not appear in Ref. BR70 were multiplied by 1.14 by Fabry (Ref. FA72) and included in his evaluation.

(4) The fast neutron flux was monitored using the following standards: 104 mb, 1.4 mb and 0.63 mb for $^{58}Ni(n,p)^{58}Co$, $^{24}Mg(n,p)^{24}Na$ and $^{27}Al(n,\alpha)^{24}Na$, respectively. New values for these standards (see Table I) lead to an average renormalization factor of 1.11.

(5) The fission spectrum averaged cross-sections $\bar{\sigma}$ were found by correcting the average cross-sections $\bar{\sigma}_0$ measured in a critical assembly of enriched uranium. In this case, our renormalized values were obtained by multiplying Nasyrov's data by Fabry's rescaling factor, which is 1.175 for these data.

(6) The core centre reaction rate measurements of McElroy have been transformed by Fabry (see Ref. FA72) into fission spectrum averaged cross-sections. Fabry's scaling is relative to a value of 0.73 ± 0.015 for the $^{27}Al(n,\alpha)$ cross-section.

(7) Fabry's data were directly quoted from Ref. FA72, although practically all of them were reported in Ref. FA70/1. Although they result from absolute measurements, using the technique described in Ref. FA67 (see Note (9) for description of a similar technique), they are all consistently scaled to the uranium-235 average fission cross-section value of 1335 mb, which can therefore rightly be considered as the standard.

(8) The double ratio measurements of Grundl (Refs GR67, GR68) have been converted to fission spectrum averaged cross-sections by Fabry. All details can be found in Ref. FA72.

(9) Depuydt et al. (Ref. DE62) have used the converter technique for their measurements. The absolute value of the fast flux Φ_f was determined from the absolute value of the thermal flux Φ_{th} by means of the relation :

$$\Phi_f = \nu \ \Sigma_f \ \Phi_{th} \ G \ f_{cor}$$

where ν = 2.43 ± 0.02 is the mean number of neutrons emitted per thermal fission of uranium-235

Σ_f = 23.8 ± 0.2 cm^{-1} is the macroscopic fission cross-section of the converter, computed for a microscopic thermal fission cross-section of (587 ± 6) b for uranium-235

G is a geometrical factor

f_{cor} takes into account the secondary processes in the facility

Φ_{th} is determined using (98.8 ± 0.3) b for the thermal capture cross-section of gold-197

We have not renormalized in this case.

(10) The data are based on the assumption that the fission-neutron flux inside the uranium receptacle slug equals the thermal neutron flux outside the slug; they were renormalized by multiplying by 69/22.5 as shown by Mellish (see Ref. ME60).

(11) Two standards were used for the neutron flux determination: 0.54 mb and 10.6 mb for ^{63}Cu(n, α) and ^{46}Ti(n, p) cross-sections, respectively.

(12) Neutron multiplication was measured in beryllium spheres. The quantity $\bar{\sigma}_{n,2n} - \bar{\sigma}_{n,\alpha}$ was determined and $\bar{\sigma}_{n,2n}$ was deduced taking 10 mb for the ^{9}Be(n, α) cross-section. No renormalization.

(13) The same method as in Note (12) was used with the same value of 10 mb for the ^{9}Be(n, α) cross-section. No renormalization.

(14) Three standards were used for the neutron flux determination: 95 ± 6 mb, 61 ± 8 mb and 9.8 ± 1.1 mb for the ^{58}Ni(n, p), ^{54}Fe(n, p) and ^{46}Ti(n, p) cross-sections, respectively.

(15) Green has used a manganese sulphate bath technique to make an accurate measurement of the ^{9}Be(n, 2n) cross-section averaged over a pure ^{252}Cf fission neutron spectrum. The technique measures neutron multiplication and therefore eliminates completely the need for a flux measurement. The ^{9}Be(n, α) reaction was corrected using a calculated average cross-section of 38.2 ± 3.8 mb. Fission neutron spectra of ^{252}Cf and ^{235}U are similar enough to justify averaging (n, 2n) cross-section values of Green and of Felber.

(16) The original value of 65 mb has been corrected by Fabry (see Ref. FA72).

(17) Data communicated by S.B. Wright to W.H. Martin and D.M. Clare.

(18) The original value was computed by integration of an evaluated excitation function σ(E) over a Watt spectrum. It is clearly our recommended value in this case. Whenever a check is possible, the agreement between our recommended values and Barrall's computed values is generally good, therefore we can arbitrarily use a 10% relative error.

(19) Nasyrov's computed values are based on the relation

$$\bar{\sigma} = \sigma_{eff} \int_{E_{eff}}^{\infty} \chi(E)\, dE \quad \left(\int_0^{\infty} \chi(E)\, dE = 1\right) \quad \text{where } \chi(E) \sim e^{-0.766E}$$

The calculation was performed whenever it was possible to choose σ_{eff} among experimental or evaluated data. When no other data are available, Nasyrov's calculated data become our recommended values with an arbitrary relative error of 30%.

(20) Two standards were used for the neutron flux determination: 72.6 mb and 0.307 mb for ^{54}Fe(n, p) and ^{75}As(n, 2n) cross-sections, respectively.

(21) Four standards were used for the neutron flux determination: 92 mb, 3.4 mb, 1.2 mb and 0.63 mb for ^{58}Ni(n, p), ^{27}Al(n, p), ^{24}Mg(n, p) and ^{27}Al(n, α) cross-sections, respectively.

(22) The standard chosen depends too much upon the shape of the fission spectrum to allow a renormalization.

(23) Ricabarra et al. have measured the following ratio:
$\bar{\sigma}[^{31}P(n,p)^{31}Si]/\bar{\sigma}[^{32}S(n,p)^{32}P]$ = 0.51 ± 0.03.

(24) Value calculated from an empirical formula valid for $8 \leq Z \leq 42$. This value becomes our recommended value for which we estimate a 30% relative error.

(25) Cross-section averaged over a reactor spectrum from 0.1 MeV to infinity. The standard reaction used was $^{28}Si(n,p)$, for which an average cross-section of (10.4 ± 2.4) mb, computed over the same energy range, has been accepted. No renormalization.

(26) Hegedüs has measured the excitation function of $^{93}Nb(n,n')^{93m}Nb$ which he integrated over a Watt spectrum (Ref. WT52) to obtain 97 ± 35 mb. He used a standard value of 595 ± 150 mb for $^{103}Rh(n,n')^{103m}Rh$. This value was computed from Butler's excitation curve (Ref. BT68) using a larger conversion coefficient ratio $\alpha k/\alpha$ for ^{103m}Rh (0.131 instead of 0.099). This explains the lower value of 595 mb instead of 716 mb obtained by Butler and Santry. The errot on the $^{93}Nb(n,n')^{93m}Nb$ cross-section includes the uncertainty of the standard.

(27) Obtained by integration of a Vogt and Cross (Ref. VC64) excitation function over a Cranberg spectrum (Ref. CR56). No renormalization.

(28) The measured excitation function was integrated over a Cranberg spectrum (Ref. CR56). Value not retained for the average (see Note (26)). No renormalization.

(29) Kimura et al. measured the excitation curve up to 4.6 MeV. Above this value, they used the curve calculated by Vogt and Cross (Ref. VC64) to compute $\bar{\sigma}$ using a Cranberg spectrum (Ref. CR56).

REFERENCES TO TABLES II-V

AM64 AMIEL, S., GILAT, J., Nucl. Sci. Eng. 18 (1964) 105.

BA68 BRAUN, H., NAGY, L., Radiochim. Acta 10 (1968) 15.

BE57 BETTS, R.H., DAHLINGER, O.F., Rep. AECL PR-CM-11 (1957) 12 (quoted in Ref. ST70).

BL65 BARRALL, R.C., McELROY, W.N., Personnel Dosimetry for Radiation Accidents (Proc. Symp. Vienna, 1965), IAEA, Vienna (1965) 251.

BO64 BOLDEMAN, J.W., J. Nucl. Energy A/B 18 (1964) 417.

BR67 BRESESTI, A.M., BRESESTI, M., RYDIN, R.A., Nucl. Sci. Eng. 29 (1967) 7.

BR70 BRESESTI, A.M., BRESESTI, M., ROTA, A., RYDIN, R.A., LESCA, L., Nucl. Sci. Eng. 40 (1970) 331.

BT68 BUTLER, J.P., SANTRY, D.C., Neutron Cross-sections and Technology (Proc. Conf. Washington, 1968) 2, NBS, Washington (1968) 803.

BU70 BRUGGEMAN, A., DE SOETE, D., HOSTE, J., Radiochim. Acta 14 (1970) 147.

BY65 BYRNE, A.R., private communication to FREEMAN, N.J., J. Nucl. Energy 23 (1969) 713.

CR56 CRANBERG, L., FRYE, G., NERESON, N., Phys. Rev. 103 (1956) 662.

DB57 DUBOVSKY, B.G., KAMAEV, A.V., MAKAROV, E.F., At. Ehnerg. 2 (1957) 279 (Engl. transl.: J. Nucl. Energy 6 (1957) 172).

DE62 DEPUYDT, H., NEVE DE MEVERGNIES, M., Reactor Science and Technology (J. Nucl. Energy) A/B 16 (1962) 447.

DI68 DURRANI, S.A., KOEHLER, W., J. Nucl. Energy 22 (1968) 632.

DR66 DRUZHININ, A.A., LBOV, A.A., BILIBIN, L.P., J. Nucl. Phys. (USSR) 4 (1966) 515 (Engl. transl.: Sov. J. Nucl. Phys. 4 (1967) 366).

DR67 DRUZHININ, A.A., LBOV, A.A., BILIBIN, L.P., J. Nucl. Phys. (USSR) 5 (1967) 18 (Engl. transl.: Sov. J. Nucl. Phys. 5 (1967) 13).

DS67 DESCHUYTER, M., HOSTE, J., Radiochim. Acta 7 (1967) 198.

DS68 DESCHUYTER, M., MASART, D.L., SPEECKE, A., HOSTE, J., Radiochim. Acta 10 (1968) 11.

DU62 DURHAM, R.W., NAVALKAR, M.P., RICCI, E., Rep. AECL-1434 (1962).

FA67 FABRY, A., Nukleonik 10 (1967) 280.

FA70/1 FABRY, A., Proc. Russian-Dutch-Belgian Meeting on Fast Reactor Physics, Melekess (1970) paper 35.

FA70/2 FABRY, A., DE COSTER, M., MINSART, G., SCHEPERS, J.C., VANDEPLAS, P., Nuclear Data for Reactors (Proc. Conf. Helsinki, 1970) 2, IAEA, Vienna (1970) 535.

FA72 FABRY, A., Rep. BLG-465 (1972).

FE66 FELBER, F.F., Jr., FARMELO, D.R., VAN SICKLE, V.C., Nucl. Sci. Eng. 25 (1966) 1.

FH64 FAEHRMANN, K., Unpublished work quoted in Rep. ZFK-RN 23 (1964) 6.

FM69 FREEMAN, N.J., BARRY, J.F., CAMPBELL, N.L., J. Nucl. Energy 23 (1969) 713.

FR67 FRANÇOIS, J.P., DE SOETE, D., HOSTE, J., Radiochim. Acta 8 (1967) 192.

GN68 GREEN, L., Nucl. Sci. Eng. 32 (1968) 30.
GI66 GILLETTE, J.H., Rep. ORNL-4013 (1966) 7.
GO62 GOPINATHAN, K.P., Proc. Indian Acad. Sci. Sect. A 56 3 (1962) 141.
GR67 GRUNDL, J.A., Nucl. Sci. Eng. 30 (1967) 39.
GR68 GRUNDL, J.A., Nucl. Sci. Eng. 31 (1968) 191.
GV72 GOVE, N.B., WAPSTRA, A.H., Nucl. Data Tables 11 (1972) 127.
HA72 HANSEN, J.R., STEINNES, E., Radiochim. Acta 17 (1972) 46.
HE58 HENDERSON, W.J., TUNNICLIFFE, P.R., Nucl. Sci. Eng. 3 (1958) 145.
HG66 HEGEDÜS, F., Helv. Phys. Acta 39 (1966) 179.
HG71 HEGEDÜS, F., Rep. EIR-195 (1971).
HO62 HOGG, C.H., WEBER, L.D., Symp. Radiation Effects on Metals and Neutron Dosimetry (Proc. Symp. Los Angeles, 1962), American Society for Testing and Materials (1963) 133.
HP69 HUPF, H.B., Rep. TID-24823 (1969) 46, 52.
HU53 HUGHES, D.J., Pile Neutron Research, Chapter 4, Addison-Wesley, Cambridge, Mass. (1953).
HW70 HOWERTON, R.J., Rep. UCRL-50400, Vol.9 (1970).
JO68 JOHANSEN, O., STEINNES, E., Radiochim. Acta 9 (1968) 47.
JA64 JANTSCH, K., unpublished, quoted in Rep. ZFK-RN 23 (1964) 6.
KI69 KIMURA, I., KOBAYASHI, K., SHIBATA, T., J. Nucl. Sci. Technol. (Tokyo) 6 (1969) 485.
KI71 KIMURA, I., KOBAYASHI, K., SHIBATA, T., J. Nucl. Sci. Technol. (Tokyo) 8 (1971) 59.
KO65 KOEHLER, W., KNOPF, K., Rep. EANDC (E)-57 (1965) 29.
KO66/1 KOEHLER, W., Nukleonik 8 (1966) 9.
KO66/2 KOEHLER, W., Nukleonik 8 (1966) 59.
KO67 KOEHLER, W., Nukleonik 10 (1967) 181.
KR65 KRAMER, H.H., WAHL, W.H., Nucl. Sci. Eng. 22 (1965) 373.
KU65 KURCHATOVA, L.N., LEVIN, V.I., MOROZOV, L.N., Radiokhimiya 7 (1965) 472 (Engl. transl.: Sov. Radiochem. 7 (1965) 469).
LA65 LAGERWALL, T., Z. Naturforsch. 20a (1965) 1583.
LE63 LEONHARDT, W., Kernenergie 6 (1963) 45.
LL65 LLORET, private communication to LISKIEN, H., quoted in J. Nucl. Energy 27 (1973) 39.
LW66 LEWIS, R.E., BUTLER, T.A., Nucl. Applics 2 (1966) 102.
LW68 LEWIS, R.E., Rep. TID-24823 (1968) 49.
MA64/1 MARTIN, W.H., CLARE, D.M., Nucl. Sci. Eng. 18 (1964) 468.
MA64/2 CLARE, D.M., MARTIN, W.H., KELLY, B.T., Nucl. Sci. Eng. 18 (1964) 448.
MA64/3 MARTIN, W.H., CLARE, D.M., Nucl. Sci. Eng. 19 (1964) 465.
MA64/4 CLARE, D.M., MARTIN, W.H., J. Nucl. Energy A/B 18 (1964) 703.
MC72 McELROY, W.N., ARMANI, R.J., TOCHILIN, E., Nucl. Sci. Eng. 48 (1972) 51.
ME58 MELLISH, C.E., PAYNE, J.A., OTLET, R.L., Rep. AERE I/R 2630 (1958).
ME60 MELLISH, C.E., Rep. AERE-R3251 (1960); see also Nucleonics 19 3, (1961) 114.
MU61 MUENZE, R., JANTSCH, K., HLADIK, O., Kernenergie 4 (1961) 293.
NI63 NIESE, S., MORZEK, P., HEROLD, C., Kernenergie 6 (1963) 37.
NI64 NIESE, S., Kernenergie 7 (1964) 105.
NI65/1 NIESE, S., Kernenergie 8 (1965) 499.
NI65/2 NIESE, S., Rep. ZFK-Rch 3 (1965) 23.
NJ70 NAJZER, M., RANT, J., SOLING, H., Nuclear Data for Reactors (Proc. Conf. Helsinki, 1970) 2, IAEA, Vienna (1970) 571.
NL63 NILSSON, R., Neutron Dosimetry (Proc. Symp. Harwell, 1962) 2, IAEA, Vienna (1963) 275.
NS68 NASYROV, F., At. Ehnerg. 25 (1968) 437 (Engl. transl.: Sov. J. At. Energy 25 (1968) 1251).
OB67 O'BRIEN, H.A., Jr., ELDRIDGE, J.S., Nucleonics 25 2 (1967) 41.
OB69 O'BRIEN, H.A., Jr., Int. J. Appl. Radiat. Isot. 20 (1969) 121.
PA61 PASSEL, T.O., HEATH, R.L., Nucl. Sci. Eng. 10 (1961) 308.
PH58 PHILLIPS, J.A., J. Nucl. Energy 7 (1958) 215.
PL73 PEARLSTEIN, S., J. Nucl. Energy 27 (1973) 81.
PO73 POPE, A.L., STORY, J.S., Rep. AEEW-M 1191 (1973).
QA71 QAIM, S.M., WÖLFLE, R., STÖCKLIN, G., Chemical Nuclear Data, Measurements and Applications (Proc. Conf. Canterbury, 1971), Inst. of Civil Engineers, London (1971) 121.
RA67/1 RAU, G., Nukleonik 9 (1967) 228.
RA67/2 RAU, G., Rep. EANDC (E) 89 (1967) 41.
RB59 ROBINSON, B.L., FINK, R.W., private communication, quoted by ROCHLIN, R.S., in Nucleonics 17 1 (1959) 54, Ref. 14.

RC59 ROCHLIN, R.S., Nucleonics 17 1 (1959) 54.
RE67 REDDY, G.R., SANKAR DAS, M., Rep. BARC-280 (1967).
RG68/1 REGGE, P. de, DAMS, R., HOSTE, J., Radiochim. Acta 9 (1968) 57.
RG68/2 REGGE, P. de, DAMS, R., HOSTE, J., Radiochim. Acta 10 (1968) 156.
RG72 REGGE, P. de, DAMS, R., HOSTE, J., Radiochim. Acta 17 (1972) 69.
RI57 RICHMOND, R., quoted by ROCHLIN, R.S., in Nucleonics 17 1 (1959) 54, Ref.12.
RN66 REYNOLDS, S.A., Rep. ORNL-3889 (1966) 53.
RO60 ROY, J.C., HAWTON, J.J., Rep. CRC-1003 (1960).
RO64 ROY, J.C., DURHAM, R.W., FOWLER, A.G., HAWTON, J.J., Rep. CRC-1101 (1964).
RR60 RICABARRA, D., TURJANSKI, R., ATEN, A.H.W., Jr., J. Nucl. Energy, Part A: Reactor Science 12 (1960) 177.
RV57 RIVIER, J., BLACHOT, J., HOCQUENGHEM, J.C., Radiochim. Acta 8 (1967) 196.
RY58 ROYS, P.A., KALMAN SHURE, Nucl. Sci. Eng. 4 (1958) 536.
SA59 SAELAND, E., SAMSAHL, K., quoted by ROCHLIN, R.S., in Nucleonics 17 1 (1959) 54, Ref.7.
SC57 SCHUMAN, R.P., MEWHERTER, A.C., Rep. KAPL-1779 (1957).
SC69 SCHUMAN, R.P., OESTREICH, D.K., unpublished (1969).
ST67 STEINNES, E., Rep. KR-123 (1967).
ST70 STEINNES, E., Radiochim. Acta 13 (1970) 169.
VC64 VOGT, E.W., CROSS, W.G., quoted by ROY, J.C., in Rep. CRC-1101 (1964).
WA62 WAGNER, K., Kernenergie 10/11 (1962) 790.
WA63 WAGNER, K., POSER, H., Kernenergie 6 (1963) 177.
WE70 WEITMAN, J., DAVERHOG, N., FARVOLDEN, S., Trans. Am. Nucl. Soc. 13 (1970) 558.
WT52 WATT, B.E., Phys. Rev. 87 (1952) 1037.
ZH63 ZHEZHERUN, I.F., SADIKOV, I.P., TARABAN'KO, V.A., CHERNYSHOV, A.A., At. Ehnerg. 15 6 (1963) 485 (Engl. transl.: Sov. J. At. Energy 15 (1963) 1271).
ZJ63 ZIJP, W.L., Neutron Dosimetry (Proc. Symp. Harwell, 1962) 1, IAEA, Vienna (1963) 589.

TABLE VI. ESTIMATED AVERAGE CROSS-SECTIONS FOR (n, p), (n, α) AND (n, 2n) REACTIONS IN A FISSION NEUTRON SPECTRUM

Samples			(n, p) reactions				(n, α) reactions				(n, 2n) reactions		
Z	Element	Mass	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)
3	Li	6	3.18	3.8	39.	+ 35, -25	-4.78				6.41	2.1	+70, -40
		7	11.91	12.5	< 0.0001		6.13				8.29	0.37	↓
4	Be	9	14.26	15.1	< 0.0001		0.67	2.1	33.	+80, -45	1.85	250.	↓
		10	24.15	24.9	< 0.0001		8.64	10.3	0.029	↓	7.49	1.0	↓
5	B	10	-0.23	0.7			-2.79	-0.8		↓	9.28	0.18	↓
		11	11.70	12.6	< 0.0001		7.24	9.2	0.15	↓	12.50	0.008	↓
6	C	12	13.64	14.7	< 0.0001		6.18	8.6	0.37	↓	20.28	< 0.0001	
		13	13.63	14.8	< 0.0001		4.13	6.5	3.3	↓	5.33	10.	+70, -40
7	N	14	-0.63	0.7			0.17	3.1	25.0	↓	11.31	0.030	↓
		15	9.59	11.0	0.001	+150, -60	8.13	11.1	0.012	↓	11.56	0.024	↓
8	O	16	10.24	11.8	0.0005	+150, -60	2.35	5.7	6.0	↓	16.65	0.0002	↓
		17	8.36	9.9	0.0006	+150, -60	-1.82	1.6		↓	4.39	31.	↓
		18	14.01	15.5	< 0.0001		5.29	8.7	0.42	↓	8.49	0.56	↓
9	F	19	4.25	5.9	0.23	+150, -60	1.60	5.4	8.0	↓	10.98	0.050	↓
10	Ne	20	6.56	8.5	0.078	+100, -50	0.62	4.8	12.	↓	17.71	0.0001	↓
		21	5.14	7.0	0.049	+150, -60	-0.70	3.5	26.	↓	7.08	2.5	↓
		22	10.53	12.4	0.0003	+150, -60	5.97	10.2	0.056	↓	10.84	0.064	↓

TABLE VI (cont.)

11	Na	23	3.75	5.8	0.31	+150, -60	4.03	8.7	0.49	+80, -45	12.96	0.008	+70, -40
12	Mg	24	4.93	7.2	0.62	+100, -50	2.66	7.8	1.8		17.22	0.0001	
		25	3.17	5.4	0.58	+150, -60	-0.48	4.7	14.		7.63	1.6	
		26	8.22	10.5	0.005	+150, -60	5.63	10.8	0.027		11.52	0.036	
13	Al	27	1.90	4.3	3.1	+150, -60	3.25	8.8	0.48		13.54	0.005	
14	Si	28	4.00	6.5	2.0	+ 60, -40	2.75	8.7	0.56		17.79	0.0001	
		29	3.00	5.5	0.56	+150, -60	0.03	5.9	7.9		8.77	0.59	
		30	8.02	10.5	0.005	+150, -60	4.34	10.2	0.069		10.96	0.0070	
15	P	31	0.73	3.5	11.	+150, -60	2.01	8.3	1.1		12.70	0.013	
16	S	32	0.96	3.9	100.	+ 35, -25	-1.53	5.1	13.		15.56	0.0008	
		33	-0.53	2.4	58.	+150, -60	-3.49	3.2	41.		8.91	0.56	
		34	4.45	7.4	0.58	+100, -50	1.37	8.0	1.7		11.75	0.035	
		36	10.44	13.4	0.0001	+150, -60	4.23	10.9	0.029		10.17	0.17	
17	Cl	35	-0.62	2.5	52.0	+150, -60	-0.94	6.1	8.0		13.01	0.010	
		36	-1.93	1.1			-2.46	4.6	19.		8.82	0.65	
		37	4.18	7.3	0.046	+150, -60	1.32	8.3	1.2		10.59	0.12	
18	A	36	-0.07	3.2	320.	+ 35, -25	-2.00	5.4	12.		15.68	0.0008	
		38	4.24	7.5	0.54	+100, -50	0.23	7.7	2.9		12.15	0.025	
		40	6.89	10.2	0.010	+150, -60	2.55	10.0	0.11		10.12	0.19	
19	K	39	-0.22	3.2	20.	+150, -60	-1.36	5.4	13.		13.42	0.007	
		40	-2.29	1.2			-3.87	3.9	31.		8.00	1.6	

TABLE VI (cont.)

Samples			(n, p) reactions				(n, α) reactions				(n, 2n) reactions		
Z	Element	Mass	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)
19	K	41	1.75	5.2	1.1	+150, -60	0.11	7.8	2.6	+80, -45	10.34	0.16	+70, -40
20	Ca	40	0.54	4.2	77.	+ 35, -25	-1.75	6.3	7.8	↓	16.02	0.0006	↓
		42	2.80	6.5	2.6	+ 60, -40	-0.35	7.8	2.7		11.75	0.040	
		43	1.06	4.7	2.3	+150, -60	-2.29	5.9	10.		8.12	1.5	
		44	4.99	8.6	0.11	+100, -50	2.81	10.9	0.033		11.39	0.059	
		46	7.08	10.7	0.005	+150, -60	6.05	14.2	0.0003		10.63	0.13	
		48	13.22	16.8	< 0.0001		8.81	16.9	< 0.0001		10.16	0.21	
21	Sc	45	-0.53	3.2	22.	+150, -60	0.40	8.8	0.67	+80, -45	11.57	0.050	
22	Ti	46	1.62	5.5	12.	+ 60, -40	0.08	8.9	0.59	↓	13.48	0.008	
		47	-0.18	3.7	11.	+150, -60	-2.18	6.6	7.3		9.06	0.61	
		48	3.27	7.2	0.98	+100, -50	2.07	10.9	0.035		11.87	0.039	
		49	1.25	5.1	1.4	+150, -60	-0.23	9.0	0.53		8.31	1.3	
		50	6.23	10.1	0.013	+150, -60	3.51	12.3	0.005		11.17	0.079	
23	V	50	-3.00	1.0			-0.76	8.3	1.5		9.52	0.40	
		51	1.71	5.7	0.60	+150, -60	2.10	11.2	0.024		11.27	0.073	
24	Cr	50	0.26	4.5	57.	+ 35, -25	-0.32	9.1	0.47		13.20	0.011	
		52	3.26	7.5	0.66	+100, -50	1.23	10.6	0.057		12.27	0.028	
		53	2.69	6.8	0.12	+150, -60	-1.80	7.6	4.1		8.09	1.7	

TABLE VI (cont.)

24	Cr	54	6.34	10.5	0.008	+150, -60	1.57	11.0	0.033	+80, -45	9.90	0.29	+70, -40
25	Mn	55	1.84	6.2	0.30	+150, -60	0.64	10.3	0.090		10.41	0.18	
26	Fe	54	-0.09	4.4	70.	+ 35, -25	-0.84	9.1	0.49		13.63	0.007	
		56	2.97	7.4	0.81	+100, -50	-0.32	9.6	0.25		11.40	0.068	
		57	1.81	6.3	0.27	+150, -60	-2.40	7.5	5.0		7.78	2.5	
		58	5.41	9.8	0.023	+150, -60	1.41	11.4	0.019		10.22	0.22	
27	Co	59	0.80	5.4	1.0	+150, -60	-0.32	9.9	0.17		10.64	0.15	
28	Ni	58	-0.39	4.3	85.	+ 35, -25	-2.89	7.6	4.4		12.41	0.026	
		59	-1.86	2.9	41.	+150, -60	-5.09	5.4	17.		9.15	0.65	
		60	2.08	6.8	2.1	+ 60, -40	-1.35	9.2	0.46		11.58	0.060	
		61	0.53	5.2	1.4	+150, -60	-3.57	6.9	7.3		7.95	2.2	
		62	4.51	9.2	0.058		0.44	11.0	0.036		10.77	0.14	
		63	2.92	7.6	0.043		-1.56	9.0	0.63		6.95	5.9	
		64	6.32	11.1	0.004		2.47	13.0	0.002		9.81	0.36	
29	Cu	63	-0.72	4.2	6.3		-1.71	9.1	0.55		11.03	0.11	
		65	1.37	6.2	0.34		0.09	10.9	0.043		10.06	0.28	
30	Zn	64	-0.21	4.8	43.	+ 35, -25	-3.87	7.3	6.0		12.04	0.040	
		66	1.88	6.8	2.2	+ 60, -40	-2.27	8.8	0.86		11.22	0.091	
		67	-0.21	4.8	2.7	+150, -60	-4.88	6.2	12.		7.16	5.0	
		68	3.86	8.9	0.098	+100, -50	-0.78	10.3	0.10		10.35	0.22	
		70	6.3	11.3	0.003	+150, -60	0.72	11.8	0.012		9.35	0.60	

TABLE VI (cont.)

Samples			(n, p) reactions				(n, α) reactions				(n, 2n) reactions		
Z	Element	Mass	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)
31	Ga	69	0.13	5.2	1.5	+150, -60	-2.58	9.0	0.67	+80, -45	10.46	0.20	+70, -40
		71	2.05	7.2	0.083	+150, -60	-0.93	10.4	0.092	↓	9.43	0.56	↓
32	Ge	70	0.88	6.1	6.5	+ 60, -40	-2.96	8.7	1.0		11.70	0.059	
		72	3.26	8.5	0.18	+100, -50	-1.48	10.2	0.12		10.90	0.13	
		73	0.78	6.0	0.49	+150, -60	-3.91	7.7	4.4		6.88	7.0	
		74	4.78	10.0	0.020	↓	0.45	12.1	0.008		10.34	0.23	
		76	6.72	11.9	0.001		2.4	14.0	0.0006		9.57	0.51	
33	As	75	0.41	5.8	0.67		-1.20	10.7	0.0063		10.38	0.23	
34	Se	74	0.58	6.0	7.9	+ 60, -40	-3.34	9.3	0.46		12.23	0.036	
		76	2.21	7.7	0.63	+100, -50	-1.69	10.5	0.084		11.31	0.091	
		77	-0.10	5.3	1.4	+150, -60	-4.47	7.7	4.6		7.51	3.9	
		78	3.53	9.0	0.092	+150, -60	-0.46	11.8	0.013		10.63	0.18	
		80	5.29	10.7	0.007	+150, -60	0.96	13.0	0.002		10.02	0.34	
		82	7.17	12.6	0.0004	+150, -60	2.58	14.7	0.0002		9.39	0.64	
35	Br	79	-0.64	5.0	2.3	+150, -60	-1.86	10.6	0.075		10.83	0.15	
		81	0.81	6.4	0.29	+150, -60	-0.43	12.0	0.010		10.29	0.26	
36	Kr	78	-0.09	5.6	15.	+ 60, -40	-3.67	9.0	0.72		12.13	0.041	
		80	1.24	6.9	2.2	+ 60, -40	-2.35	10.4	0.10		11.67	0.066	

TABLE VI (cont.)

36	Kr	82	2.33	8.0	0.42	+100, -50	-0.99	11.8	0.014	+80, -45	11.11	0.12	+70, -40
		83	0.19	5.9	0.62	+150, -60	-3.42	9.1	0.66		7.56	3.9	
		84	3.97	9.6	0.039		0.40	13.1	0.002		10.64	0.19	
		86	6.60	12.3	0.0007		2.20	14.9	0.0002		9.97	0.37	
37	Rb	85	-0.10	5.7	0.85		-0.99	12.0	0.011		10.60	0.20	
		87	3.15	9.0	0.007		1.22	14.3	0.0004		10.04	0.35	
38	Sr	84	0.11	6.0	8.6	+ 60, -40	-2.69	10.6	0.078		12.16	0.042	
		86	1.00	7.0	2.0	-	-1.12	12.2	0.0081		11.62	0.073	
		87	-0.51	5.4	1.3	+150, -60	-3.21	10.1	0.16		8.53	1.6	
		88	4.57	10.5	0.011	+150, -60	0.80	14.1	0.0006		11.24	0.11	
39	Y	89	0.72	6.8	0.17	+150, -60	-0.70	12.9	0.003		11.60	0.076	
40	Zr	90	1.52	7.7	0.71	+100, -50	-1.75	12.1	0.010		12.07	0.048	
		91	0.77	7.0	0.13	+150, -60	-5.66	8.3	2.2		7.28	5.5	
		92	2.87	9.0	0.10		-3.39	10.5	0.096		8.73	1.3	
		94	4.26	10.5	0.011		-2.07	11.8	0.015		8.28	2.1	
		96	6.08	12.2	0.0009		-0.17	13.8	0.0009		7.91	3.1	
41	Nb	93	-0.72	5.6	1.0		-4.91	9.2	0.61		8.92	1.1	
		94	-1.68	4.6	75.		-5.63	8.6	1.5		7.31	5.4	
42	Mo	92	-0.43	6.0	9.1	+ 60, -40	-3.69	10.7	0.072		12.83	0.023	
		94	1.28	7.7	0.73	+100, -50	-5.13	9.3	0.54		9.78	0.48	
		95	0.14	6.6	0.24	+150, -60	-6.39	8.0	3.4		7.45	4.8	

TABLE VI (cont.)

Samples			(n, p) reactions				(n, α) reactions				(n, 2n) reactions		
Z	Element	Mass	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)
42	Mo	96	2.43	8.9	0.12	+100, -50	-3.99	10.4	0.11	+80, -45	9.25	0.81	+70, -40
		97	1.16	7.6	0.057	+150, -60	-5.37	9.0	0.84		6.89	8.4	
		98	3.86	10.3	0.015		-3.20	11.2	0.037		8.73	1.4	
		100	5.27	11.7	0.002		-2.39	12.0	0.012		8.38	2.0	
43	Tc	97	-1.13	5.4	1.4	↓	-4.81	9.9	0.23		9.51	0.63	
		98	-2.37	4.1	160.	+ 35, -25	-5.91	8.8	1.1		7.47	4.8	
		99	0.60	7.2	0.10	+150, -60	-3.92	10.8	0.065		8.97	1.1	
44	Ru	96	-0.57	6.1	8.1	+ 60, -40	-6.38	8.5	1.7		10.81	0.17	
		98	0.93	7.6	0.87	+100, -50	-5.14	9.8	0.27		10.35	0.28	
		99	-0.49	6.2	0.45	+150, -60	-6.82	8.1	3.1		7.54	4.5	
		100	2.62	9.3	0.069		-3.97	10.9	0.057		9.77	0.50	
		101	0.86	7.5	0.067		-5.80	9.1	0.75		6.87	8.8	
		102	3.76	10.5	0.012		-2.50	12.4	0.007		9.31	0.80	
		104	4.56	11.2	0.004		-1.06	13.8	0.0009		9.00	1.1	
45	Rh	103	-0.02	6.7	0.22	↓	-3.48	11.8	0.016		9.40	0.74	
46	Pd	102	0.37	7.2	1.6	+100, -50	-5.34	10.1	0.18		10.69	0.20	
		104	1.70	8.6	0.20	+100, -50	-4.19	11.3	0.033		10.12	0.36	
		105	-0.22	6.7	0.22	+150, -60	-6.33	9.1	0.77	↓	7.14	6.9	↓

TABLE VI (cont.)

46	Pd	106	2.78	9.7	0.040	+150, -60	-3.00	12.4	0.007	+80, -45	9.65	0.59	+70, -40
		107	0.73	7.6	0.061		-5.37	10.0	0.22		6.59	12.	
		108	3.75	10.6	0.010		-2.05	13.6	0.001		9.31	0.83	
		110	4.66	11.6	0.002		-1.02	14.5	0.0004		8.89	1.3	
47	Ag	107	-0.75	6.2	0.47		-4.18	11.5	0.025		9.64	0.60	
		109	0.34	7.3	0.095	↓	-3.29	12.4	0.007		9.27	0.87	
48	Cd	106	-0.58	6.5	4.7	+ 60, -40	-5.98	10.3	0.14		11.02	0.15	
		108	0.87	8.0	0.51	+100, -50	-4.81	11.2	0.039		10.42	0.28	
		110	2.13	9.2	0.086	+150, -60	-3.67	12.3	0.008		9.97	0.44	
		111	0.25	7.4	0.083		-5.92	10.1	0.19		7.04	7.9	
		112	3.25	10.4	0.014		-2.68	13.7	0.001		9.48	0.72	
		113	1.24	8.3	0.022		-4.94	11.1	0.046		6.60	12.	
		114	4.26	11.4	0.003		-1.66	14.3	0.0005		9.12	1.0	
		116	5.57	12.7	0.0005		-0.19	15.8	0.0001		8.77	1.5	
49	In	113	-0.49	6.7	0.24		-3.76	12.4	0.007		9.51	0.70	
		115	0.67	7.9	0.041	↓	-2.68	13.6	0.001		9.11	1.1	
50	Sn	112	-0.12	7.2	1.7	+100, -50	-5.54	11.1	0.046		10.90	0.18	
		114	1.21	8.6	0.22	+100, -50	-4.33	12.2	0.010		10.41	0.29	
		115	-0.30	7.1	0.13	+150, -60	-6.20	10.3	0.15		7.60	4.7	
		116	2.51	9.9	0.031		-3.17	13.4	0.002		9.64	0.63	
		117	0.69	8.0	0.036		-5.27	11.2	0.041		7.00	8.5	
		118	3.45	10.8	0.008	↓	-2.09	14.4	0.0004	↓	9.41	0.80	↓

TABLE VI (cont.)

Samples			(n, p) reactions				(n, α) reactions				(n, 2n) reactions		
Z	Element	Mass	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)
50	Sn	119	1.58	8.9	0.009	+150, -60	-4.30	11.9	0.015	+80, -45	6.54	14.	+70, -40
		120	4.86	12.2	0.001		-0.96	15.6	0.0001	+80, -45	9.18	1.0	
		122	5.97	13.3	0.0002		0.08	16.5	< 0.0001		8.88	1.4	
		124	6.67	14.0	0.0001		1.98	18.5	< 0.0001		8.56	1.9	
51	Sb	121	-0.40	7.0	0.16		-3.51	14.5	0.0004	+80, -45	9.32	0.89	
		123	0.63	8.1	0.032	↓	-1.92	14.8	0.0003		9.04	1.2	
52	Te	120	0.21	7.7	0.86	+100, -50	-6.64	10.4	0.13		10.37	0.31	
		122	1.21	8.8	0.17	+100, -50	-5.40	11.6	0.024		9.87	0.52	
		123	-0.84	6.7	0.25	+150, -60	-7.58	9.4	0.56		6.99	8.9	
		124	2.13	9.7	0.044		-4.34	12.6	0.006		9.50	0.76	
		125	-0.02	7.5	0.078		-6.56	10.4	0.13		6.64	13.	
		126	2.97	10.5	0.013		-3.39	13.6	0.001		9.18	1.0	
		128	3.53	11.0	0.006		-2.55	14.5	0.0004		8.84	1.5	
		130	4.25	11.8	0.002		-1.81	15.1	0.0002		8.48	2.1	
53	I	127	-0.09	7.6	0.068		-4.28	13.0	0.003		9.21	1.0	
		129	0.72	8.4	0.021	↓	-3.47	13.8	0.001		8.91	1.4	
54	Xe	124	-0.69	7.0	2.5	+ 60, -40	-6.79	10.8	0.076		10.31	0.34	
		126	0.47	8.2	0.42	+100, -50	-5.64	11.8	0.018		10.17	0.39	
		128	1.35	9.1	0.11	+150, -60	-4.81	12.6	0.006	↓	9.69	0.64	↓

TABLE VI (cont.)

54	Xe	129	-0.59	7.2	0.12	+150, -60	-7.02	10.5	0.12	+80, -45	6.96	9.5	+70, -40
		130	2.23	10.0	0.029	↓	-4.06	13.4	0.002	↓	9.33	0.92	↓
		131	0.19	8.0	0.038	↓	-6.22	11.2	0.044	↓	6.66	13.	↓
		132	2.82	10.6	0.012	↓	-3.37	14.1	0.0007	↓	9.00	1.3	↓
		134	3.40	11.2	0.005	↓	-2.72	14.8	0.0003	↓	8.60	1.9	↓
		136	6.27	14.0	0.0001	↓	-2.12	15.3	0.0001	↓	8.05	3.4	↓
55	Cs	133	-0.36	7.5	0.081	↓	-4.45	13.3	0.002	↓	9.05	1.2	↓
		135	0.38	8.3	0.025	↓	-3.67	14.1	0.0007	↓	8.89	1.5	↓
		137	3.59	11.5	0.0002	↓	-3.06	14.7	0.0003	↓	8.34	2.5	↓
56	Ba	130	-0.34	7.6	1.0	+100, -50	-6.67	11.4	0.033	↓	10.30	0.35	↓
		132	0.49	8.5	0.28	+100, -50	-5.89	12.1	0.012	↓	9.88	0.54	↓
		134	1.29	9.3	0.084	+150, -60	-5.10	12.9	0.004	↓	9.54	0.76	↓
		135	-0.57	7.4	0.095	↓	-7.06	11.0	0.06	↓	7.03	9.1	↓
		136	1.78	9.8	0.040	↓	-4.40	13.6	0.0015	↓	9.17	1.1	↓
		137	0.39	8.4	0.022	↓	-6.04	12.0	0.015	↓	6.95	10.	↓
		138	4.65	12.7	0.0005	↓	-3.88	14.2	0.0006	↓	8.67	1.8	↓
57	La	138	-2.58	5.5	25.	+ 60, -40	-6.83	11.5	0.030	↓	7.37	6.6	↓
		139	1.49	9.6	0.004	+150, -60	-4.82	13.5	0.002	↓	8.84	1.6	↓
58	Ce	136	-0.36	7.8	0.80	+100, -50	-6.76	11.8	0.019	↓	10.08	0.45	↓
		138	0.28	8.5	0.28	+100, -50	-5.98	12.5	0.007	↓	9.64	0.71	↓
		140	3.01	11.2	0.005	+150, -60	-5.34	13.1	0.003	↓	9.27	1.0	↓
		142	3.76	11.9	0.002	↓	-6.09	12.4	0.008	↓	7.21	7.9	↓

TABLE VI (cont.)

Samples			(n, p) reactions				(n, α) reactions				(n, 2n) reactions		
Z	Element	Mass	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)
59	Pr	141	-0.20	8.1	0.035	+150, -60	-6.15	12.5	0.007	+80, -45	9.46	0.86	+70, -40
60	Nd	142	1.39	9.8	0.042		-6.64	12.3	0.010		9.88	0.57	
		143	0.15	8.6	0.017		-9.72	9.3	0.71		6.17	22.	
		144	2.23	10.6	0.013		-7.33	11.6	0.027		7.87	4.2	
		145	1.03	9.4	0.005		-8.73	10.2	0.20		5.80	32.	
		146	3.32	11.7	0.002		-6.34	12.7	0.006		7.62	5.4	
		148	4.15	12.5	0.0008		-5.37	13.5	0.002		7.37	6.9	
		150	4.25	12.7	0.0006	↓	-4.21	14.7	0.0003		7.41	6.7	
62	Sm	144	-0.22	8.3	0.39	+100, -50	-7.92	11.5	0.031		10.63	0.27	
		147	-0.56	7.9	0.048	+150, -60	-10.11	9.4	0.63		6.42	18.	
		148	1.69	10.2	0.023		-7.73	11.7	0.024		8.20	3.1	
		149	0.29	8.8	0.013		-9.43	10.2	0.20		5.91	29.	
		150	2.74	11.3	0.005		-6.74	12.8	0.005		8.04	3.6	
		152	2.64	11.2	0.005		-5.28	14.1	0.0008		8.32	2.8	
		154	3.24	11.7	0.003		-4.10	15.4	0.0001		8.03	3.7	
63	En	151	-0.71	7.9	0.049		-7.87	11.8	0.021		8.03	3.7	
		153	0.02	8.7	0.015		-5.83	13.8	0.001		8.61	2.1	
64	Gd	152	1.05	9.7	0.050		-8.07	11.9	0.018		8.65	2.0	
		154	1.20	9.9	0.038	↓	-6.51	13.4	0.002	↓	8.71	1.9	↓

TABLE VI (cont.)

64	Gd	155	-0.54	8.2	0.032	+150, -60	-8.33	11.7	0.024	+80, -45	6.49	17.	+70, -40
		156	1.68	10.3	0.021		-5.67	14.3	0.0006		8.59	2.2	
		157	0.58	9.3	0.006		-7.28	12.7	0.006		6.41	19.	
		158	2.67	11.4	0.004		-5.16	14.8	0.0003	↓	7.98	4.0	
		160	3.64	12.4	0.0009		-3.5	16.9	< 0.0001		7.50	6.4	
65	Tb	159	0.17	9.0	0.010	↓	-6.22	14.1	0.0008	+80, -45	8.19	3.2	
66	Dy	156	-0.52	8.3	0.42	+100, -50	-8.26	12.3	0.010		9.50	0.88	
		158	0.16	9.1	0.13	+150, -60	-7.33	13.3	0.003		9.12	1.3	
		160	1.06	9.9	0.039		-6.82	13.7	0.001		8.64	2.1	
		161	-0.20	8.7	0.016		-8.30	12.2	0.012		6.49	17.	
		162	1.69	10.6	0.014		-6.05	14.5	0.0005		8.25	3.1	
		163	0.91	9.8	0.003		-7.23	13.3	0.003		6.31	21.	
		164	2.58	11.6	0.003		-5.21	15.3	0.0002		7.70	5.4	
67	Ho	165	0.52	9.6	0.004	↓	-6.46	14.3	0.0006		8.04	3.9	
68	Er	162	-0.46	8.7	0.23	+100, -50	-8.49	12.5	0.008		9.27	1.1	
		164	0.18	9.4	0.083	+150, -60	-7.76	13.3	0.003		8.91	1.6	
		166	1.08	10.3	0.022		-7.09	13.9	0.001		8.53	2.4	
		167	0.19	9.4	0.006		-8.31	12.7	0.006		6.47	18.	
		168	2.00	11.2	0.006		-6.26	14.7	0.0004	↓	7.82	4.8	
		170	2.94	12.1	0.002		-4.58	16.4	< 0.0001		7.31	8.1	
69	Tm	169	-0.43	8.8	0.014	↓	-7.44	13.8	0.001	+80, -45	8.11	3.7	↓

TABLE VI (cont.)

Samples			(n, p) reactions				(n, α) reactions				(n, 2n) reactions		
Z	Element	Mass	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)
70	Yb	168	-0.50	8.9	0.18	+100, -50	-8.60	12.9	0.005	+80, -45	9.11	1.4	+70, -40
		170	0.19	9.6	0.063	+150, -60	-8.17	13.3	0.003		8.52	2.4	
		171	-0.69	8.7	0.016		-9.33	12.2	0.013		6.66	15.	
		172	1.09	10.5	0.017		-7.31	14.2	0.0007		8.07	3.8	
		173	0.54	10.0	0.002		-8.20	13.3	0.003		6.40	20.	
		174	2.29	11.7	0.003		-6.41	15.1	0.0002		7.51	6.7	
		176	3.38	12.8	0.0005		-5.58	15.9	0.0001		6.92	12.	
71	Lu	175	-0.31	9.2	0.008	↓	-7.87	13.8	0.001		7.70	5.6	
		176	-0.90	8.5	0.33	+100, -50	-8.49	13.2	0.003		6.33	22.	
72	Hf	174	-0.58	9.0	0.16	+100, -50	-9.17	12.8	0.005		8.64	2.2	
		176	0.41	10.0	0.036	+150, -60	-8.62	13.4	0.002		8.13	3.7	
		177	-0.29	9.3	0.007		-9.71	12.3	0.011		6.42	20.	
		178	1.48	11.1	0.007		-7.91	14.1	0.0009		7.67	5.8	
		179	0.57	10.1	0.002		-8.68	13.3	0.003		6.13	27.	
		180	2.53	12.2	0.001	↓	-6.86	15.2	0.0002		7.43	7.4	
73	Ta	180	-1.71	8.0	0.72	+100, -50	-9.18	13.0	0.004		6.62	17.	
		181	0.24	10.0	0.003	+150, -60	-7.41	14.8	0.0003		7.69	5.8	
74	W	180	0.03	9.8	0.049		-8.86	13.6	0.002		8.54	2.5	
		182	1.03	10.9	0.009	↓	-7.89	14.9	0.0003	↓	8.10	3.9	↓

TABLE VI (cont.)

74	W	183	0.29	10.1	0.002	+150, -60	-9.09	13.6	0.002	+80, -45	6.23	25.	+70, -40
		184	2.26	12.1	0.002		-7.37	15.4	0.0001	+80, -45	7.45	7.4	
		186	3.14	13.0	0.0004		-6.39	16.4	< 0.0001		7.24	9.2	
75	Re	185	-0.35	9.4	0.006		-8.28	14.4	0.0006	+80, -45	7.83	5.1	
		187	0.53	10.2	0.002		-7.10	15.8	0.0001		7.41	7.8	
76	Os	184	-0.68	10.4	0.020		-9.71	13.2	0.003		8.91	1.8	
		186	0.30	10.3	0.024		-9.02	13.9	0.001		8.31	3.2	
		187	-0.78	9.2	0.008		-10.13	12.7	0.007		6.33	23.	
		188	1.34	11.3	0.005		-7.89	15.0	0.0003		8.03	4.2	
		189	0.23	10.2	0.002		-9.17	13.7	0.002		5.95	33.	
		190	2.41	12.4	0.001		-6.84	16.0	0.0001		7.83	5.2	
		192	3.19	13.2	0.0003		-5.24	17.7	< 0.0001		7.60	6.6	
77	Ir	191	-0.47	9.6	0.005		-7.96	15.5	0.0001	+80, -45	8.16	3.8	
		193	0.35	10.4	0.001		-6.64	16.5	< 0.0001		7.81	5.4	
78	Pt	190	-0.11	10.1	0.032		-9.54	13.9	0.001	+80, -45	8.86	1.9	
		192	0.68	10.9	0.010		-8.34	15.1	0.0002		8.70	2.2	
		194	1.46	11.6	0.003		-7.28	16.1	0.0001		8.41	3.0	
		195	0.15	10.3	0.002		-8.71	14.7	0.0004		6.16	28.	
		196	2.40	12.6	0.0008		-6.38	17.1	< 0.0001		7.96	4.7	
		198	3.64	13.8	0.0001		-5.59	17.8	< 0.0001		7.60	6.7	
79	Au	197	-0.04	10.2	0.002		6.98	16.4	< 0.0001		8.12	4.0	

TABLE VI (cont.)

Samples			(n, p) reactions				(n, α) reactions				(n, 2n) reactions		
Z	Element	Mass	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	E_{eff} (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)	E_T (MeV)	$\bar{\sigma}$ (mb)	$\Delta\bar{\sigma}/\bar{\sigma}$ (%)
80	Hg	196	-0.10	10.3	0.024	+150, -60	-8.25	15.0	0.0003	+80, -45	8.79	2.1	+70, -40
		198	0.59	11.0	0.009		-7.46	16.3	< 0.0001		8.34	3.2	
		199	-0.33	10.0	0.003		-8.73	15.0	0.0003	+80, -45	6.68	17.	
		200	1.43	11.8	0.003		-6.55	17.3	< 0.0001		8.07	4.3	
		201	0.72	11.1	0.0005		-7.89	15.9	< 0.0001		6.26	25.	
		202	2.73	13.1	0.0004		-5.71	18.0	< 0.0001		7.79	5.6	
		204	3.74	14.1	0.0001		-4.46	19.2	< 0.0001		7.53	7.3	
81	Tl	203	-0.29	10.2	0.002		-7.20	16.8	< 0.0001		7.76	5.8	
		204	-1.13	9.4	0.096		-7.46	16.2	0.0001	+80, -45	6.69	17.	
		205	0.75	11.2	0.0005		-5.68	18.0	< 0.0001		7.58	7.0	
82	Pb	204	-0.02	10.5	0.019		-8.20	16.1	0.0001	+80, -45	8.44	3.0	
		206	0.75	11.3	0.006		-7.14	17.1	< 0.0001		8.12	4.1	
		207	0.65	11.2	0.0005	↓	-7.89	16.4	< 0.0001		6.77	16.	
		208	4.23	14.8	< 0.0001		-6.19	18.2	< 0.0001		7.40	8.5	
83	Bi	208	-3.65	7.3	2.2	+100, -50	-10.58	14.1	0.001	+80, -45	6.94	13.	
		209	-0.14	10.5	0.001	+150, -60	-9.63	14.9	0.0003	+80, -45	7.49	7.8	
		210	-0.72	9.9	0.046	+150, -60	-11.88	12.6	0.008	+80, -45	4.62	130.	↓

EXCITATION FUNCTIONS FOR CHARGED-PARTICLE-INDUCED NUCLEAR REACTIONS IN LIGHT ELEMENTS AT LOW PROJECTILE ENERGIES

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ABSTRACT. This compilation of data should be useful in various fields of nuclear applications, with the emphasis on charged particle activation analysis. Activation analysis of light elements using charged particles has proved to be an important tool in solving various problems in analytical chemistry, e.g. those associated with metal surfaces. Scientists desiring to evaluate the distribution of light elements on the surface of various matrices using charged-particle reactions require accurate data on cross-sections in the MeV-region. Also, a knowledge of cross-section data and yield functions is of great interest in many applied investigations involving work with charged particles, such as radiological protection and health physics, material research, semiconductor material investigations and corrosion chemistry. The authors therefore decided to collect a limited number of data which find use in these fields. Although the compilation is far from being complete, it is expected to be of assistance in devising measurements of charged-particle reactions in Van de Graaff or other low-energy accelerators.

INTRODUCTION

It is well known that nuclear reactions with charged particles are hindered by the repulsive Coulomb interaction with the nucleus. Thus, charged-particle reactions with acceptable yields occur only where low- or medium-weight nuclei are involved. Elements heavier than $Z > 12$ have therefore been omitted from this compilation. The central problem in activation analysis is the identification of a given nuclide and a quantitative determination of its concentration in a more or less complex matrix. In this connection it is necessary to search for special reactions which exclude competitive processes. This can be done, for example, by using selected bombarding energies which lead to as few competitive reactions as possible. Thus, resonances in the excitation function have been used in order to obtain a dominant yield from the selected nuclide, or coincidence measurements with reaction products have been made. Consequently, differential cross-sections have been included, wherever they were available, as well as integral curves. Furthermore, the compilation contains various yield curves.

In some cases the emerging particle is specified with an index i. This denotes whether the light product is produced in the ground-state (0) or in the i-th excited state of the product nucleus. The excited states and the corresponding gamma-ray energies can be obtained for instance in: Nuclear Data Sheets, National Academy of Sciences, National Research Council, Washington, D.C. (1962).

Where the values for angular distribution are related to the centre-of-mass system this is denoted by the index c.m. for the units of the cross-section in the graphs. Otherwise the graphs show values in the laboratory system.

The authors are of the opinion that a diagram showing the shape of cross-sections or excitation functions provides a more rapid and useful source of information than do data from tables. For this reason, only diagrams of absolute, normalized experimental values have been presented, even in those instances where tables were provided by the experimentalists. Unified symbols and units (see below) have been used, and abbreviated references and comments have been included. The absolute errors as determined by the experimentalists are shown in the diagrams.

Following the compilation of graphs, a list of references is given which is arranged in P (number) for proton, D (number) for deuteron, A (number) for alpha and H (number) for ^{3}He-particle-induced reactions.

In some cases there are several publications concerned with the same reaction. Where the cross-section was measured in different energy regions an attempt was made to fit and normalize the different results to a mean value at the point of intersection. Where identical information was presented by several authors the choice was restricted to that of the most recent origin.

In most cases the cross-sections collected for this compilation are up to 20 MeV. To optimize irradiation conditions, it may be necessary to know whether the cross-section increases at higher energies or whether the resonance for the reaction concerned is already exceeded at low bombarding energies. Unfortunately, there are only very few measurements for reactions induced by charged particles at higher energies. Therefore, a request was made to H. Münzel at the Kernforschungszentrum Karlsruhe for permission to publish parts of the systematic study made by him and his co-worker on experimental cross-sections for charged-particle-induced reactions at higher energies.[1] We received the kind permission to select from this report the parts of interest. This reduced version is given in Appendix 1.[2]

(p, γ) reactions exhibit several resonances in the MeV region. These resonances are of special interest in charged-particle activation analysis. For calibration purposes and depth distribution studies of light elements in heavy matrices, these sharp resonances can be used favourably. In most of the cases the shape of the resonances is not so important as the characteristic data, such as position (resonance energy in keV), resonance width (FWHM in keV) and height (cross-section in mb). Therefore, a request was made to J.W. Butler, U.S. Naval Research Laboratory, Washington, D.C., for permission to publish the systematic collection made by him on (p, γ)-resonances[3] (see Appendix 2).

In Table A2-I, the cross-section given is the total cross-section in millibarns at the resonance peak. Where more than one primary gamma ray is emitted, the tabulated cross-section value is the sum of all such individual primary gamma-ray cross-sections. For those resonances which are too narrow for such cross-section measurements, the integrated

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[1] LANGE, J., MÜNZEL, H., Estimation of Unknown Excitation Functions for (α, xn)-, (α, pxn)-, (d, pxn)-, and (p, xn)-Reactions, Rep. KFK-767 (1968).

[2] A more comprehensive compilation is published in Landolt-Börnstein, New Series I/5, Vol. a, Q-Values; Vol. b, Excitation Functions for Charged Particle Induced Nuclear Reactions, Springer Verlag (1973).

[3] BUTLER, J.W., Table of (p, γ) Resonances, Rep. NRL-5282 (Apr. 1959).

cross-section, $\int \sigma dE$, has been tabulated where this measurement has been made. In these instances, the abbreviation "evb" for "electron-volt barn" has been inserted in the cross-section column.

As far as the gamma energies are concerned, only the most predominant ones have been compiled in Table A2-I. A question mark means doubt about the number.

Finally, Appendix 3 is a Bibliography listing publications containing various data for charged-particle-induced reactions.

ACKNOWLEDGEMENT

The authors wish to express their gratitude to the various contributors to this compilation, especially to Dr. McGowan of the Data Centre at Oak Ridge, Tennessee.

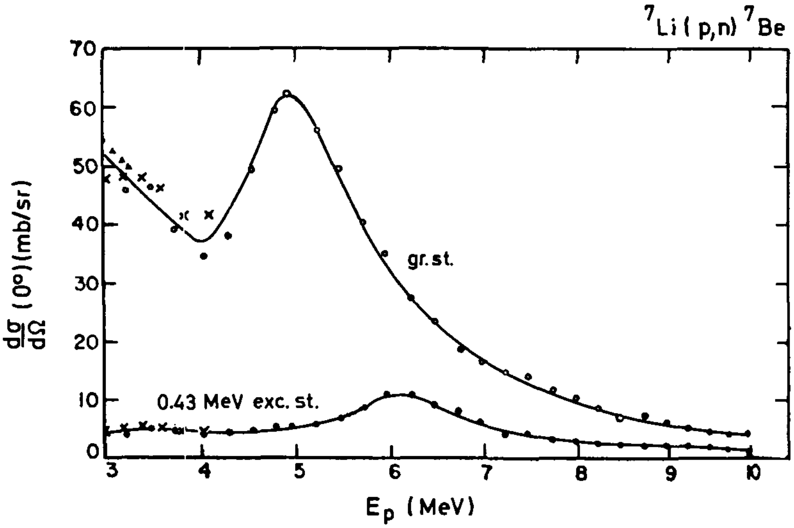
GRAPHS OF EXCITATION FUNCTIONS

Conventions and symbols

σ	total cross-section
σ_{exc}	excitation function
$\frac{d\sigma}{d\Omega}$	angular distribution
$\frac{d\sigma}{d\Omega}(0°)$	diffusion cross-section for 0°
c.m.	centre-of-mass system
θ	laboratory angle of measurement in angular distributions
E	energy in laboratory system
p	subscripts refer to proton
d	subscripts refer to deuteron
^3He	subscripts refer to helium-3
α	subscripts refer to alpha particle
gr. st.	ground-state
exc. st.	excited state
*	residual nucleus left in excited state
(p, p')	inelastic proton scattering
dpm	disintegrations per minute

PROTON

	Reaction	Cross-section and angular distribution	Energy range (MeV)	Page
1.	$^{7}Li(p,n)^{7}Be$	σ (0°)	3 - 13	329
2.	$^{7}Li(p,\alpha)^{4}He$	σ (90°, 120°)	0.5 - 2.3	330
3.	$^{7}Be(p,\gamma)^{8}B$	σ	1 - 3.5	330
4.	$^{9}Be(p,\alpha)^{6}Li$	$\frac{d\sigma}{d\Omega}$	6 - 11.5	332
5.	$^{10}Be(p,\gamma)^{11}B$	σ (0°, 90°)	0 - 6	334
6.	$^{10}B(p,\gamma)^{11}C$	σ (90°)	3 - 17	334
7.	$^{11}B(p,\gamma)^{12}C$	σ, $\frac{d\sigma}{d\Omega}$ (90°)	1 - 14	335
8.	$^{12}C(p,\gamma)^{13}N$	σ	0 - 2.2	337
9.	$^{13}C(p,n)^{13}N$	σ; σ (5°, 40°)	3 - 14	337
10.	$^{14}N(p,\gamma)^{15}O$	σ (90°)	2 - 19	339
11.	$^{15}N(p,n)^{15}O$	σ; σ (5°, 40°)	4 - 14	340
12.	$^{18}O(p,p')^{18}O^{*}$	σ (0°)	3.2 - 5.4	341
13.	$^{18}O(p,\alpha)^{15}N$	σ (0°)	3.2 - 5.4	342
14.	$^{19}F(p,\alpha)^{16}O$	σ; $\frac{d\sigma}{d\Omega}$	4 - 12	342
		σ (70°, 165°); $\frac{d\sigma}{d\Omega}$	9 - 12	343
15.	$^{19}F(p,\alpha\gamma)^{16}O$	relative yield	0 - 5.6	347



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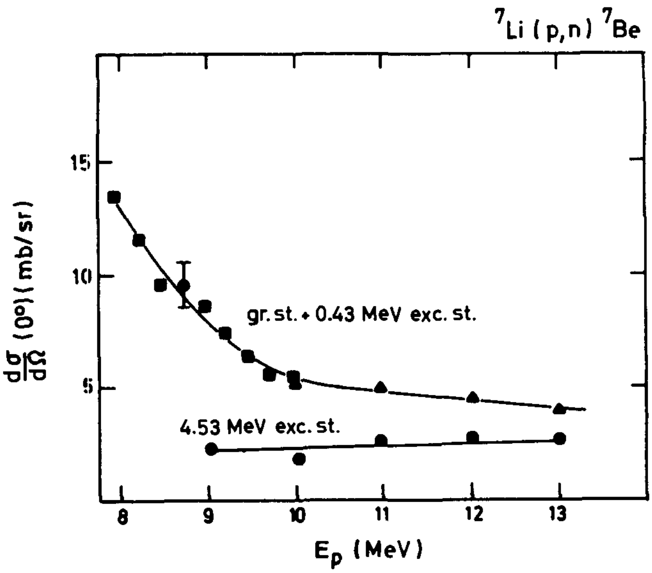

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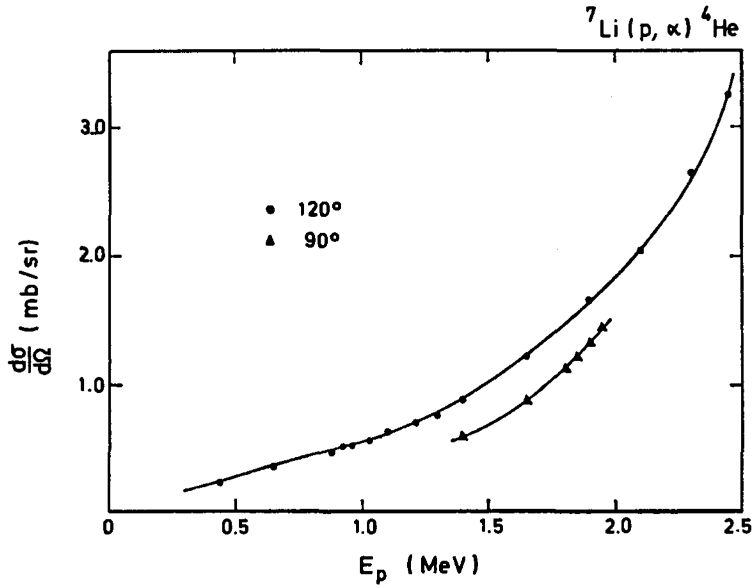

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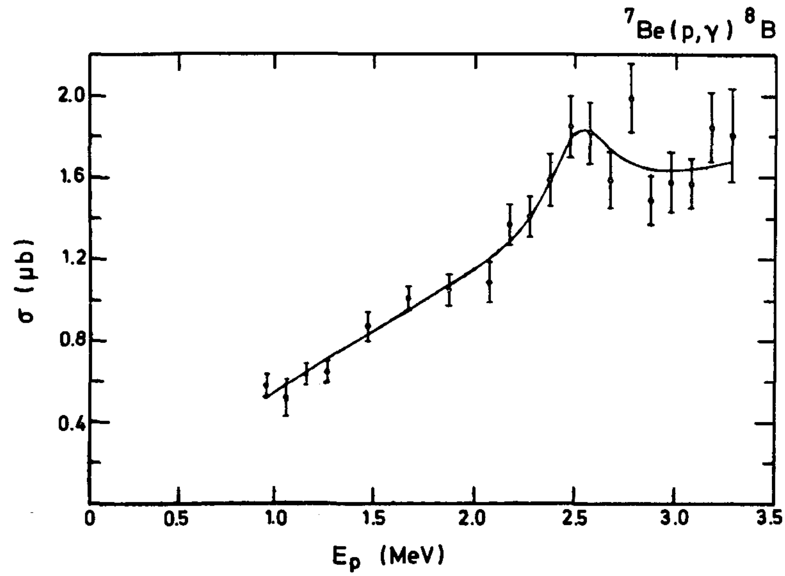

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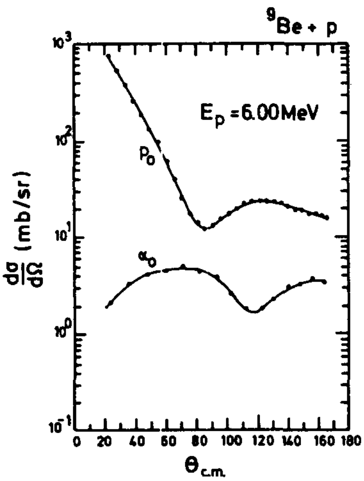
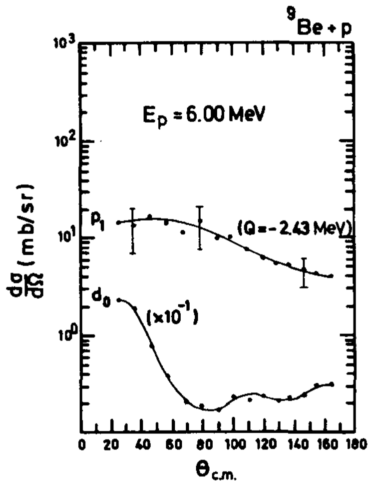


9Be + p
Ep = 6.00 MeV
p0
α0
dσ/dΩ (mb/sr)
θc.m.



9Be + p
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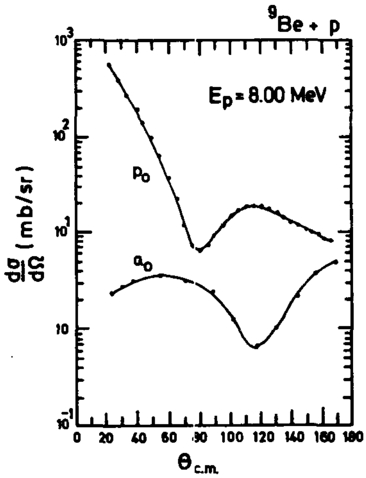
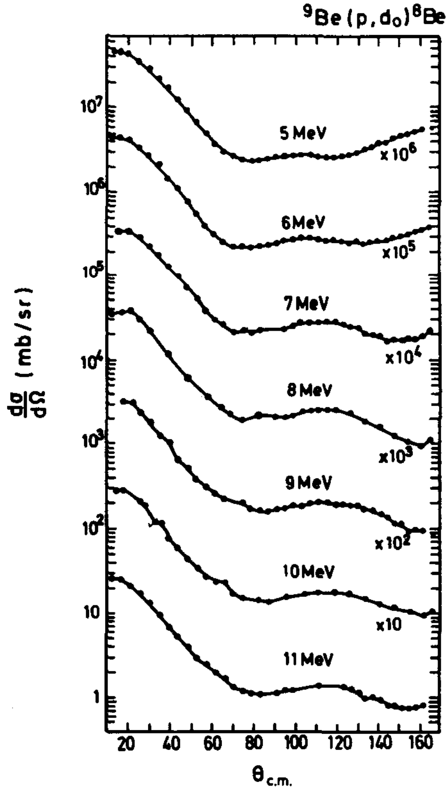
p1
(Q = - 2.43 MeV)
d0
(x10-1)
dσ/dΩ (mb/sr)
θc.m.

Ref. P4

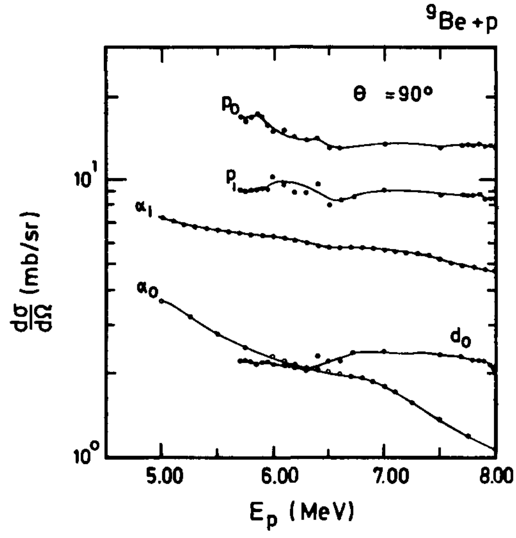


9Be + p
Ep = 8.00 MeV
p0
α0
dσ/dΩ (mb/sr)
θc.m.



9Be (p, d0)8Be
5 MeV
x10^6
6 MeV
x10^5
7 MeV
x10^4
8 MeV
x10^3
9 MeV
x10^2
10 MeV
x10
11 MeV
dσ/dΩ (mb/sr)
θc.m.

Ref. P4



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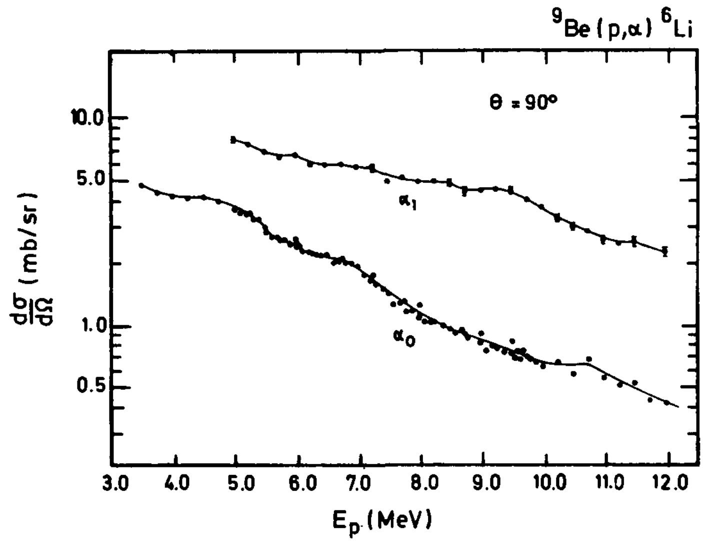

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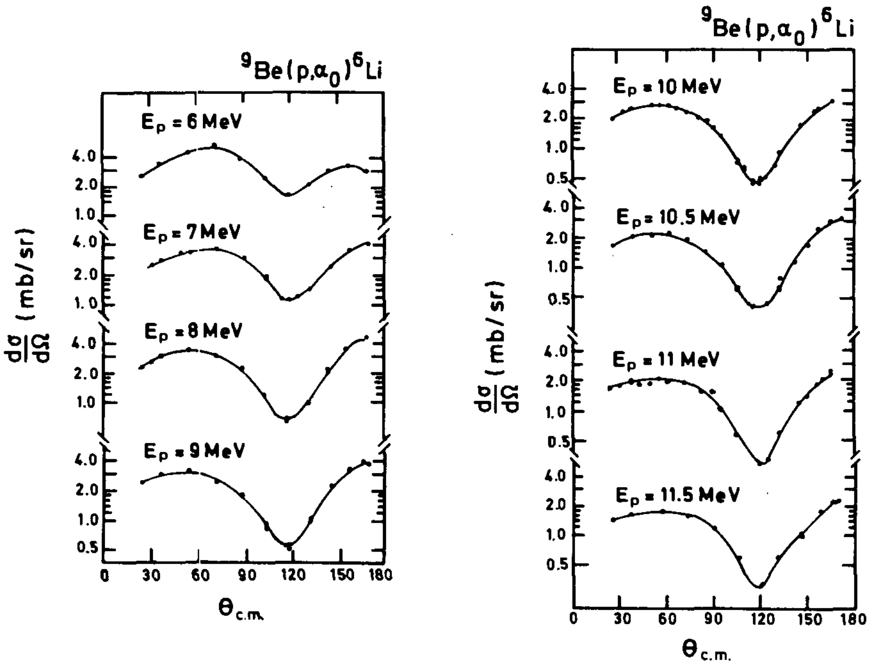

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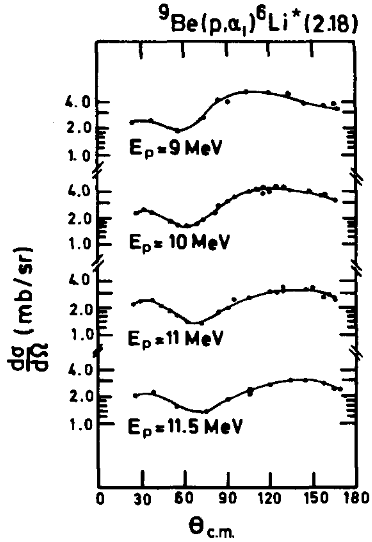

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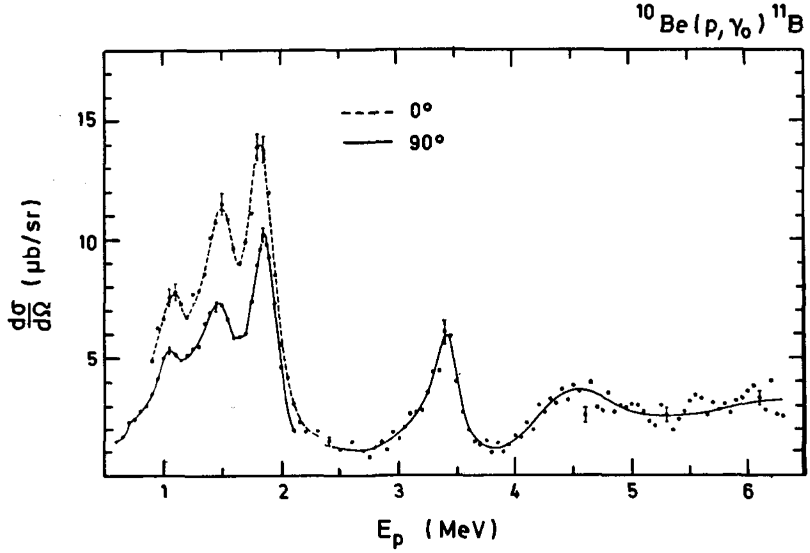

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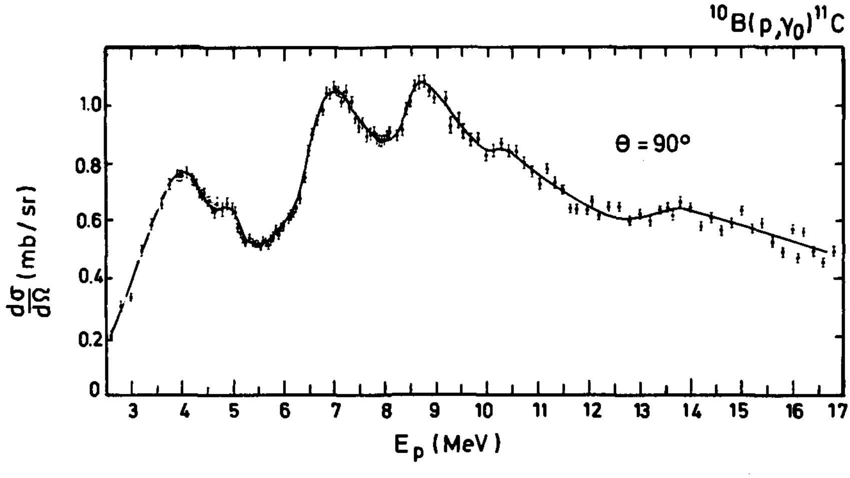

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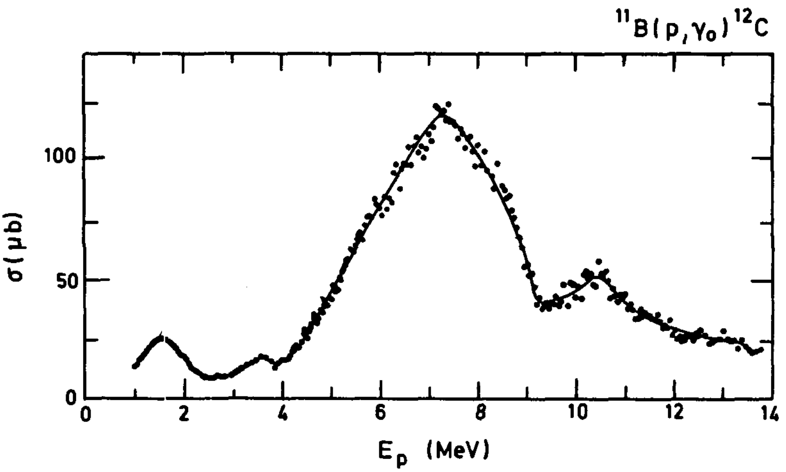

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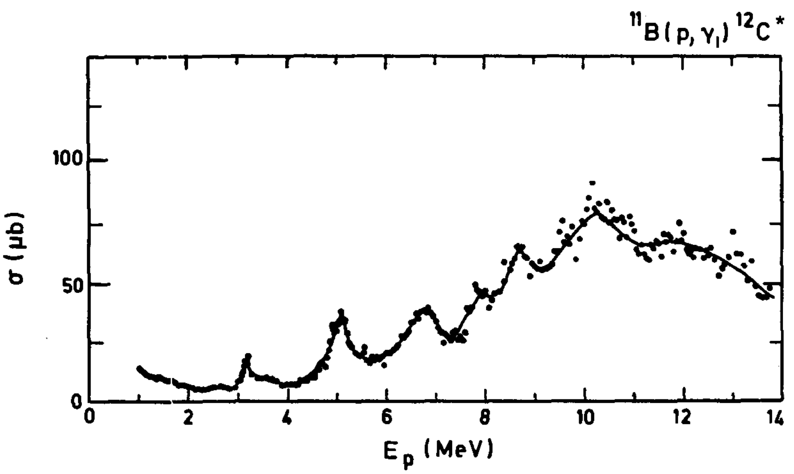

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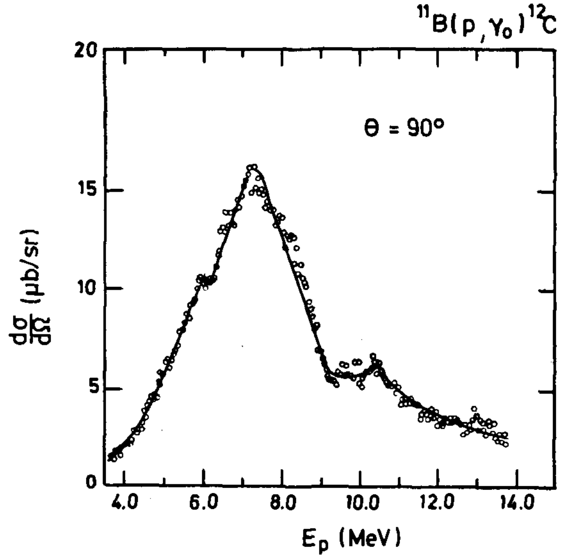

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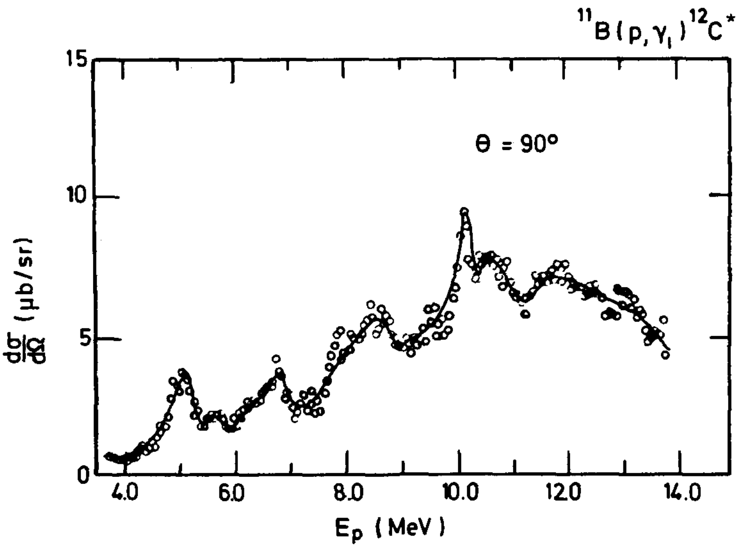

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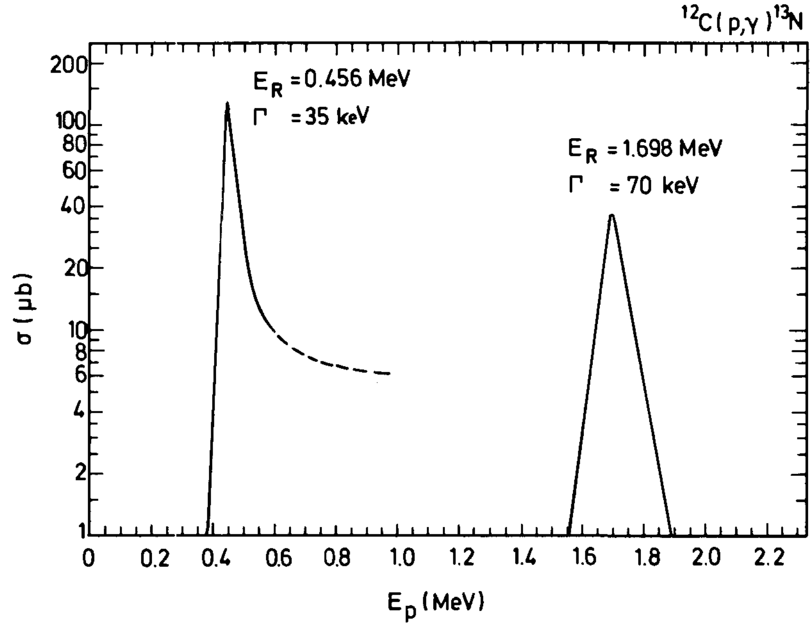

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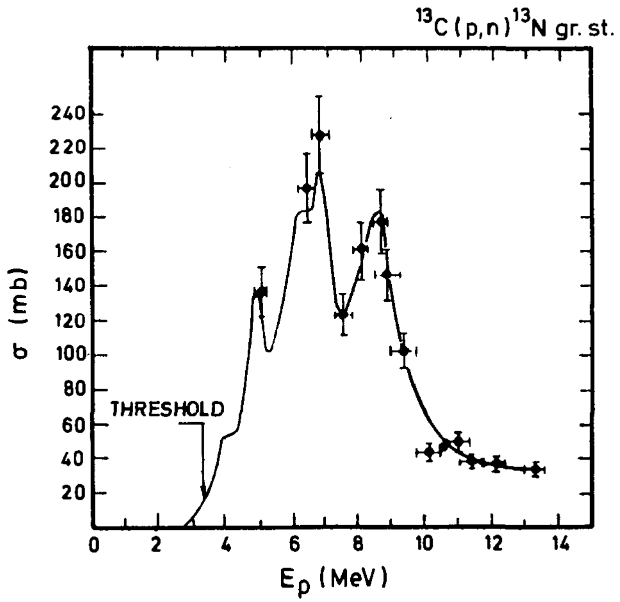

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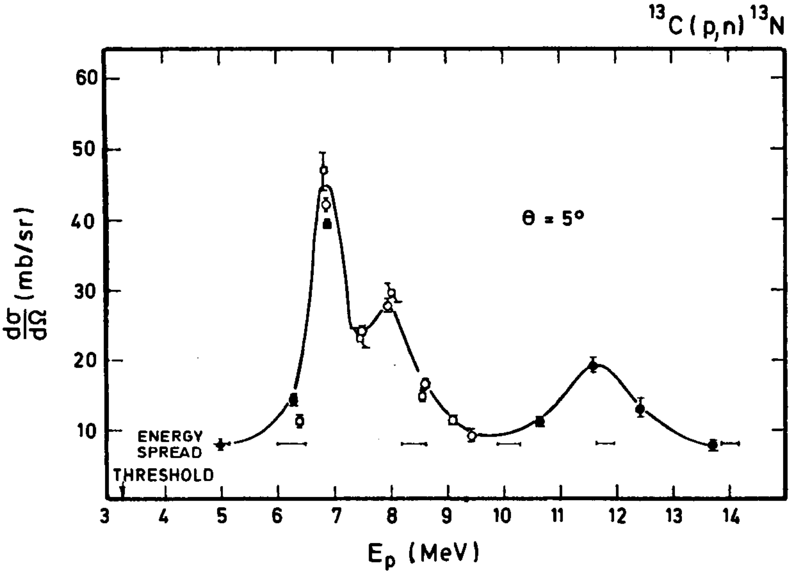

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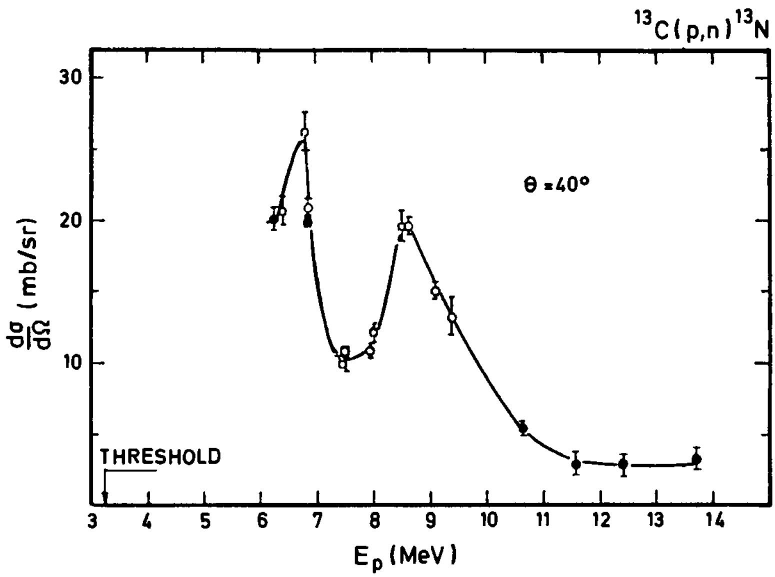

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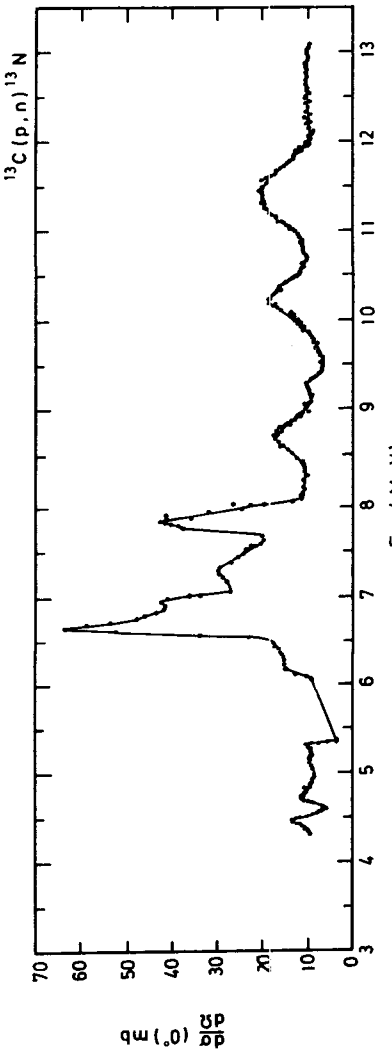

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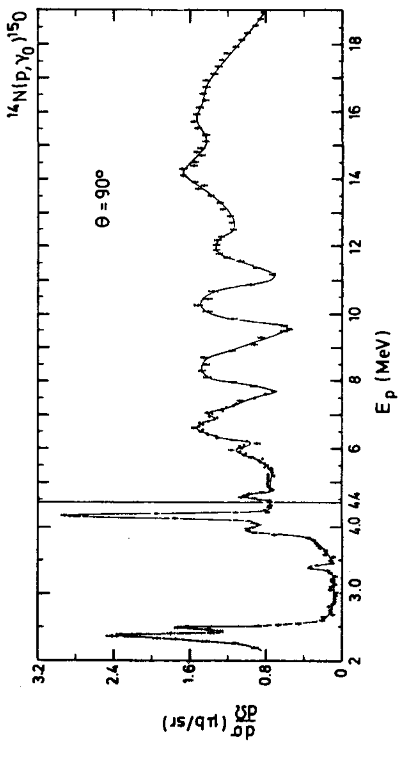

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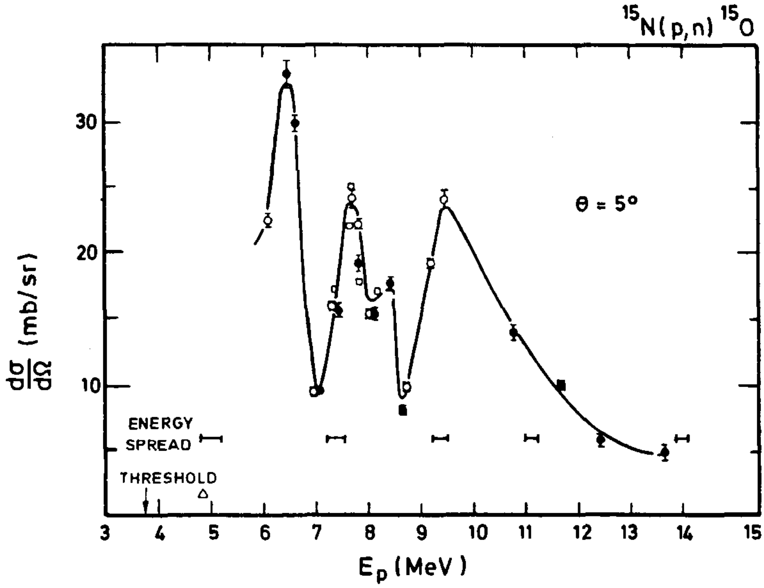

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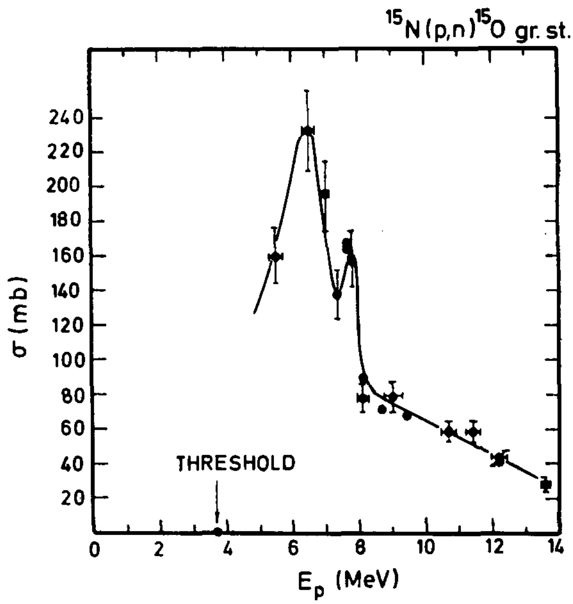

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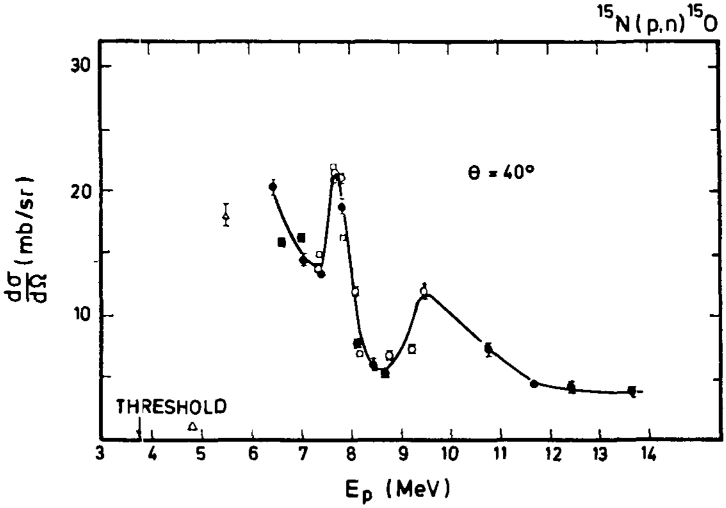

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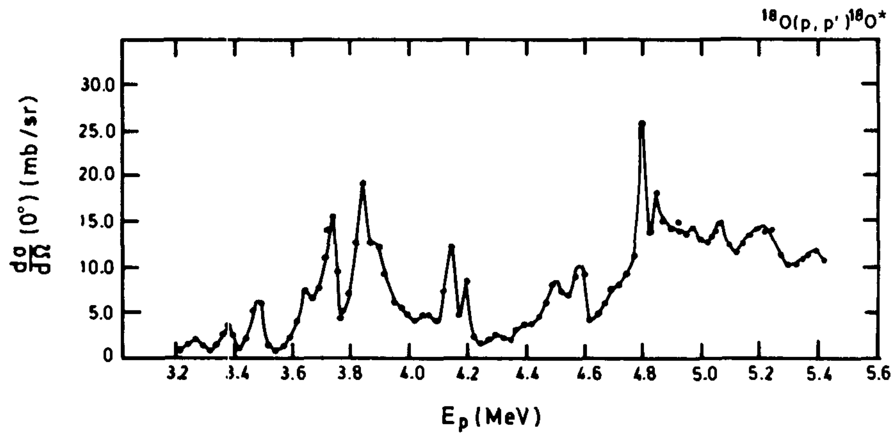

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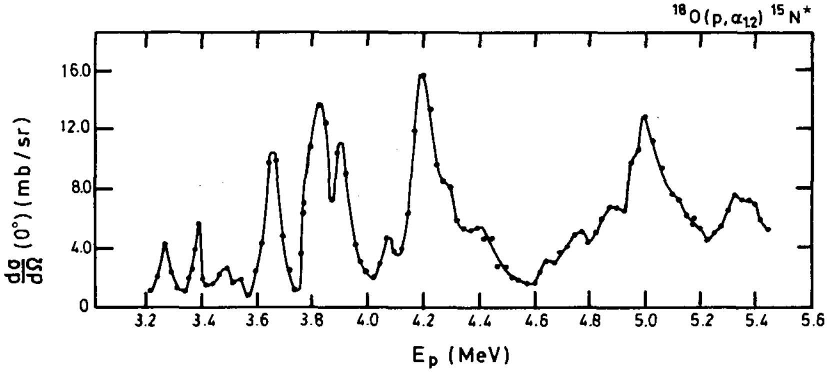

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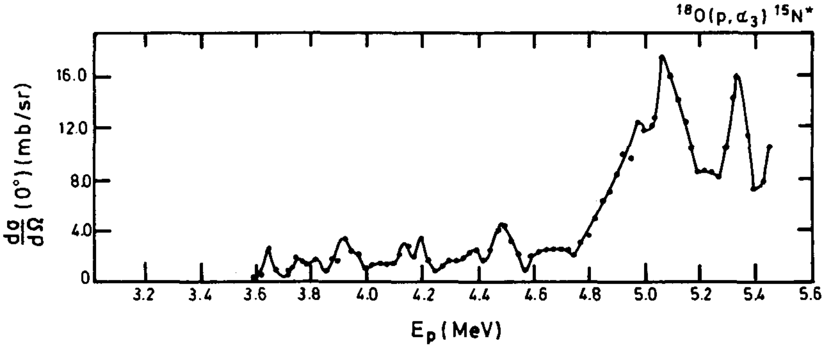

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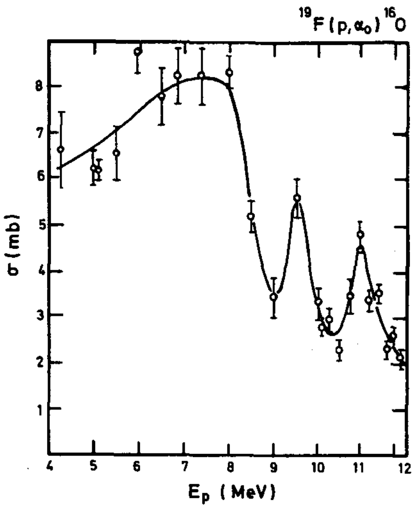

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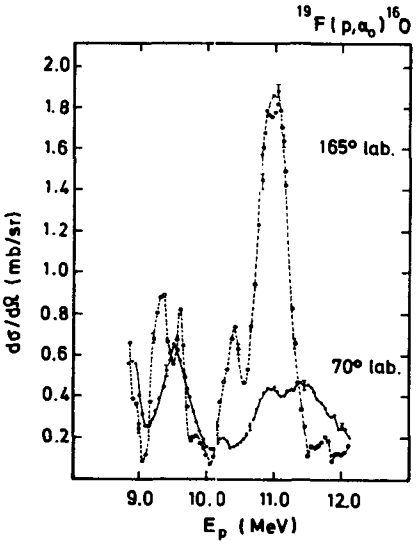

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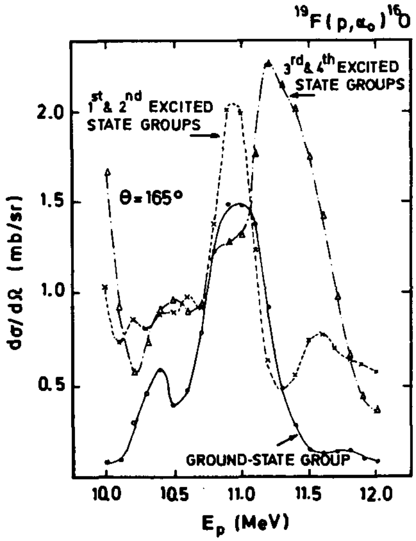

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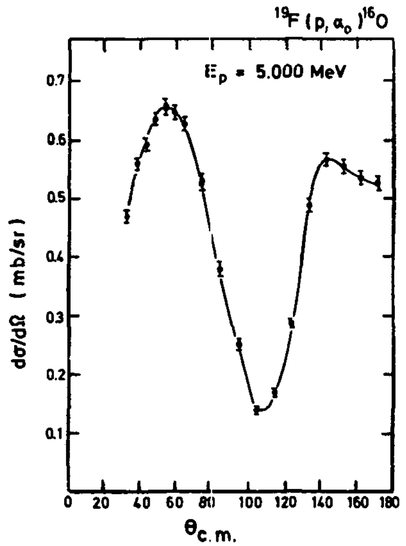

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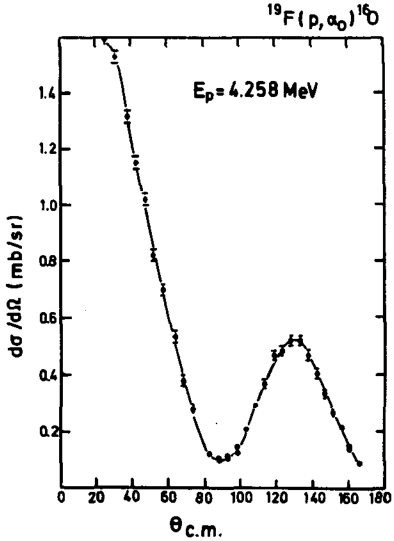

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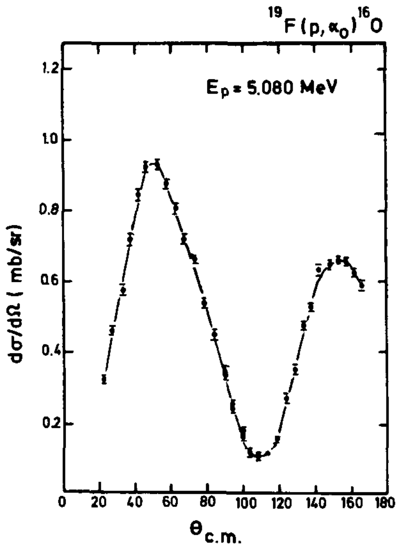

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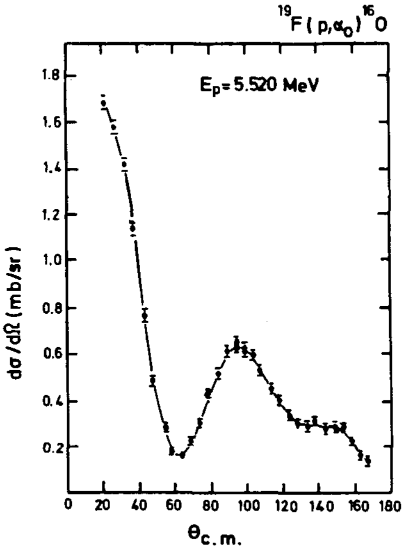

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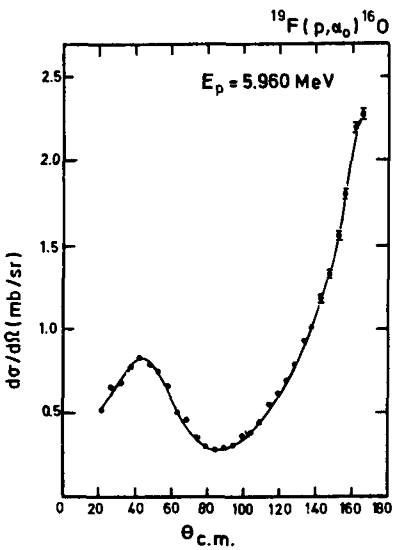

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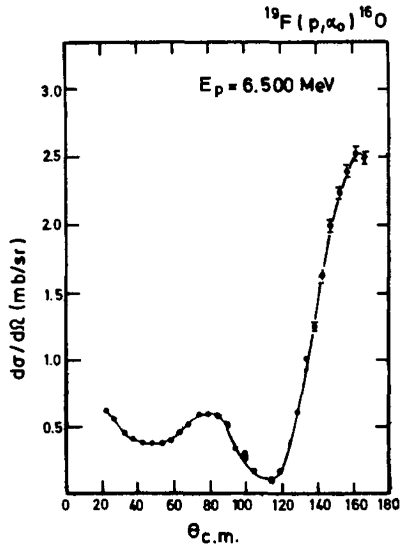

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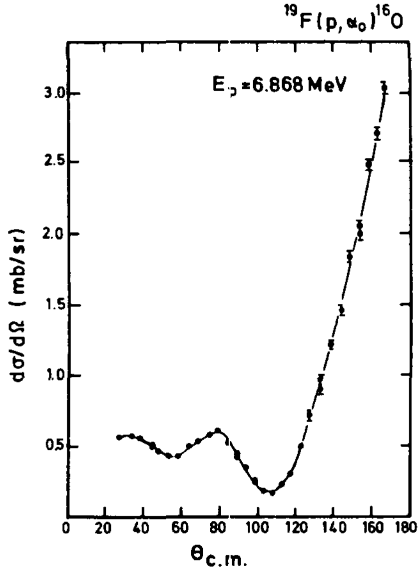

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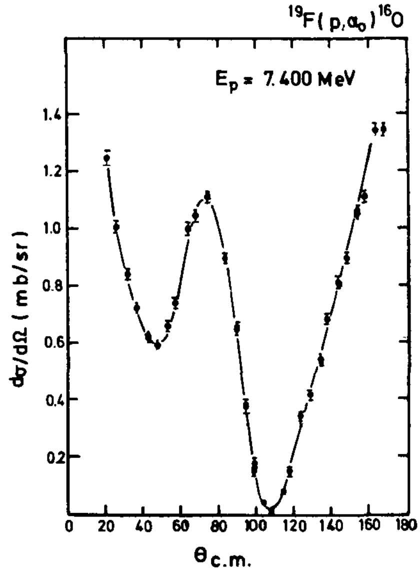

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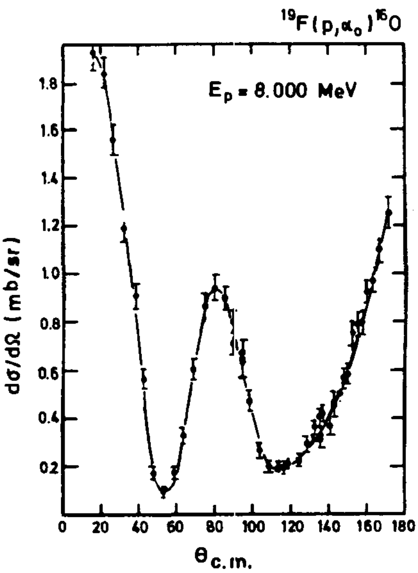

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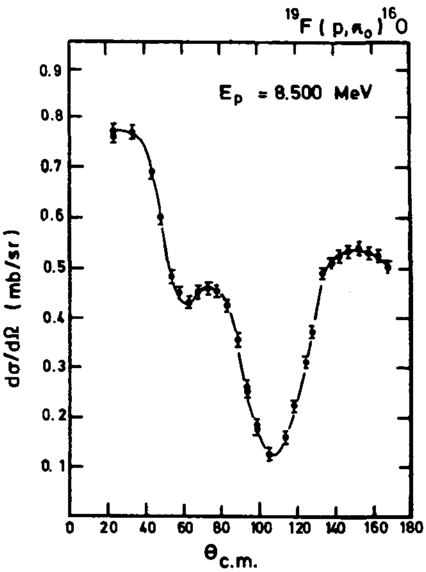

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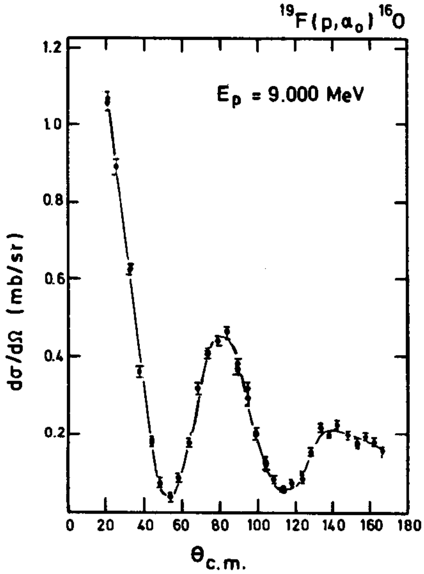

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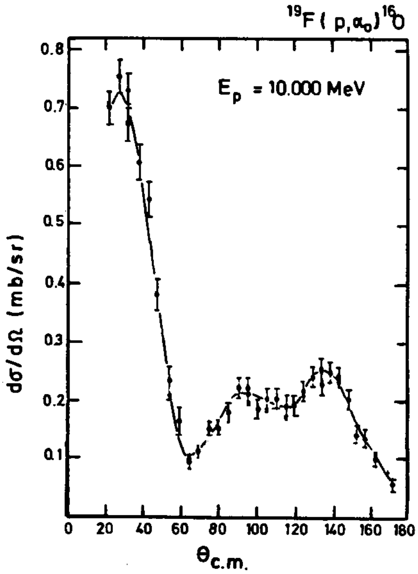

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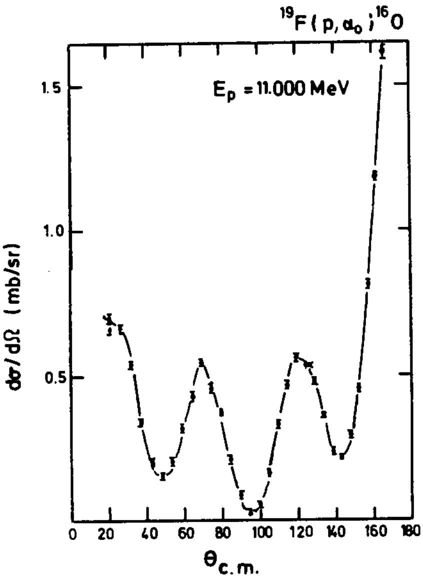

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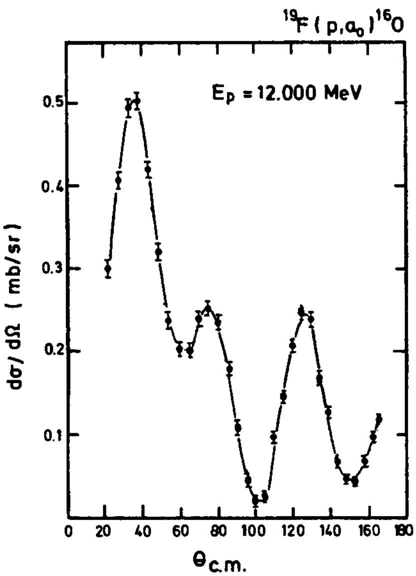

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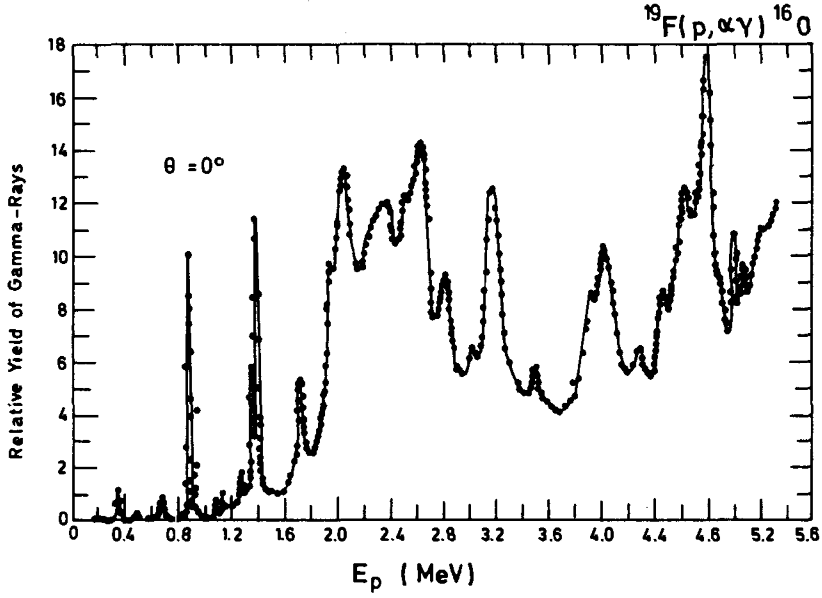

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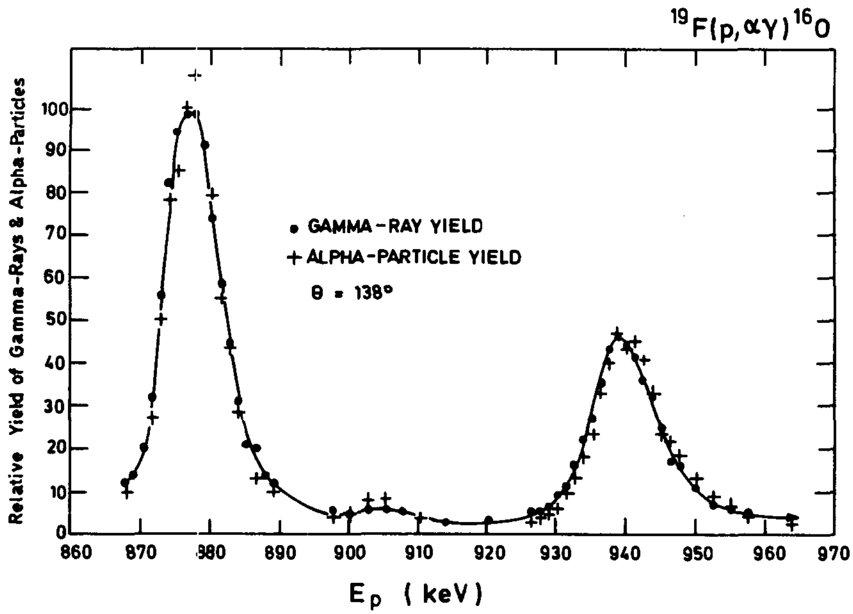

Reaction 15, Ref. P14

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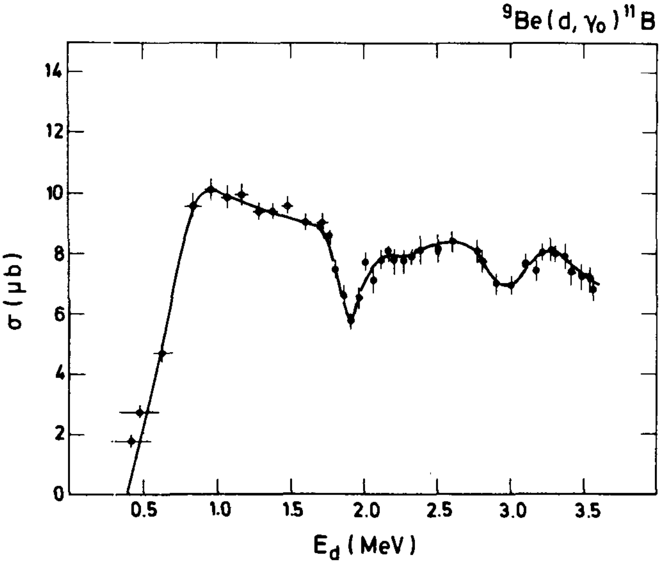
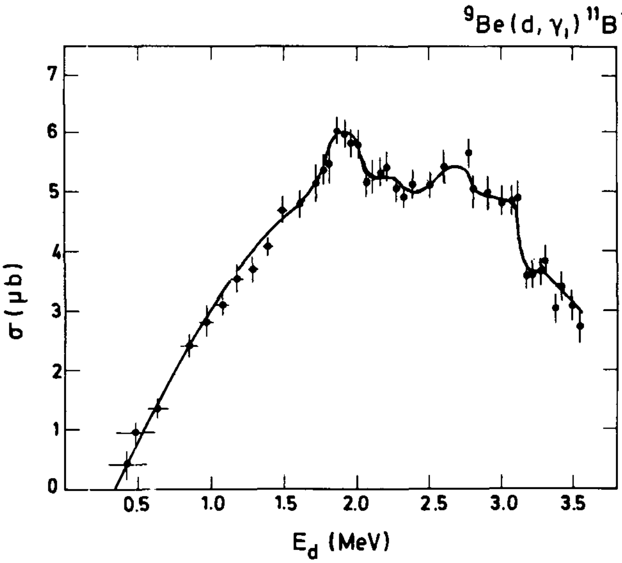
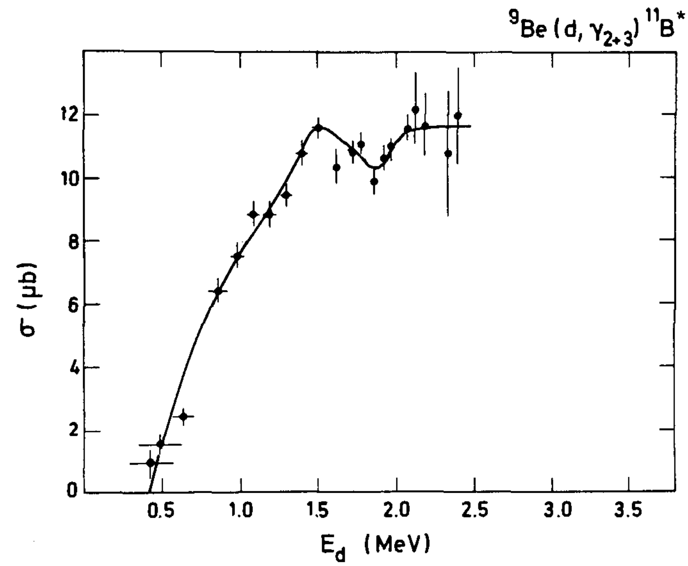


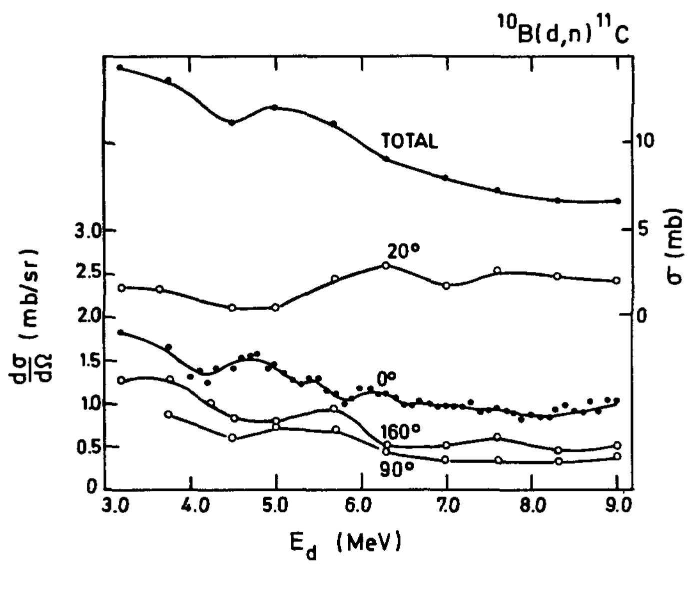
Reaction 1, Ref. D1



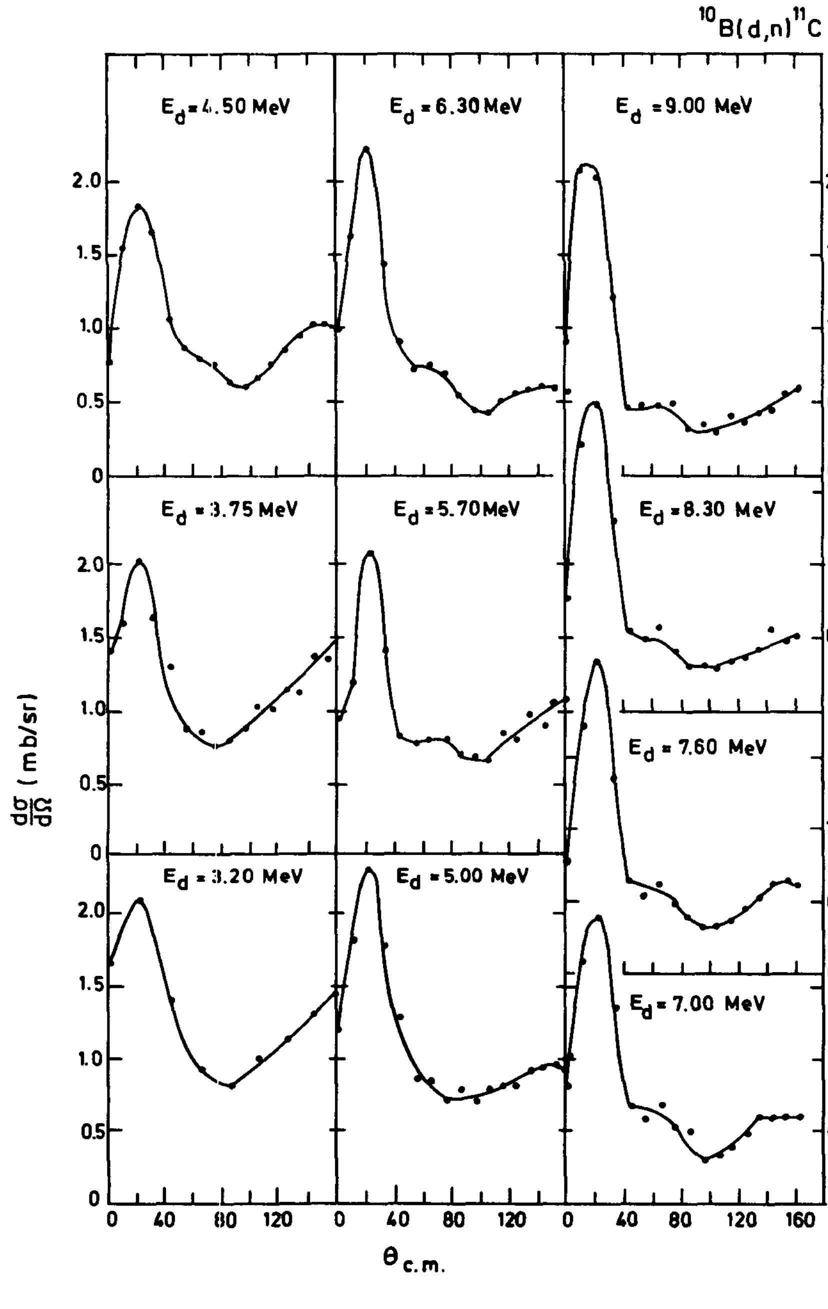
Reaction 1, Ref. D1



Reaction 1, Ref. D1



Reaction 2, Ref. D2



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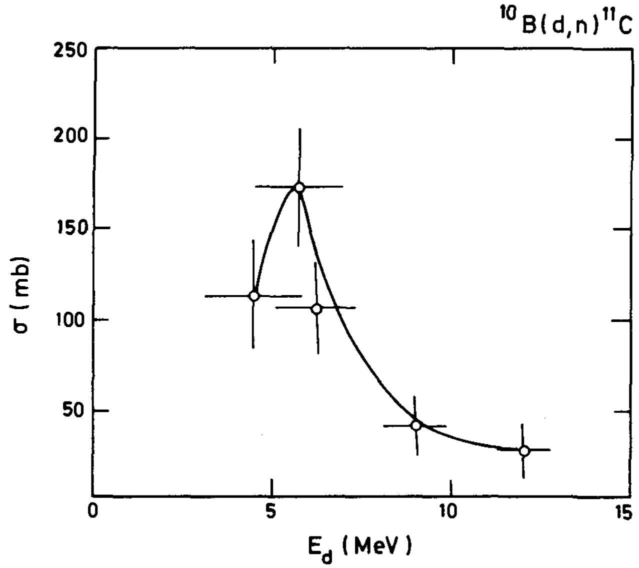

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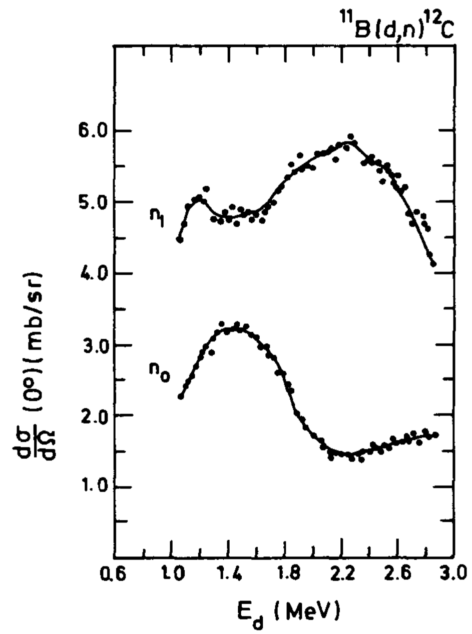

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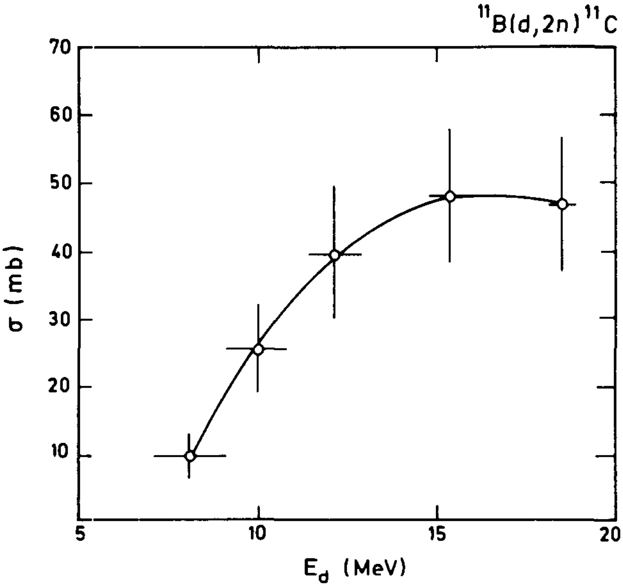

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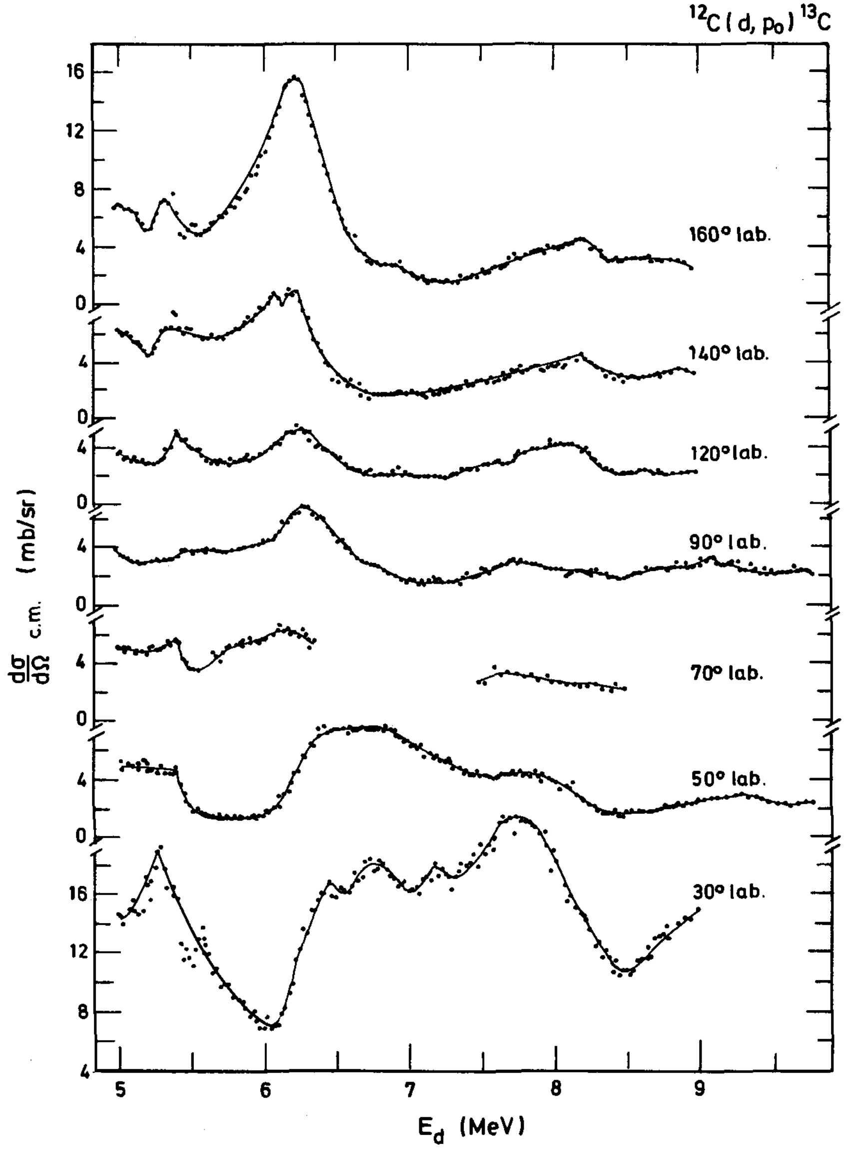

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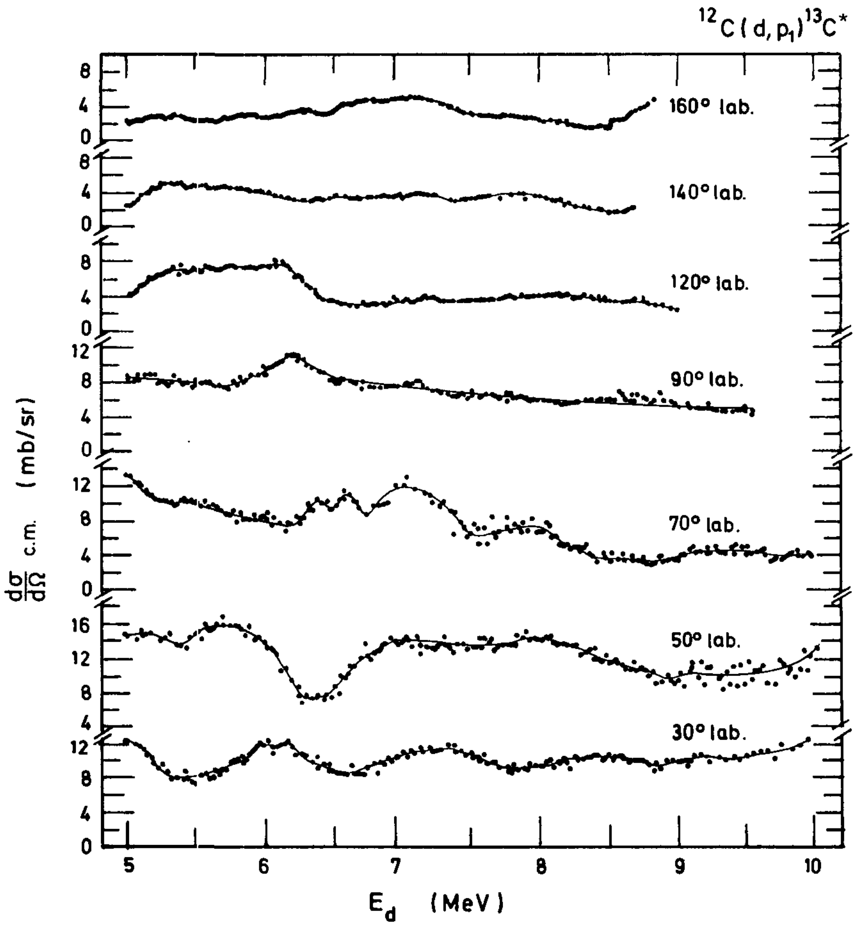

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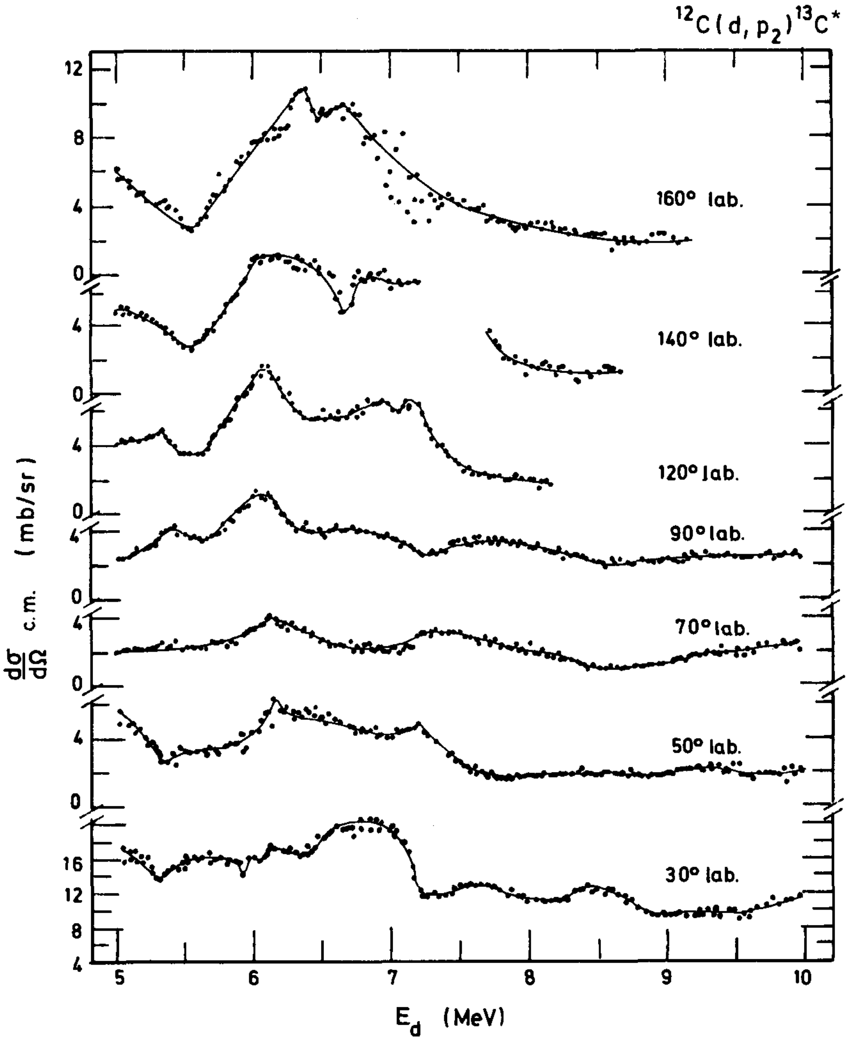

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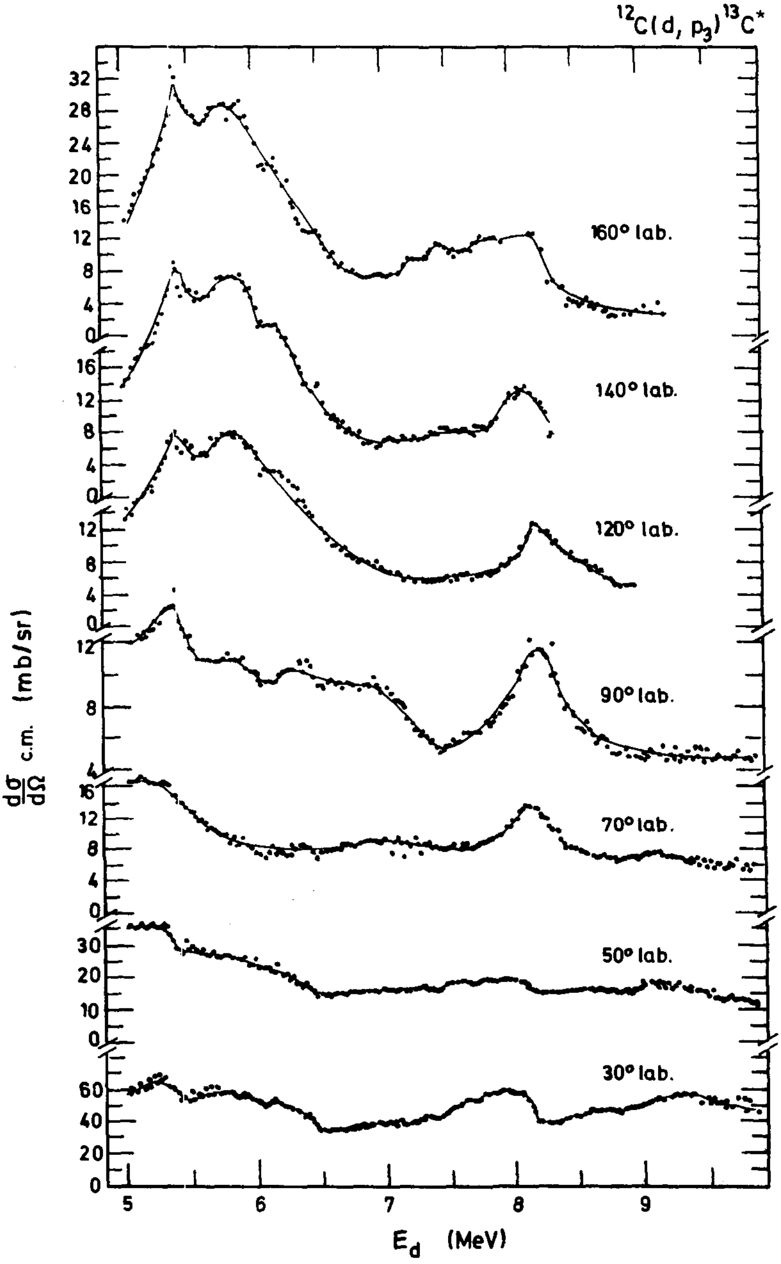

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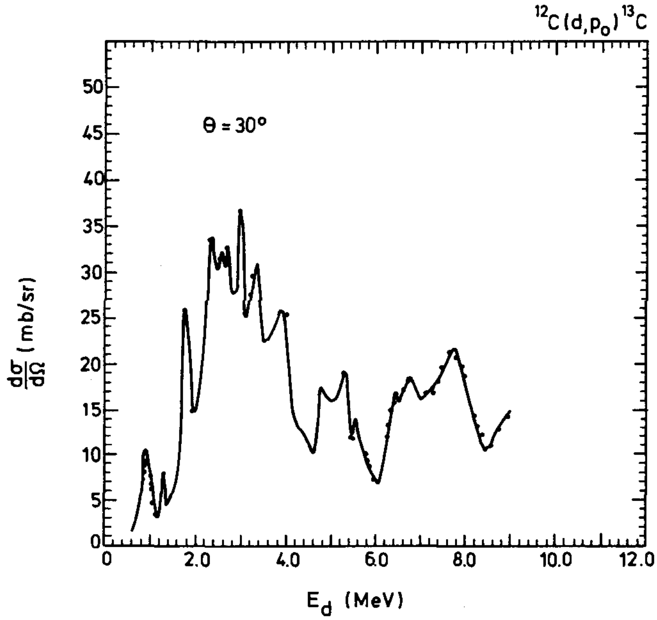
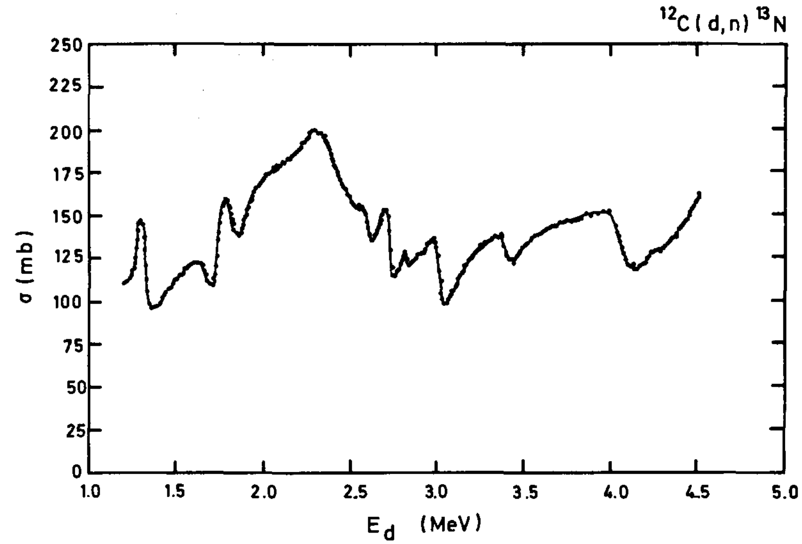
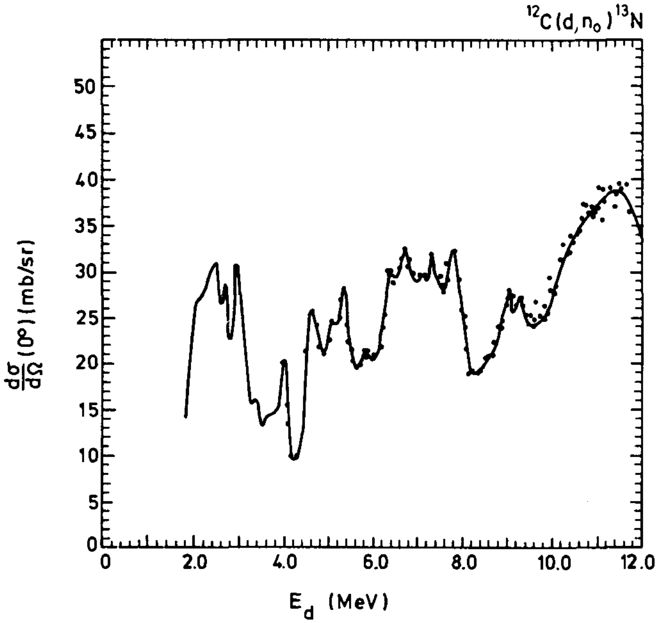


Reaction 5, Ref. D5



Reaction 6, Ref. D6



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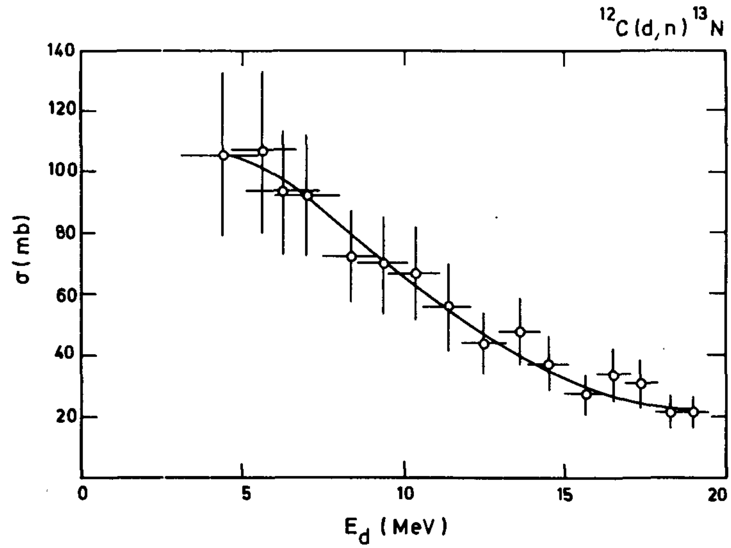
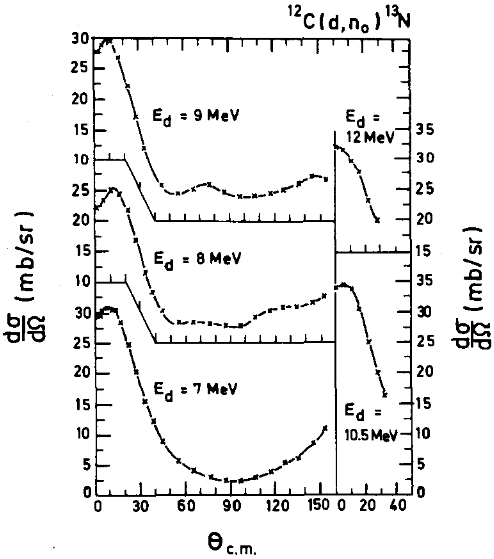


Reaction 6, Ref. D3



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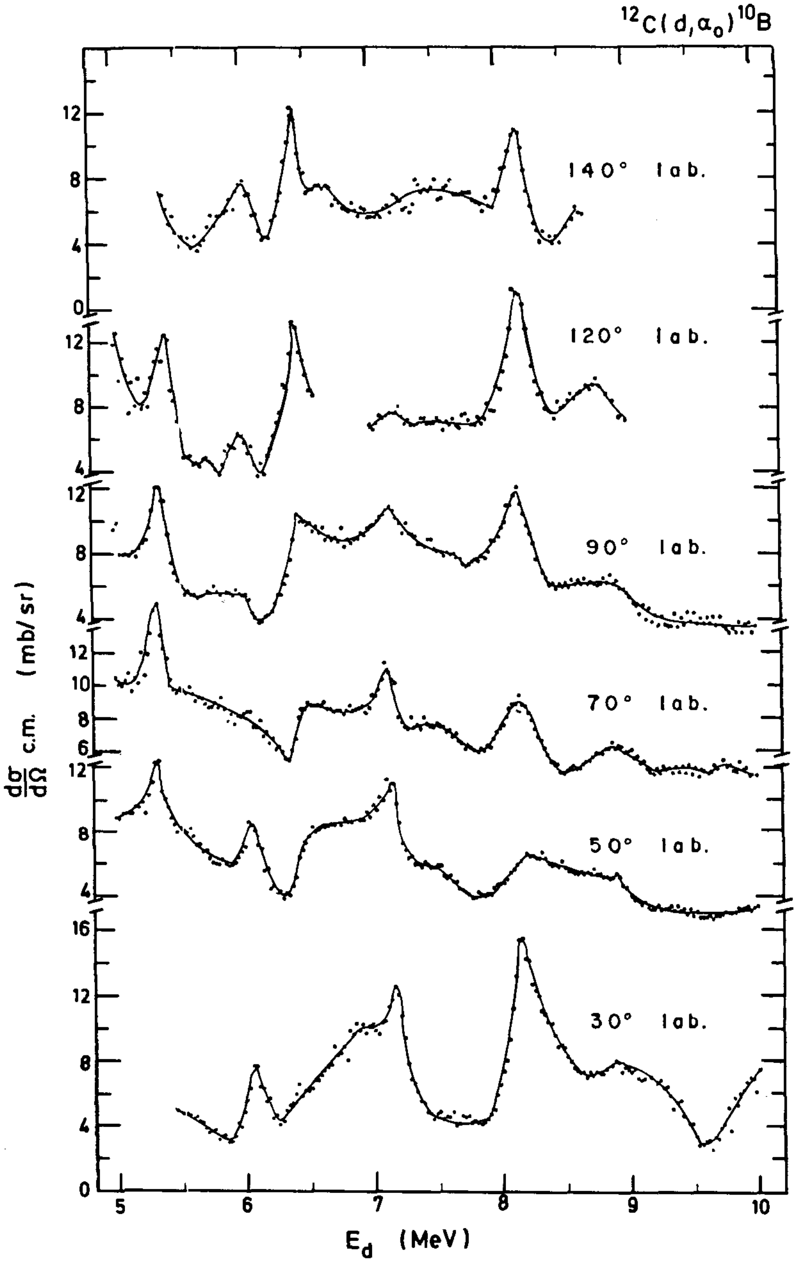
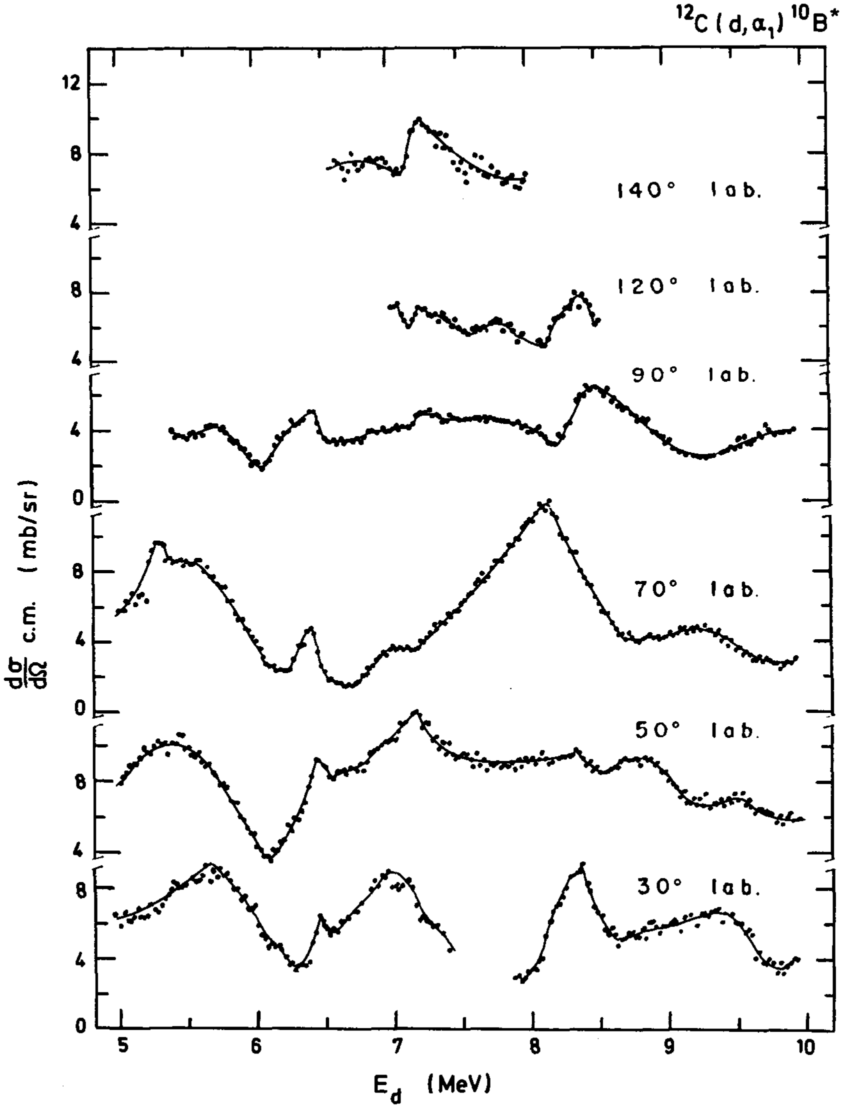


Reaction 7, Ref. D4



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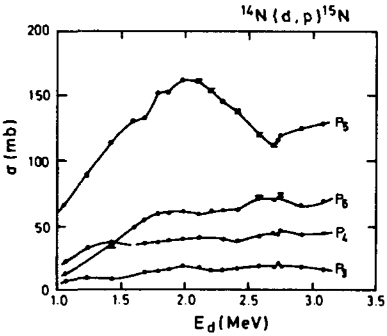

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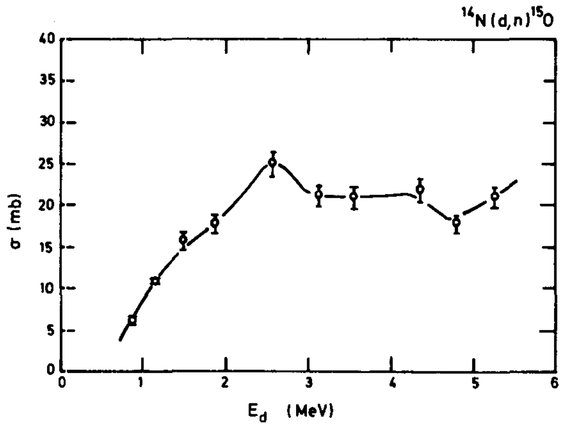
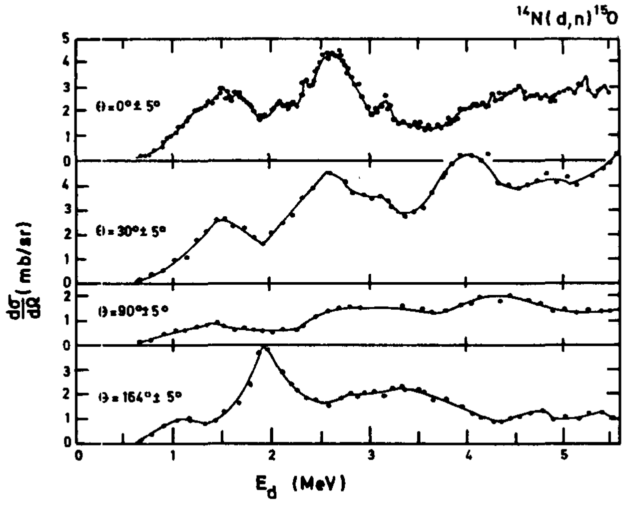


Reaction 9, Ref. D8



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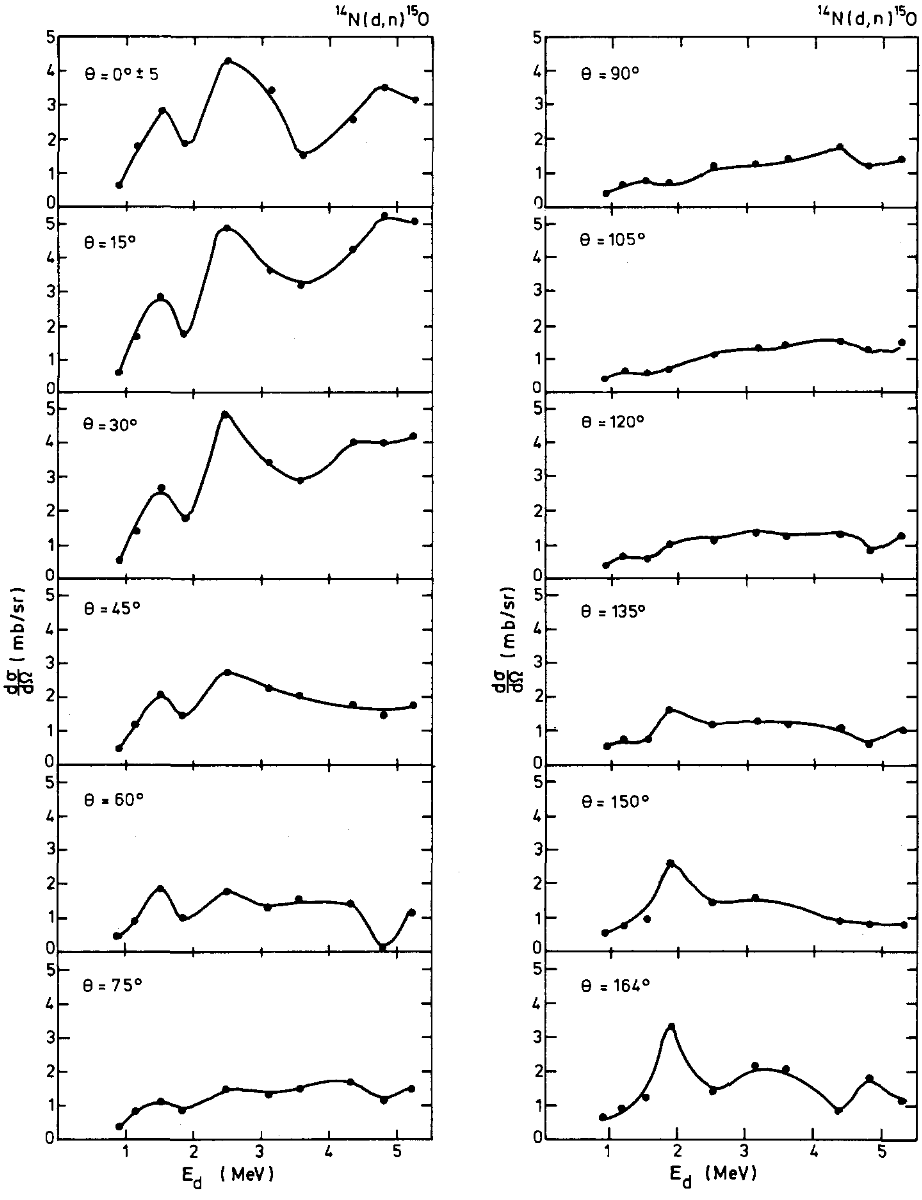

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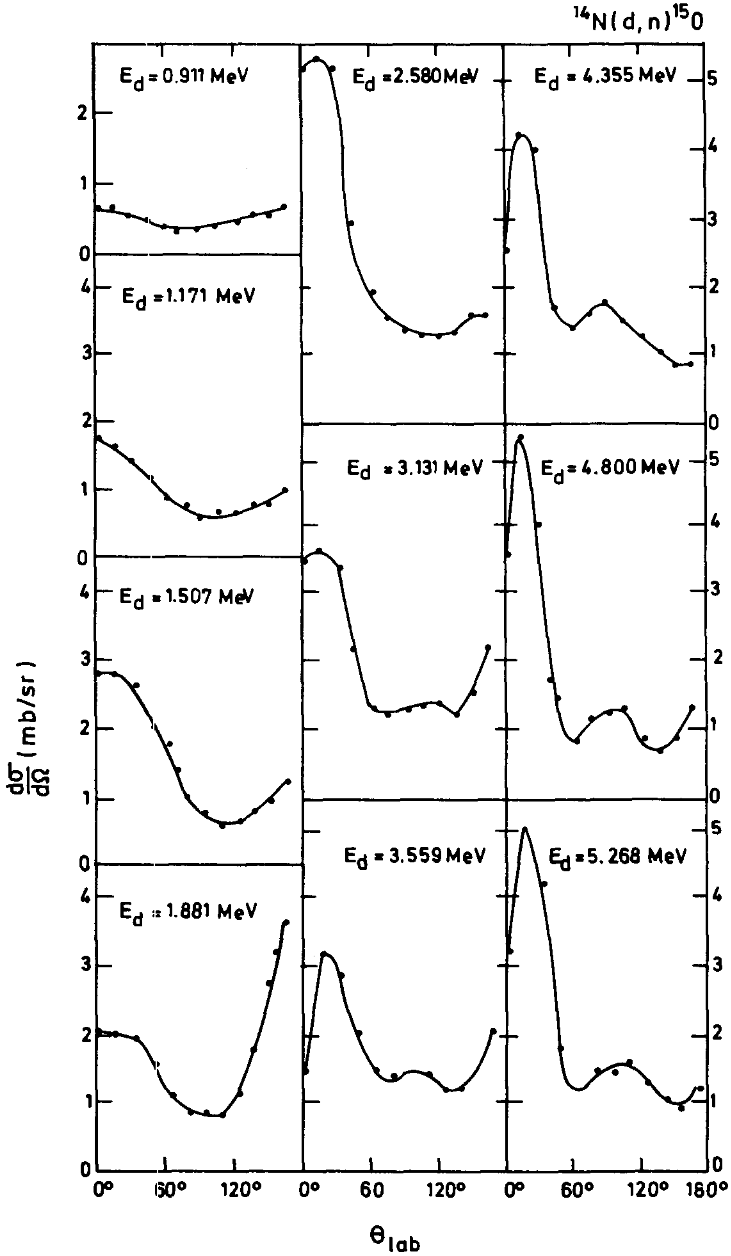

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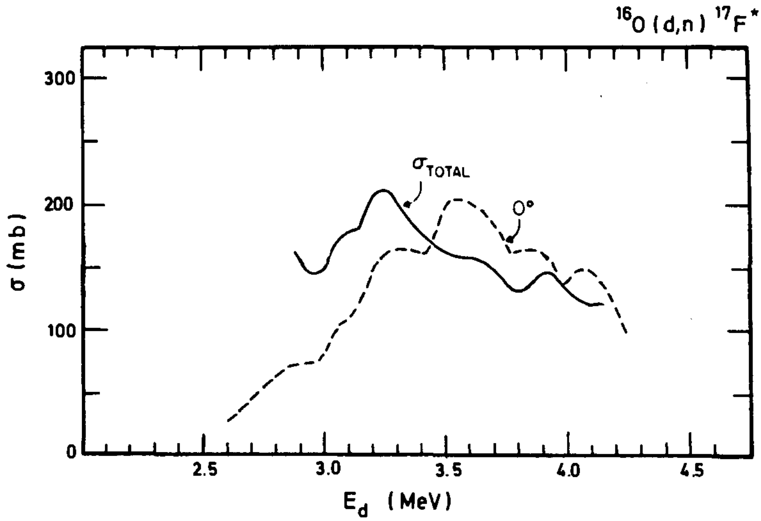

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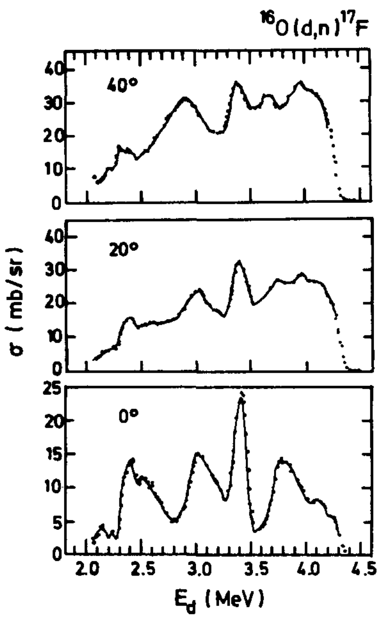

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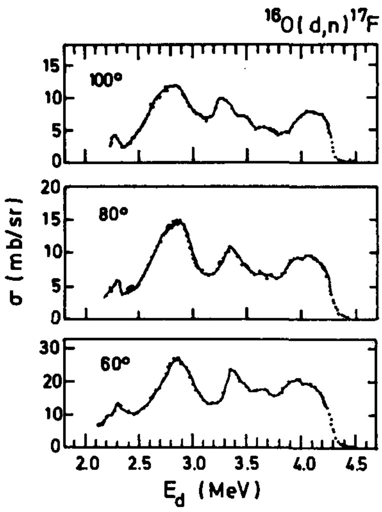

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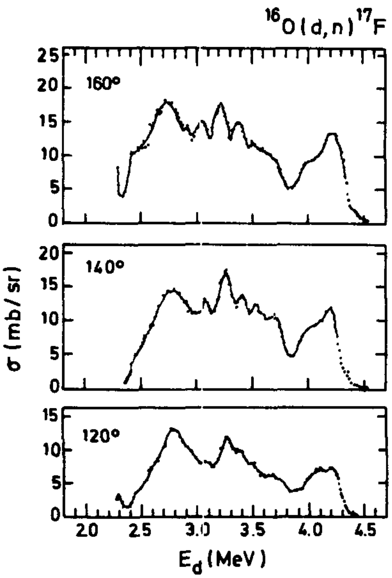

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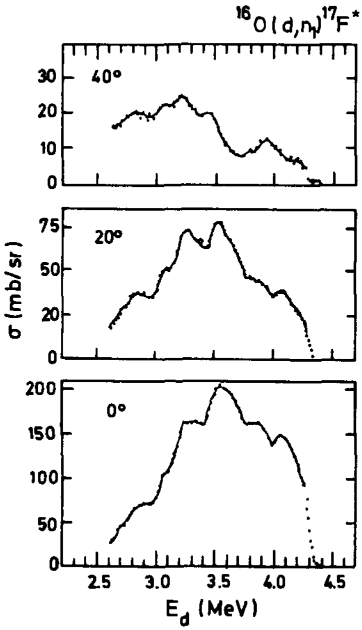

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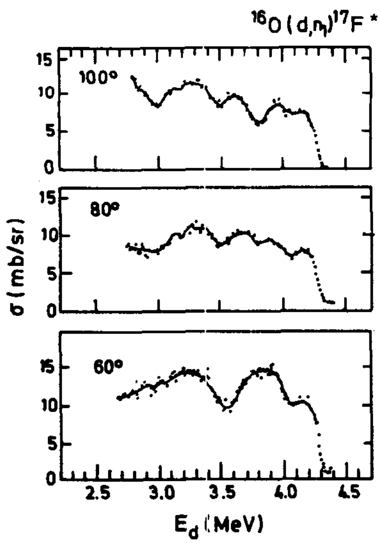

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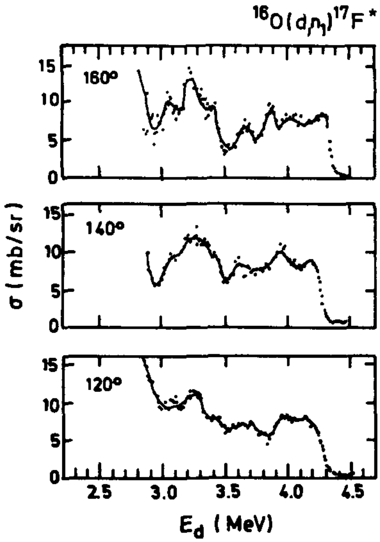

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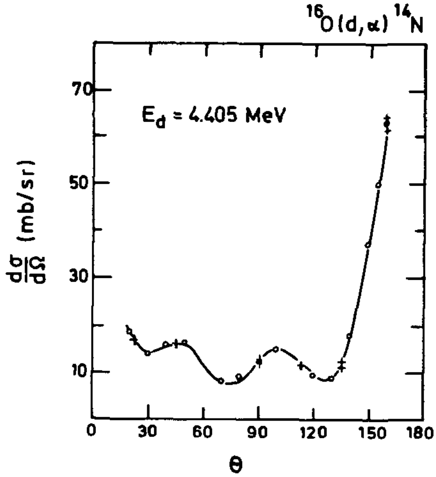
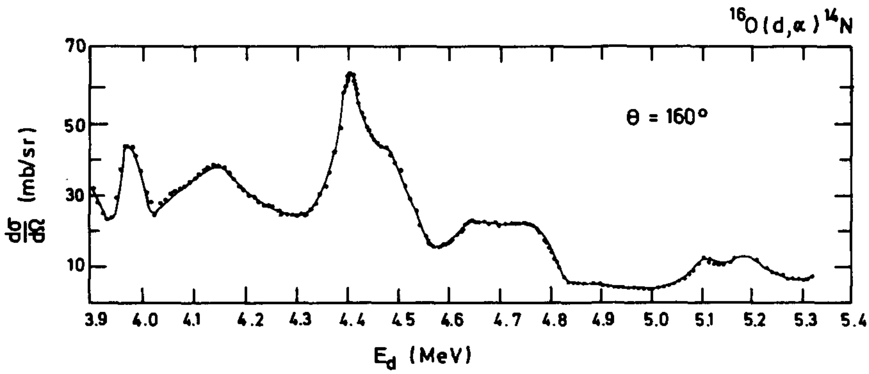
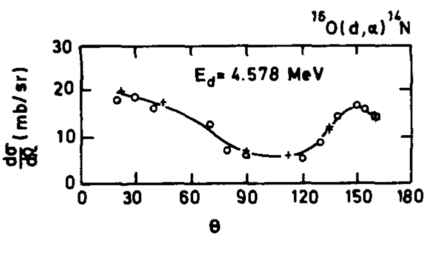
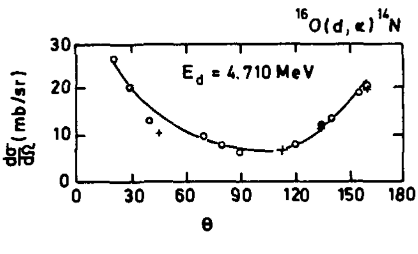


Reaction 11, Ref. D10



Reaction 11, Ref. D10





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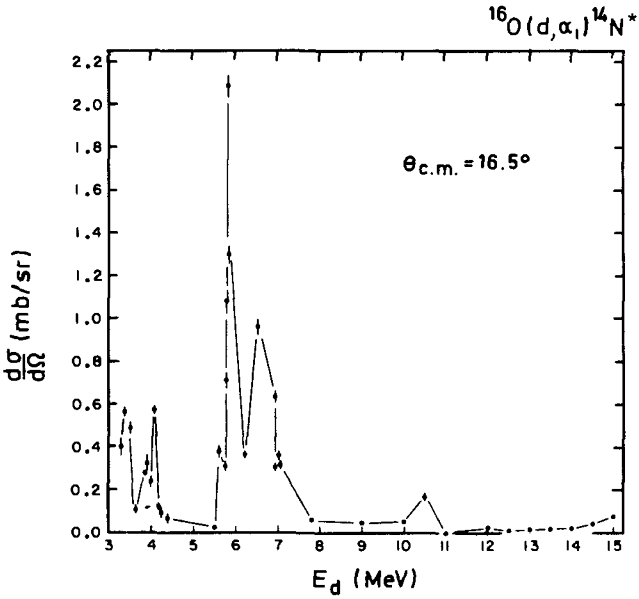

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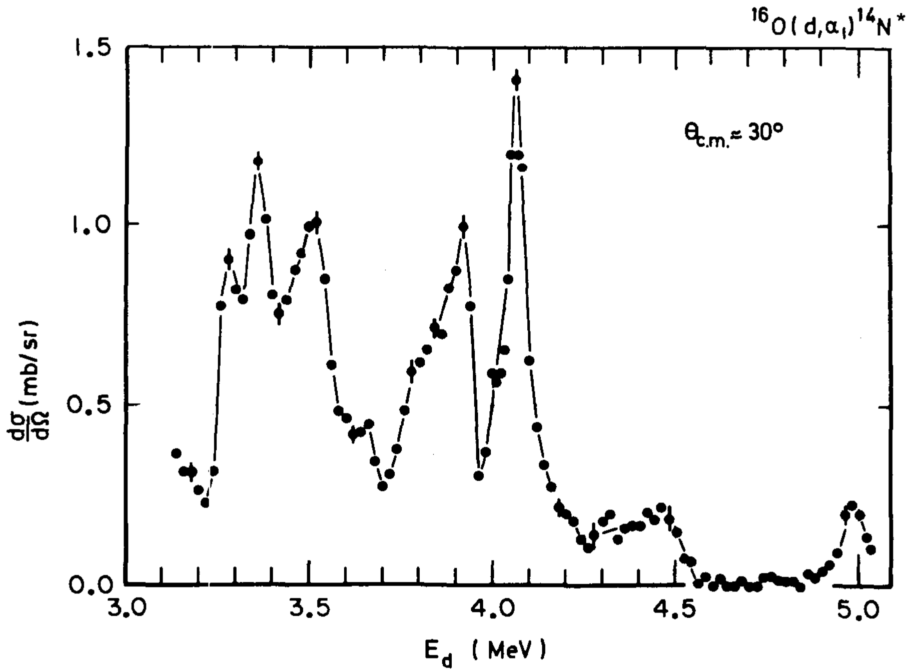

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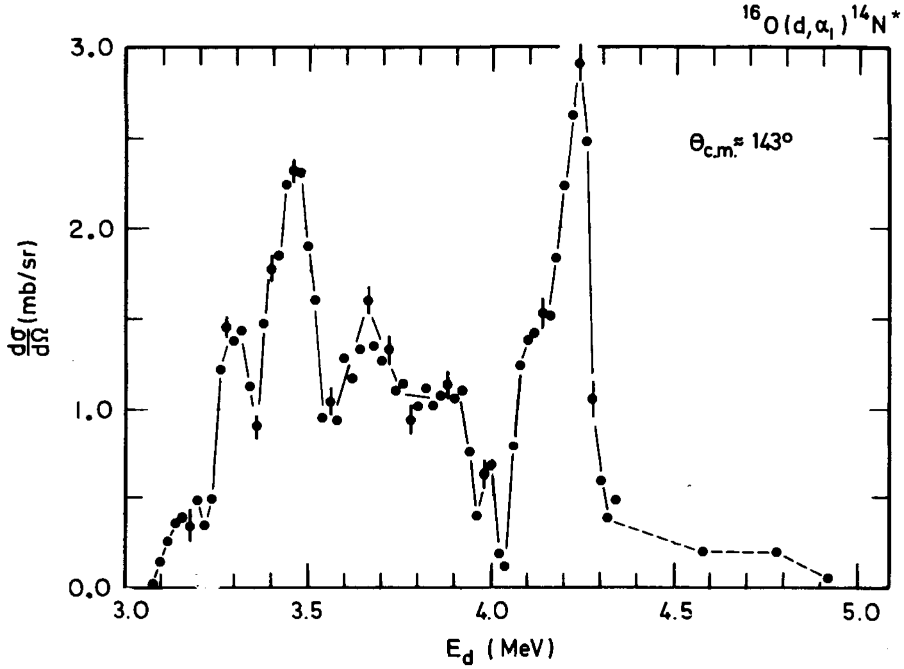

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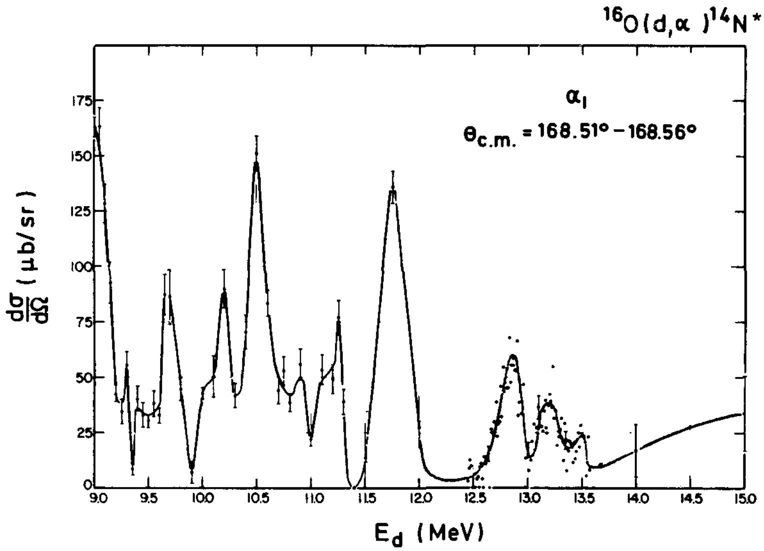

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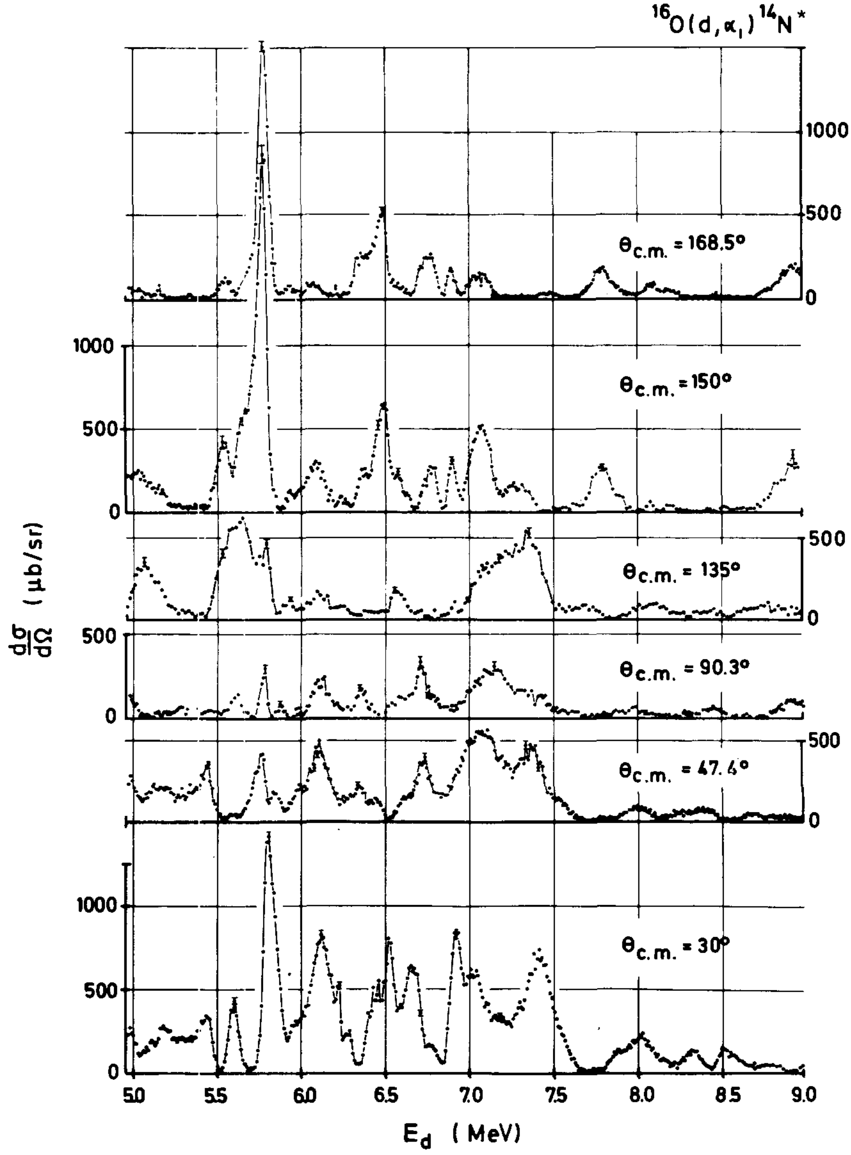

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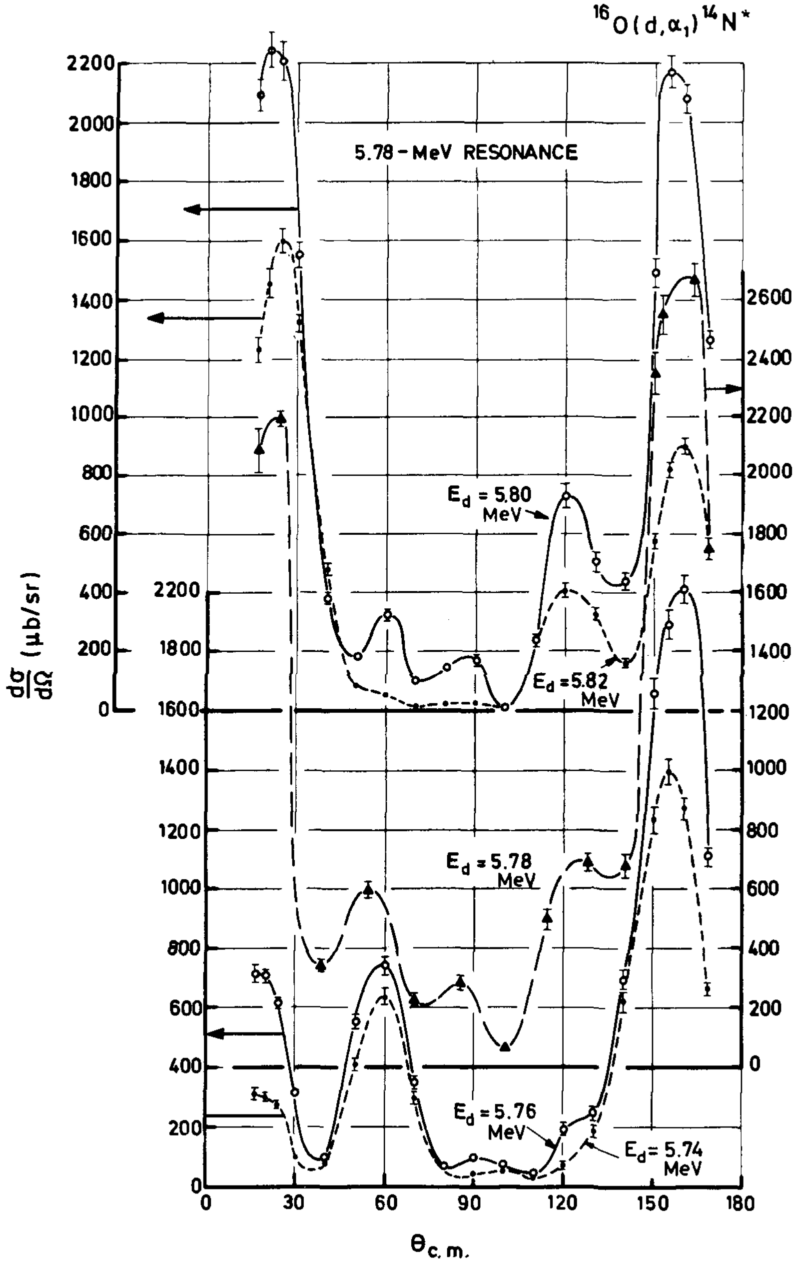

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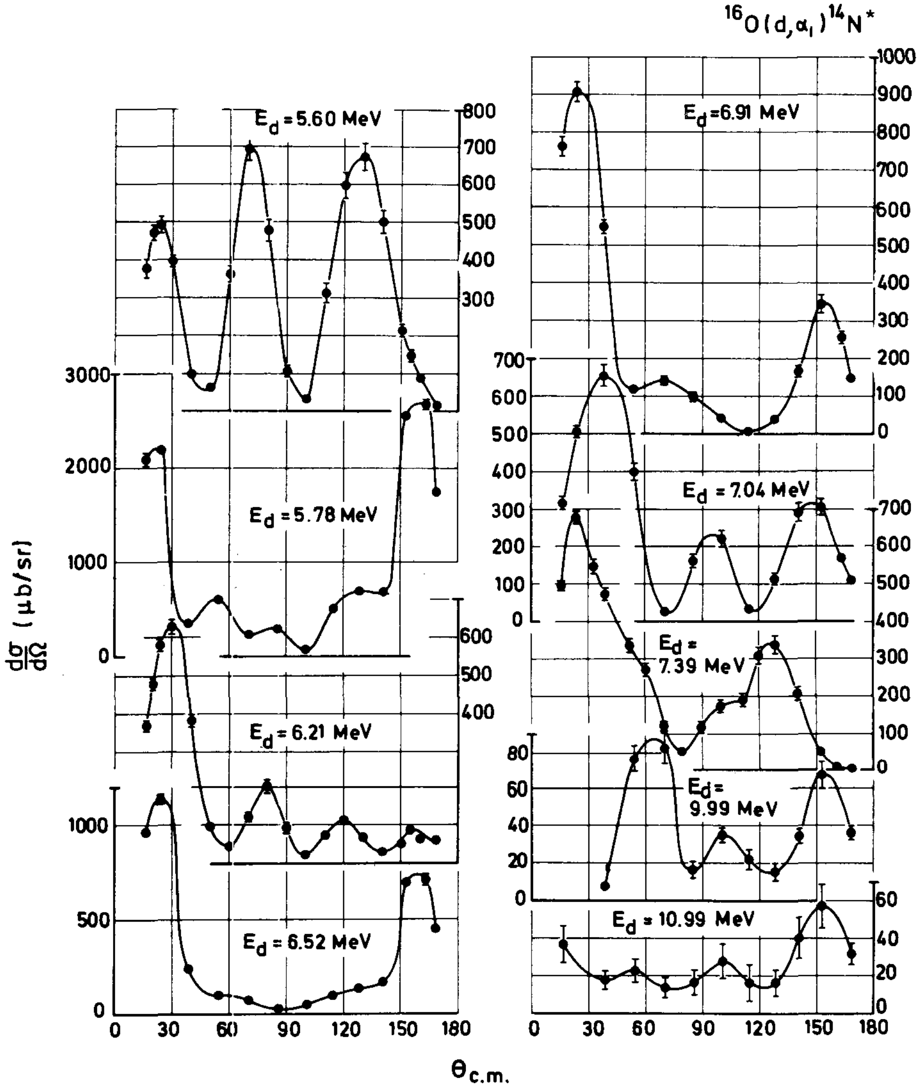

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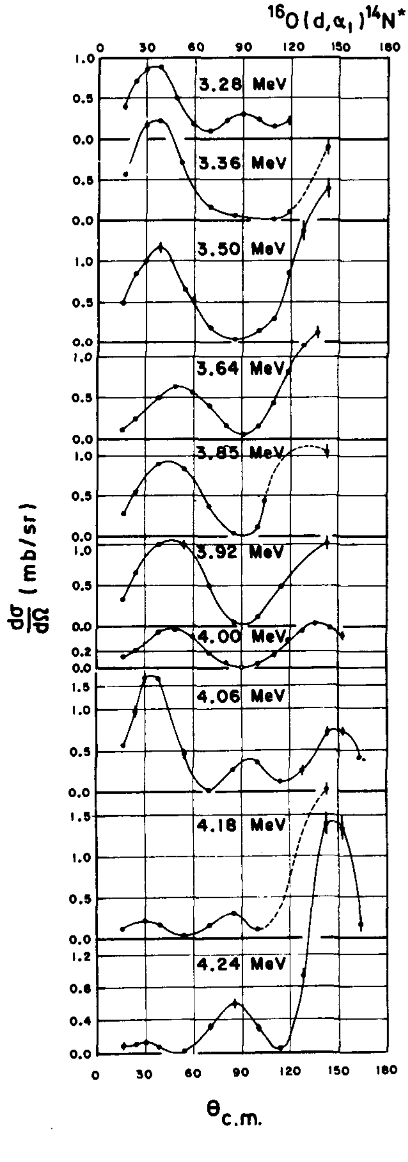

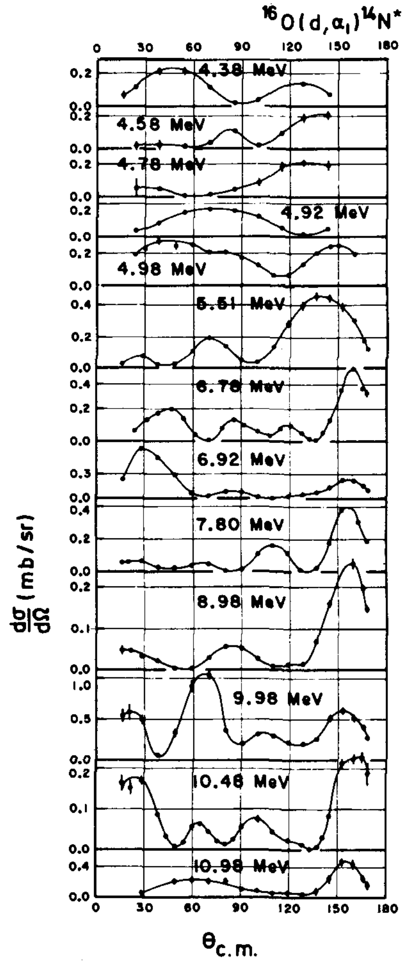

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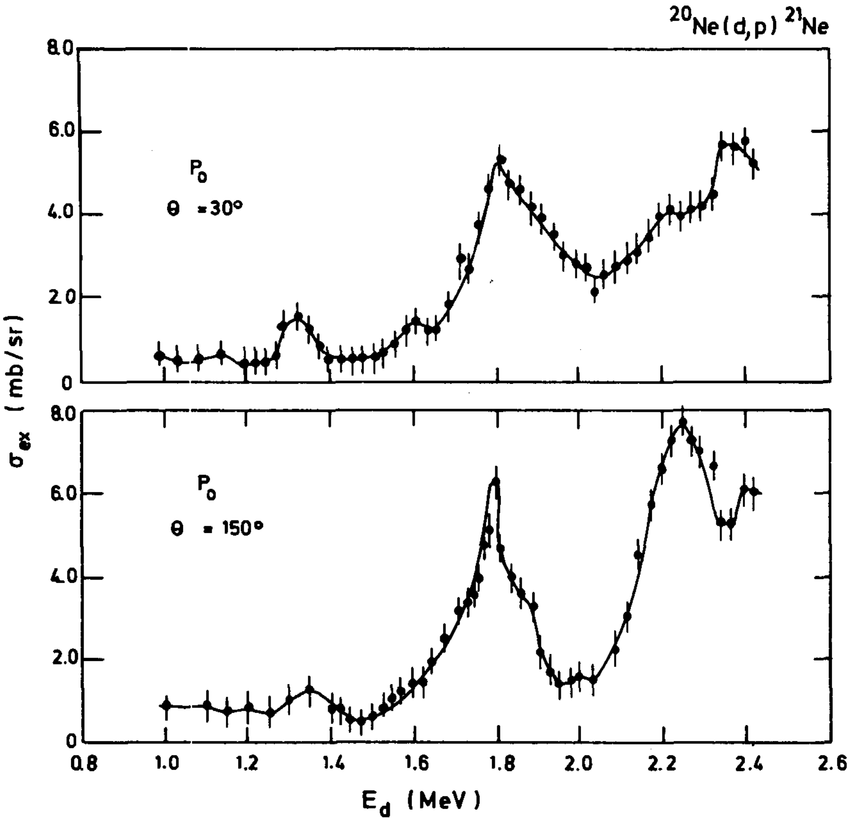
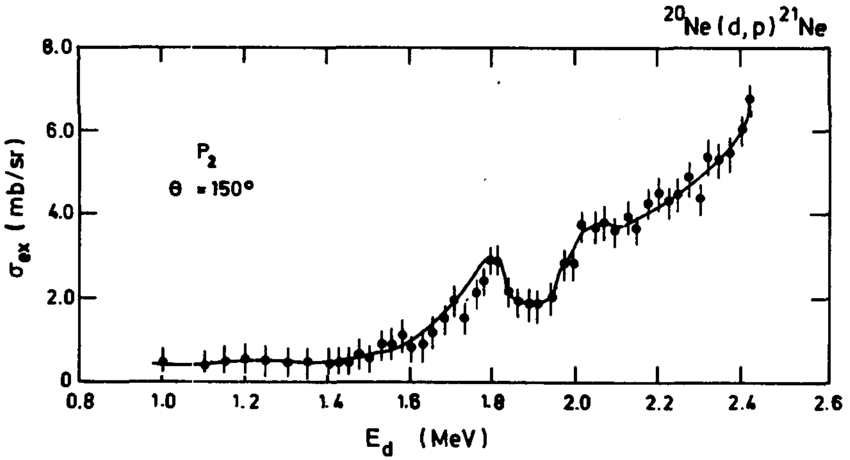
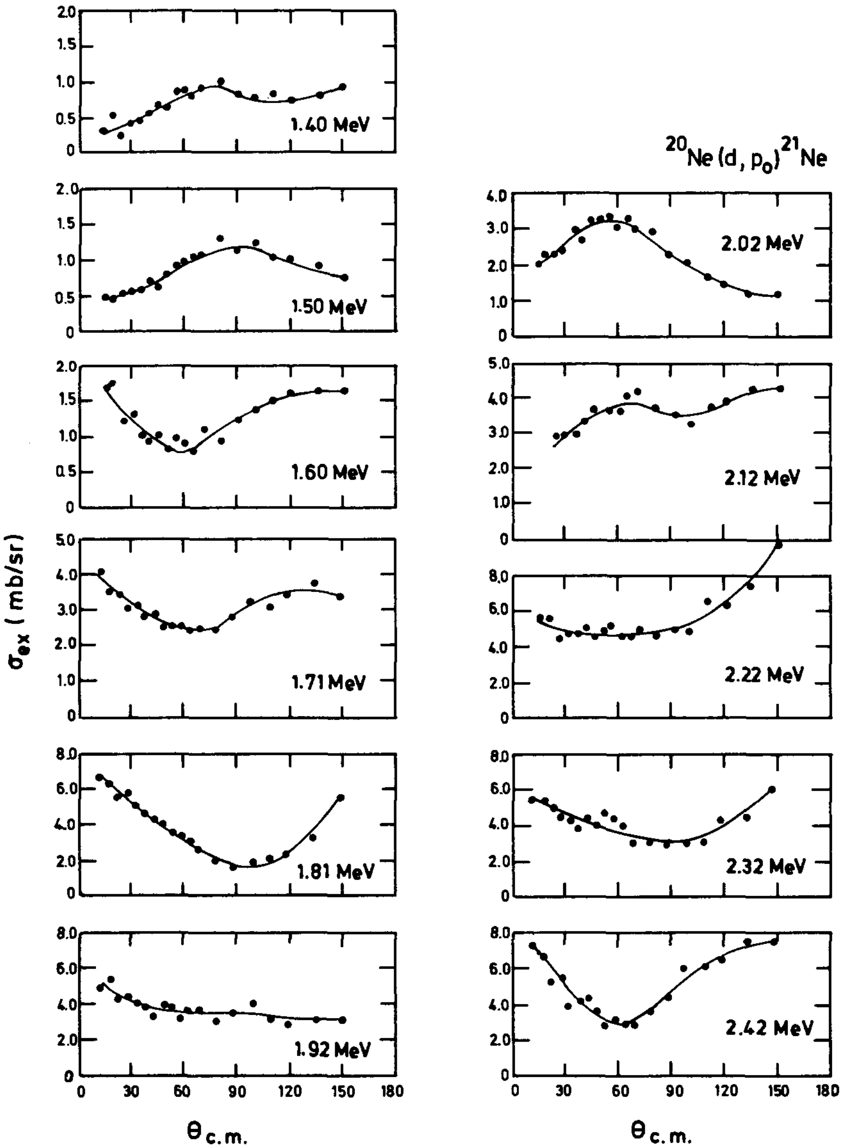


Reaction 12, Ref. D12



Reaction 12, Ref. D12



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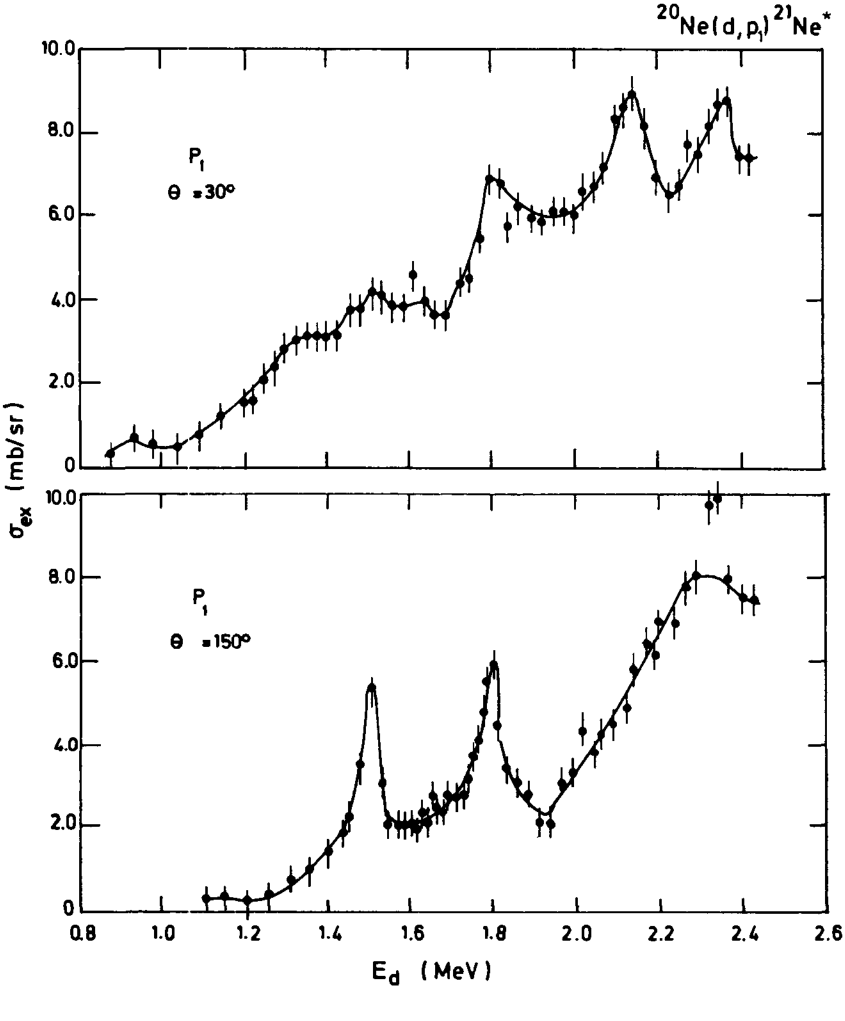

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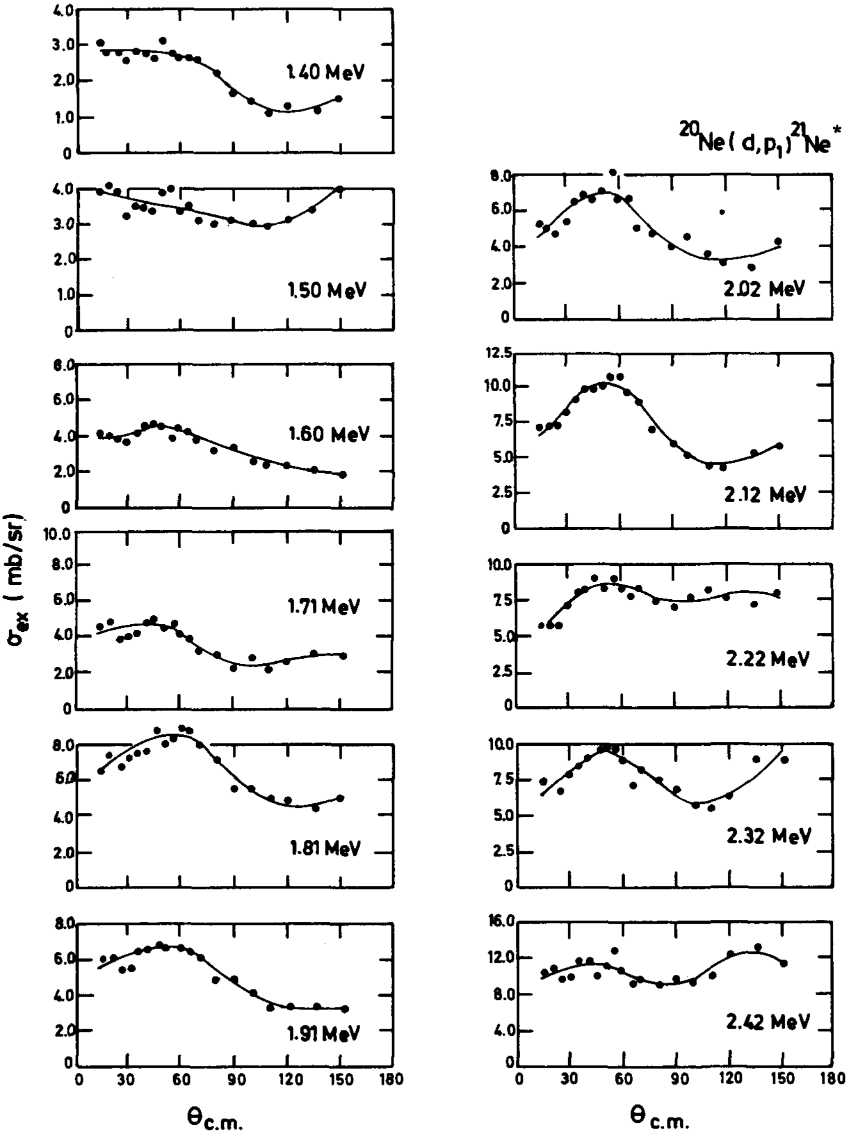
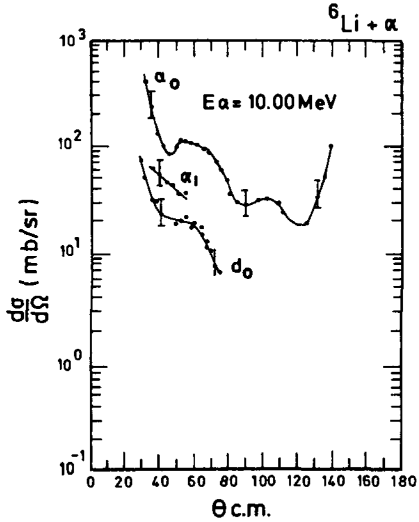


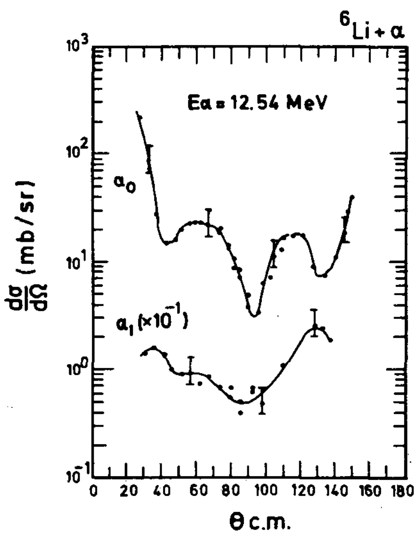
Reaction 12, Ref. D12

ALPHA

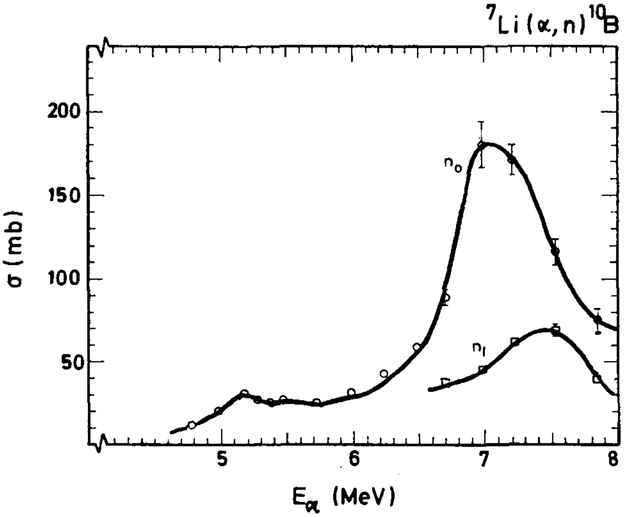
	Reaction	Cross-section and angular distribution	Energy range (MeV)	Page
1.	$^{6}Li + \alpha$	$\frac{d\sigma}{d\Omega}$	10; 12.5	380
2.	$^{7}Li(\alpha, n)^{10}B$	σ; σ (0°)	4 - 8	381
		$\frac{d\sigma}{d\Omega}$	4.8 - 7.8	382
3.	$^{9}Be(\alpha, n)^{12}C$	σ; σ (0°)	1.6 - 6.4	383
		$\frac{d\sigma}{d\Omega}$ (0°)	0.34 - 0.7	384
		$\frac{d\sigma}{d\Omega}$	3.2 - 6.4	385
4.	$^{9}Be(\alpha, 2n)^{11}C$	σ	24 - 38	389
5.	$^{13}C(\alpha, n)^{16}O$	σ	2 - 5.3	389
6.	$^{16}O(\alpha, n)^{19}Ne$	σ	6 - 17.5	390
7.	$^{20}Ne(\alpha, n)^{23}Mg$	σ	11 - 28	390



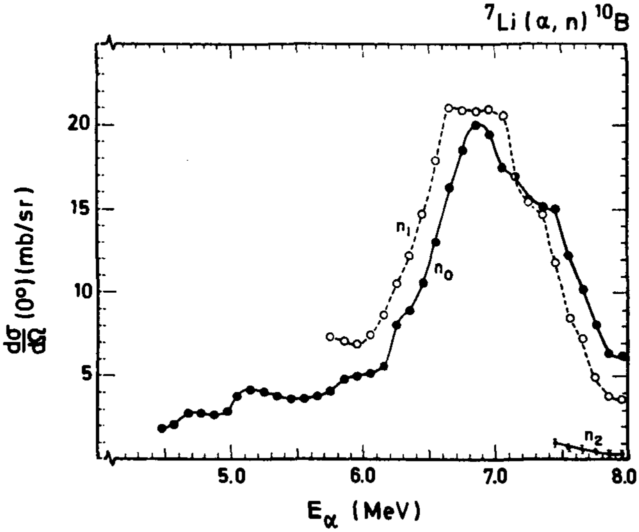
Reaction 1, Ref. A1



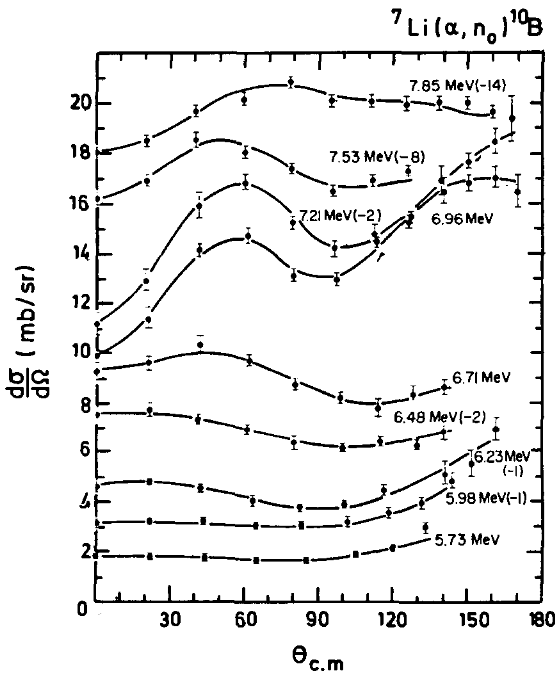
Reaction 1, Ref. A1



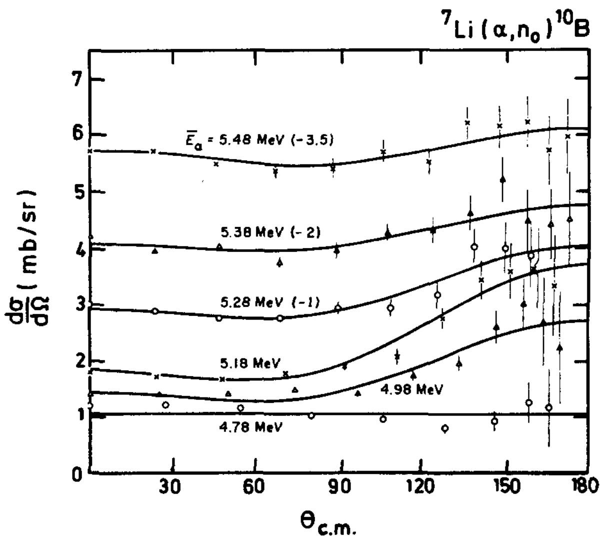
Reaction 2, Ref. A2



Reaction 2, Ref. A2

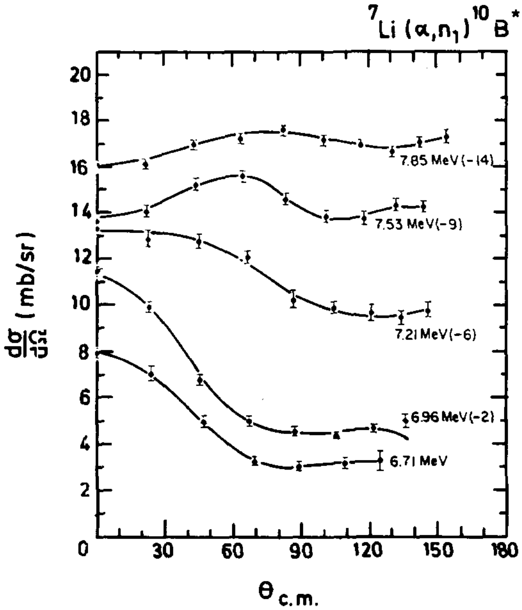


Reaction 2, Ref. A2



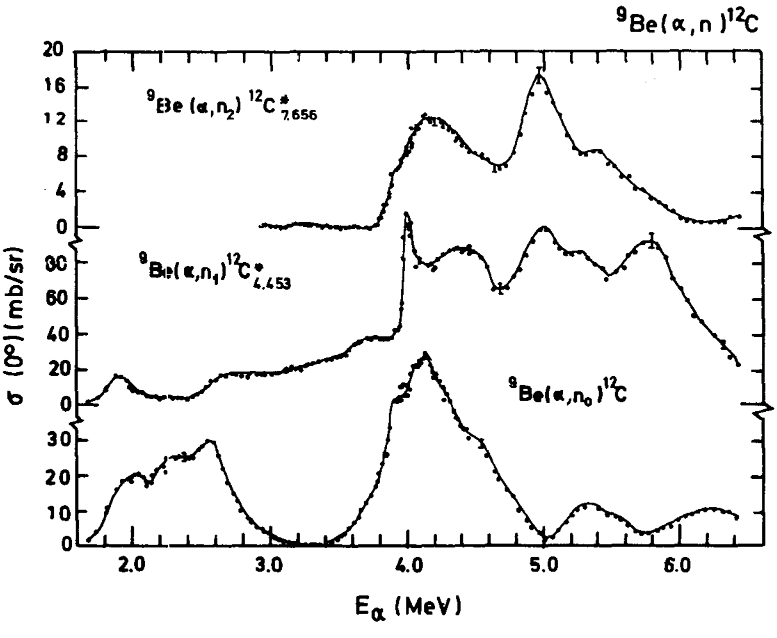
(For clarity some curves have been raised by the number in mb/sr in brackets.)

Reaction 2, Ref. A2



(For clarity some curves have been raised by the number in mb/sr in brackets.)

Reaction 2, Ref. A2



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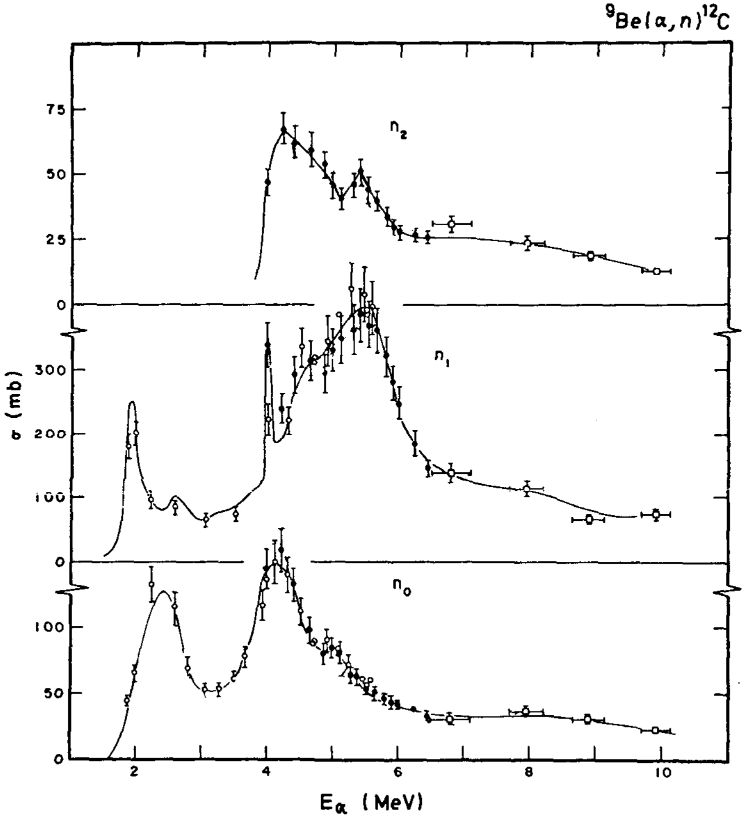
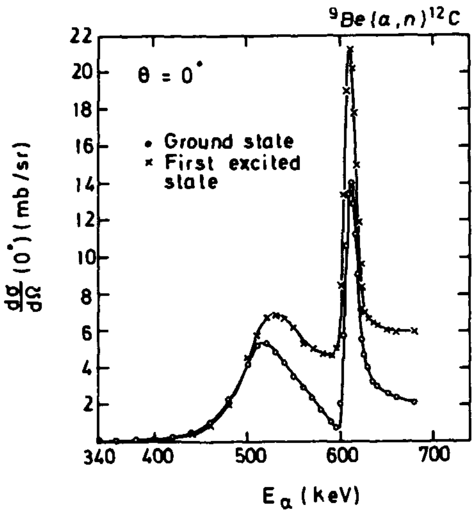
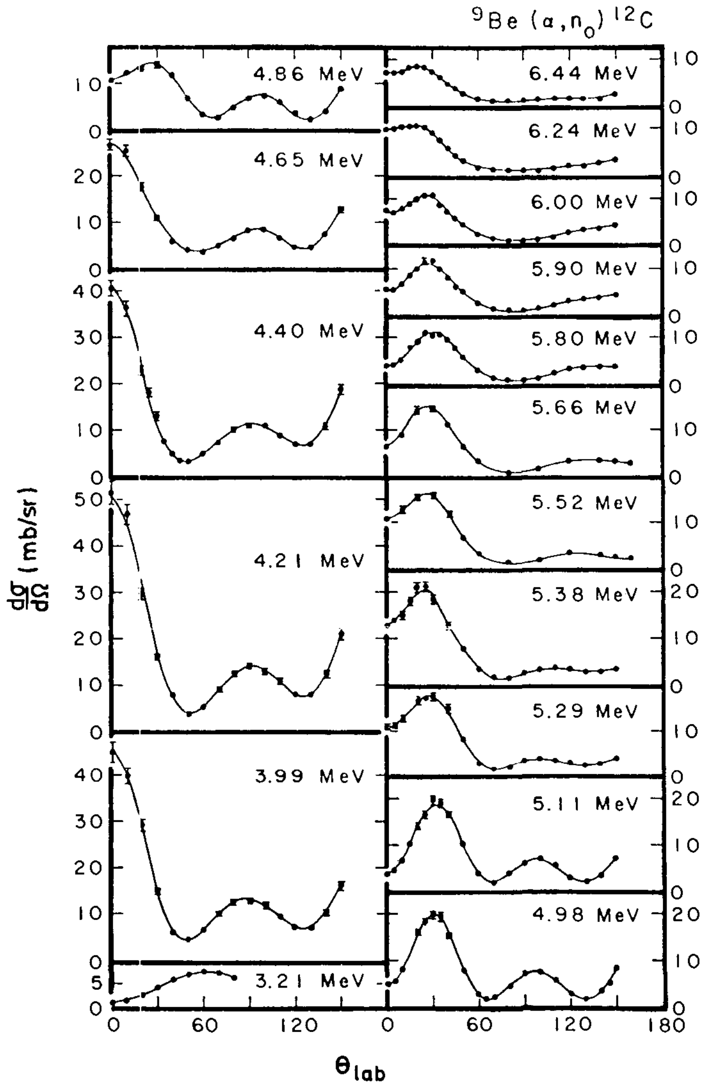


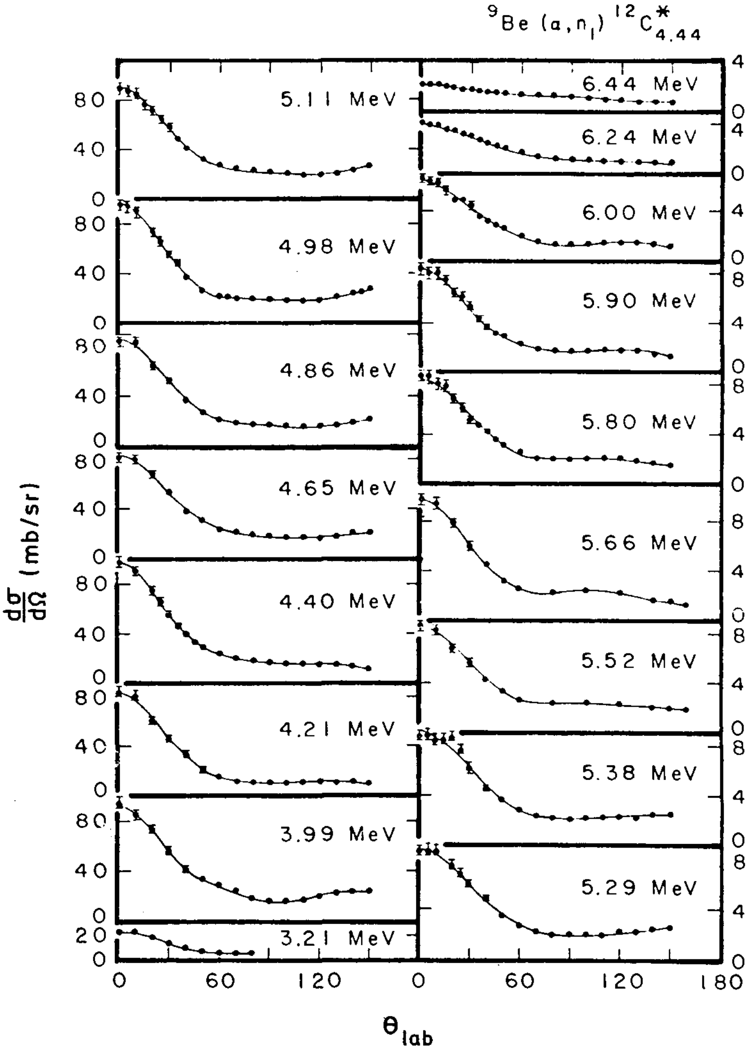
Reaction 3, Ref. A3



Reaction 3, Ref. A4



Reaction 3, Ref. A3



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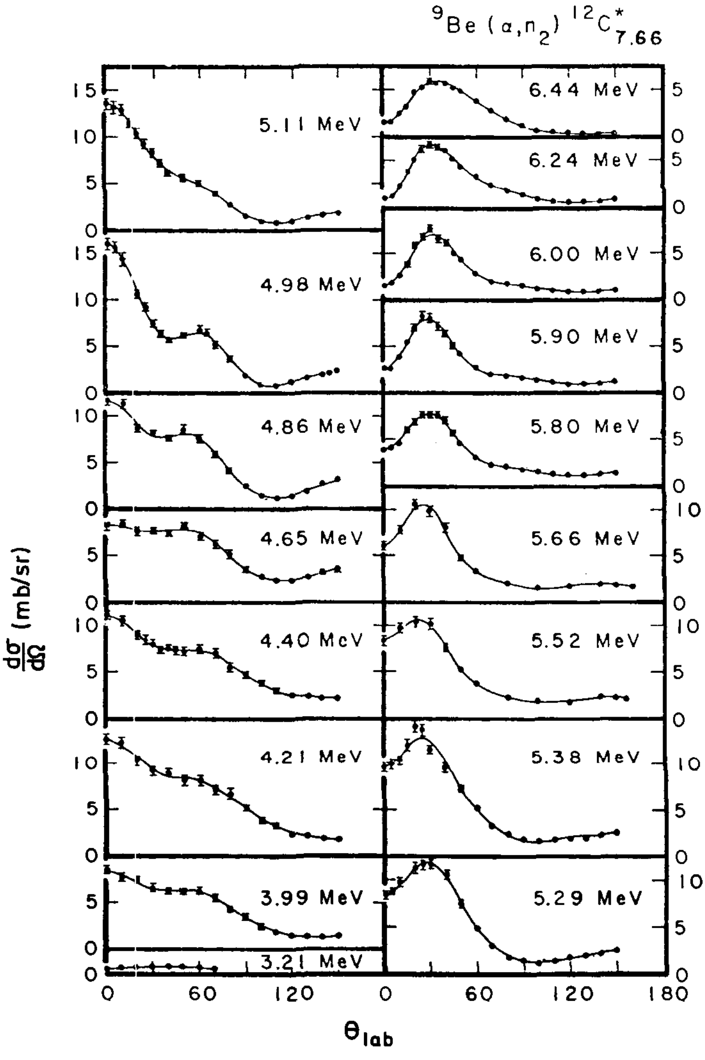
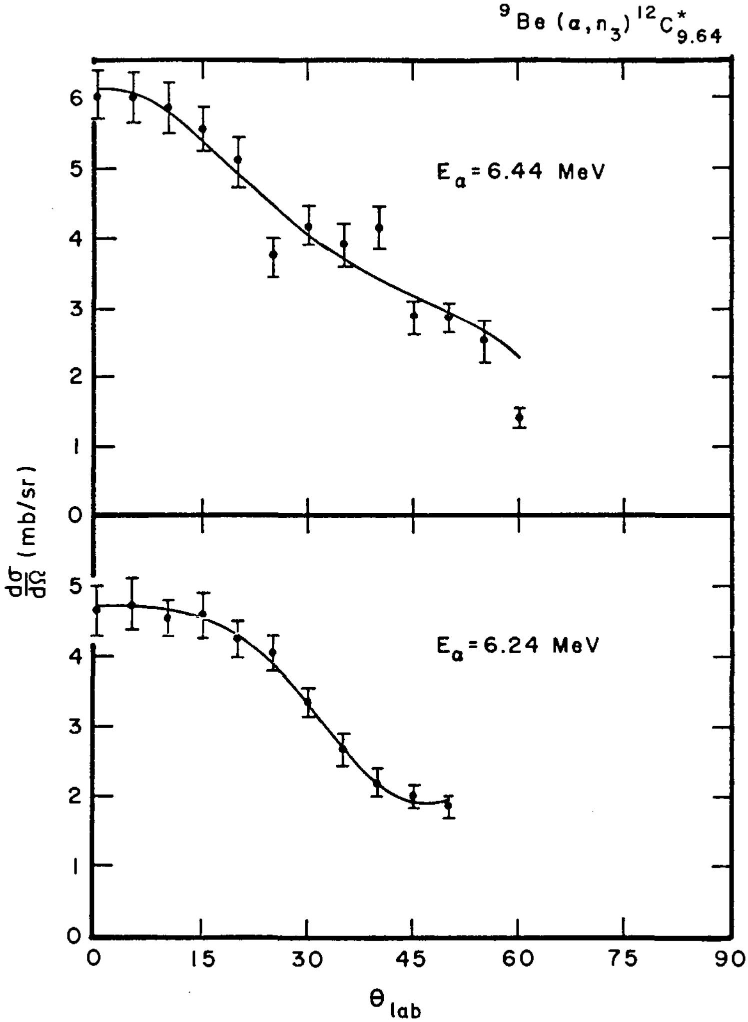
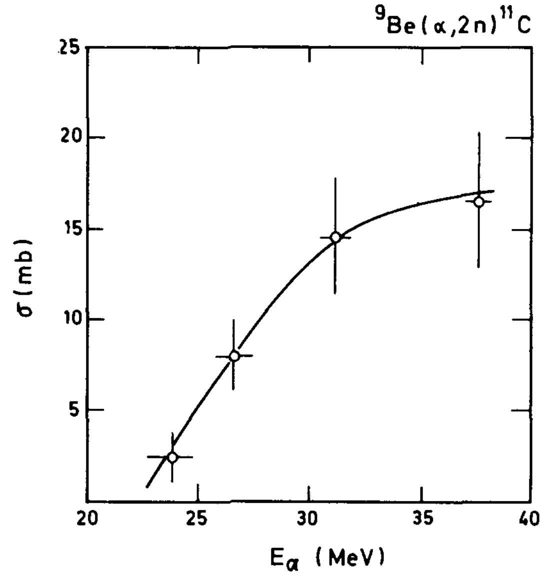


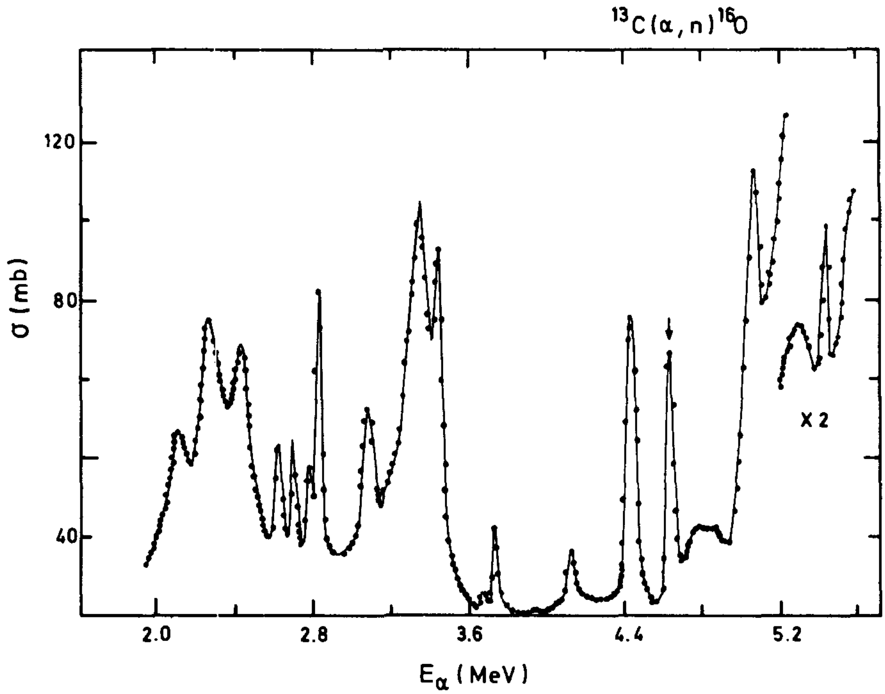
Reaction 3, Ref. A3



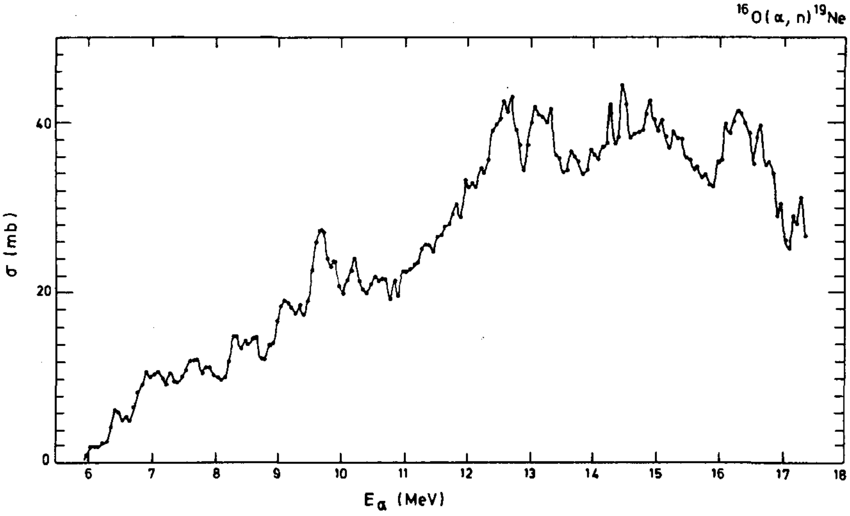
Reaction 3, Ref. A3



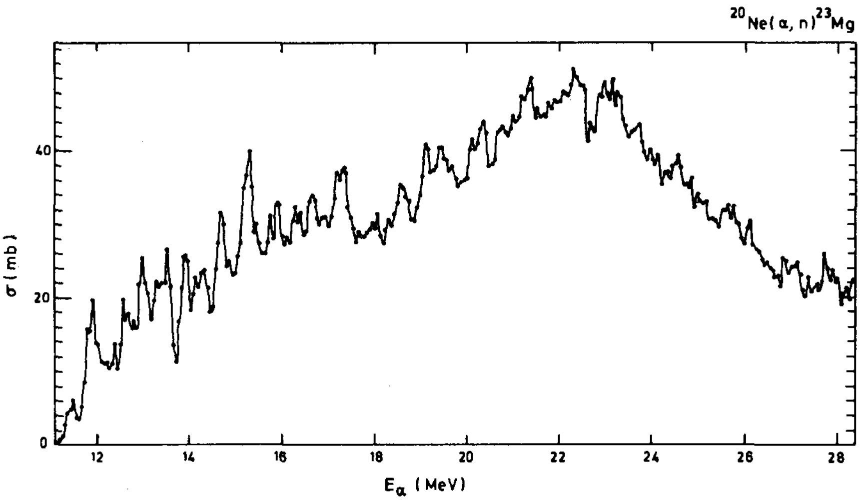
Reaction 4, Ref. A5



Reaction 5, Ref. A6

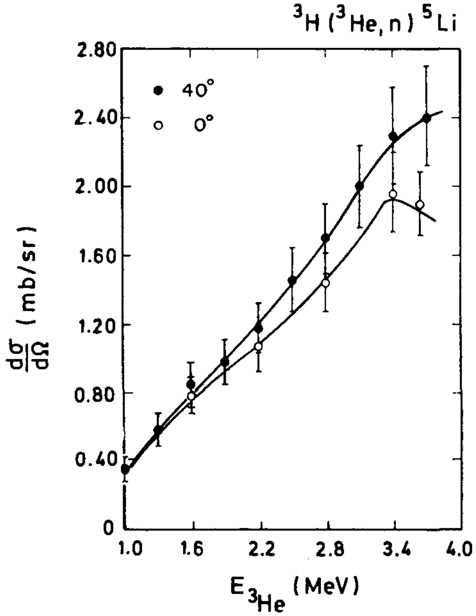


Reaction 6, Ref. A7

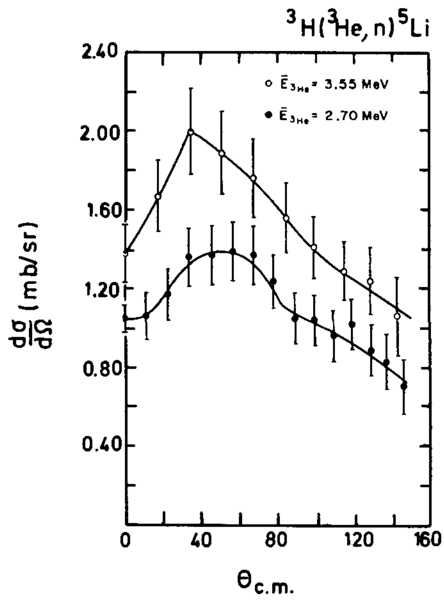


Reaction 7, Ref. A7

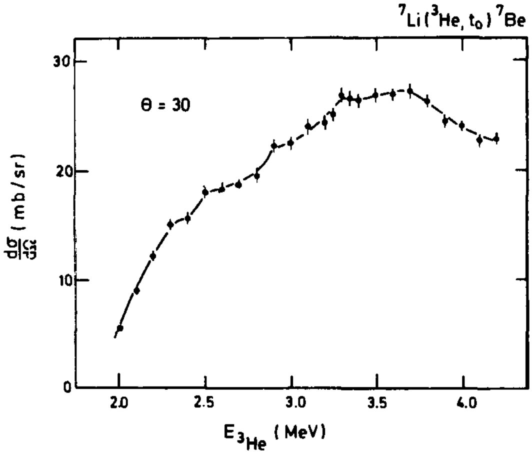
HELIUM-3



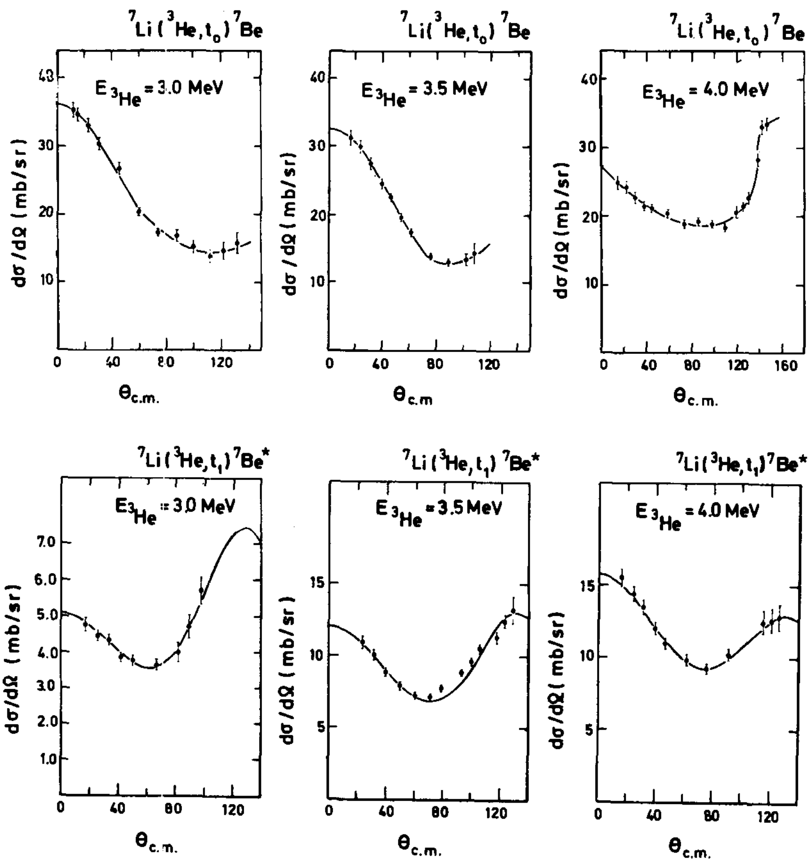
Reaction 1, Ref. H1



Reaction 1, Ref. H1



Reaction 2, Ref. H2



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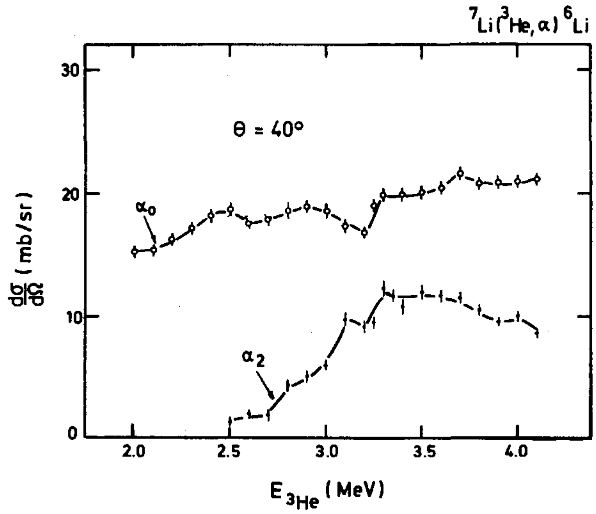

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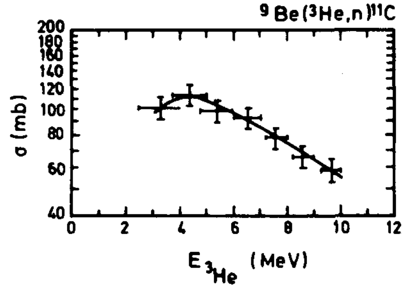
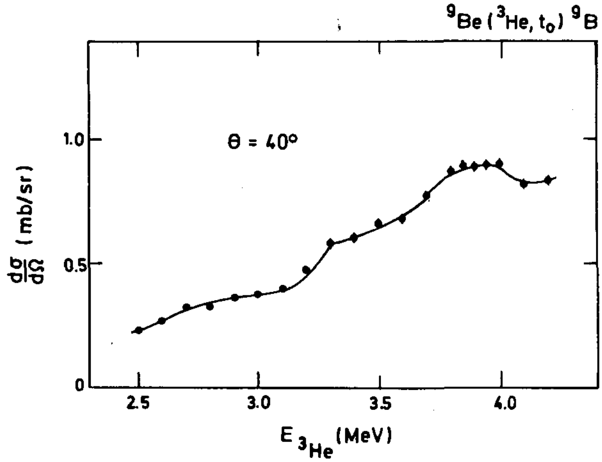
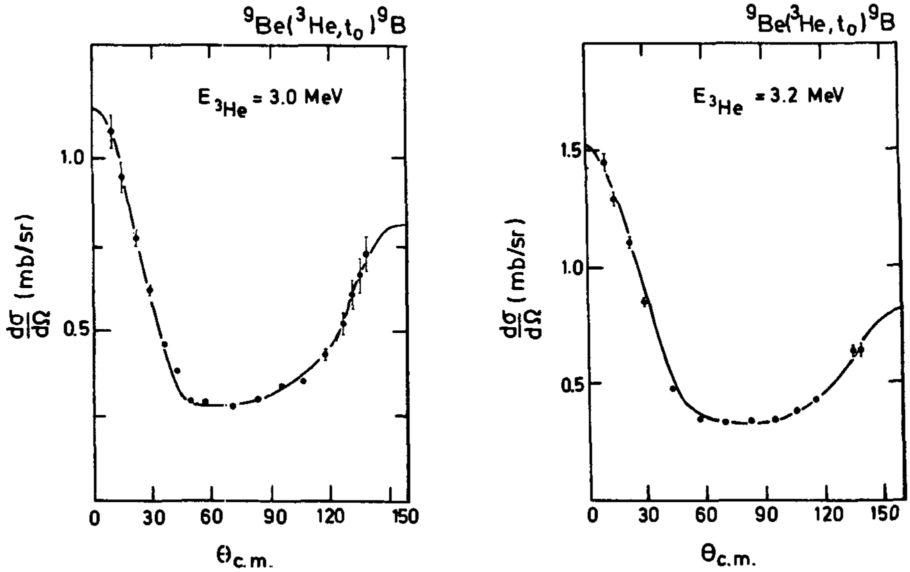


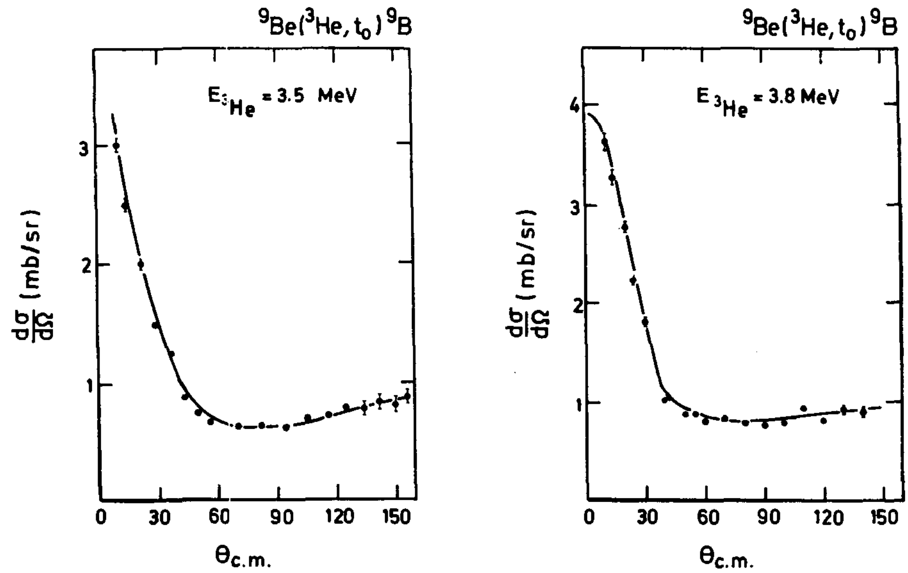
Reaction 4, Ref. H2



Reaction 5, Ref. H2



Reaction 5, Ref. H2



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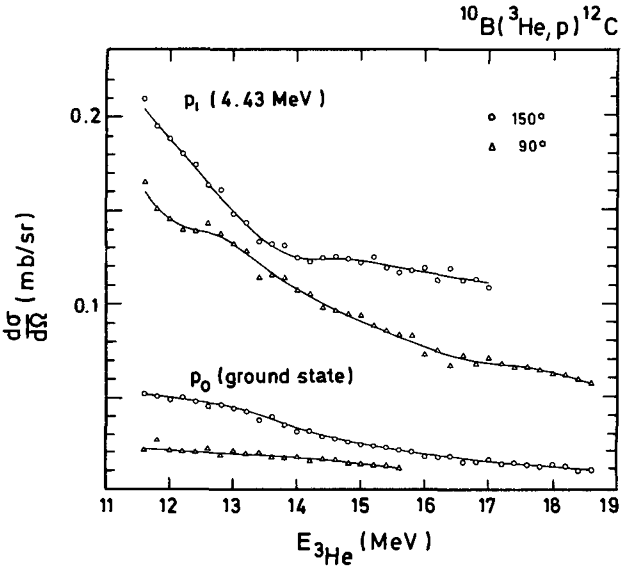
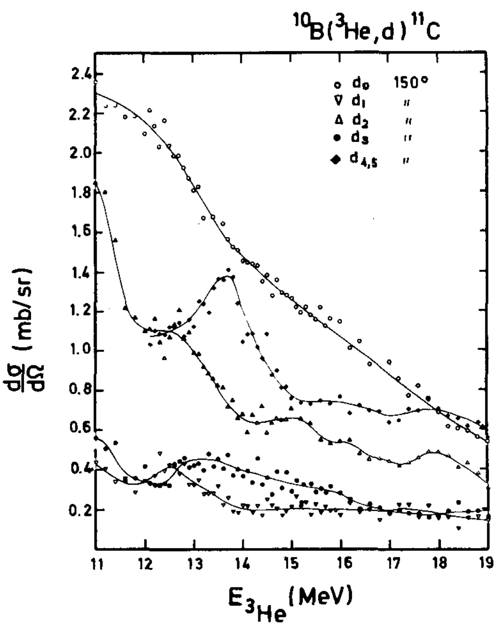
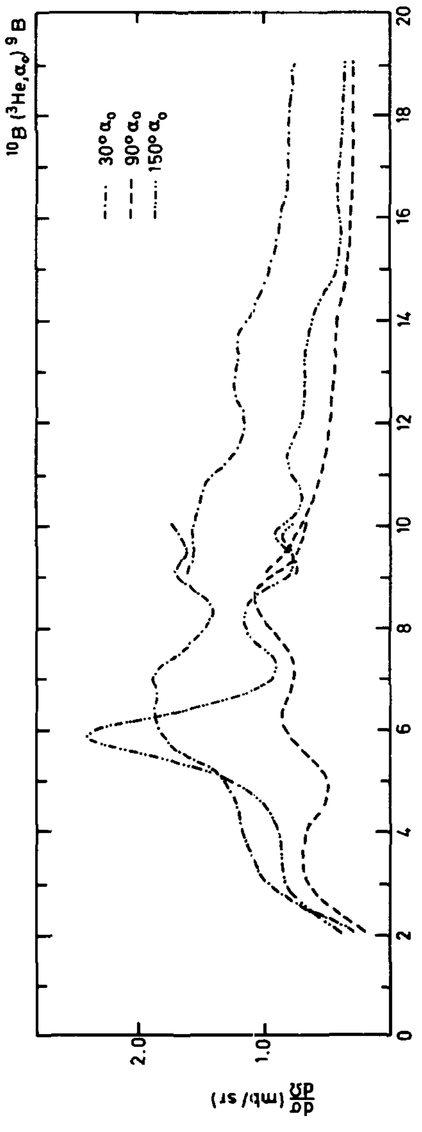


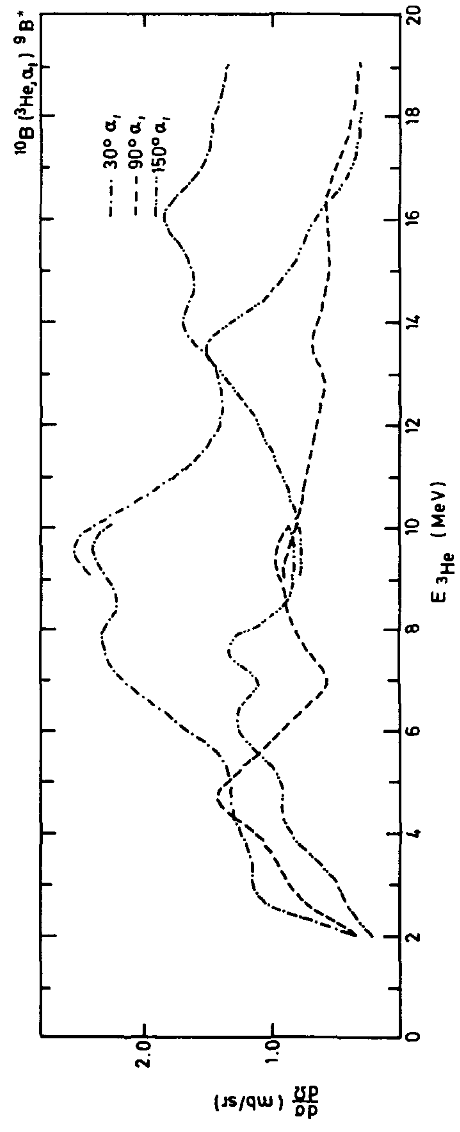
Reaction 6, Ref. H4



Reaction 7, Ref. H4



Reaction 8, Ref. H4



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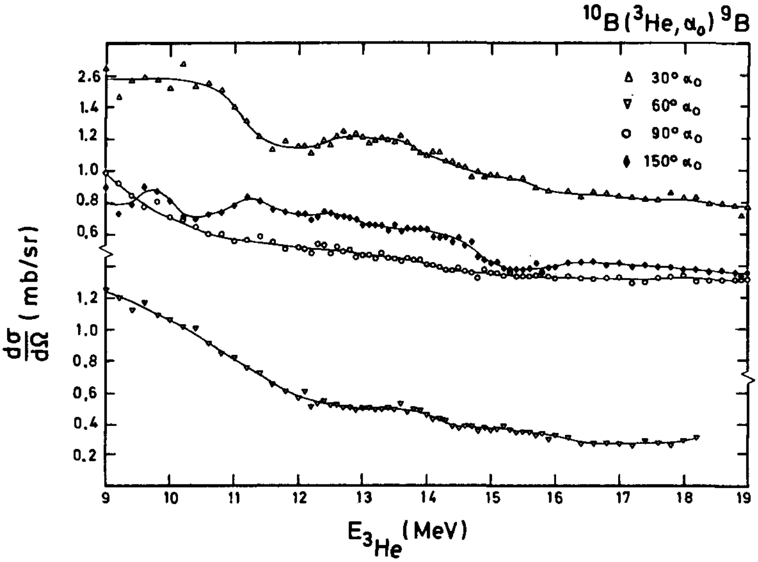

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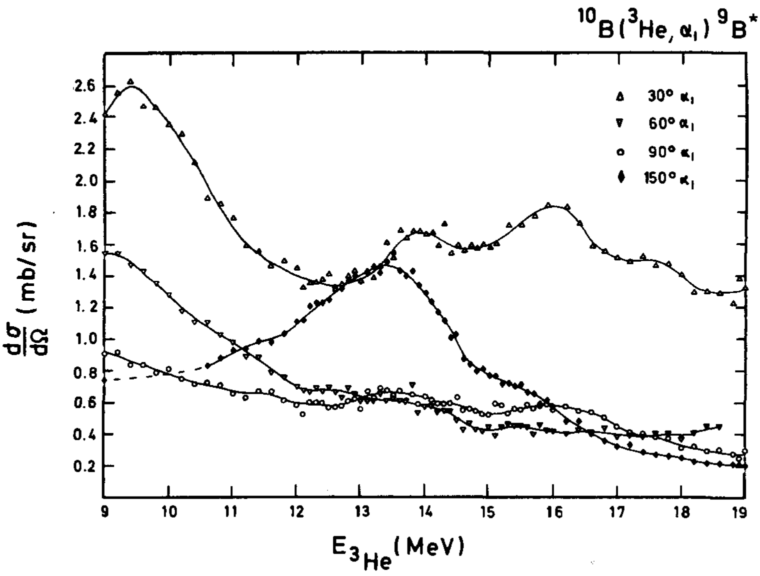

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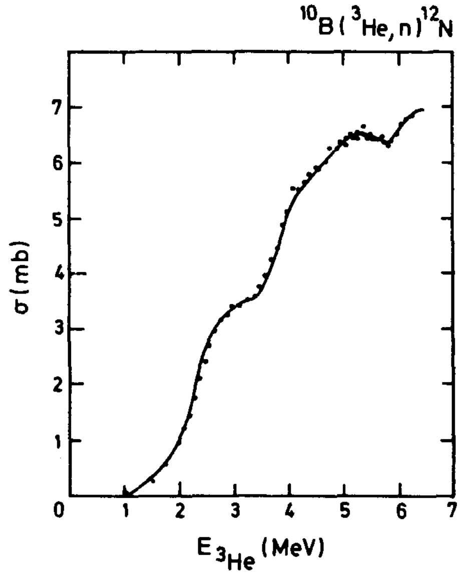
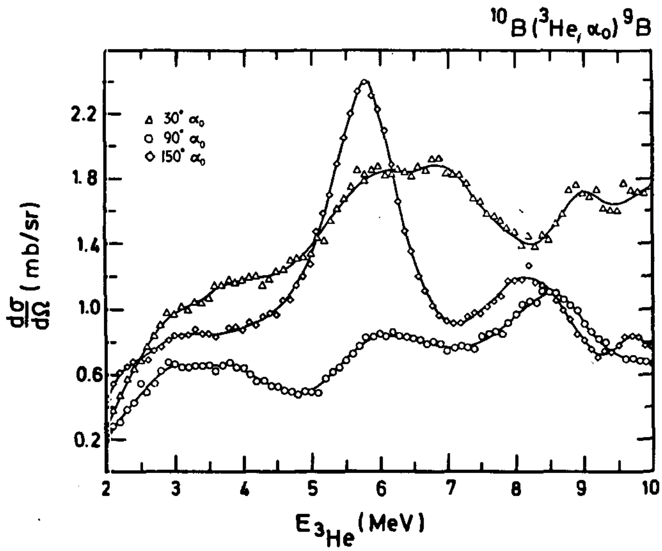
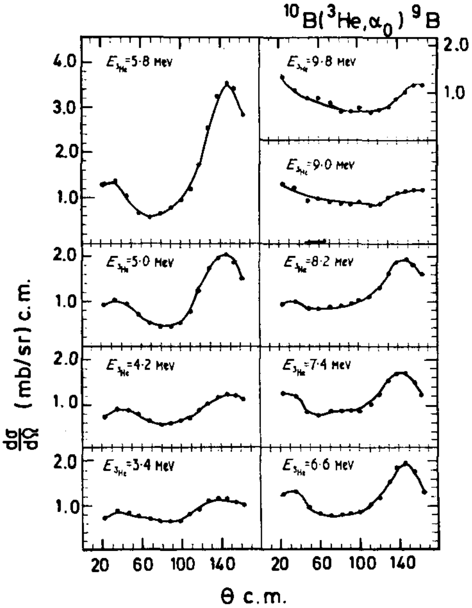


Reaction 9, Ref. H5



Reaction 10, Ref. H6



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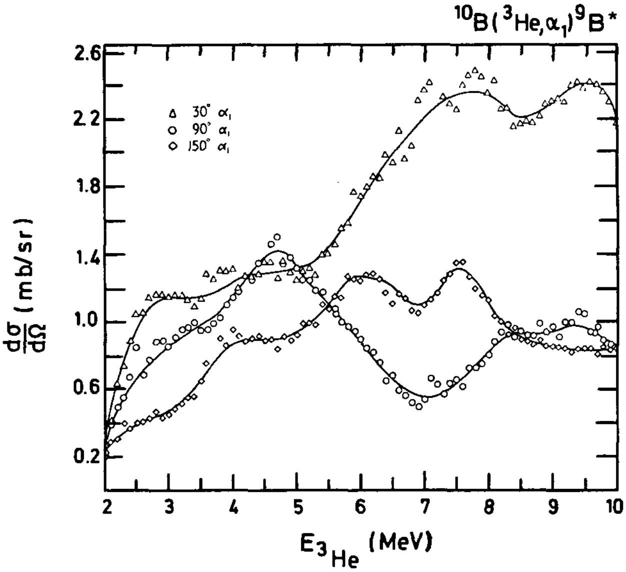

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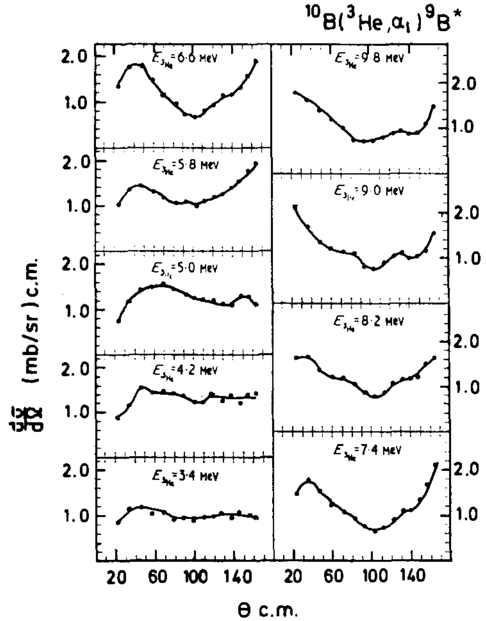

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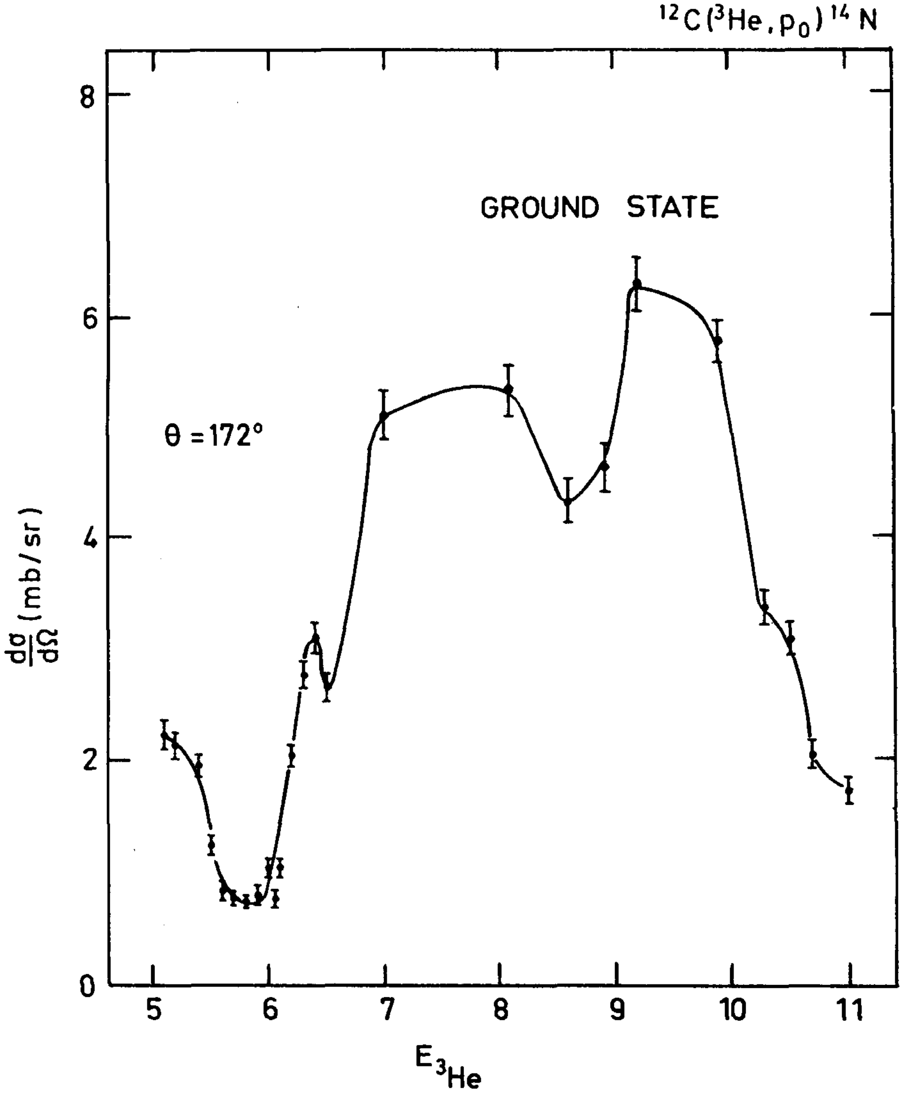
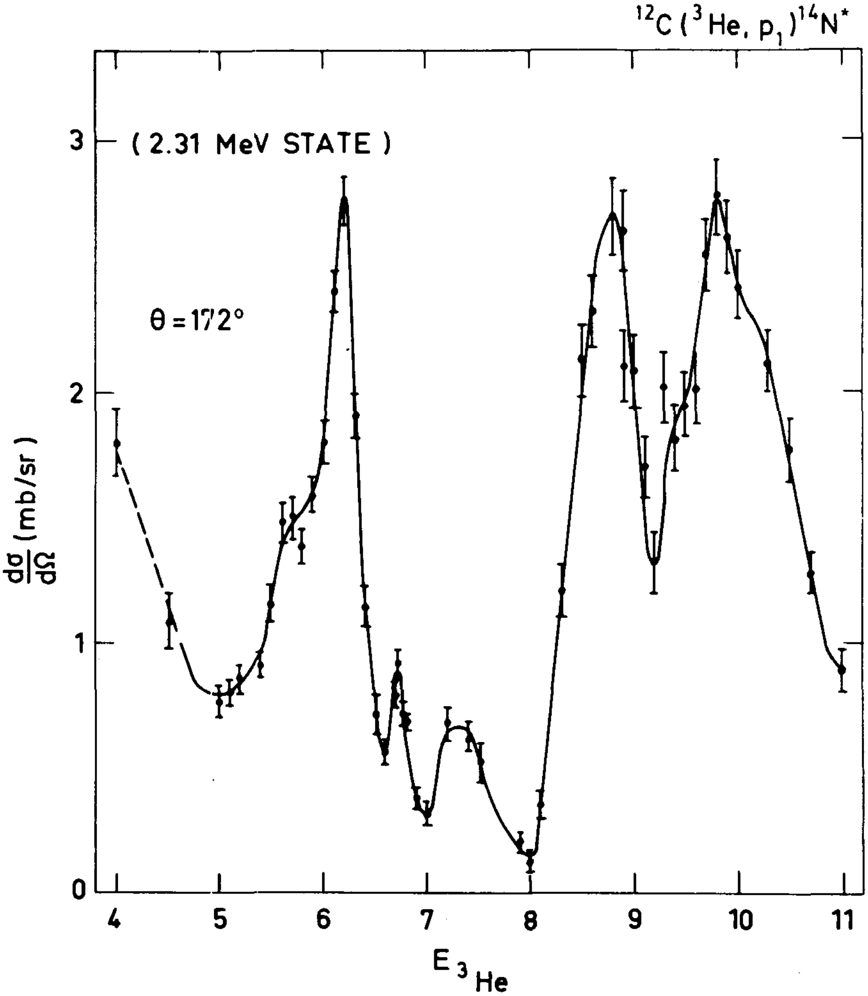


Reaction 11, Ref. H7



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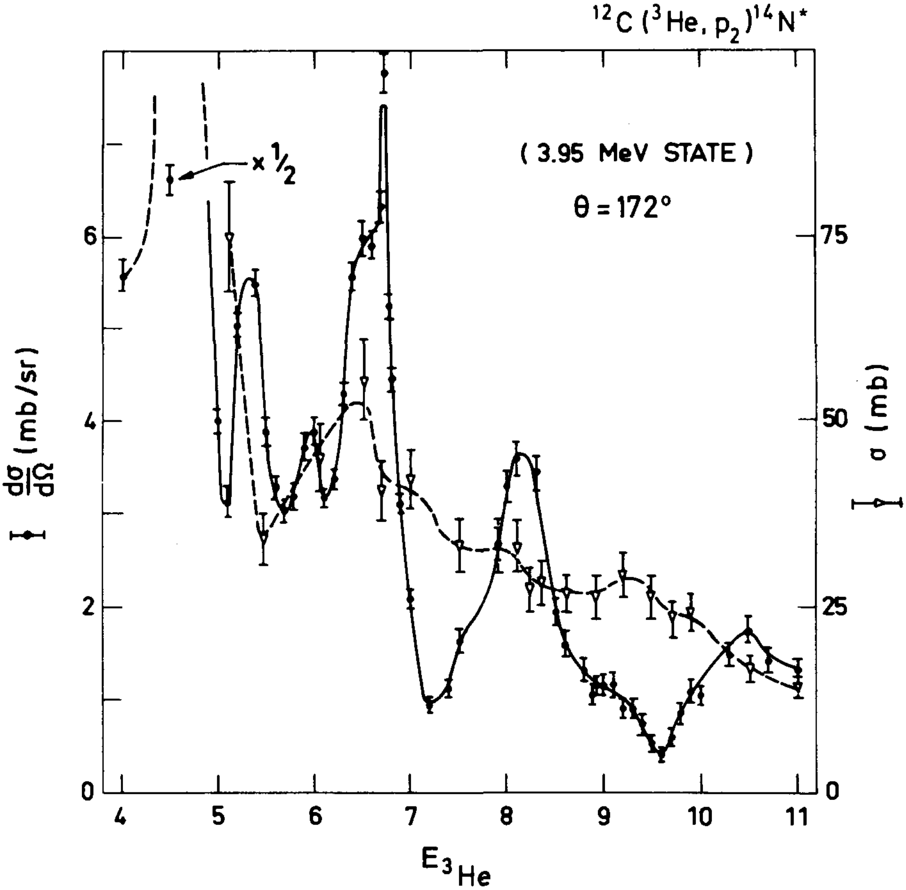

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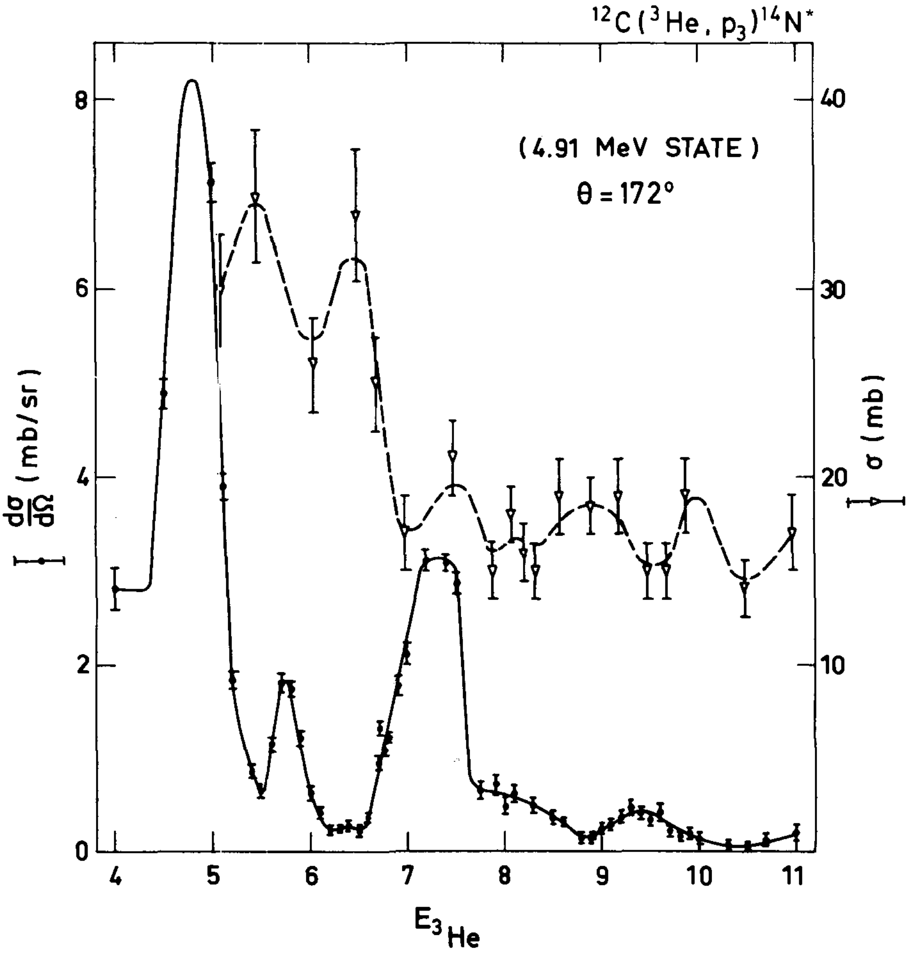

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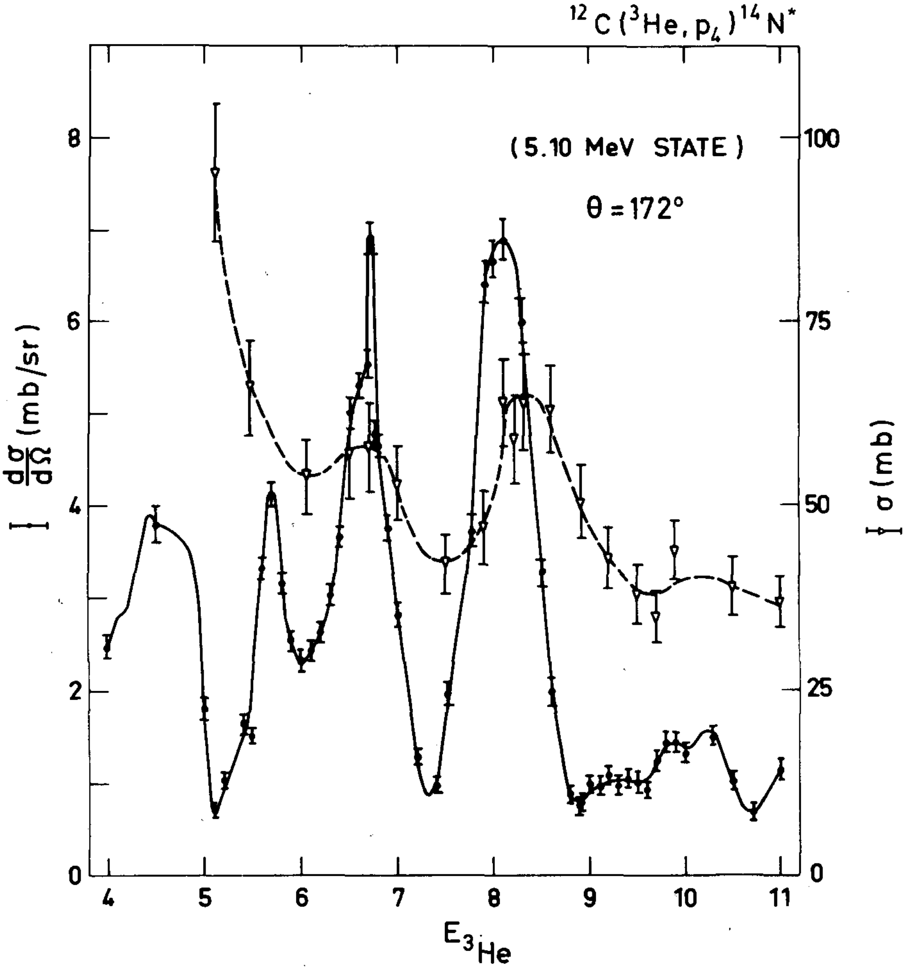

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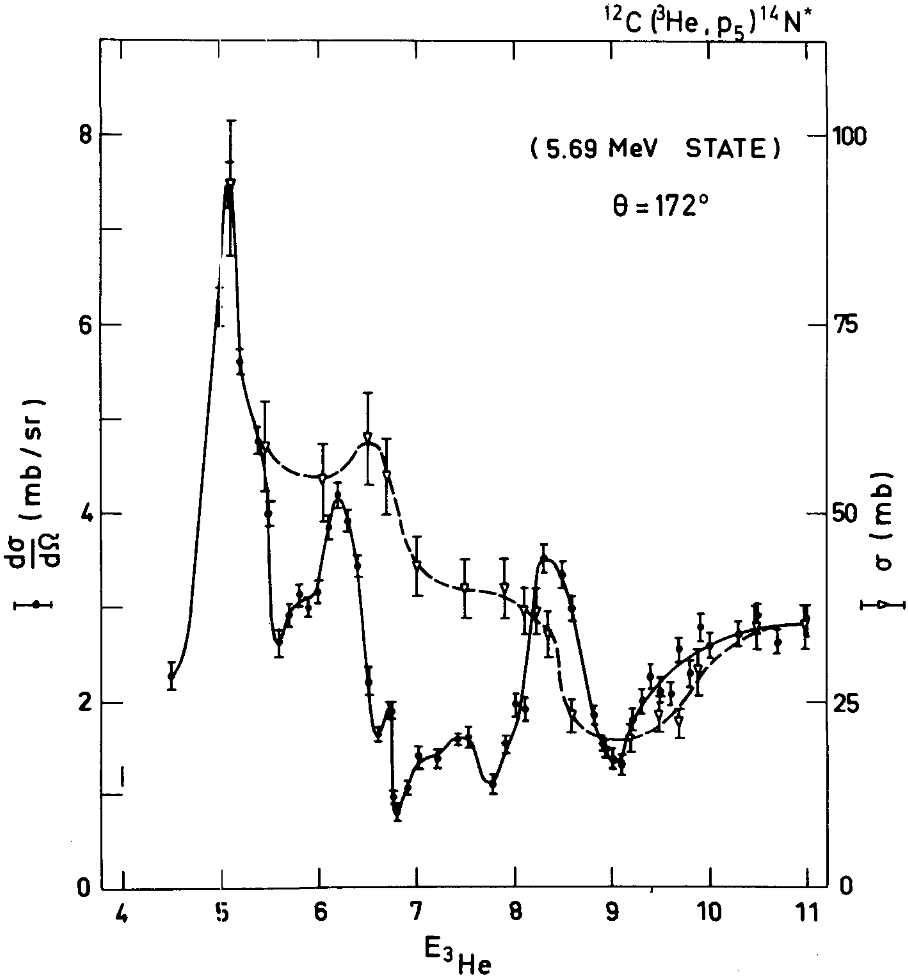

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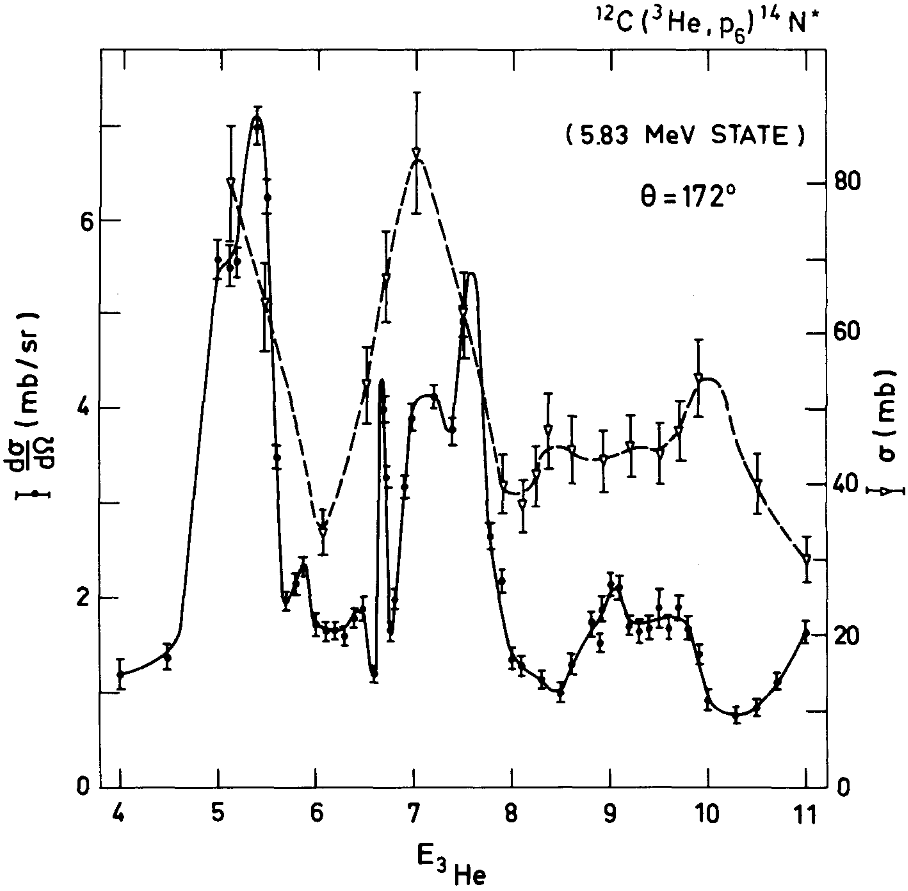

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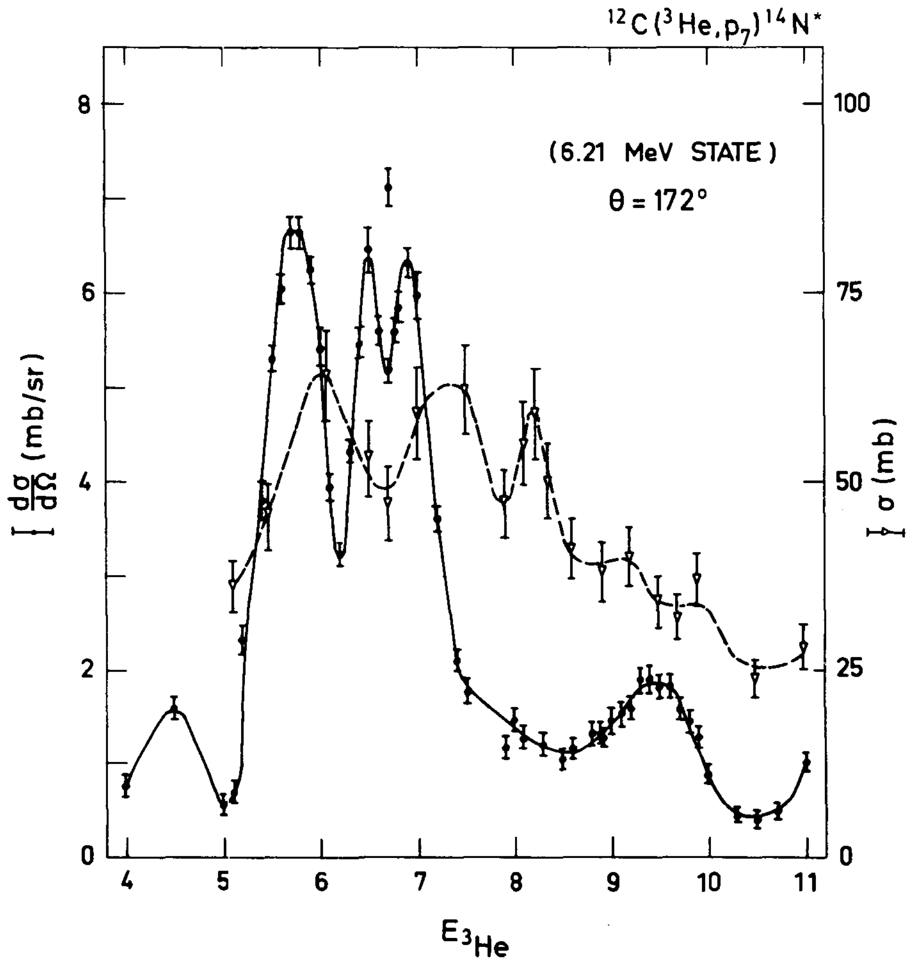

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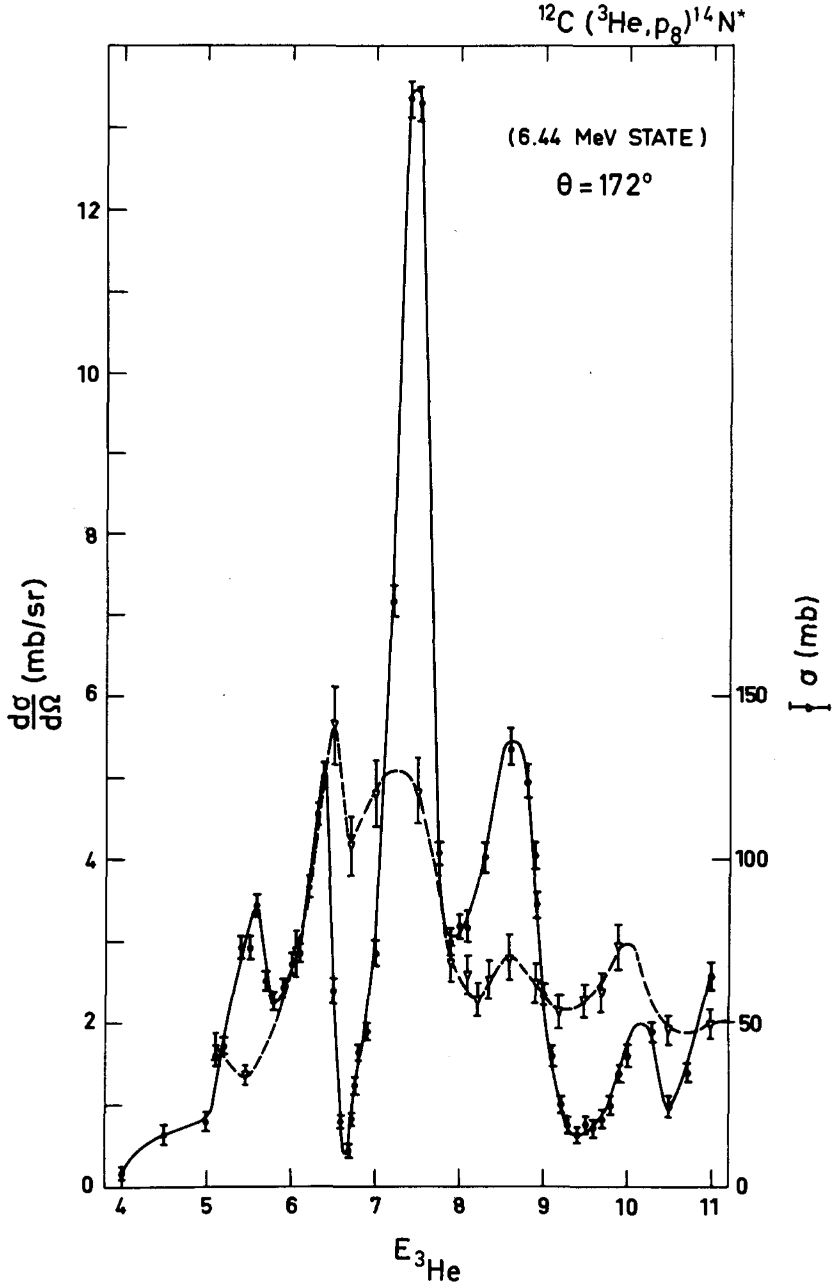

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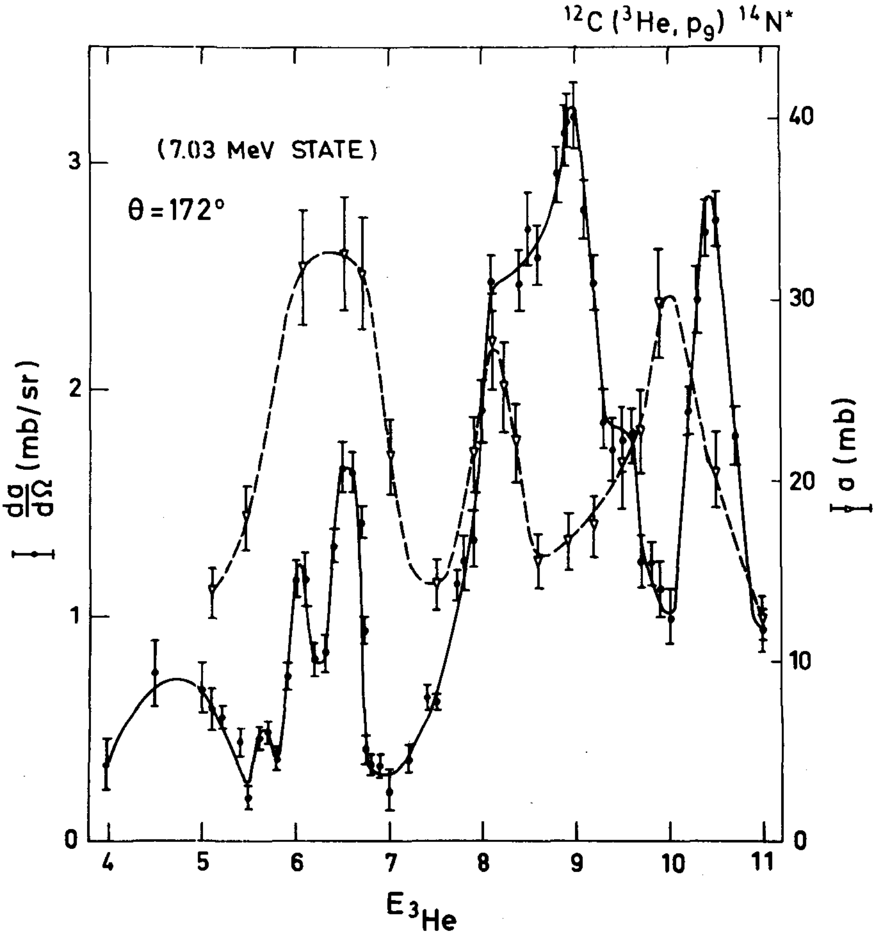

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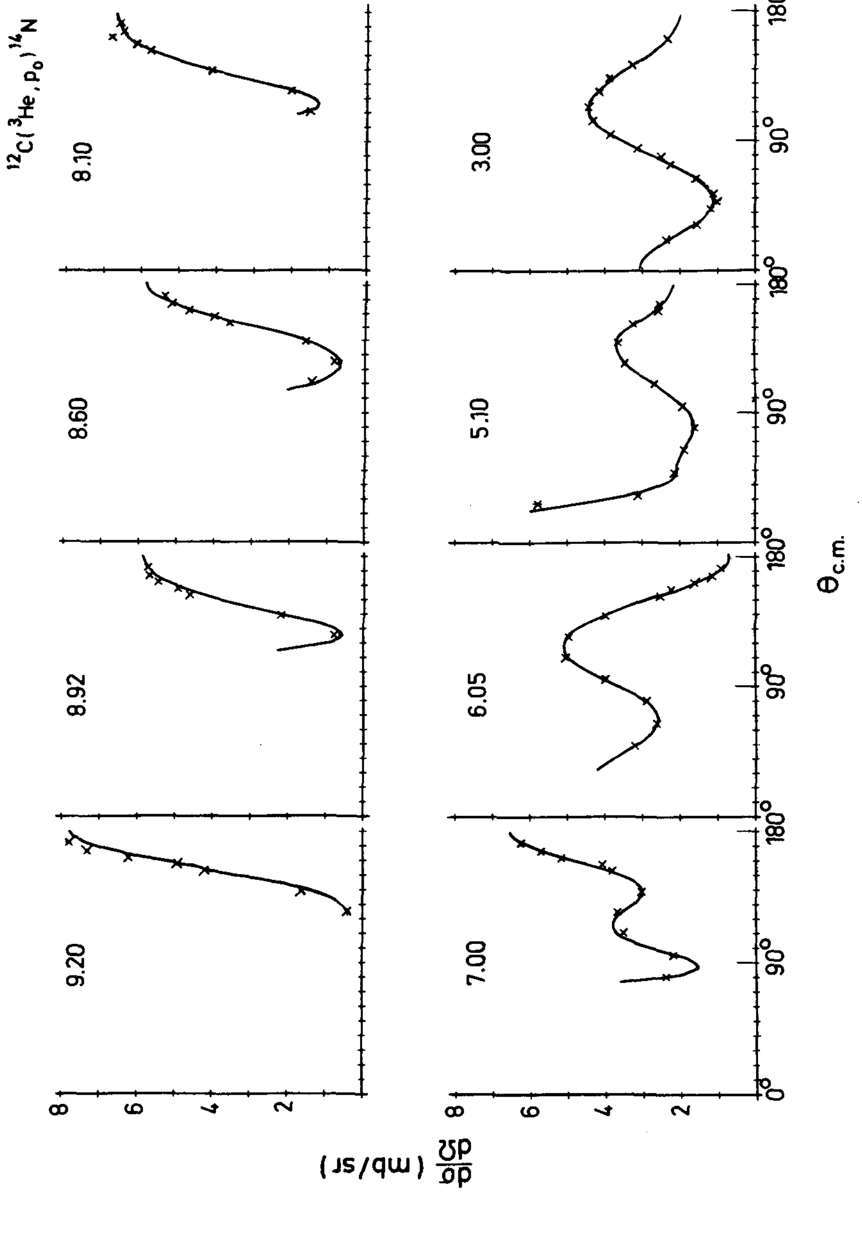

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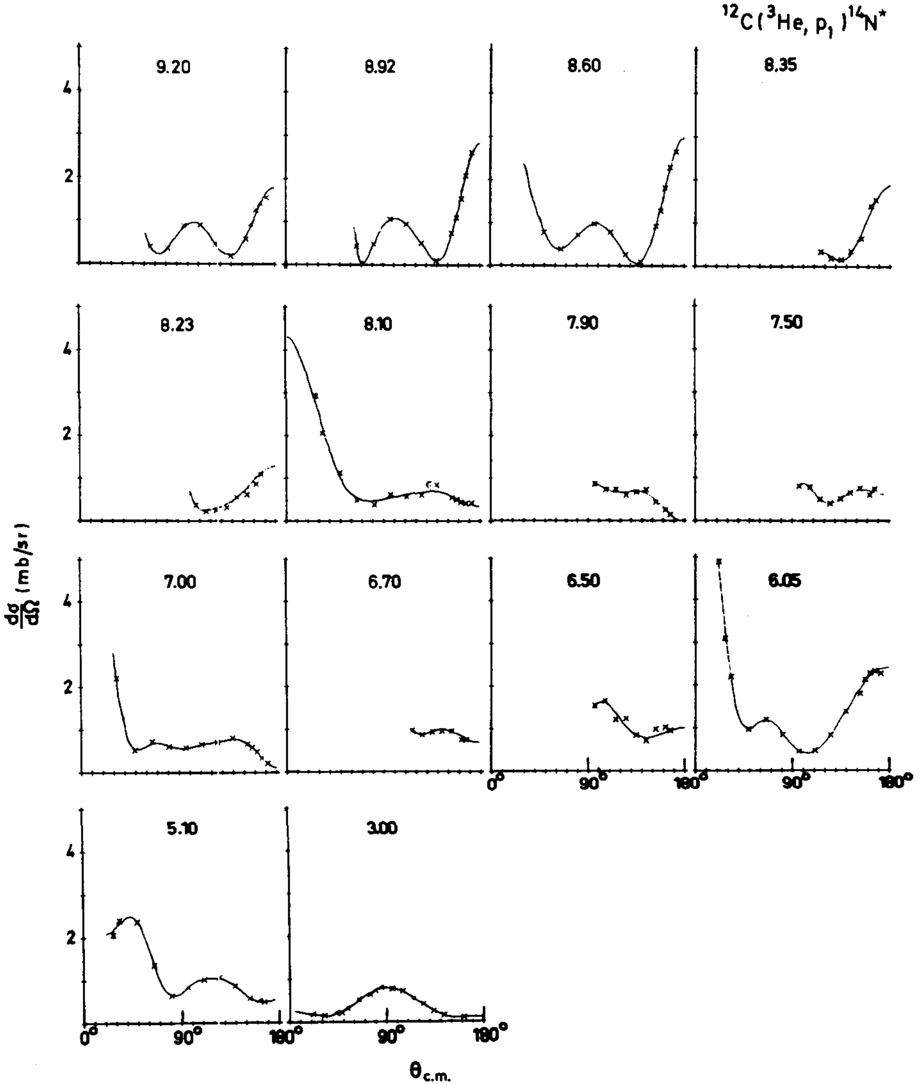

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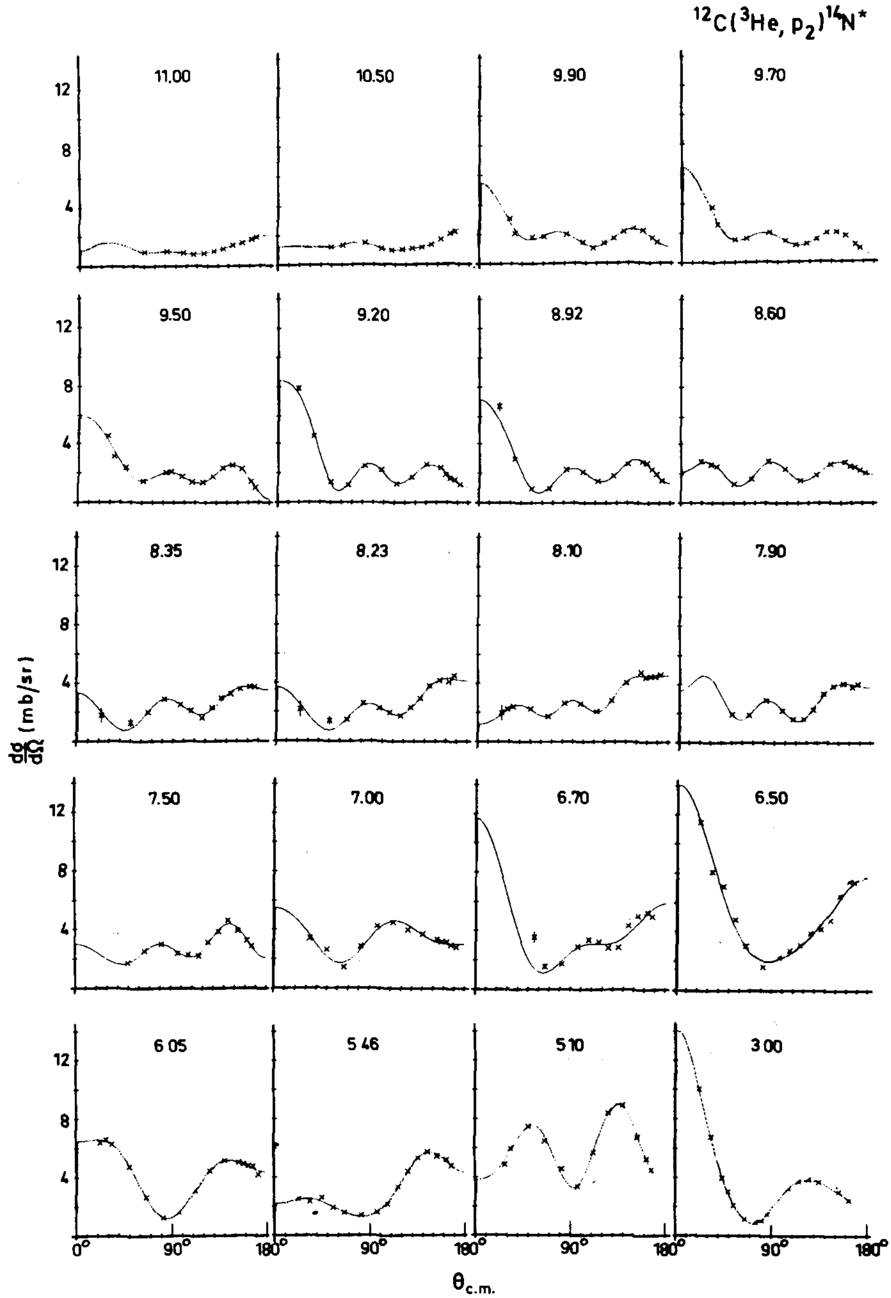

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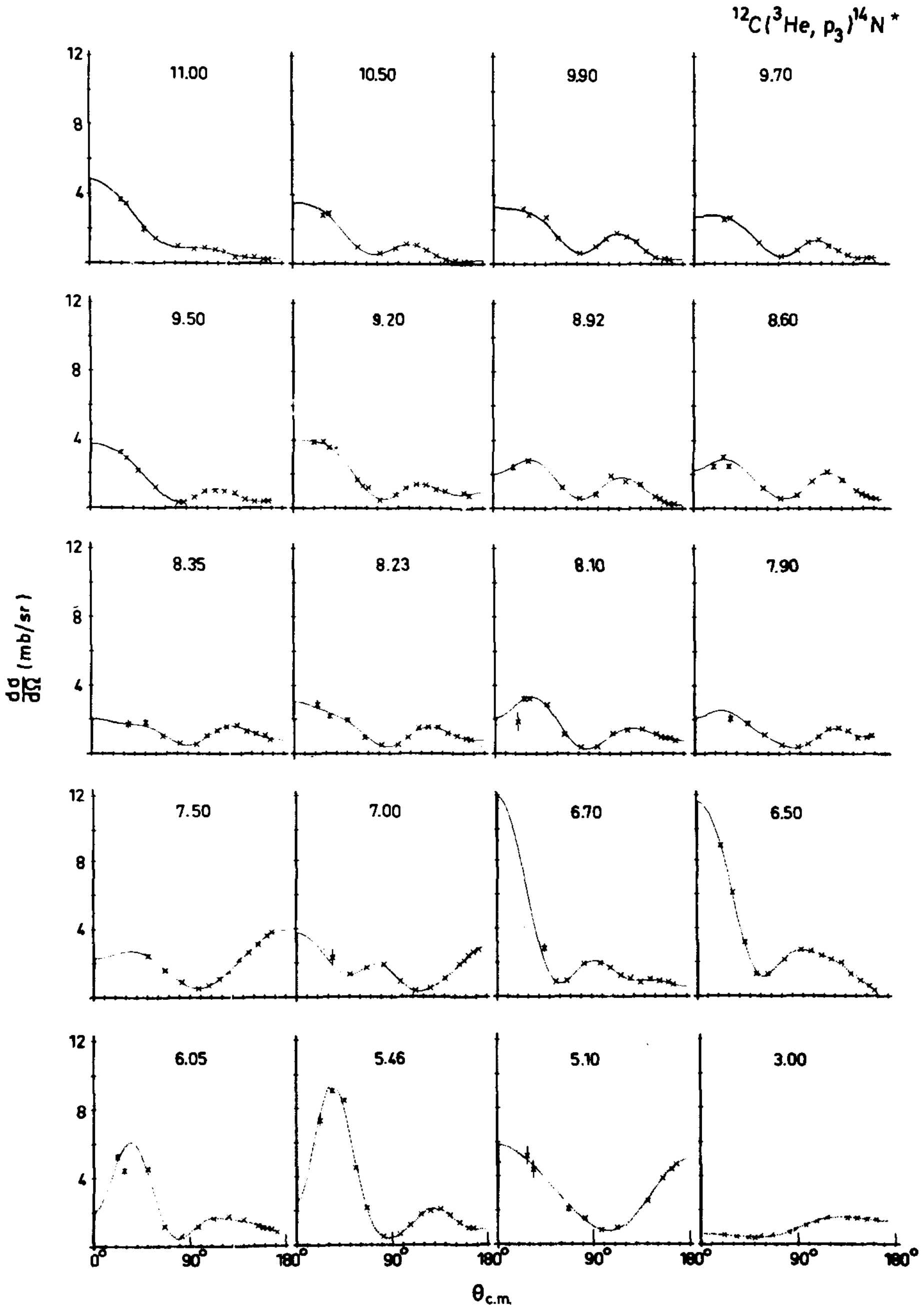

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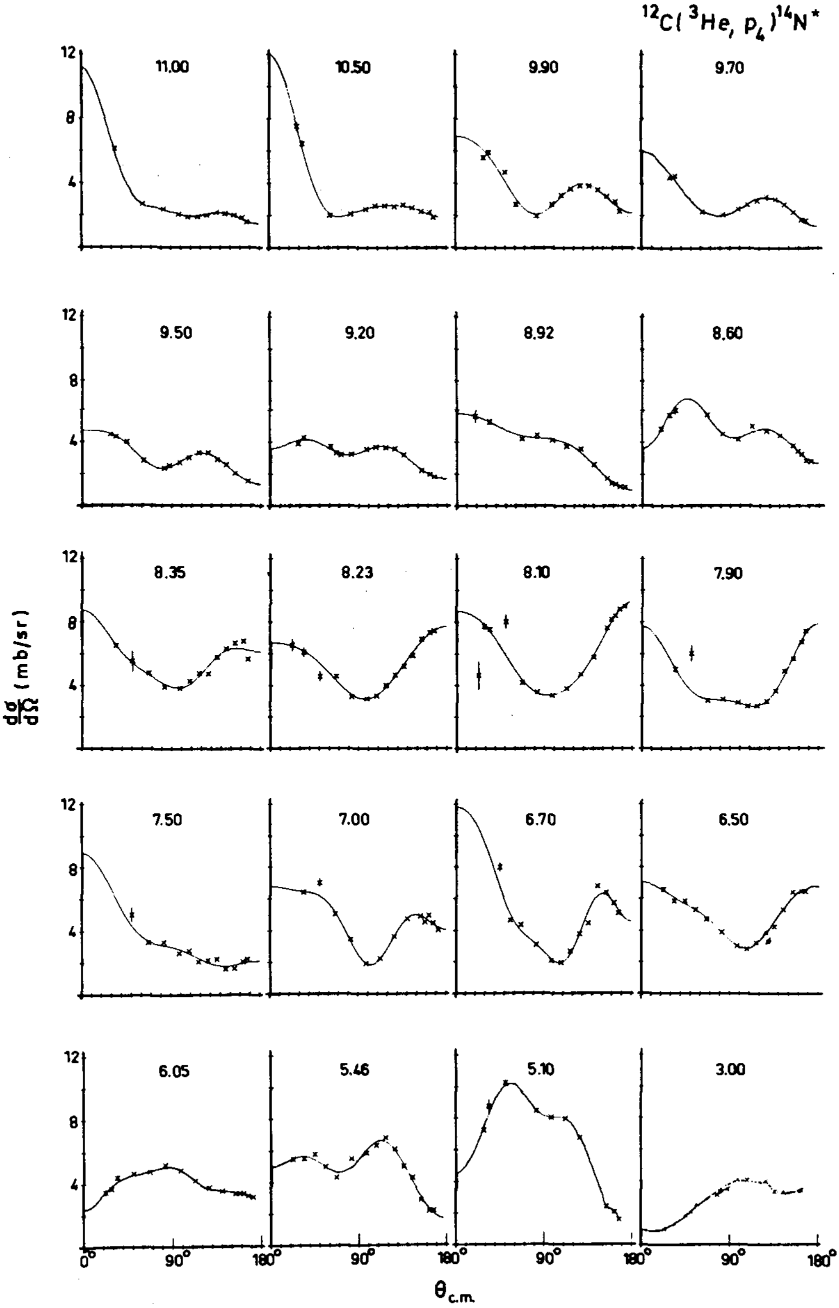

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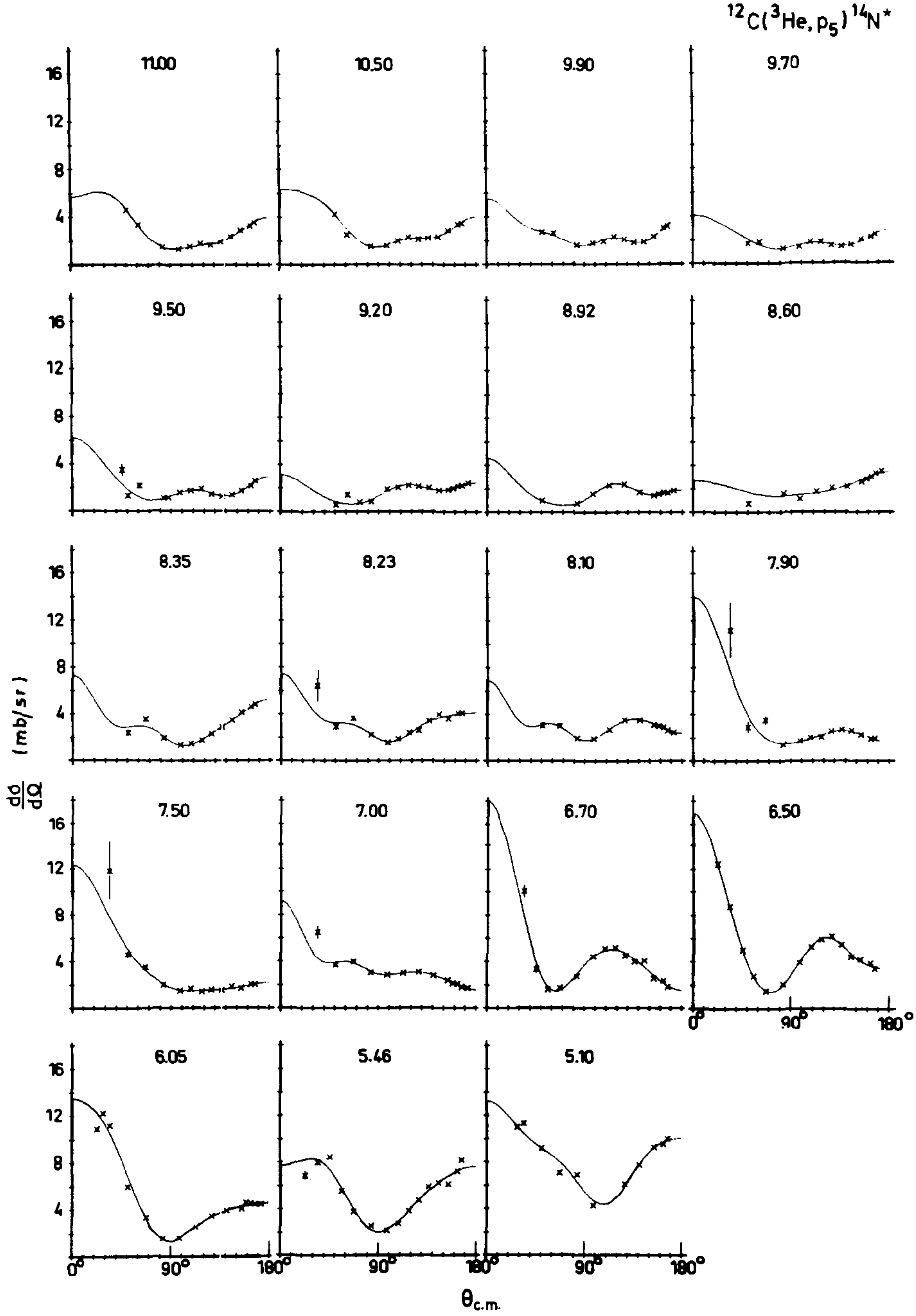

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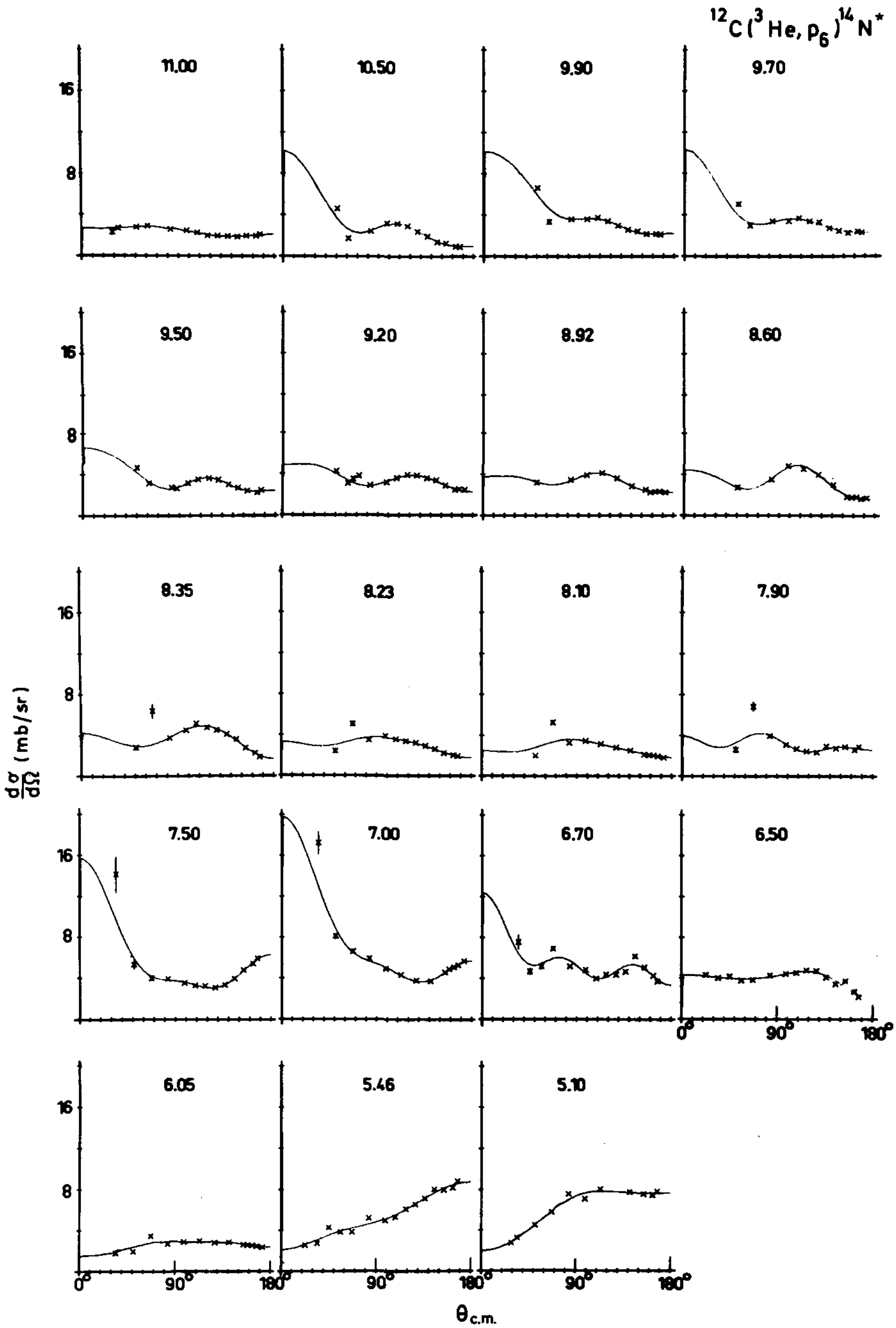

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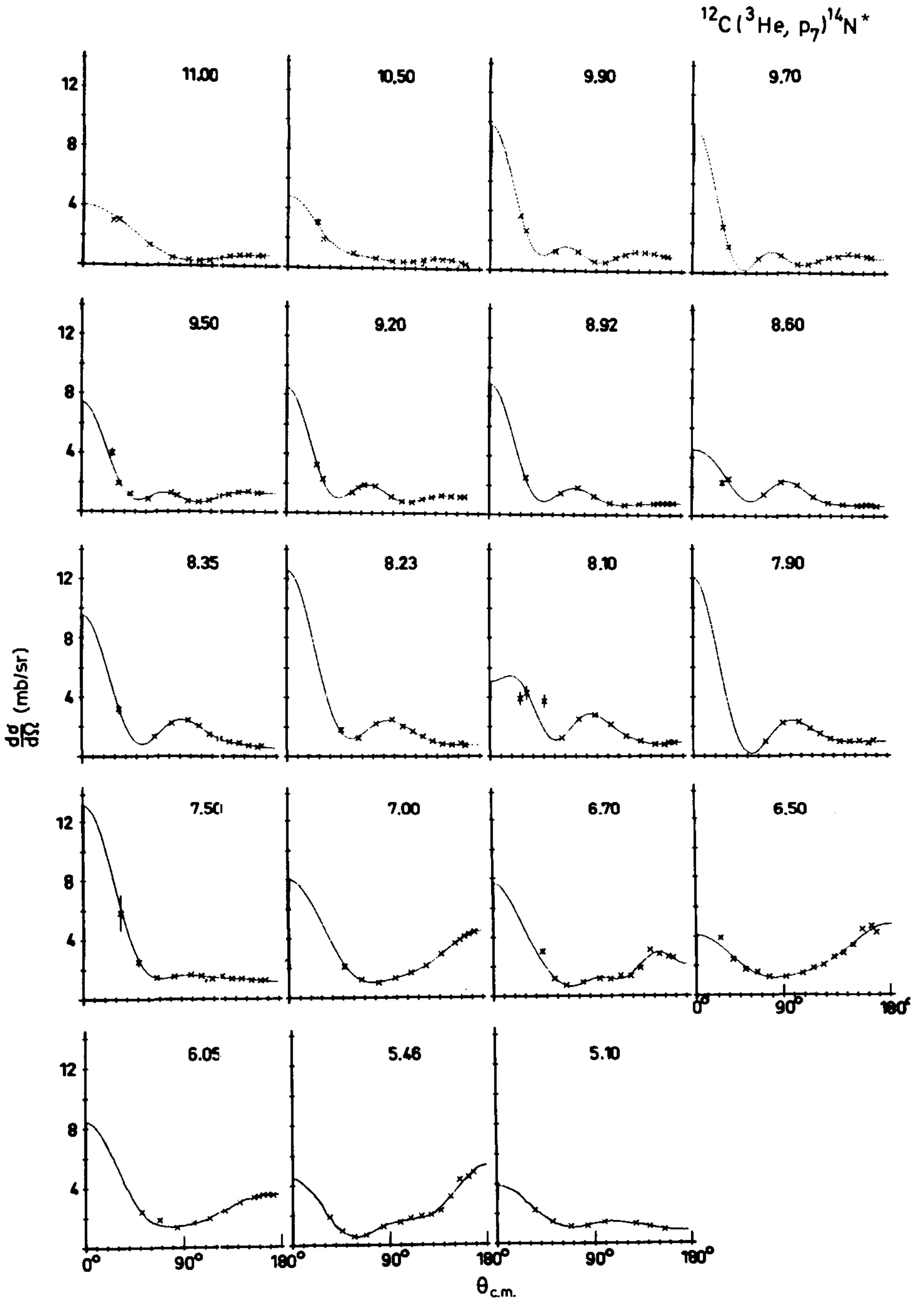

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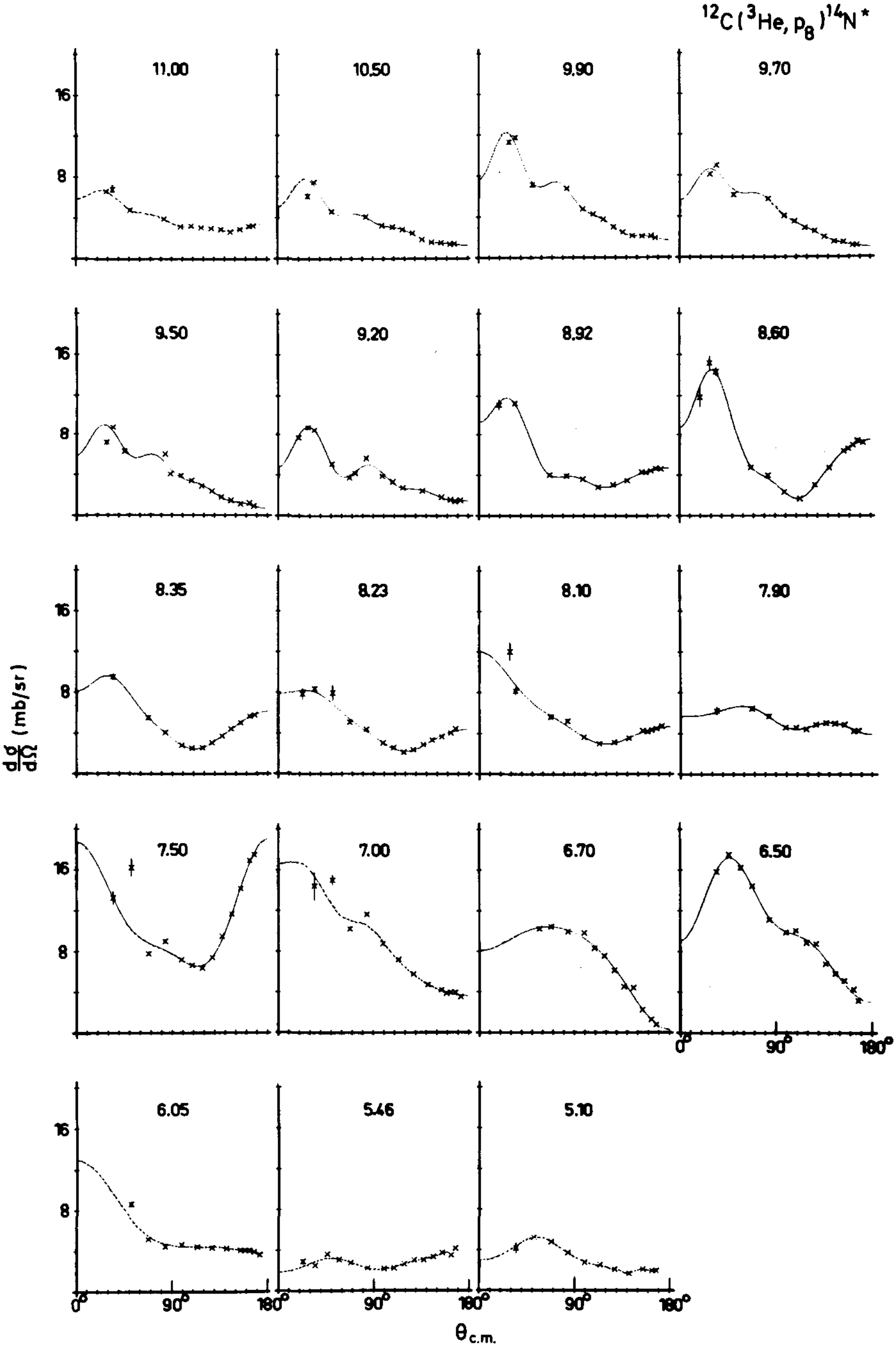

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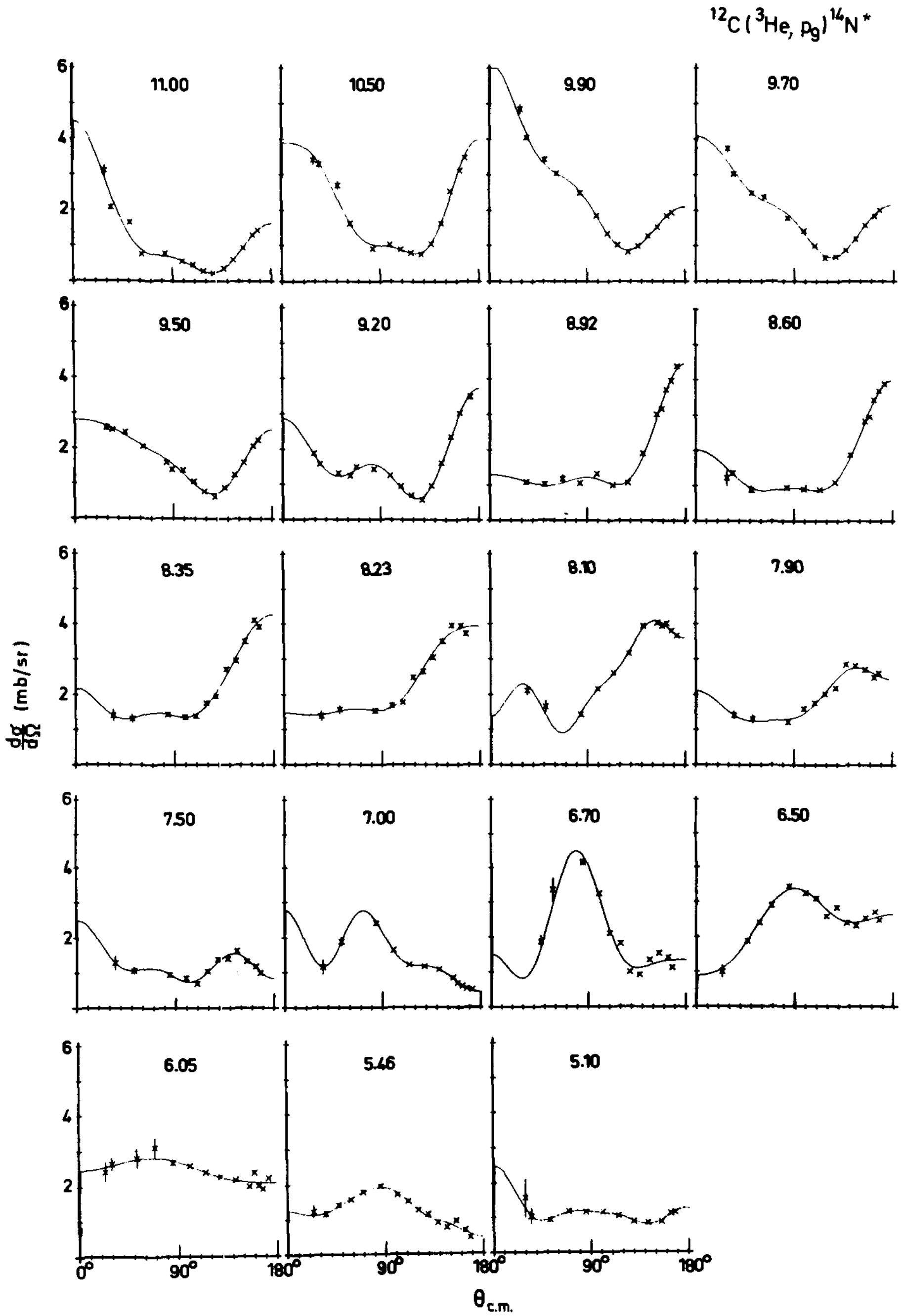

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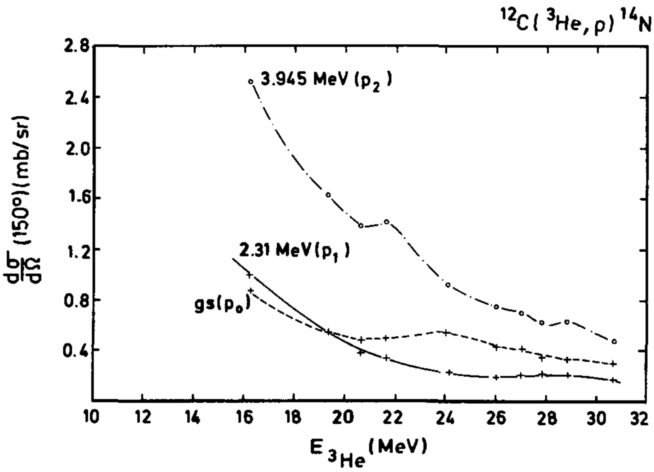
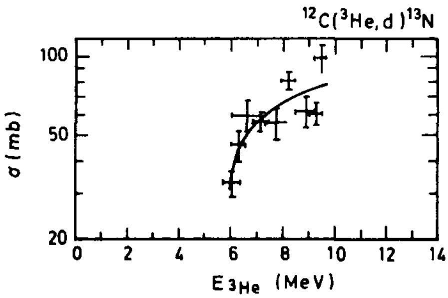
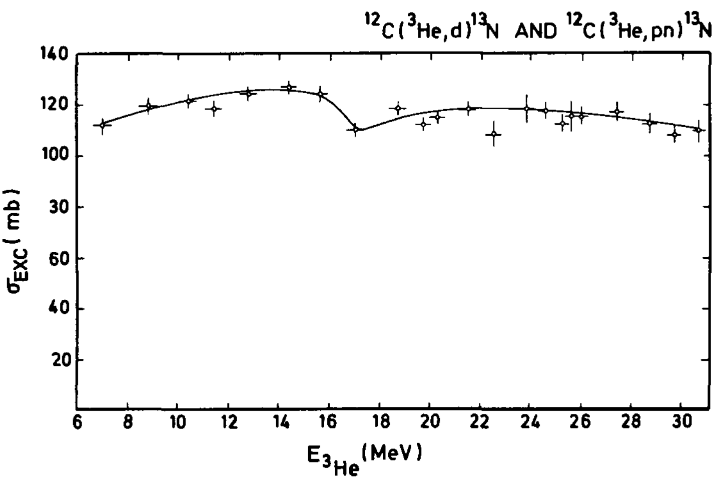


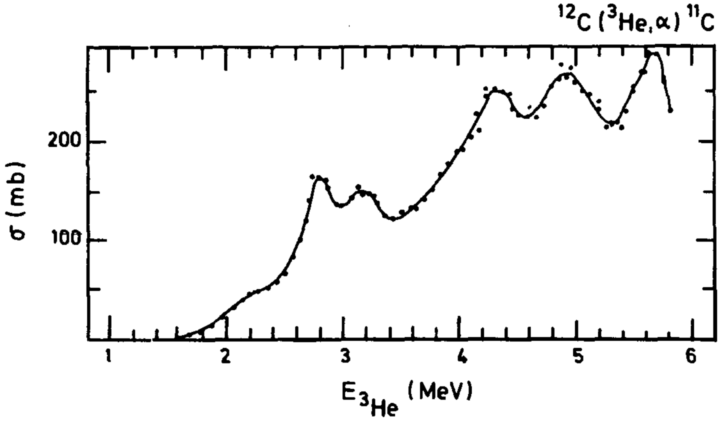
Reaction 11, Ref. H8



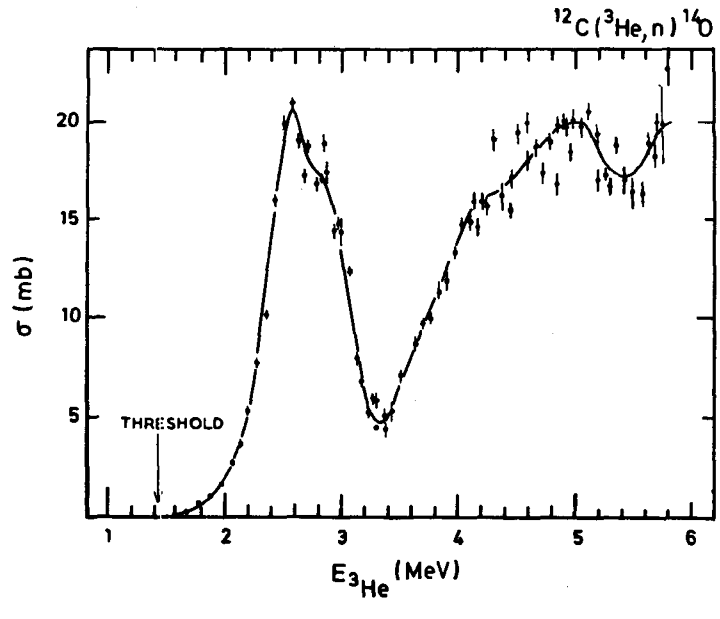
Reaction 12, Ref. H3



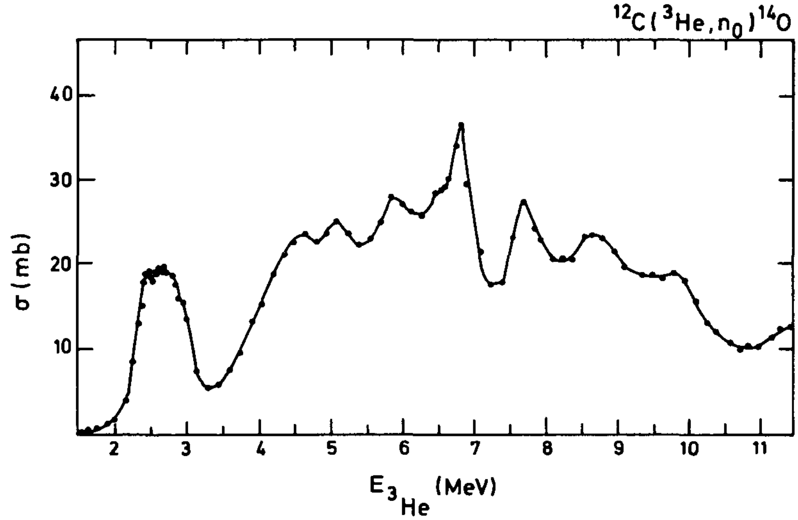
Reaction 13, Ref. H8



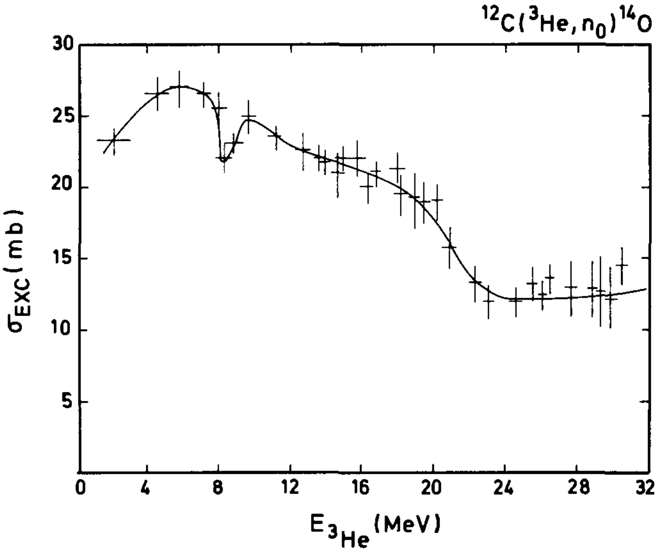
Reaction 14, Ref. H9



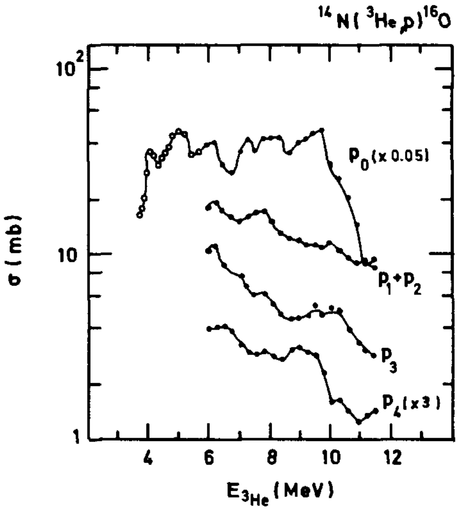
Reaction 15, Ref. H9



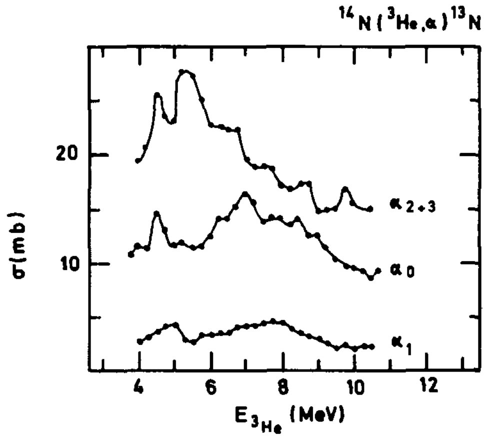
Reaction 15, Ref. H10



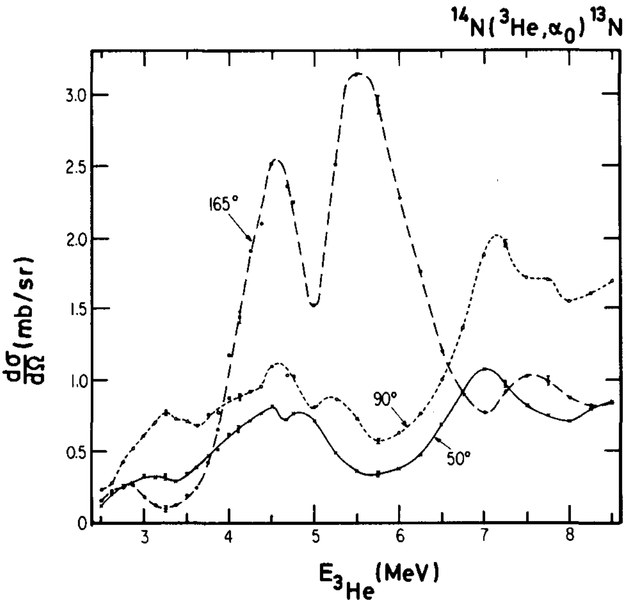
Reaction 15, Ref. H8



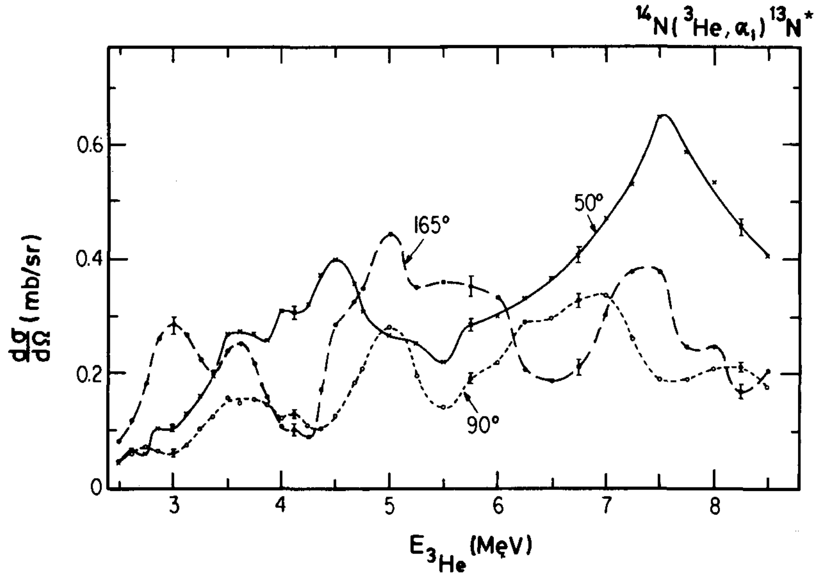
Reaction 16, Ref. H11



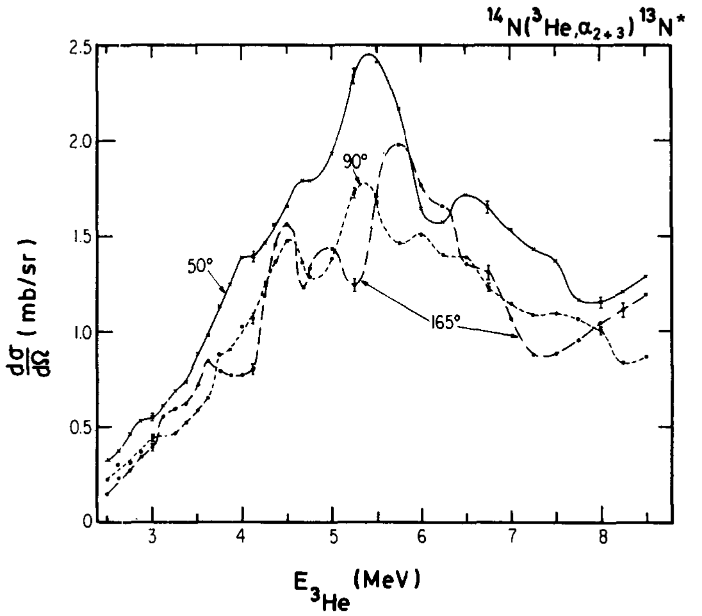
Reaction 17, Ref. H11



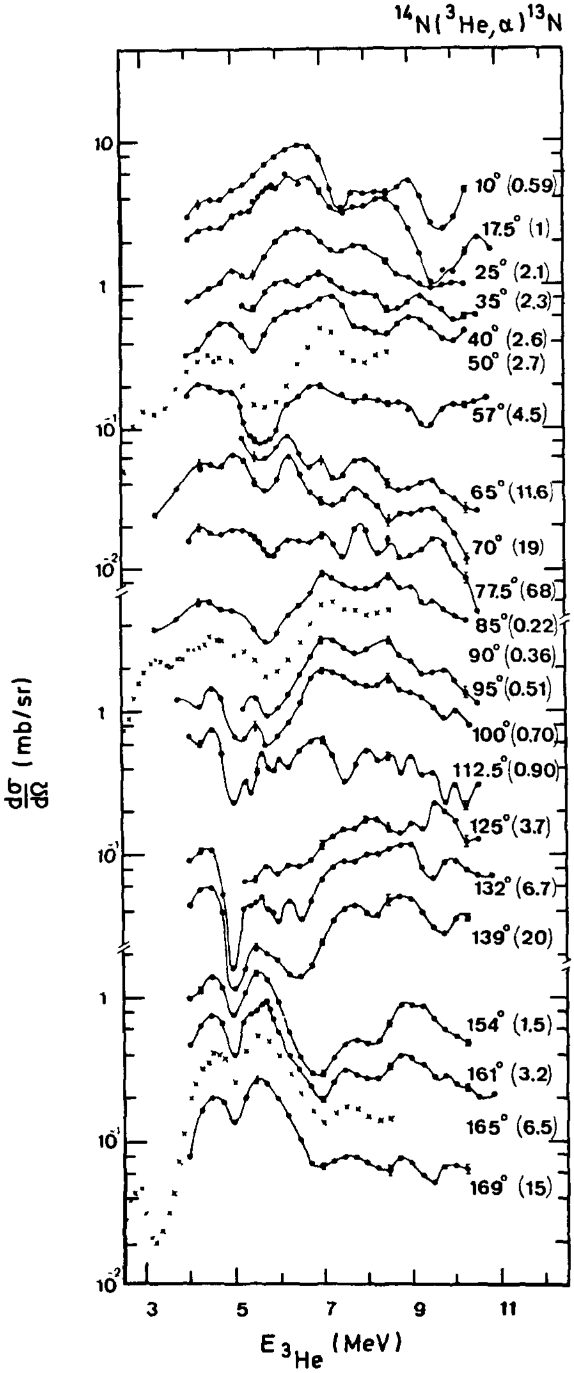
Reaction 17, Ref. H12



Reaction 17, Ref. H12

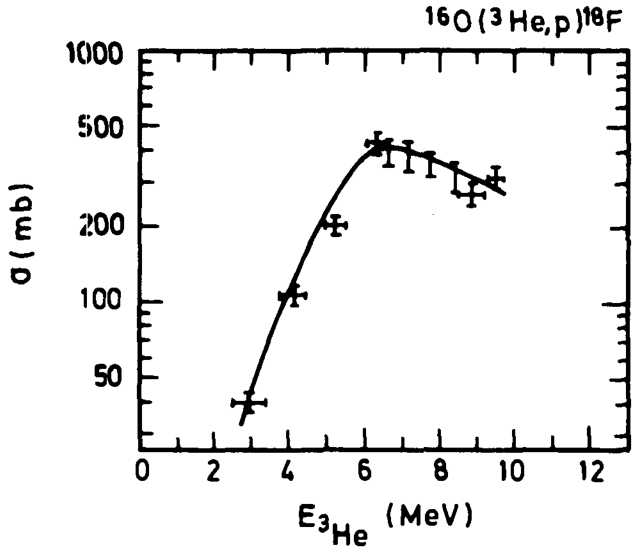


Reaction 17, Ref. H12

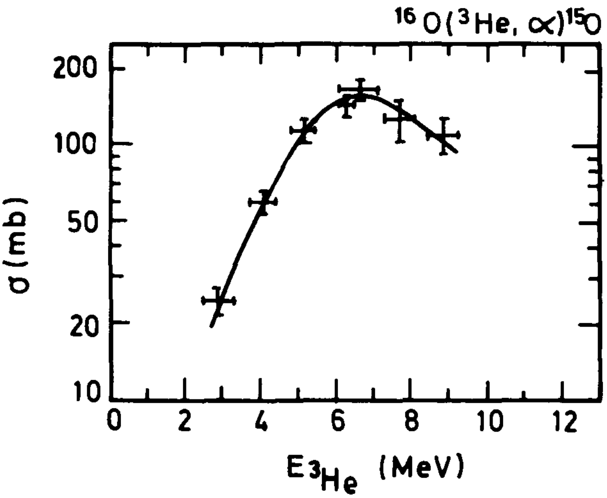


x Indicates data from: KNUDSON, YOUNG, Nucl. Phys. A 149 (1970) 323.
The plotted cross-section must be multiplied by the number in brackets to obtain the true cross-section.

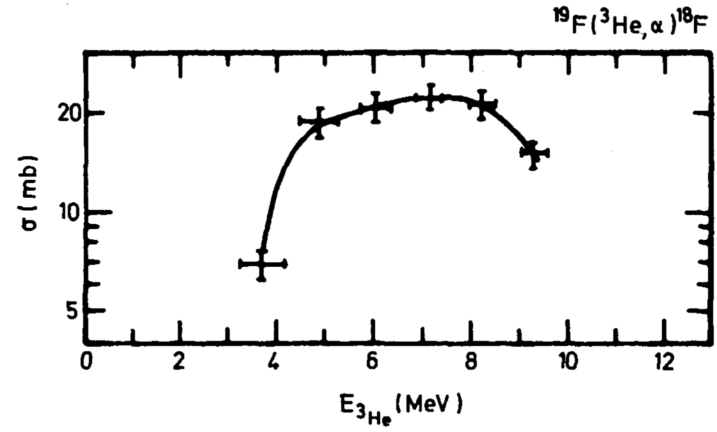
Reaction 17, Ref. H11



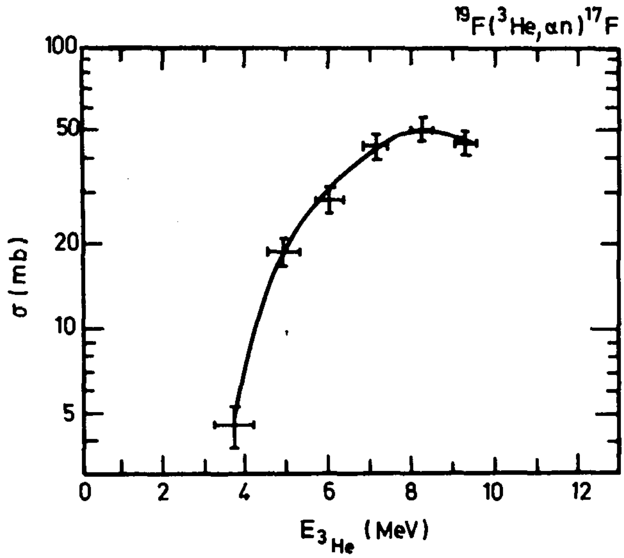
Reaction 18, Ref. H3



Reaction 19, Ref. H3



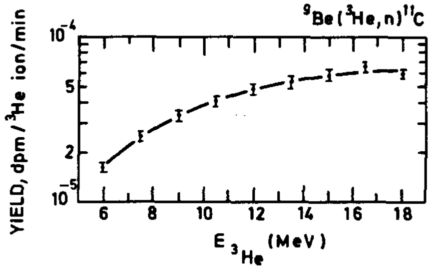
Reaction 20, Ref. H3



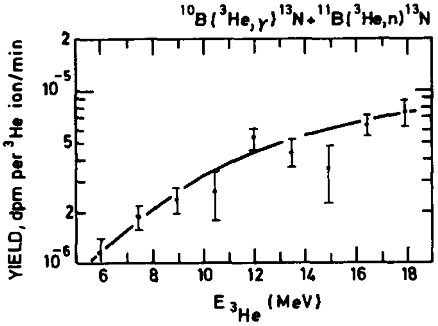
Reaction 21, Ref. H3

YIELD CURVES

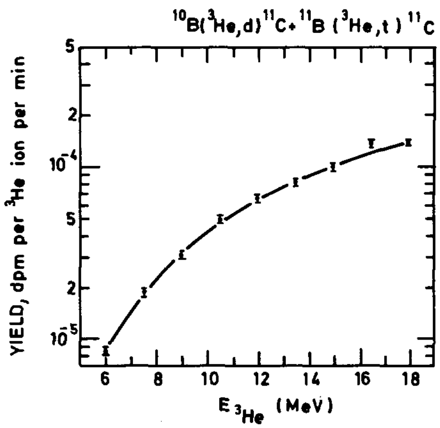
	Reaction	Energy range (MeV)	Page
1.	$^{9}Be(^{3}He, n)^{11}C$	6 - 18	432
2.	$^{10}B(^{3}He, \gamma)^{13}N + ^{11}B(^{3}He, n)^{13}N$	6 - 18	432
3.	$^{10}B(^{3}He, d)^{11}C + ^{11}B(^{3}He, t)^{11}C$	6 - 18	432
4.	$^{14}N(^{3}He, d)^{15}O$	6 - 18	433
5.	$^{14}N(^{3}He, \alpha)^{13}N$	6 - 18	433
6.	$^{23}Na(^{3}He, 2p)^{24}Na$	9 - 18	433
7.	$^{9}Be(^{3}He, n)^{11}C$	0 - 18	434
	$^{10}B(^{3}He, d)^{11}C + ^{11}B(^{3}He, t)^{11}C$	0 - 18	
	$^{12}C(^{3}He, \alpha)^{11}C$	0 - 18	
	$^{11}B(^{3}He, n)^{13}N$	0 - 18	
	$^{12}C(^{3}He, d)^{13}N$	0 - 18	
	$^{14}N(^{3}He, \alpha)^{13}N$	0 - 18	
	$^{12}C(^{3}He, n)^{14}O$	0 - 18	
8.	$^{14}N(^{3}He, d)^{15}O$	0 - 18	435
	$^{16}O(^{3}He, \alpha)^{15}O$	0 - 18	
	$^{19}F(^{3}He, \alpha n)^{17}F$	0 - 18	
	$^{16}O(^{3}He, p)^{18}F$	0 - 18	
	$^{19}F(^{3}He, \alpha)^{18}F$	0 - 18	



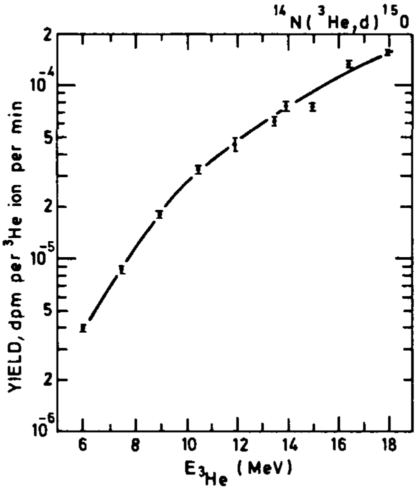
Reaction 1, Ref. Y1



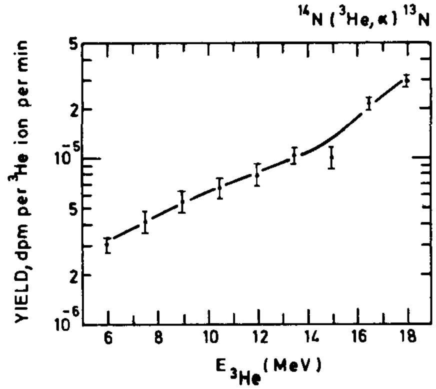
Reaction 2, Ref. Y1



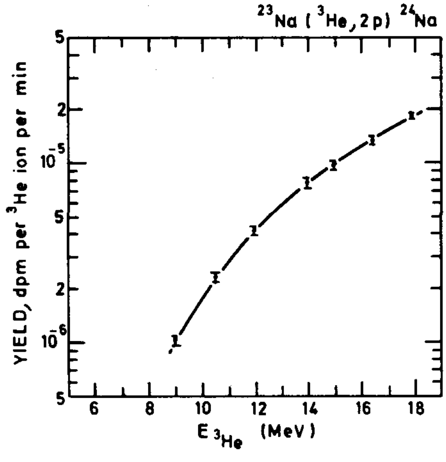
Reaction 3, Ref. Y1



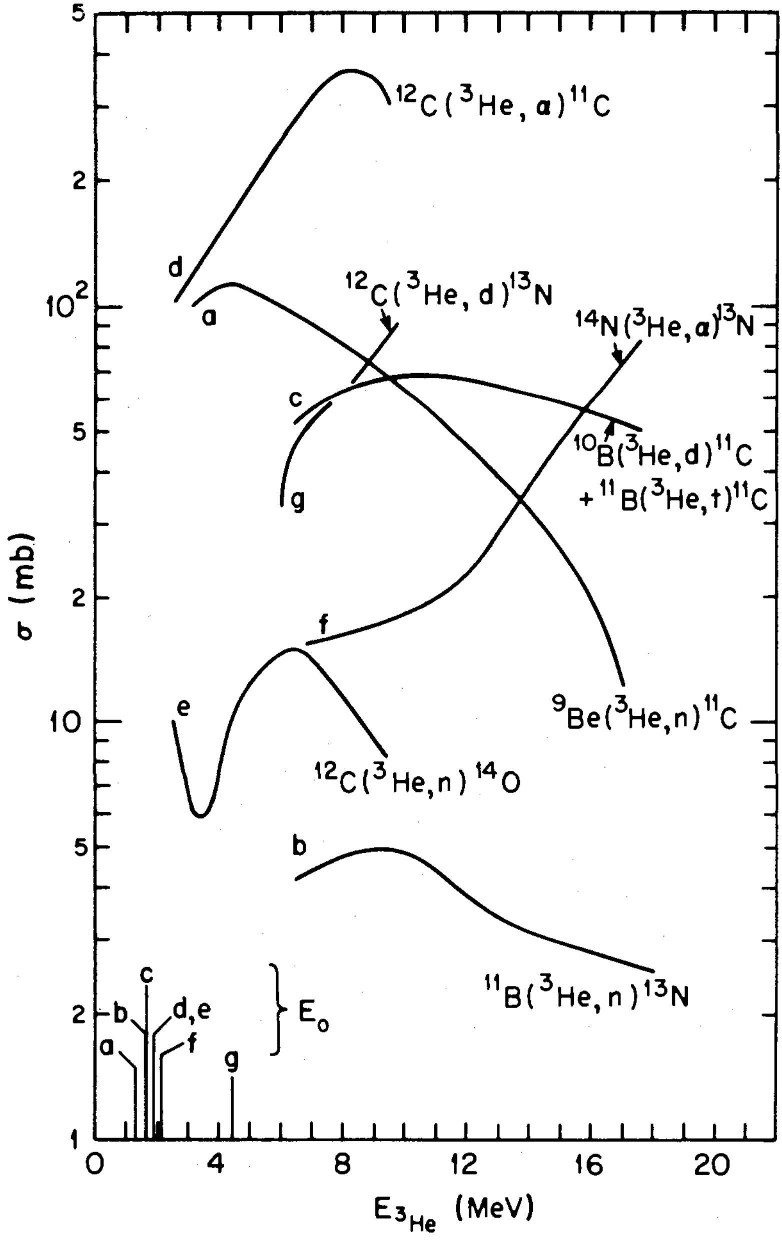
Reaction 4, Ref. Y1



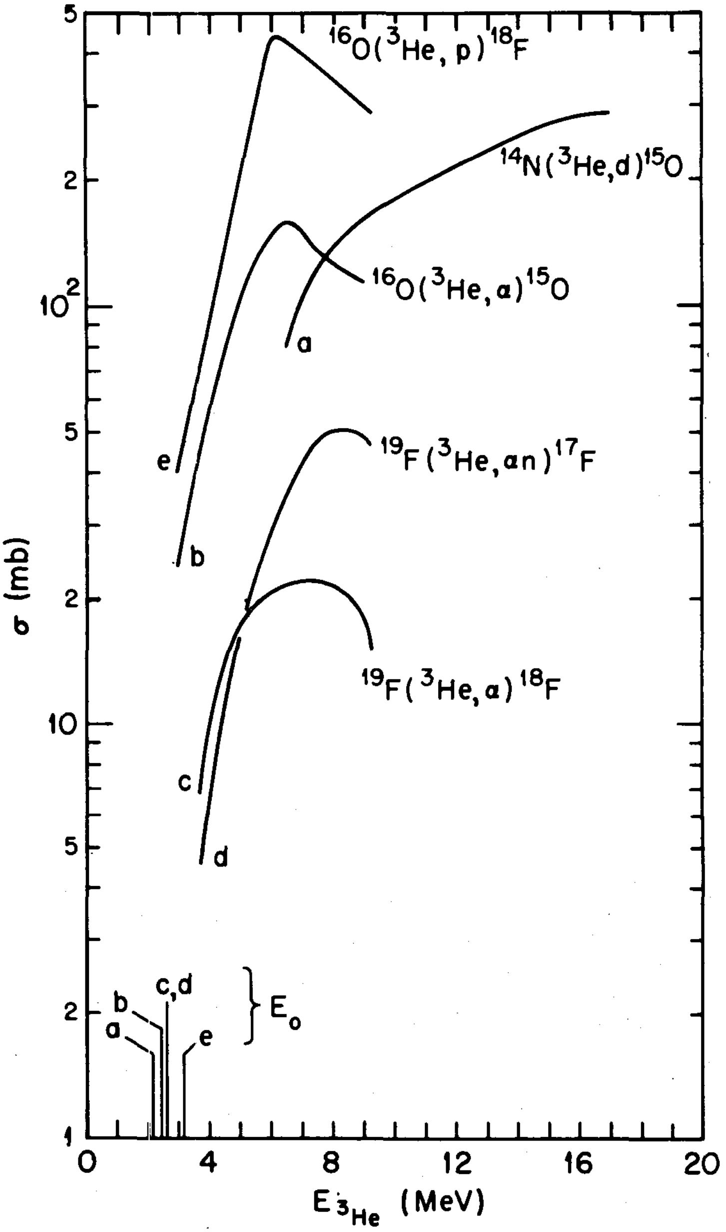
Reaction 5, Ref. Y1



Reaction 6, Ref. Y1



Reactions 7, Ref. Y2



Reactions 8, Ref. Y2

REFERENCES TO GRAPHS

Proton

P1 BORCHERS, R.R., POPPE, C.H., Phys. Rev. 129 (1963) 2679.
P2 SWEENY, W.E., MARION, J.B., Phys. Rev. 182 (1969) 1007.
P3 VAUGHN, F.J., et al., Phys. Rev. 2 (1970) 1657.
P4 BLIEDEN, H.R., TEMMER, G.M., WARSH, K.L., Nucl. Phys. 49 (1963) 209.
P5 GOOSMAN, D.R., ADELBERGER, E.G., SNOVER, K.A., Phys. Rev. 1 (1970) 123.
P6 KUAN, H.M., et al., Nucl. Phys. A151 (1970) 129.
P7 ALLAS, R.G., et al., Nucl. Phys. 58 (1964) 122.
P8 JARMIE, N., SEAGRAVE, J.D., Rep. LA-2014 (1957).
P9 WONG, C., et al., Phys. Rev. 123 (1961) 598.
P10 DAGLEY, P., HAEBERLI, W., SALADIN, J.X., Nucl. Phys. 24 (1961) 353.
P11 BERGDOLT, G., GUILLAUME, G., J. Phys. 30 (1969) 145.
P12 WARSH, K.L., TEMMER, G.M., BLIEDEN, H.R., Phys. Rev. 131 (1963) 1690.
P13 WILLARD, H.B., et al., Phys. Rev. 85 (1952) 849.
P14 CHAO, C.Y., et al., Phys. Rev. 79 (1950) 108.

Deuteron

D1 BATTLESON, K., McDANIELS, D.K., Phys. Rev. 4 (1971) 1601.
D2 DIN, G.U., NAGARAJAN, M.A., POLLARD, R., Nucl. Phys. A93 (1967) 190.
D3 BRILL, O.D., SUMIN, L.V., At. Ehnerg. 7 (1959) 377.
D4 CORDS, H., DIN, G.U., ROBSON, B.A., Nucl. Phys. A127 (1969) 95.
D5 DAVIS, J.R., DIN, G.U., Nucl. Phys. A179 (1972) 101.
D6 JASZCZAK, R.J., MACKLIN, R.L., GIBBONS, J.H., Phys. Rev. 181 (1969) 1428.
D7 PORTO, V.G., et al., Nucl. Phys. A136 (1969) 385.
D8 RETZ-SCHMIDT, T., WEIL, J.L., Phys. Rev. 119 (1960) 1079.
D9 BAHNSEN, R.M., WYLIE, W.R., LEFEVRE, H.W., Phys. Rev. 2 (1970) 859.
D10 THORNTON, S.T., et al., Phys. Rev. 3 (1971) 1065.
D11 JOBST, J., MESSELT, S., RICHARDS, H.T., Phys. Rev. 178 (1969) 1663.
D12 COMSAN, M.N.H., Atomkernenergie 18 (1971) 317.

Alpha

A1 BLIEDEN, H.R., TEMMER, G.M., WARSH, K.L., Nucl. Phys. 49 (1963) 209.
A2 VAN DER ZWAN, L., GEIGER, K.W., Nucl. Phys. A180 (1972) 615.
A3 OBST, A.W., GRANDY, T.B., WEIL, J.L., Phys. Rev. C 5 (1972) 738.
A4 DAVIDS, C.N., Nucl. Phys. A110 (1968) 619.
A5 BRILL, O.D., SUMIN, L.V., At. Ehnerg. 7 (1959) 377.
A6 SEKHARAN, K.K., et al., Phys. Rev. 156 (1967) 1187.
A7 GRUHLE, W., SCHMIDT, W., BURGMER, W., Nucl. Phys. A186 (1972) 257.

Helium

H1 KLOPCIC, J.T., DARDEN, S.E., Phys. Rev. C 3 (1971) 2171.
H2 ORIHARA, H., et al., Nucl. Phys. A139 (1969) 226.
H3 HAHN, R.L., RICCI, E., Phys. Rev. 146 (1966) 650.
H4 BELL, R.A.I., et al., Rep. ANU-P/550 (1972).
H5 PETERSON, R.W., GLASS, N.W., Phys. Rev. 130 (1963) 292.
H6 PATTERSON, J.R., POATE, J.M., TITTERTON, E.W., Proc. Phys. Soc. 85 (1965) 1085.
H7 HAAS, F., et al., Phys. Rev. 188 (1969) 1625.
H8 SINGH, J., Nucl. Phys. A155 (1970) 443.
H9 CIRILOV, S.D., NEWTON, J.O., SCHAPIRA, J.P., Nucl. Phys. 77 (1966) 472.
H10 OSGOOD, D.R., PATTERSON, J.R., TITTERTON, E.W., Nucl. Phys. 60 (1964) 503.
H11 GUAZZONI, P., MICHELETTI, S., PIGNANELLI, M., Phys. Rev. C 4 (1971) 1086.
H12 KNUDSON, A.R., YOUNG, R.C., Nucl. Phys. A149 (1970) 323.

Yield curves

Y1 HAHN, R.L., RICCI, E., Nucl. Phys. A101 (1967) 353.
Y2 RICCI, E., HAHN, R.L., Anal. Chem. 40 (1968) 54.

APPENDIX 1

EXCITATION FUNCTIONS OF CHARGED-PARTICLE-INDUCED REACTIONS AT HIGHER ENERGIES*

Systematics

Table A1-I. Characteristic data for the excitation functions.

Figure A1-1. Positions of the maxima for the excitation functions dependent on the atomic number Z of the target nucleus.

Figure A1-2. Full width at half maximum for the excitation functions dependent on the atomic number Z of the target nucleus.

Figure A1-3. Heights of maxima for the excitation functions dependent on the atomic number Z of the target nucleus.

Figure A1-4. Characteristic data of the excitation functions dependent on the atomic number Z of the target nucleus.

Figures A1-5 to A1-12. Estimated and experimental excitation functions.

Figure A1-13. Yield from irradiation of thick targets.

* From: LANGE, J., MÜNZEL, H., Estimation of Unknown Excitation Functions for (α,xn)-, (α,pxn)-, (d,xn)-, (d,pxn)-, and (p,xn)-Reactions, Rep. KFK-767 (1968), with kind permission from the authors.

TABLE A1-I. CHARACTERISTIC DATA FOR THE EXCITATION FUNCTIONS

No.[a]	Target nucleus	Reaction Q-value (MeV)	Position of maximum[b] (MeV)	Height of maximum (mb)
(α, n)				
1	21 Sc-45	-2.2	12.7	630
2a	25 Mn-55	-3.5	8.7	680
2b	25 Mn-55	-3.5	10.9	520
3	26 Fe-54	-5.8	10.5	190
4	27 Co-59	-5.1	-	-
5	28 Ni-60	-7.9	11.1	550
6	Ni-62	-6.5	9.7	950
7	29 Cu-63	-7.5	8.9	700
8a	Cu-65	-5.8	-	-
8b	Cu-65	-5.8	11.8	820
9a	30 Zn-64	-9.2	10.9	770
9b	30 Zn-64	-9.2	10.2	320
10	Zn-68	-5.7	-	-
11	37 Rb-85	-3.5	12.0	250
12	Rb-87	-3.8	10.0	240
13a	41 Nb-93	-7.0	9.4	470
13b	41 Nb-93	-7.0	-	-
14	42 Mo-92	-8.4	11.6	370
15	Mo-100	-4.6	9.6	760
16a	47 Ag-107	-7.6	9.2	420
16b	47 Ag-107	-7.6	10.8	340
17	Ag-109	-6.4	10.0	360
18	48 Cd-106	-10.1	10.9	670

[a] The numbers refer to the numbered excitation function curves in Figs A1-5 to A1-12.

[b] With respect to the energy scale E + Q.

TABLE A1-I (cont.)

No.	Target nucleus	Reaction Q-value (MeV)	Position of maximum (MeV)	Height of maximum (mb)
(α, n)				
19	49 In-115	-7.2	12.1	300
20	50 Sn-112	-13.0	6.4	550
21	Sn-114	-11.1	7.0	290
22	Sn-124	-5.6	13.4	160
23a	56 Ba-138	-8.6	7.4	130
23b	56 Ba-138	-8.6	17.2	900
24a	57 La-139	-9.2	9.1	115
24b	57 La-139	-9.2	8.4	110
24c	57 La-139	-9.2	8.3	110
25a	67 Ho-165	-9.2	11.8	79
25b	67 Ho-165	-9.2	8.8	30
26	68 Er-164	-11.1	6.9	260
27	79 Au-197	-9.8	-	-
28	82 Pb-207	-12.1	10.3	110
29	Pb-208	-15.0	6.4	90
30	92 U-235	-10.9	-	-
31	94 Pu-238	-13.1	-	-
(α, 2n)				
1	21 Sc-45	-12.8	13.3	200
2a	25 Mn-55	-12.1	-	640
2b	25 Mn-55	-12.1	-	670
3	26 Fe-54	-16.0	16.3	10
4	27 Co-59	-14.0	14.4	390
5	28 Ni-60	-17.1	14.9	180
6	29 Cu-63	-16.6	14.4	260
7a	Cu-65	-14.1	13.4	650
7b	Cu-65	-14.1	-	1000
8	30 Zn-64	-19.0	13.5	86
9	32 Ge-70	-16.1	16.9	320
10	35 Br-79	-14.4	-	2300
11	37 Rb-85	-12.7	12.3	810
12	47 Ag-107	-15.6	11.4	1000

TABLE A1-I (cont.)

No.	Target nucleus	Reaction Q-value (MeV)	Position of maximum (MeV)	Height of maximum (mb)
(α, 2n)				
13	Ag-109	-14.3	10.2	1050
14	48 Cd-106	-19.2	12.3	430
15	52 Te-130	-11.8	13.7	66
16	67 Ho-165	-16.2	7.3	750
17	68 Er-164	-18.0	11.0	820
18a	79 Au-197	-16.4	12.6	640
18b	79 Au-197	-16.4	13.6	800
18c	79 Au-197	-16.4	12.4	650
19	82 Pb-206	-20.0	11.0	1050
20	Pb-208	-19.5	10.5	1000
21a	83 Bi-209	-20.3	9.9	900
21b	83 Bi-209	-20.3	10.5	910
22	92 U-233	-19.1	8.9	6.5
23	U-235	-17.9	8.3	16
24	93 Np-237	-18.3	9.7	16
25	94 Pu-238	-17.8	8.2	15.5
26	Pu-239	-18.2	10.8	13
27	Pu-242	-17.2	7.8	10.5
28	98 Cf-252	-18.2	10.4	9.5
(α, 3n)				
1	25 Mn-55	-23.5	-	-
2	26 Fe-56	-26.3	17.3	16
3	30 Zn-64	-31.5	-	-
4	37 Rb-85	-24.7	15.1	600
5	47 Ag-107	-26.1	13.1	550
6a	Ag-109	-24.1	11.9	1000
6b	Ag-109	-24.1	13.9	950
7	49 In-115	-24.4	-	-
8	50 Sn-124	-21.0	15.0	1400
9	57 La-139	-24.5	11.7	1400
10	67 Ho-165	-24.7	10.1	840
11	68 Er-164	-27.5	12.9	1180

TABLE A1-I (cont.)

No.	Target nucleus	Reaction Q-value (MeV)	Position of maximum (MeV)	Height of maximum (mb)
(α, 3n)				
12a	79 Au-197	-25.4	13.6	1100
12b	79 Au-197	-25.4	12.8	1400
13	82 Pb-206	-28.5	-	-
14	Pb-207	-26.8	12 8	1400
15	83 Bi-209	-28.0	-	-
16	83 Bi-209	-28.0	11.5	1200
17	92 U-233	-25.3	9.1	1
18	U-235	-23.8	9.8	8
19	93 Np-237	-25.4	13.4	14
20	94 Pu-239	-23.8	13.2	4.5
21	98 Cf-252	-25.0	12.4	3.3
(α, p)				
1	26 Fe-54	-1.8	16.2	600
2	28 Ni-58	-3.1	-	-
3	30 Zn-64	-4.0	15.0	520
4	42 Mo-92	-5.6	14.4	185
5	48 Cd-106	-5.6	17.3	245
6	50 Sn-124	-6.4	23.0	18
(α, pn)				
1a	26 Fe-54	-13.2	14.8	750
1b	26 Fe-54	-13.2	14.6	470
2a	Fe-56	-13.7	13.7	840
2b	Fe-56	-13.7	14.7	790
2c	Fe-56	-13.7	16.3	630
3	28 Ni-60	-14.6	16.4	890
4	Ni-62	-14.3	17.2	495
5	29 Cu-63	-12.6	17.4	870
6a	30 Zn-64	-16.0	-	-
6b	30 Zn-64	-16.0	16.6	790
7	Zn-66	-15.5	-	-
8	Zn-70	-13.9	17.1	88
9	32 Ge-70	-15.3	15.7	575

TABLE A1-I (cont.)

No.	Target nucleus	Reaction Q-value (MeV)	Position of maximum (MeV)	Height of maximum (mb)
(α, pn)				
10	47 Ag-107	-13.6	17.4	91
11	48 Cd-106	-16.7	18.6	225
12	50 Sn-124	-14.8	24.2	46
13	57 La-139	-15.6	-	-
14	94 Pu-238	-18.3	20.7	15
(d, n)				
1	22 Ti-47	4.6	12.4	200
2	24 Cr-50	2.9	8.3	265
3	26 Fe-54	2.8	10.5	155
4	30 Zn-66	3.1	11.4	450
5	32 Ge-70	2.4	10.4	270
6a	40 Zr-94	4.6	13.8	120
6b	40 Zr-94	4.6	12.3	130
7a	Zr-96	5.2	12.7	85
7b	Zr-96	5.2	13.0	85
8	42 Mo-92	1.9	10.9	190
9	52 Te-130	5.2	16.2	75
10a	58 Ce-142	3.5	-	-
10b	58 Ce-142	3.5	15.9	60
11a	83 Bi-209	2.8	20.8	34
11b	83 Bi-209	2.8	-	32
12	92 U-235	2.6	22.2	10
13	94 Pu-239	2.2	24.2	14
(d, 2n)				
1	22 Ti-47	-5.9	9.5	400
2	Ti-48	-7.0	10.0	38
3a	24 Cr-52	-7.7	-	-
3b	24 Cr-52	-7.7	14.3	200
4	26 Fe-56	-7.6	10.0	310
5	29 Cu-63	-6.4	-	-
6a	Cu-65	-4.4	11.3	920
6b	Cu-65	-4.4	9.6	820
7a	30 Zn-66	-8.2	-	-

TABLE A1-I (cont.)

No.	Target nucleus	Reaction Q-value (MeV)	Position of maximum (MeV)	Height of maximum (mb)
(d, 2n)				
7b	30 Zn-66	-8.2	-	-
8	Zn-68	-5.9	-	-
9	32 Ge-70	-9.2	-	-
10	34 Se-82	-3.1	-	-
11a	40 Zr-96	-2.8	-	-
11b	40 Zr-96	-2.8	8.2	1050
12	52 Te-126	-5.2	7.3	750
13	Te-128	-4.3	9.0	800
14a	Te-130	-3.4	8.8	700
14b	Te-130	-3.4	8.5	750
15	53 J-127	-3.7	10.9	700
16	55 Cs-133	-3.5	10.3	600
17a	58 Ce-142	-3.8	-	-
17b	58 Ce-142	-3.8	7.8	750
18	73 Ta-181	-3.2	8.4	660
19	74 W-184	-4.7	-	-
20	W-186	-3.6	9.2	380
21	79 Au-197	-3.8	10.8	600
22	83 Bi-209	-4.9	9.9	540
23	92 U-234	-4.8	9.2	32
24a	U-235	-3.1	8 6	19
24b	U-235	-3.1	10.8	25
25	U-236	-3.9	8.4	43
26a	U-238	-3.1	8.9	48
26b	U-238	-3.1	10.5	70
27	94 Pu-239	-3.8	10.6	28
(d, 3n)				
1	40 Zr-96	-10.0	-	-
2	53 J-127	-10.9	-	-
3	59 Pr-141	-12.7	12.9	1200
4a	83 Bi-209	-11.9	-	-
4b	83 Bi-209	-11.9	-	-
5	92 U-234	-10.9	7.9	19

TABLE A1-I (cont.)

No.	Target nucleus	Reaction Q-value (MeV)	Position of maximum (MeV)	Height of maximum (mb)
(d, 3n)				
6a	92 U-235	-10.1	10.1	26
6b	92 U-235	-10.1	8.9	24
7	U-236	-9.6	9.4	57
8	94 Pu-239	-10.9	-	-
(d, p)				
1	27 Co-59	5.3	13.1	300
2	29 Cu-63	5.7	14.7	275
3	30 Zn-68	4.3	12.5	450
4	32 Ge-70	5.2	13.4	450
5	33 As-75	5.1	13.6	250
6	35 Br-81	5.4	13.9	370
7	39 Y-89	4.6	13.6	205
8	40 Zr-94	4.2	13.4	280
9a	Zr-96	3.4	12.8	220
9b	Zr-96	3.4	12.6	300
10	45 Rh-103	4.8	14.5	200
11	46 Pd-110	3.5	12.8	285
12	48 Cd-114	3.9	13.3	265
13	52 Te-130	3.7	13.5	200
14	55 Cs-133	3.9	13.5	175
15a	58 Ce-142	2.9	-	-
15b	58 Ce-142	2.9	12.9	230
16	59 Pr-141	3.6	15.8	260
17	73 Ta-181	3.8	15.8	230
18	74 W-184	3.5	15.8	280
19	W-186	3.3	15.7	310
20	75 Re-187	3.0	17.0	210
21	78 Pt-196	3.1	-	-
22a	79 Au-197	4.3	18.8	280
22b	79 Au-197	4.3	19.3	160
23	82 Pb-208	1.7	15.1	205
24	83 Bi-209	2.4	15.4	115
25	Bi-209	2.4	15.6	110
26	92 U-238	2.6	18.6	220

TABLE A1-I (cont.)

No.	Target nucleus	Reaction Q-value (MeV)	Position of maximum (MeV)	Height of maximum (mb)
(p, n)				
1	22 Ti-47	-3.7	6.5	300
2	Ti-48	-4.8	7.2	510
3a	23 V-51	-1.5	-	-
3b	23 V-51	-1.5	11.5	700
4a	24 Cr-52	-5.5	7.1	600
4b	24 Cr-52	-5.5	-	-
5	25 Mn-55	-1.0	-	-
6	26 Fe-56	-5.4	6.6	450
7	Fe-57	-1.6	7.4	400
8	27 Co-59	-1.9	8.1	500
9	28 Ni-61	-3.0	6.6	700
10	Ni-62	-4.7	-	-
11	Ni-64	-2.5	7.9	850
12	29 Cu-63	-4.2	8.2	500
13	Cu-65	-2.1	-	-
14	31 Ga-69	-2.2	-	-
15	39 Y-89	-3.6	9.4	730
16	47 Ag-107	-2.2	-	-
17	Ag-109	-1.0	8.2	360
18	48 Cd-110	-4.7	8.3	870
19a	Cd-111	-1.9	11.1	530
19b	Cd-111	-1.9	-	-
20	Cd-112	-3.4	-	-
21	Cd-114	-2.2	-	-
22	50 Sn-124	-1.4	-	-
23	57 La-139	-1.1	-	-
24	58 Ce-142	-1.6	7.4	120
25	59 Pr-141	-2.6	-	-
26a	73 Ta-181	-1.0	8.5	100
26b	73 Ta-181	-1.0	9.0	100
26c	73 Ta-181	-1.0	9.0	105
26d	73 Ta-181	-1.0	12	100
27	79 Au-197	-1.6	9.2	95

TABLE A1-I (cont.)

No.	Target nucleus	Reaction Q-value (MeV)	Position of maximum (MeV)	Height of maximum (mb)
(p, 2n)				
1	23 V-51	-10.8	4.2	240
2	27 Co-59	-10.9	-	-
3	28 Ni-62	-13.6	9.9	210
4	29 Cu-63	-13.3	11.7	180
5	31 Ga-69	-11.6	7.4	500
6	39 Y-89	-12.8	13.2	1300
7	41 Nb-93	-9.3	-	-
8	47 Ag-107	-10.1	-	-
9	48 Cd-110	-12.7	-	-
10	Cd-111	-11.7	-	-
11	Cd-112	-11.3	9.7	1050
12a	73 Ta-181	-7.9	-	-
12b	73 Ta-181	-7.9	6.8	900
13a	79 Au-197	-8.2	-	-
13b	79 Au-197	-8.2	-	-
14	82 Pb-206	-11.6	9.4	1050
(p, 3n)				
1	23 V-51	-23.7	16.3	100
2	27 Co-59	-23.1	17.9	11
3	29 Cu-65	-22.0	16.0	160
4	31 Ga-69	-23.8	13.2	65
5	Ga-71	-20.0	10.0	550
6	39 Y-89	-20.8	20.2	390
7	48 Cd-112	-21.1	9.9	780
8	73 Ta-181	-15.5	9.5	1200
9	82 Pb-206	-20.0	9.0	900
10	83 Bi-209	-18.0	12.0	850

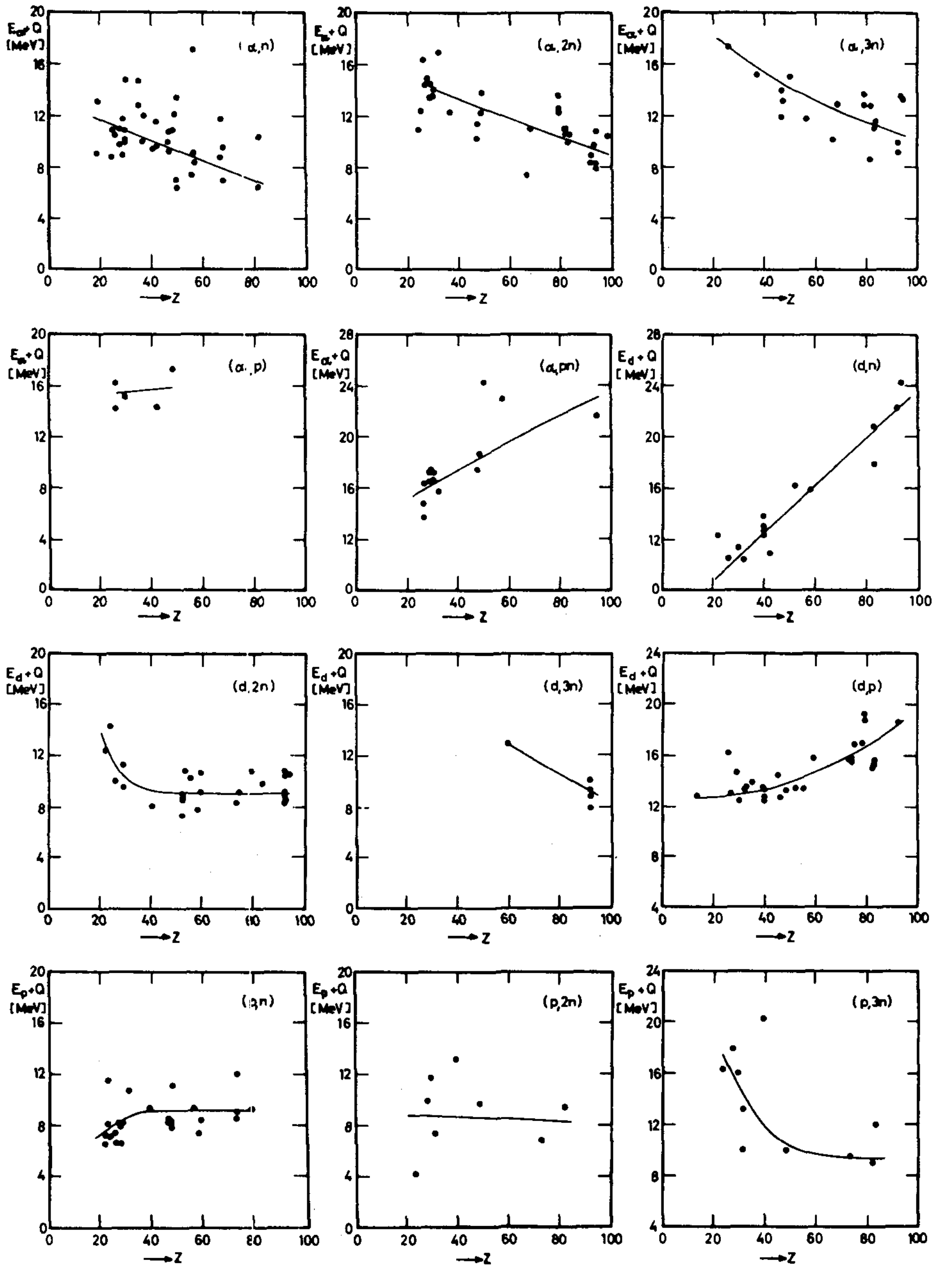


FIG. A1-1. Positions of the maxima for the excitation functions dependent on the atomic number Z of the target nucleus.

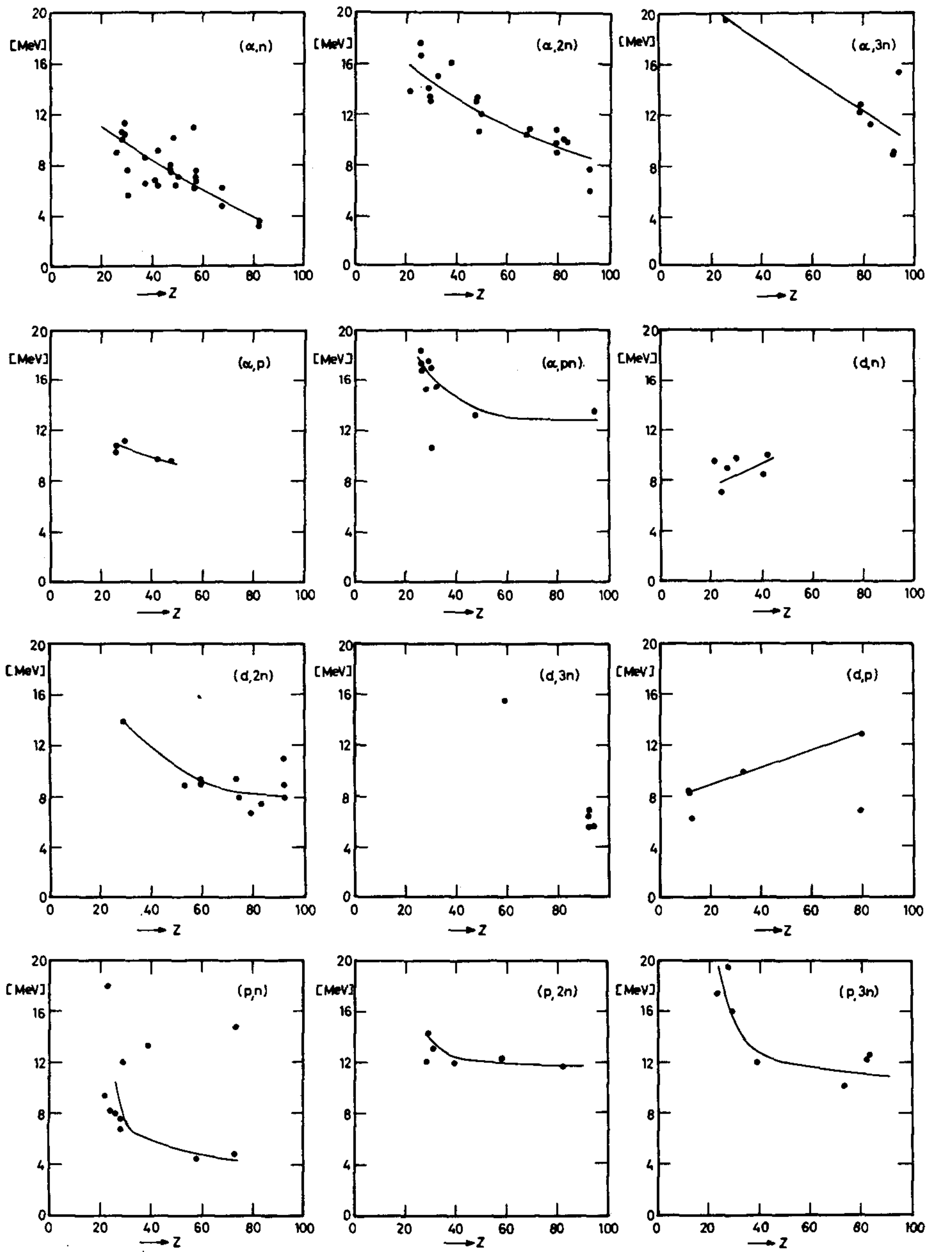


FIG. A1-2. Full width at half maximum for the excitation functions dependent on the atomic number Z of the target nucleus.

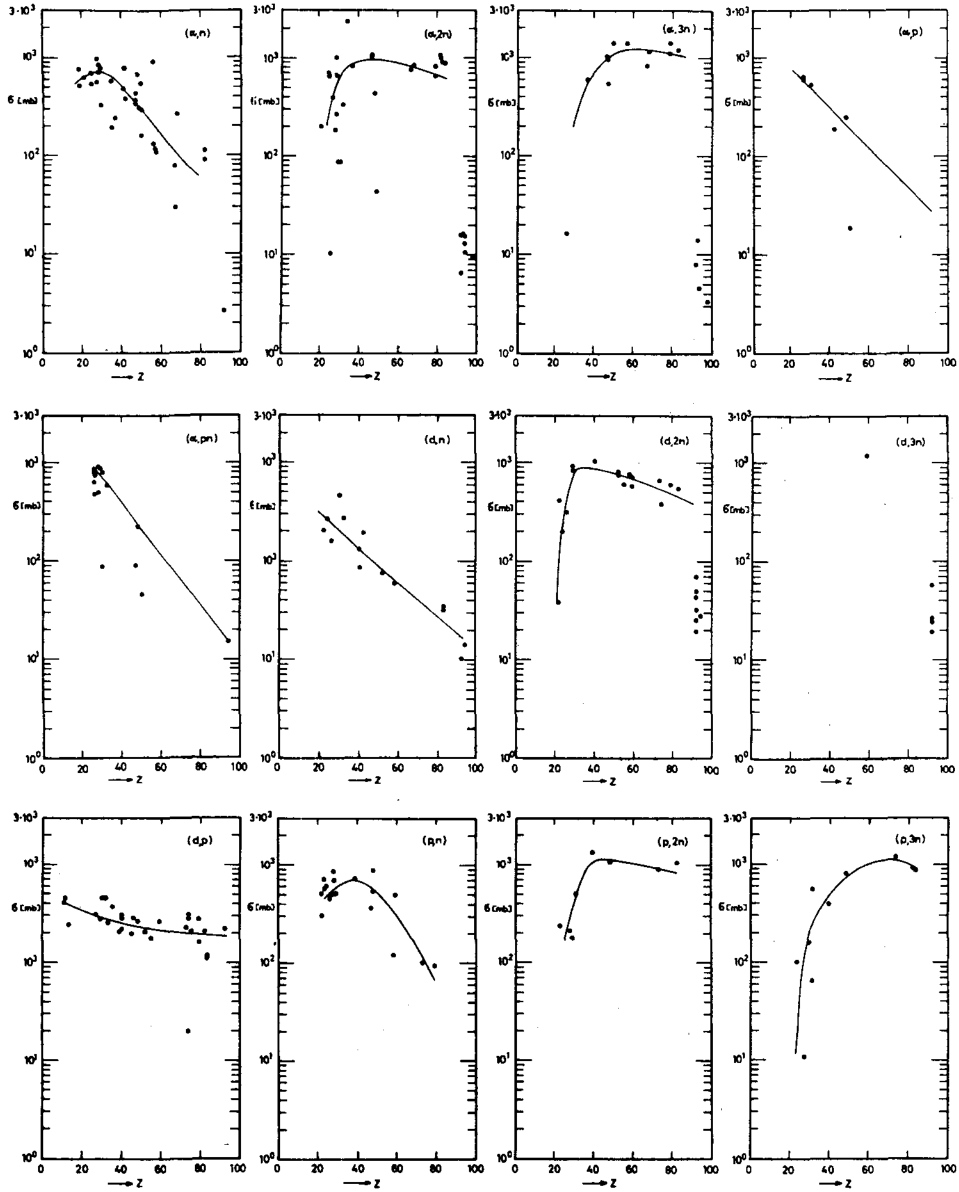


FIG. A1-3. Heights of maxima for the excitation functions dependent on the atomic number Z of the target nucleus.

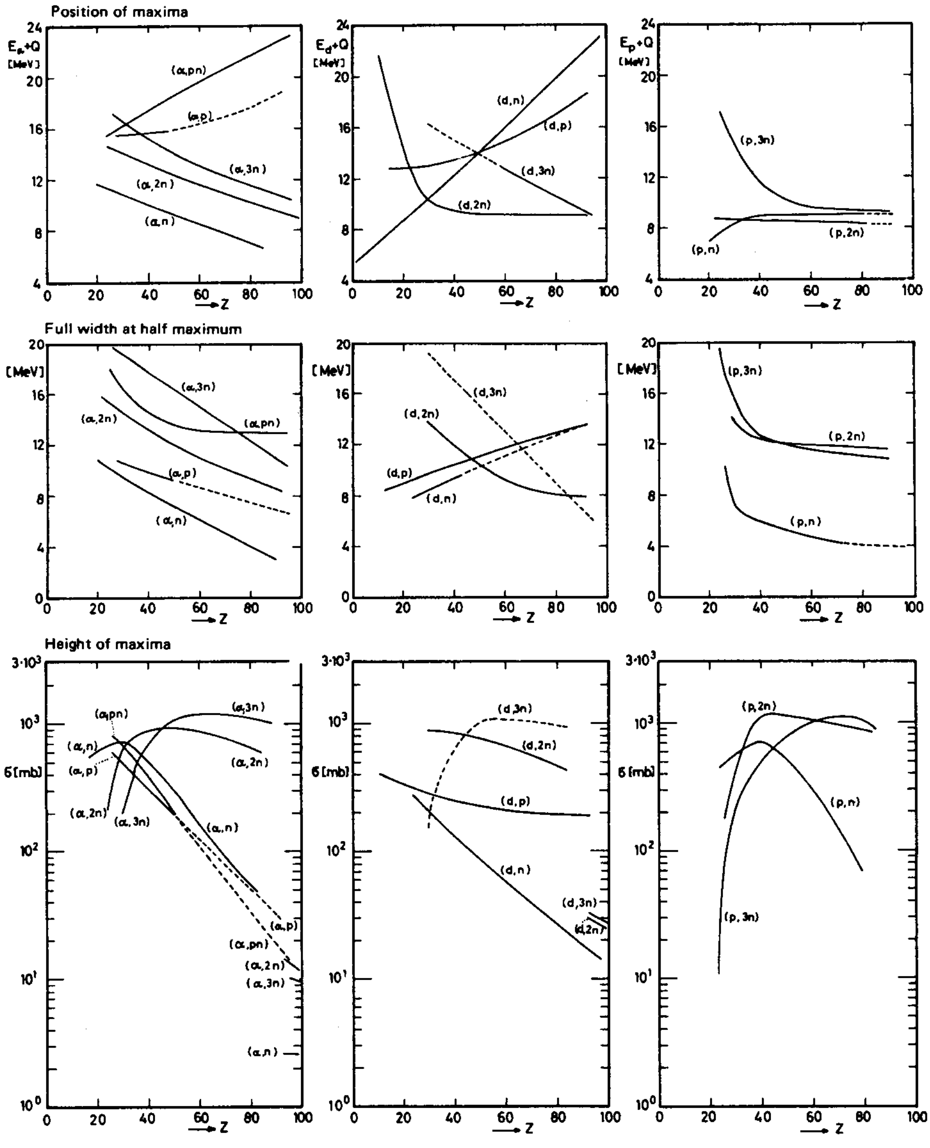


FIG. A1-4. Characteristic data of the excitation functions dependent on the atomic number Z of the target nucleus.
——— structure corresponding to Figs. A1-1 to A1-3;
----- structure estimated.

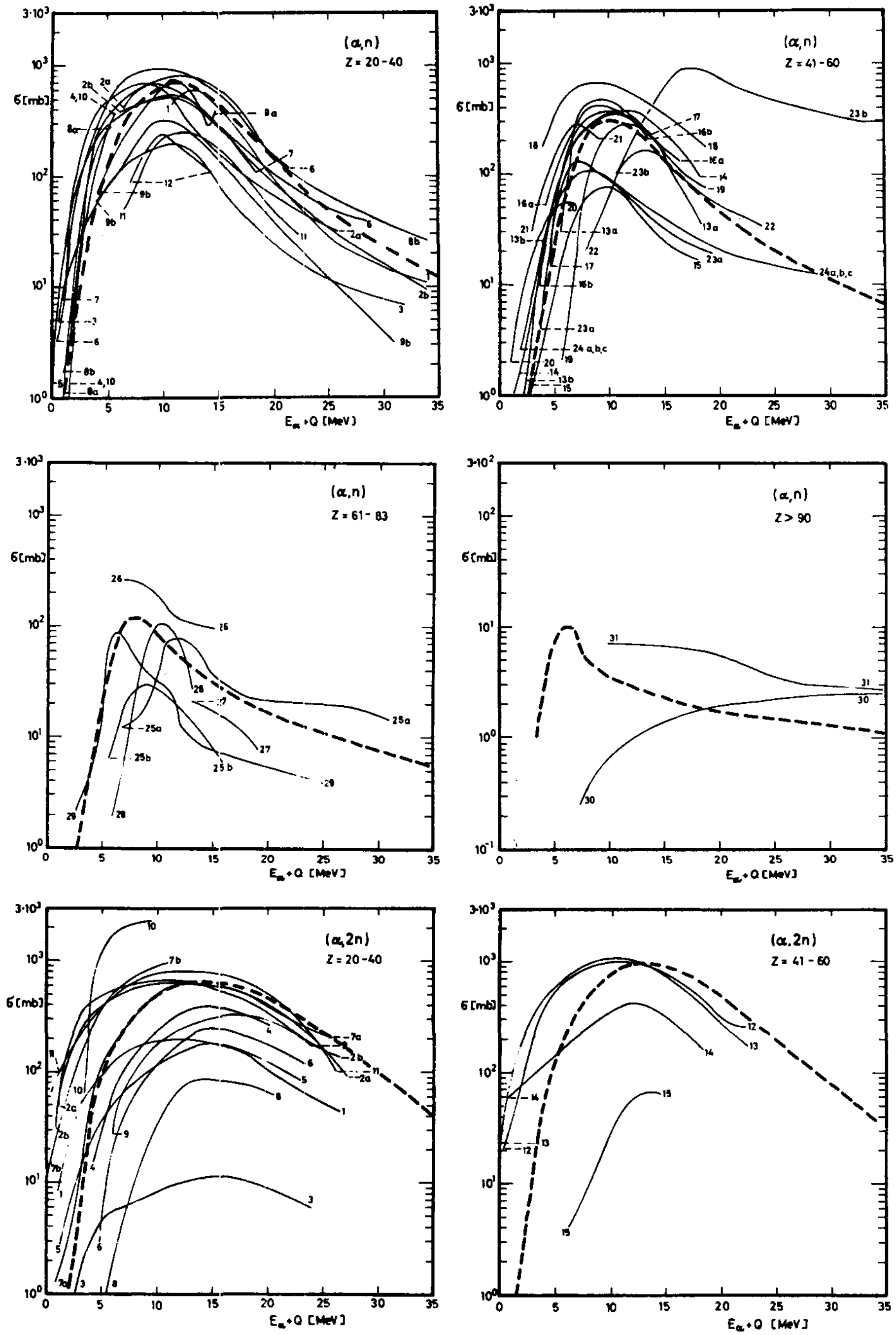


FIG. A1-5. Estimated and experimental excitation functions.
——— experimental excitation functions;
----- excitation functions estimated for the middle of the Z-region given in the figures.

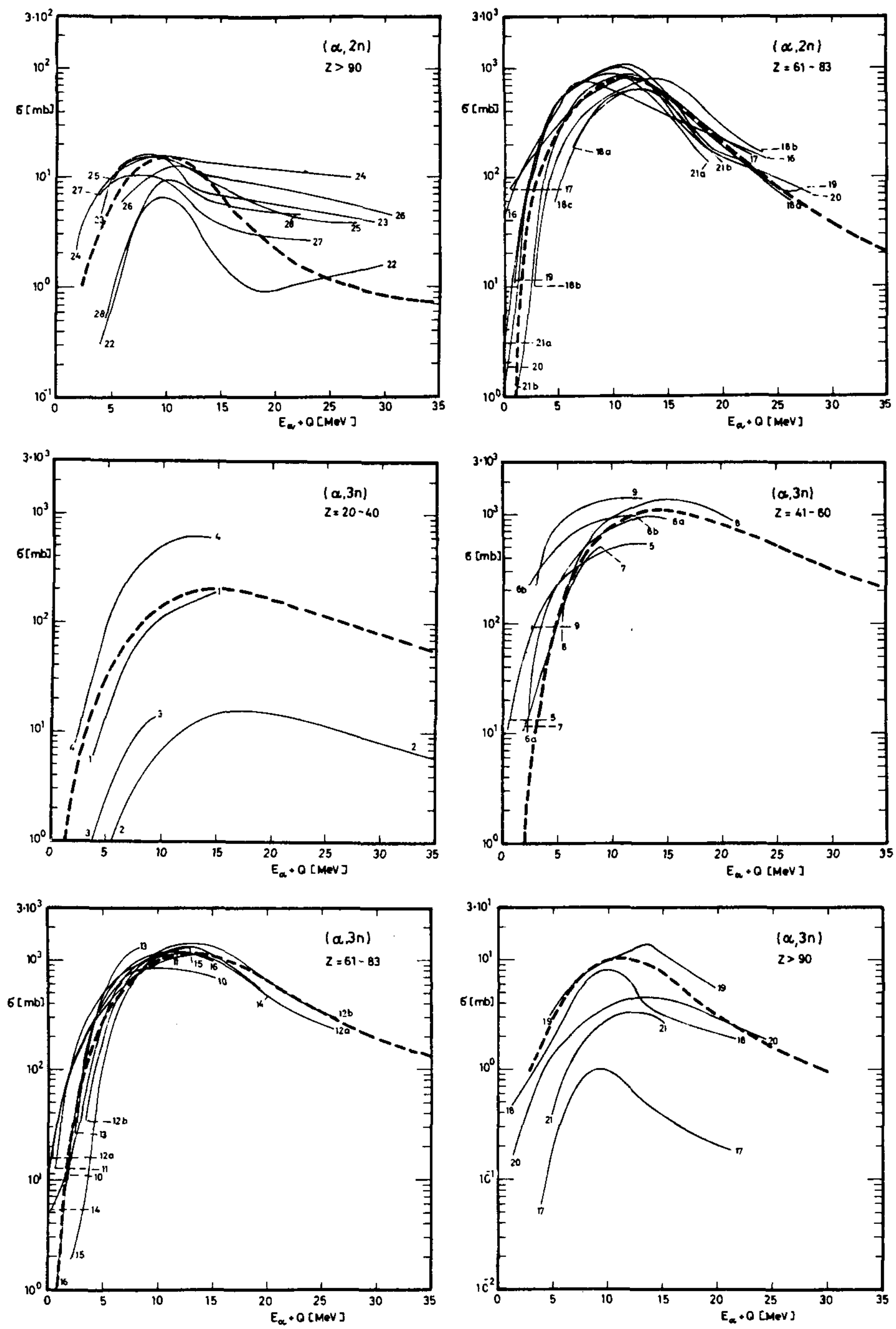


FIG. A1-6. Estimated and experimental excitation functions.
——— experimental excitation functions;
- - - - excitation functions estimated for the middle of the Z-region given in the figures.

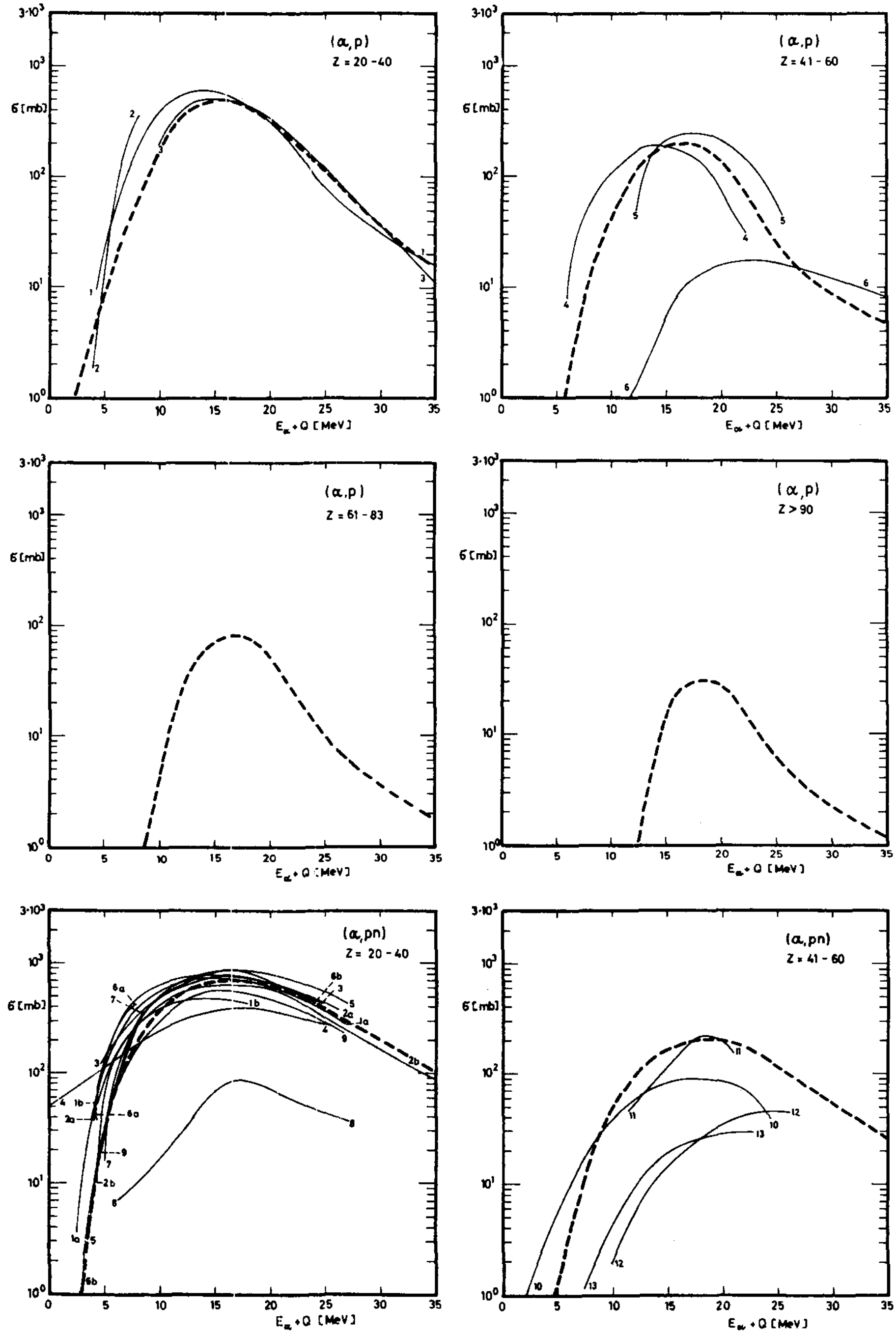


FIG. A1-7. Estimated and experimental excitation functions.
——— experimental excitation functions;
- - - - excitation functions estimated for the middle of the Z-region given in the figures.

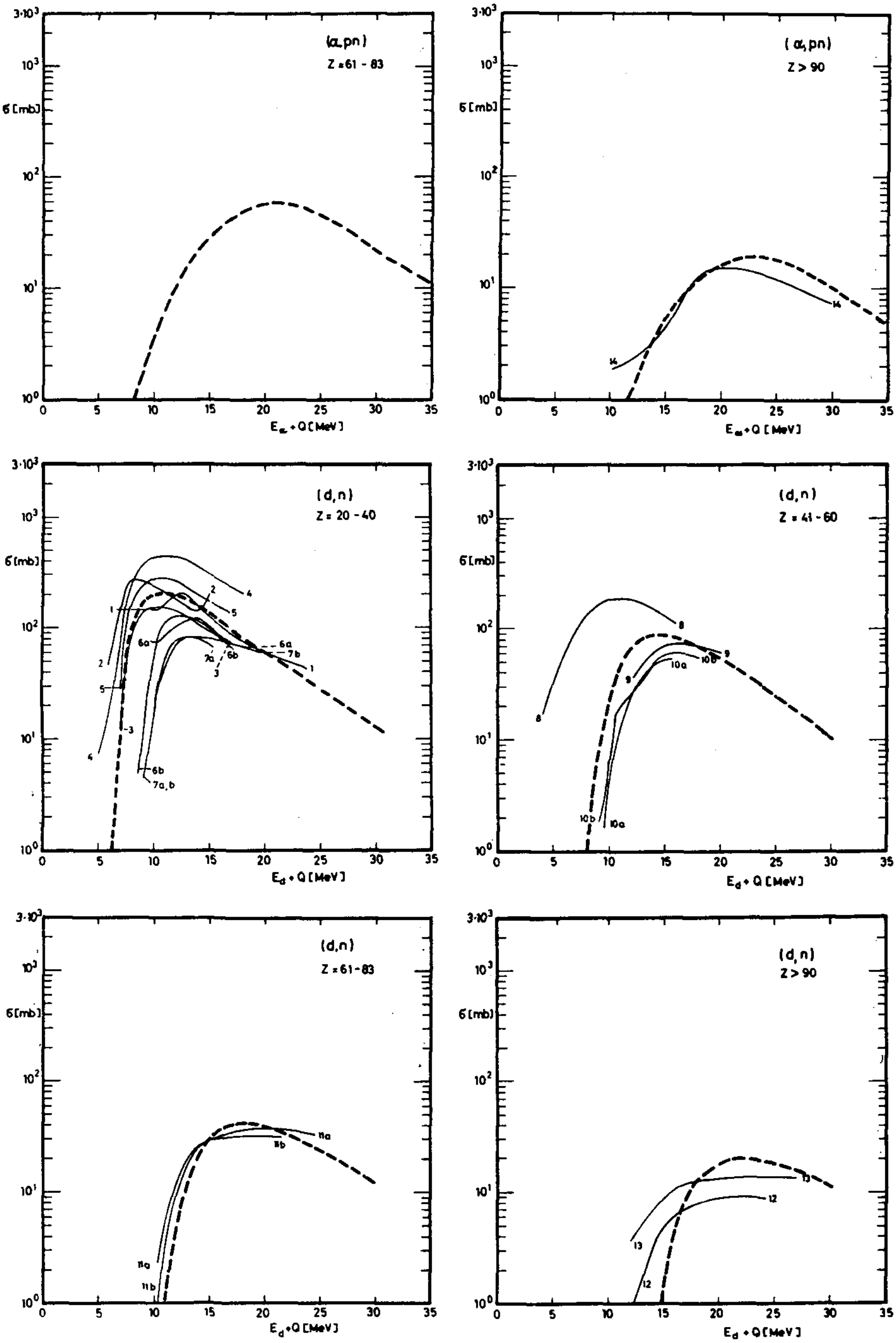


FIG. A1-8. Estimated and experimental excitation functions.
——— experimental excitation functions;
- - - - excitation functions estimated for the middle of the Z-region given in the figures.

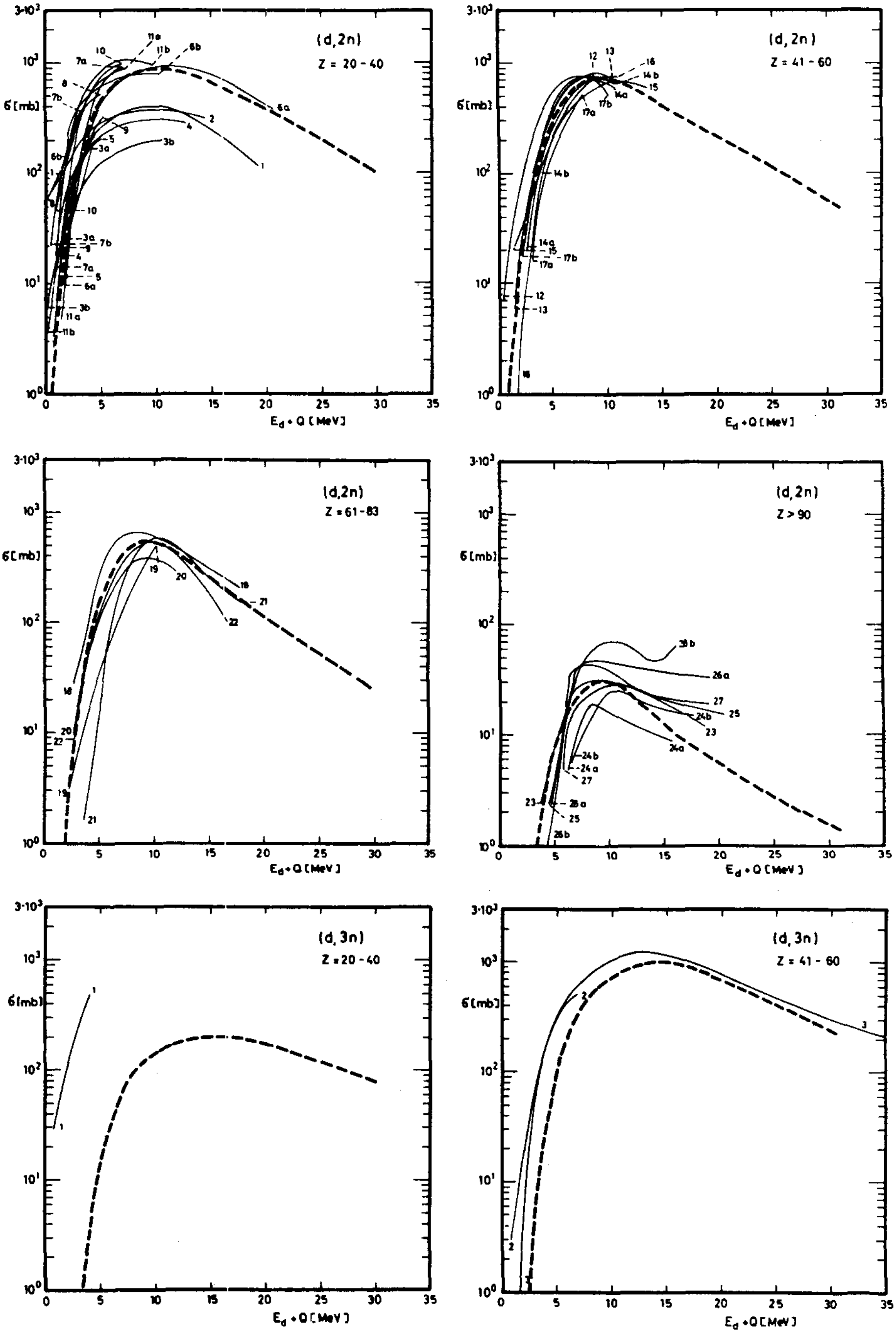


FIG. A1-9. Estimated and experimental excitation functions.
——— experimental excitation functions;
- - - - excitation functions estimated for the middle of the Z-region given in the figures.

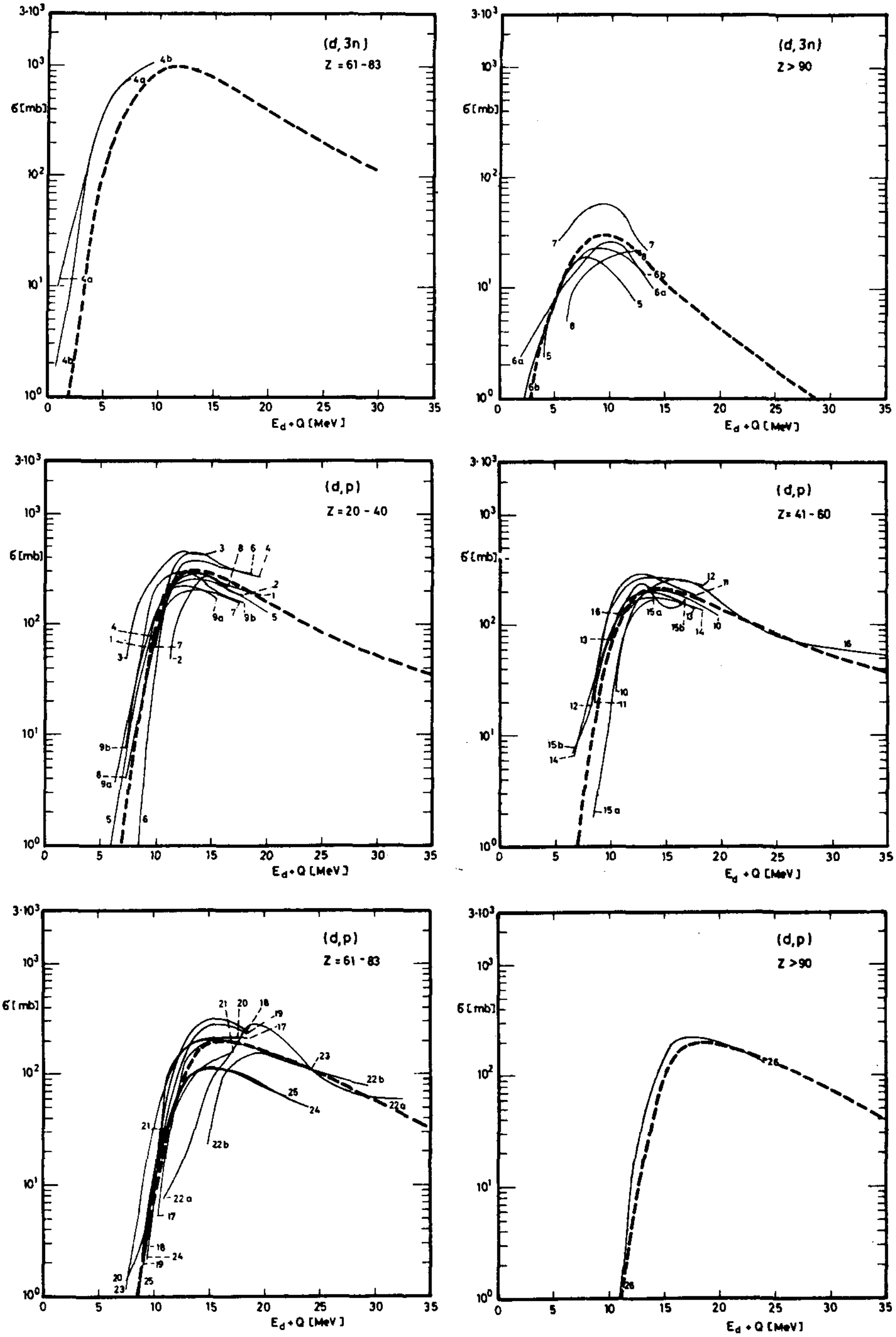


FIG. A1-10. Estimated and experimental excitation functions.
——— experimental excitation functions;
- - - - - excitation functions estimated for the middle of the Z-region given in the figures.

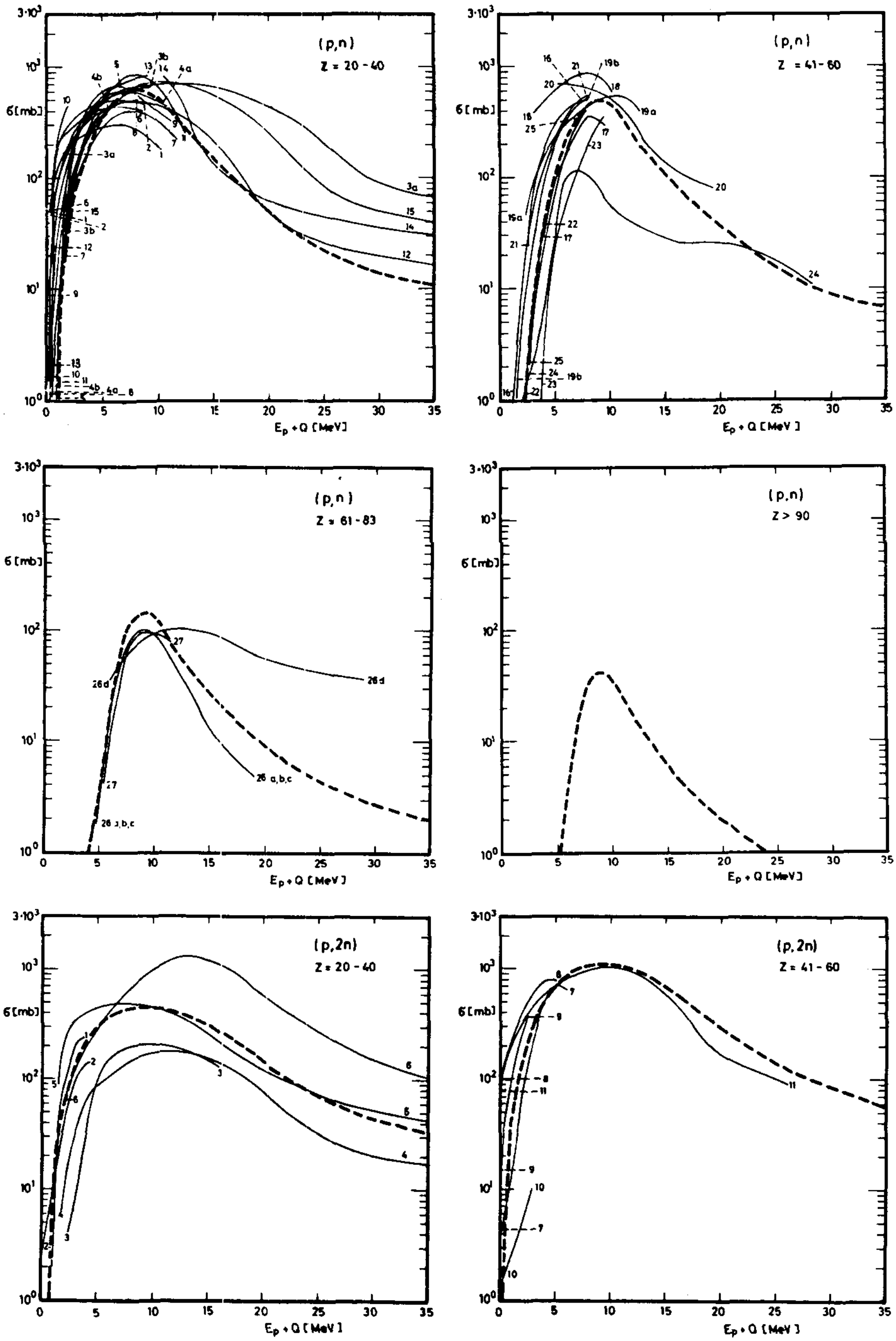


FIG. A1-11. Estimated and experimental excitation functions.
——— experimental excitation functions;
- - - - - excitation functions estimated for the middle of the Z-region given in the figures.

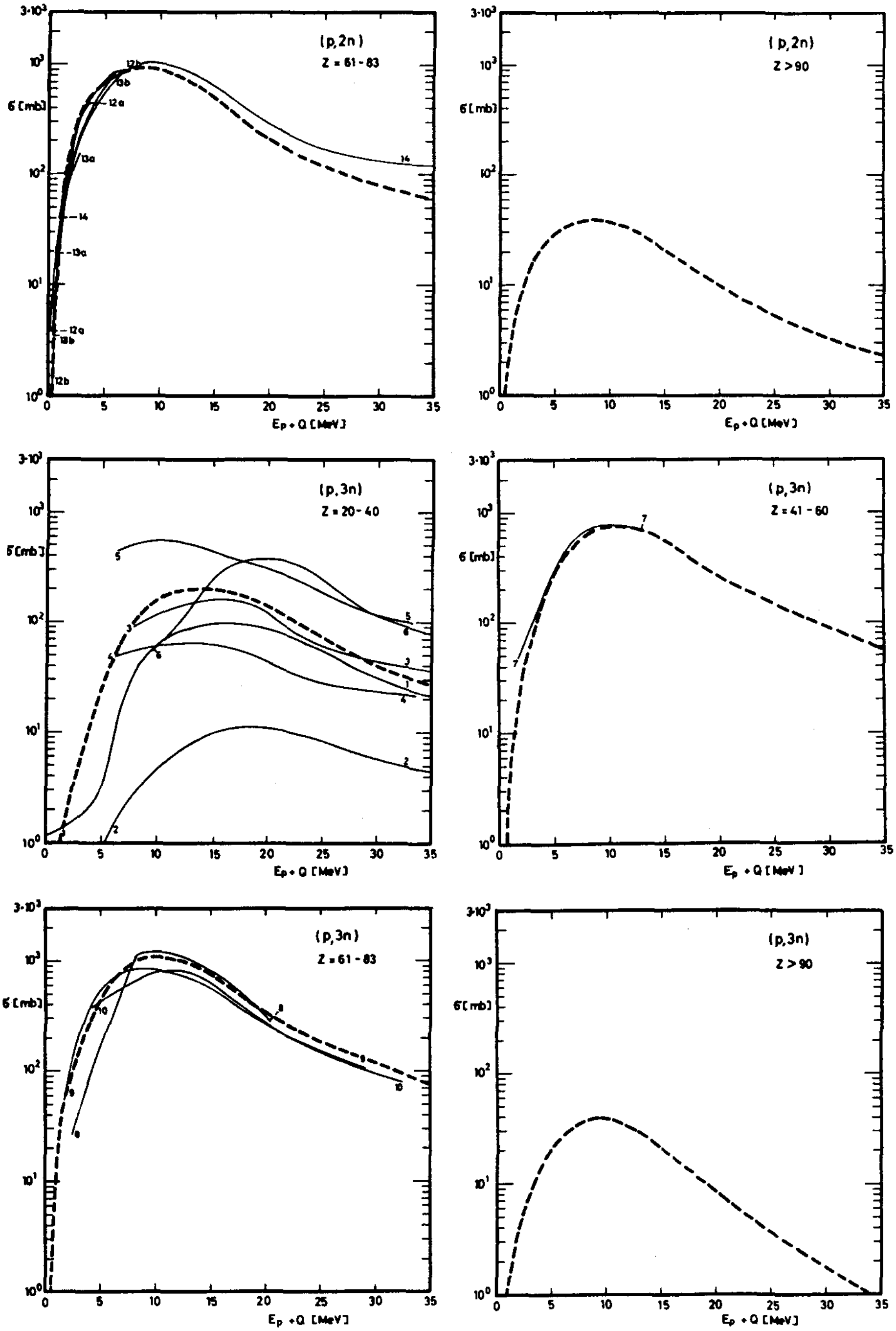


FIG. A1-12. Estimated and experimental excitation functions.
——— experimental excitation functions;
- - - - excitation functions estimated for the middle of the Z-region given in the figures.

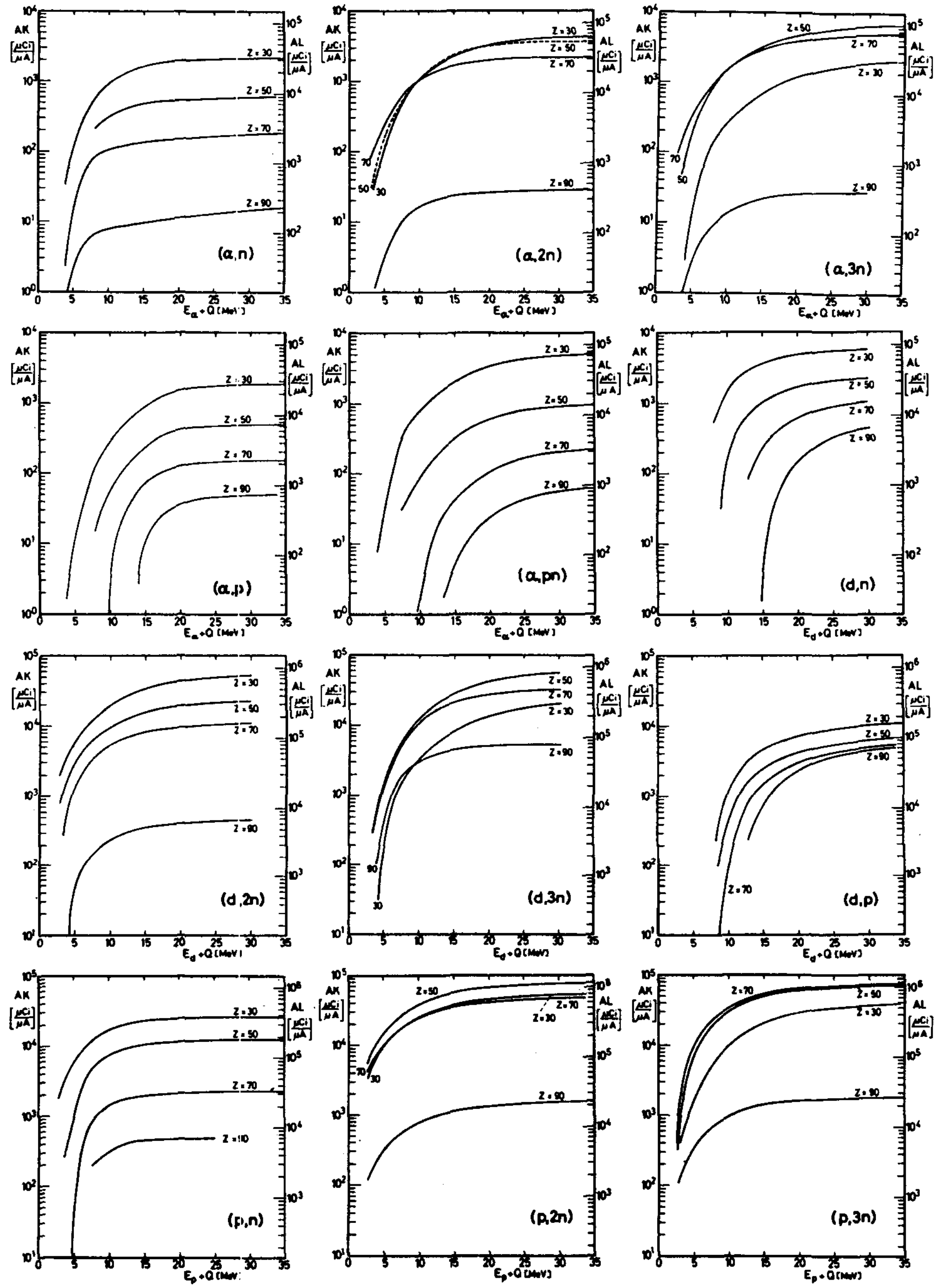


FIG. A1-13. Yield from irradiation of thick targets. AK = yield after short irradiation times (t = 0.1 T); AL = yield after long irradiation times (t >> T).

APPENDIX 2

TABLE A2-I. (p, γ) RESONANCES AS A FUNCTION OF PROTON ENERGIES RANGING FROM 163 keV TO 3.0 MeV*

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy[a] (MeV)
163	$B^{11}(p,\gamma)C^{12}$	16.11, 11.68, 4.43	0.157	7	
224	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	>0.2	1	
226	$Mg^{24}(p,\gamma)Al^{25}$	2.06, 1.56, 0.95		1?	7.2 s; 3.3
226	$Al^{27}(p,\gamma)Si^{28}$				
251	$Na^{23}(p,\gamma)Mg^{24}$			0.3	
261	$C^{14}(p,\gamma)N^{15}$				
278	$N^{14}(p,\gamma)O^{15}$	6.82, 6.14, 1.47		1.6	2.03 min; 1.7
294	$Al^{27}(p,\gamma)Si^{28}$			<1	
295	$Mg^{26}(p,\gamma)Al^{27}$				
308	$Na^{23}(p,\gamma)Mg^{24}$	10.6, 7.8, 6.7		0.8	
317	$Mg^{25}(p,\gamma)Al^{26}$	6.19, 4.86, 0.82		12	6.4 s; 3.2
326	$Al^{27}(p,\gamma)Si^{28}$	7.6, 7.2, 6.2		<1	
326	$Si^{29}(p,\gamma)P^{30}$	5.88, 5.17			2.50 min; 3.2
330	$Be^{9}(p,\gamma)B^{10}$	6.9, 6.2, 5.2		160	
339	$Mg^{26}(p,\gamma)Al^{27}$	7.74, 5.85, 5.61			
340	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	160	3	
355	$P^{31}(p,\gamma)S^{32}$				
356	$C^{14}(p,\gamma)N^{15}$	10.5, 7.1, 5.4			
360	$N^{15}(p,\gamma)O^{16}$	12.43, 6.37	0.007	94	
360	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	0.03	94	
374	$Na^{23}(p,\gamma)Mg^{24}$	6.26	2		
392	$Mg^{25}(p,\gamma)Al^{26}$	6.26, 4.6?, 3.5?	4	8	6.4 s; 3.2
405	$Al^{27}(p,\gamma)Si^{28}$	7.3, 5.1, 2.8			
414	$Si^{29}(p,\gamma)P^{30}$	5.25, 0.70			2.5 min; 3.2
418	$Mg^{24}(p,\gamma)Al^{25}$	2.70, 2.25, 0.89		1	7.2 s; 3.3
429	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	300	0.9	
429	$N^{15}(p,\gamma)O^{16}$	6.46	0.001	0.9	
437	$Mg^{25}(p,\gamma)Al^{26}$	6.72, 6.30, 4.66?			6.4 s; 3.2
439	$Al^{27}(p,\gamma)Si^{28}$				
440	$P^{31}(p,\gamma)S^{32}$			34	
441	$Li^{7}(p,\gamma)Be^{8}$	17.64, 14.74, 12.24	6	12	

* From: BUTLER, J.W., Table of (p, γ) Resonances, Rep. NRL-5282 (1959), with kind permission from the author.

a From: Chart of the Nuclides, 3rd Edn, Federal Ministry for Education and Science, Bonn (1968).

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
444	$Na^{23}(p,\gamma)Mg^{24}$			0.8	
448	$C^{13}(p,\gamma)N^{14}$				
454	$Mg^{26}(p,\gamma)Al^{27}$	7.85, 7.68, 5.71			
457	$C^{12}(p,\gamma)N^{13}$	2.36	0.127	39.5	9.96 min; 1.2
473	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
484	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	>32	0.9	
496	$Mg^{25}(p,\gamma)Al^{26}$	6.36, 4.24, 4.21?		5	6.4 s; 3.2
500	$Si^{30}(p,\gamma)P^{31}$	7.75, 6.48, 4.62			
504	$Al^{27}(p,\gamma)Si^{28}$	12.07		<0.20	
506	$Al^{27}(p,\gamma)Si^{28}$	10.29		<0.17	
511	$Na^{23}(p,\gamma)Mg^{24}$	10.8, 8.0, 6.9		0.8	
513	$Mg^{25}(p,\gamma)Al^{26}$			3	6.4 s; 3.2
530	$Mg^{25}(p,\gamma)Al^{26}$			3	6.4 s; 3.2
532	$C^{14}(p,\gamma)N^{15}$	10.7, 5.3			
540	$P^{31}(p,\gamma)S^{32}$				
550	$C^{13}(p,\gamma)N^{14}$	8.06, 4.11	1.44	32.5	
580	$Mg^{25}(p,\gamma)Al^{26}$	6.85?, 6.43, 4.28			6.4 s; 3.2
594	$Na^{23}(p,\gamma)Mg^{24}$	10.9, 8.0, 7.0		2	
594	$S^{32}(p,\gamma)Cl^{33}$	2.86, 2.05, 0.806			2.53 s; 4.5
597	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	7.1	30	
607	$Mg^{25}(p,\gamma)Al^{26}$	6.88?, 6.46, 4.34			6.4 s; 3.2
612	$Al^{27}(p,\gamma)Si^{28}$			<1	
625	$Si^{30}(p,\gamma)P^{31}$	7.87			
630	$O^{18}(p,\gamma)F^{19}$	8.5		2.6	
632	$Al^{27}(p,\gamma)Si^{28}$	10.41, 7.59, 1.77		<0.06	
636	$Ne^{22}(p,\gamma)Na^{23}$	9.40			
640	$C^{14}(p,\gamma)N^{15}$	10.8, 5.3			
648	$P^{31}(p,\gamma)S^{32}$			17	
650	$Ca^{40}(p,\gamma)Sc^{41}$				0.596 s; 5.6
654	$Al^{27}(p,\gamma)Si^{28}$	10.43, 7.61		<0.06	
660?	$Ne^{22}(p,\gamma)Na^{23}$				
661	$Mg^{26}(p,\gamma)Al^{27}$	7.88, 6.68, 5.9			
667	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
672	$F^{19}(p,\gamma)Ne^{20}$	11.88, 1.63	0.5	6.0	
672	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	57	6.0	
675	$B^{11}(p,\gamma)C^{12}$	12.15, 4.43	0.050	322	
675	$Na^{23}(p,\gamma)Mg^{24}$	11.0, 8.1, 7.1		≤1	
675	$Mg^{25}(p,\gamma)Al^{26}$	6.55, 5.21, 3.30			6.4 s; 3.2
675	$Si^{30}(p,\gamma)P^{31}$	7.92, 6.65, 1.27			
678	$Al^{27}(p,\gamma)Si^{28}$	10.45, 7 63		<1	
693	$Si^{29}(p,\gamma)P^{30}$	6.26, 4.29, 3.51			2.5 min; 3.2
700	$N^{14}(p,\gamma)O^{15}$	8.0		100	
703?	$Si(p,\gamma)P$				2.03 min; 1.7
710	$N^{15}(p,\gamma)O^{16}$	6.72		40	
717?	$Si(p,\gamma)P$				
720	$Mg^{25}(p,\gamma)Al^{26}$	6.59, 4.93, 2.46			6.4 s; 3.2
720	$Mg^{26}(p,\gamma)Al^{27}$	6.74, 5.96, 5.28			
725	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.52	0.01 evb	<1	3.3 h; 1.2
730	$Si^{29}(p,\gamma)P^{30}$	3.33			2.5 min; 3.2
731	$Al^{27}(p,\gamma)Si^{28}$			<0.16	
736	$Al^{27}(p,\gamma)Si^{28}$			<0.09	
740	$Na^{23}(p,\gamma)Mg^{24}$	11		<3	
741	$Al^{27}(p,\gamma)Si^{28}$			<1	
744	$Na^{23}(p,\gamma)Mg^{24}$	8		<3	
759	$Al^{27}(p,\gamma)Si^{28}$			<0.06	
760	$Si^{30}(p,\gamma)P^{31}$	6.71, 4.57, 1.27			
765	$Ne^{21}(p,\gamma)Na^{22}$				2.62 yr; 0.5, 1.8
766	$Al^{27}(p,\gamma)Si^{28}$			<0.08	
773	$Al^{27}(p,\gamma)Si^{28}$	12.33		0.009	
775	$Si^{30}(p,\gamma)P^{31}$	8.00, 6.73, 1.27			
777	$Mg^{25}(p,\gamma)Al^{26}$	6.65?, 4.99, 3.90			
780	$F^{19}(p,\alpha\gamma)O^{16}$			7.6	6.4 s; 3.2
800?	$Si(p,\gamma)P$				
813	$Mg^{26}(p,\gamma)Al^{27}$				
816	$P^{31}(p,\gamma)S^{32}$	7.39			
820	$Mg^{25}(p,\gamma)Al^{26}$	7.69, 5.04, 4.56			6.4 s; 3.2
825	$Mg^{24}(p,\gamma)Al^{25}$	3.09, 2.64, 2.14		1.5	
825	$P^{31}(p,\gamma)S^{32}$	9.64			7.2 s; 3.3
828	$Ne^{22}(p,\gamma)Na^{23}$				

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
835	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	19	6.5	
840	$Mg^{26}(p,\gamma)Al^{27}$				
840	$Si^{30}(p,\gamma)P^{31}$	6.82, 4.80, 1.27			
849	$O^{18}(p,\gamma)F^{19}$	8.8		40	
854	$Ne^{22}(p,\gamma)Na^{23}$	9.61, 9.17, 5.70			
855	$Cl^{35}(p,\gamma)A^{36}$	7.2, 5.1, 4.3		≤5	
855	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.26	0.007 evb	<1	81 s; 3.7
872	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	540	4.5	
877	$Na^{23}(p,\gamma)Mg^{24}$	11		8	
883?	$K^{39}(p,\gamma)Ca^{40}$	9?			
884	$Al^{27}(p,\gamma)Si^{28}$			<1	
888	$Cl^{35}(p,\gamma)A^{36}$				
890	$Mg^{25}(p,\gamma)Al^{26}$				
892	$P^{31}(p,\gamma)S^{32}$			9	
895?	Si(p,γ)P				
895	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.69	0.01 evb	<1	3.3 h; 1.2
898	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	800	2.2	
900	$A^{40}(p,\gamma)K^{41}$				
901	$Ne^{22}(p,\gamma)Na^{23}$	9.66?, 9.22?			
902	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	23	5.1	
916	$Si^{29}(p,\gamma)P^{30}$	5.74, 4.48			2.5 min; 3.2
922	$Al^{27}(p,\gamma)Si^{28}$			<0.19	
925?	$K^{39}(p,\gamma)Ca^{40}$	9?			
933	$Ne^{22}(p,\gamma)Na^{23}$	9.69?, 9.25?			
935	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	180	8.6	
936	$Al^{27}(p,\gamma)Si^{28}$			0.34	
940	$Mg^{25}(p,\gamma)Al^{26}$	6.99, 5.15			6.4 s; 3.2
943?	$Ne^{22}(p,\gamma)Na^{23}$				
944?	Si(p,γ)P				
947	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.35	0.14 evb	<1	81 s; 3.7
954	$Mg^{26}(p,\gamma)Al^{27}$				
955	$Si^{30}(p,\gamma)P^{31}$	8.19, 6.92, 1.27			
956	$Si^{29}(p,\gamma)P^{30}$	6.49, 5.04, 4.52			2.5 min; 3.2
960	$Mg^{25}(p,\gamma)Al^{26}$	5.17, 4.70, 3.57?			6.4 s; 3.2
980?	$F^{19}(p,\gamma)Ne^{20}$				

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
980	$Si^{30}(p,\gamma)P^{31}$	4.96, 4.84, 1.27			
980	$K^{39}(p,\gamma)Ca^{40}$	9?			
982	$Ne^{22}(p,\gamma)Na^{23}$				
989	$Na^{23}(p,\gamma)Mg^{24}$	9		<1	
990	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
991	$Be^{9}(p,\gamma)B^{10}$	7.5, 6.8, 5.8		89	
992	$Mg^{26}(p,\gamma)Al^{27}$				
992	$Al^{27}(p,\gamma)Si^{28}$	10.78, 7.93, 1.77		0.05	
995	$Si^{30}(p,\gamma)P^{31}$	6.98, 6.02, 1.27			
1000	$Si^{30}(p,\gamma)P^{31}$	8.25, 6.98, 5.12			
1001	$Al^{27}(p,\gamma)Si^{28}$			<1	
1002	$Ne^{22}(p,\gamma)Na^{23}$				
1006	$Ge^{74}(p,\gamma)As^{75}$			<2.5	
1010	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.41	0.007 evb	<1	81 s; 3.7
1011	$Na^{23}(p,\gamma)Mg^{24}$			≤0.5	
1015	$Mg^{26}(p,\gamma)Al^{27}$				
1022	$Na^{23}(p,\gamma)Mg^{24}$	9		6.6	
1024	$Al^{27}(p,\gamma)Si^{28}$			<0.24	
1029	$Ni^{60}(p,\gamma)Cu^{61}$	<5.82	0.02 evb	<1	3.3 h; 1.2
1030	$Li^{7}(p,\gamma)Be^{8}$	18.15, 15.25, 0.478		168	
1040	$N^{15}(p,\gamma)O^{16}$	13.09	1	130	
1040	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	15	130	
1046	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
1050	$P^{31}(p,\gamma)S^{32}$			<5	
1050	$A^{40}(p,\gamma)K^{41}$				
1056	$Mg^{26}(p,\gamma)Al^{27}$				
1059	$N^{14}(p,\gamma)O^{15}$	8.34, 5.27, 3.04		4	
1066	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.86	0.05 evb	<1	2.03 min; 1.7
1068	$P^{31}(p,\gamma)S^{32}$			6	3.3 h; 3.2
1070	$Ne^{22}(p,\gamma)Na^{23}$				
1070	$Cl^{37}(p,\gamma)Ar^{38}$	9.1, 7.5, 6.3		≤5	
1078	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.87	0.03 evb	<1	
1080	$A^{40}(p,\gamma)K^{41}$				
1084	$Be^{9}(p,\gamma)B^{10}$	6.9, 5.4, 0.7		3.8	
1086	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
1087	$Na^{23}(p,\gamma)Mg^{24}$			1.1	
1088	$Ne^{22}(p,\gamma)Na^{23}$				
1089	$Al^{27}(p,\gamma)Si^{28}$			<0.11	
1090	$F^{19}(p,\gamma)Ne^{20}$	12.28, 8.84, 1.63	>0.05	0.7	
1090	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	>13	0.7	
1090	$Cl^{37}(p,\gamma)Ar^{38}$				
1096	$Al^{27}(p,\gamma)Si^{38}$			<1	
1094	$Ge^{74}(p,\gamma)As^{75}$			9.5	
1100	$A^{40}(p,\gamma)K^{41}$				
1100	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.50	0.05 evb	<1	81 s; 3.7
1101	$P^{31}(p,\gamma)S^{32}$				
1102	$Cl^{35}(p,\gamma)Ar^{36}$				
1105	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
1106	$Ne^{22}(p,\gamma)Na^{23}$				
1117	$Al^{27}(p,\gamma)Si^{28}$			0.80	
1117	$P^{31}(p,\gamma)S^{32}$	9.92		5	
1120	$K^{39}(p,\gamma)Ca^{40}$	9.5, 6.1, 3.8		≤5	
1123?	$F^{19}(p,\alpha\gamma)O^{16}$			22	
1132	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.92	0.04 evb	<1	3.3 h; 1.2
1135	$Cl^{37}(p,\gamma)Ar^{38}$	9.1, 7.5, 6.3		<5	
1140	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	15	2.5	
1146	$B^{10}(p,\gamma)C^{11}$	9.7, 5.5?, 4.2?	0.0055	450	20.3 min; 1.0
1146	$P^{31}(p,\gamma)S^{32}$	7.71			
1160	$C^{13}(p,\gamma)N^{14}$	8.62, 4.67, 2.39	0.56	6	
1163	$C^{14}(p,\gamma)N^{15}$	11.30		12	
1165	$Ne^{20}(p,\gamma)Na^{21}$	<4			22.8 s; 2.5
1166	$Na^{23}(p,\gamma)Mg^{24}$			1.2	
1167	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.96	0.15 evb	<1	3.3 h; 1.2
1167	$Ge^{74}(p,\gamma)As^{75}$			4.5	
1169	$O^{18}(p,\gamma)F^{19}$	6.3		1	
1171	$Al^{27}(p,\gamma)Si^{28}$			0.25	
1172	$Mg^{26}(p,\gamma)Al^{27}$				
1176	$Na^{23}(p,\gamma)Mg^{24}$			2.5	
1180	$B^{10}(p,\gamma)C^{11}$	9.4	0.0075	570	20.3 min; 1.0
1182	$Al^{27}(p,\gamma)Si^{28}$			0.71	

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
1185	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
1189	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	19	110	
1197	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.99	0.13 evb	<1	3.3 h; 1.2
1198	$Al^{27}(p,\gamma)Si^{28}$			6.3	
1200	$Mg^{24}(p,\gamma)Al^{25}$	3.44, 1.83, 1.61		<10	7.2 s; 3.3
1209	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.00	0.14 evb	<1	3.3 h; 1.2
1210	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	425	22.5	
1212	$Al^{27}(p,\gamma)Si^{28}$			<0.21	
1213	$Na^{23}(p,\gamma)Mg^{24}$			0.4	
1213	$Ge^{74}(p,\gamma)As^{75}$			<2.5	
1227	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.63	0 045 evb	<1	81 s; 3.7
1235	$A^{40}(p,\gamma)K^{41}$				
1239	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.03	0.13 evb		3.3 h; 1.2
1247	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.04	0.1 evb	<1	3.3 h; 1.2
1248	$P^{31}(p,\gamma)S^{32}$	10.05, 7.80		9	
1250	$C^{13}(p,\gamma)N^{14}$	8.71	0.062	500	
1255	$Mg^{26}(p,\gamma)Al^{27}$				
1257	$Ge^{74}(p,\gamma)As^{75}$			<2.5	
1258	$Cl^{35}(p,\gamma)A^{36}$				
1261	$Al^{27}(p,\gamma)Si^{28}$			<0.20	
1262	$Ne^{23}(p,\gamma)Na^{23}$				
1273	$Na^{23}(p,\gamma)Mg^{24}$				
1274	$Al^{27}(p,\gamma)Si^{28}$			<1	
1278	$Ne^{22}(p,\gamma)Na^{23}$				
1283	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	29	19	
1295	$Mg^{26}(p,\gamma)Al^{27}$				
1300	$K^{39}(p,\gamma)Ca^{40}$	9.6, 6.3, 3.8		≤5	
1308	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.71	0.11 evb	<1	
1312	$C^{14}(p,\gamma)N^{15}$	11.43		43	
1313	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.10	0.21 evb	<1	3.3 h; 1.2
1315	$Al^{27}(p,\gamma)Si^{28}$			<0.16	
1316	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.71	0.08 evb	<1	81 s; 3.7
1319	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.11	0.25 evb	<1	3.3 h; 1.2
1321	$Na^{23}(p,\gamma)Mg^{24}$	11		2.1	
1322?	$F^{19}(p,\gamma)Ne^{20}$	12.50, 1.63	0.081	4.0	

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
1322	$Ne^{22}(p,\gamma)Na^{23}$				
1232	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.11	0.29 evb	<1	3.3 h; 1.2
1327	$Al^{27}(p,\gamma)Si^{28}$			<0.16	
1331	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.12	0.06 evb	<1	3.3 h; 1.2
1332	$Ge^{74}(p,\gamma)As^{75}$			5.0	
1338	$K^{39}(p,\gamma)Ca^{40}$	5.91, 5.74, 3.8		≤5	
1343	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.13	0.45 evb	<1	3.3 h; 1.2
1347	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.14	0.40 evb	<1	3.3 h; 1.2
1348	$F^{19}(p,\gamma)Ne^{20}$		0.1	5.6	
1348	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	89	5.6	
1350	$Ne^{22}(p,\gamma)Na^{23}$				
1362	$Al^{27}(p,\gamma)Si^{28}$			<0.12	
1370?	$S^{34}(p,\gamma)Cl^{35}$				
1371	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.16	0.15 evb	<1	3.3 h; 1.2
1375	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	300	11	
1375	$Ne^{22}(p,\gamma)Na^{23}$				
1376	$Ni^{58}(p,\gamma)Cu^{59}$	4.77, 4.28, 3.86	0 19 evb	<1	
1380	$Al^{27}(p,\gamma)Si^{28}$			0.70	
1387	$Al^{27}(p,\gamma)Si^{28}$			0.29	
1381	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.17	0.2 evb	<1	3.3 h; 1.2
1386	$Ne^{22}(p,\gamma)Na^{23}$				
1388	$B^{11}(p,\gamma)C^{12}$	17.23, 12.80	0 053	1270	
1395	$P^{31}(p,\gamma)S^{32}$			15	
1398	$Na^{23}(p,\gamma)Mg^{24}$	8		0.5	
1399	$O^{18}(p,\gamma)F^{19}$	9.3		<15	
1408	$P^{31}(p,\gamma)S^{32}$			15	
1415	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.20	0.35 evb	<1	3.3 h; 1.2
1419	$Na^{23}(p,\gamma)Mg^{24}$	9		≤0.3	
1422	$Ge^{74}(p,\gamma)As^{75}$			<2.5	
1424	$Ni^{58}(p,\gamma)Cu^{59}$	4.82, 4.33	1.7 evb	≤0.05	
1425	$Mg^{26}(p,\gamma)Al^{27}$				
1431?	$F^{19}(p,\gamma)Ne^{20}$	12.60, 1.63	0.19	15.7	
1431	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.22	0.18 evb	<1	3.3 h; 1.2
1433	$Ne^{22}(p,\gamma)Na^{23}$				
1443	$P^{31}(p,\gamma)S^{32}$			12	

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
1451	$Ni^{60}(p,\gamma)Cu^{61}$	6.24	0.75 evb	<1	3.3 h; 1.2
1461	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.25	0.14 evb	<1	3.3 h; 1.2
1465	$Mg^{26}(p,\gamma)Al^{27}$				
1465	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.25	0.11 evb	<1	3.3 h; 1.2
1470	$C^{13}(p,\gamma)N^{14}$	5.83, 5.10, 3.07	0.074	20	
1482	$P^{31}(p,\gamma)S^{32}$			6	
1483	$Ni^{60}(p,\gamma)Cu^{61}$	<6.27	0.14 evb	<1	3.3 h; 1.2
1484	$Cl^{35}(p,\gamma)Ar^{36}$	9.9		≤5	
1490	$Mg^{24}(p,\gamma)Al^{25}$	3.72, 1.91		0.3	7.2 s; 3.3
1491	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.28	0.14 evb	<1	3.3 h; 1.2
1492	$Ne^{22}(p,\gamma)Na^{23}$				
1500	$C^{14}(p,\gamma)N^{15}$	11.61		520	
1500	$Al^{27}(p,\gamma)Si^{28}$				
1502	$Ne^{22}(p,\gamma)Na^{23}$				
1510	$Cl^{35}(p,\gamma)Ar^{36}$	9.9		≤5	
1515	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.30	0.4 evb	<1	3.3 h; 1.2
1519	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.30	0.7 evb	<1	3.3 h; 1.2
1520?	$Si(p,\gamma)P$			9.0	
1522	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.92	0.012 evb	<1	81 s; 3.7
1527	$P^{31}(p,\gamma)S^{32}$			14	
1529	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.31	0.06 evb	<1	3.3 h; 1.2
1530	$Ge^{74}(p,\gamma)As^{75}$			9.0	
1533	$Cl^{37}(p,\gamma)Ar^{38}$	9.5		≤5	
1538	$Ni^{60}(p,\gamma)Cu^{61}$	6.32	0.35 evb	<1	3.3 h; 1.2
1540	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.93	0.020 evb	<1	81 s; 3.7
1544	$N^{14}(p,\gamma)O^{15}$	8.8?		34	2.03 min; 1.7
1550	$C^{13}(p,\gamma)N^{14}$	8.99	0.037	7	
1559	$Ge^{74}(p,\gamma)As^{75}$			6.5	
1566	$K^{39}(p,\gamma)Ca^{40}$	9.9, 6.6, 6.1		≤5	
1566	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.35	0.22 evb	<1	3.3 h; 1.2
1570	$Al^{27}(p,\gamma)Si^{28}$				
1571	$P^{31}(p,\gamma)S^{32}$			7	
1577	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.36	0.35 evb	<1	3.3 h; 1.2
1580	$Cl^{35}(p,\gamma)Ar^{36}$	10		≤5	

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
1582	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.98	0.066 evb	<1	81 s; 3.7
1588	$Ni^{60}(p,\gamma)Cu^{61}$	6.37, 5.90	0.9 evb	<1	3.3 h; 1.2
1598	$P^{31}(p,\gamma)S^{32}$			5	
1599	$Ni^{60}(p,\gamma)Cu^{61}$	6.38, 5.00	2.3 evb	<1	3.3 h; 1.2
1605	$Ni^{60}(p,\gamma)Cu^{61}$	6.39, 5.01	2.0 evb	<1	3.3 h; 1.2
1607	$F^{19}(p,\alpha\gamma)O^{16}$			6.0	
1610?	$S^{34}(p,\gamma)Cl^{35}$				
1618?	$Si(p,\gamma)P$				
1620	$Mg^{24}(p,\gamma)Al^{25}$	3.40, 2.90, 1.34		36	7.2 s; 3.3
1620	$Ni^{60}(p,\gamma)Cu^{61}$	6.40, 5.02	1.8 evb	<1	3.3 h; 1.2
1635?	$Si(p,\gamma)P$				
1635	$Cl(p,\gamma)Ar$				
1639	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.42	0.14 evb	<1	3.3 h; 1.2
1640	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	340	68	
1640	$Al^{27}(p,\gamma)Si^{28}$				
1643	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.43	0.35 evb	<1	3.3 h; 1.2
1643	$Ge^{74}(p,\gamma)As^{75}$			~15	
1645	$Cl(p,\gamma)Ar$				
1649	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.43	0.29 evb	<1	3.3 h; 1.2
1650	$Si^{28}(p,\gamma)P^{29}$	4.30		50	4.20 s; 4.0
1653	$Ni^{58}(p,\gamma)Cu^{59}$	≤5.05	0.045 evb	<1	81 s; 3.7
1656	$Ni^{60}(p,\gamma)Cu^{61}$	6.44, 5.97	1.0 evb	<1	3.3 h; 1.2
1659	$Al^{27}(p,\gamma)Si^{28}$				
1660	$Mg^{24}(p,\gamma)Al^{25}$	3.88, 3.43, 2.93		0.1	7.2 s; 3.3
1660	$Cl(p,\gamma)Ar$				
1663?	$Si(p,\gamma)P$				
1663	$Ni^{58}(p,\gamma)Cu^{59}$	5.06, 4.15, 3.28	0.16 evb	<1	81 s; 3.7
1665	$Ge^{74}(p,\gamma)As^{75}$			~15	
1669	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.45	0.4 evb	<1	3.3 h; 1.2
1670	$Cl(p,\gamma)Ar$				
1674	$Ni^{60}(p,\gamma)Cu^{61}$	5.50, 5.08	1.0 evb	<1	3.3 h; 1.2
1679	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.46	0.5 evb	<1	3.3 h; 1.2
1680?	$Si(p,\gamma)P$				
1680	$Cl(p,\gamma)Ar$				
1685	$O^{18}(p,\gamma)F^{19}$	9.6		15	

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
1690	$S^{34}(p,\gamma)Cl^{35}$				
1690	$Ge^{74}(p,\gamma)As^{75}$			~30	
1691	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13		35	
1694	$Ni^{60}(p,\gamma)Cu^{61}$	6.48, 5.52	1.0 evb	<1	3.3 h; 1.2
1698	$C^{12}(p,\gamma)N^{13}$	3.51, 2.37, 1.14	0.035	70	9.98 min; 1.2
1698	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.48	0.3 evb	<1	3.3 h; 1.2
1699?	Si(p, γ)P				
1700	$Al^{27}(p,\gamma)Si^{28}$				
1710	Cl(p, γ)Ar				
1711	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.49	0.23 evb	<1	3.3 h; 1.2
1716	$Ni^{58}(p,\gamma)Cu^{59}$	5.11, 4.20	0.35 evb	<1	81 s; 3.7
1721	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.50	0.11 evb	<1	3.3 h; 1.2
1725	$Cl^{37}(p,\gamma)A^{38}$	5.2, 3		≤5	
1726	$Al^{27}(p,\gamma)Si^{28}$				
1734	$Ni^{60}(p,\gamma)Cu^{61}$	6.52	0.7 evb	<1	3.3 h; 1.2
1739	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.52	0.3 evb	<1	3.3 h; 1.2
1742	$N^{14}(p,\gamma)O^{15}$	9.0?		5	2.03 min; 1.7
1748	$C^{13}(p,\gamma)N^{14}$	9.17, 6.43, 2.74	340	0.075	
1755	Cl(p, γ)Ar				
1757	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.54	0.5 evb	<1	3.3 h; 1.2
1764	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.55	0.6 evb	<1	3.3 h; 1.2
1765	Cl(p, γ)Ar				
1769	$O^{18}(p,\gamma)F^{19}$	9.6		4	
1770	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.55	0.75 evb	<1	3.3 h; 1.2
1774?	Si(p, γ)P				
1781	$Al^{27}(p,\gamma)Si^{28}$				
1783	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.56	0.55 evb	<1	3.3 h; 1.2
1797	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.57	0.45 evb	<1	3.3 h; 1.2
1800?	$S^{34}(p,\gamma)Cl^{35}$				
1805	$Ge^{74}(p,\gamma)As^{75}$			20	
1810?	Si(p, γ)P				
1807	$N^{14}(p,\gamma)O^{15}$	9.0?		5	2.03 min; 1.7
1833	$Mg^{24}(p,\gamma)Al^{25}$	4.05, 2.43, 1.62			7.2 s; 3.3
1833	$Ni^{58}(p,\gamma)Cu^{59}$	≤5.22	0.063 evb	<1	81 s; 3.7
1844	$Ni^{58}(p,\gamma)Cu^{59}$	5.23	2.1 evb	≤0.1	81 s; 3.7
1849?	Si(p, γ)P				

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
1860?	$S^{34}(p,\gamma)Cl^{35}$				
1870	$Ca^{40}(p,\gamma)Sc^{41}$				0.596 s; 5.6
1879?	Si(p, γ)P				
1890	$Al^{27}(p,\gamma)Si^{28}$				
1892	$P^{31}(p,\gamma)S^{32}$	10.68		24	
1906	$Ge^{74}(p,\gamma)As^{75}$			~15	
1916	$P^{31}(p,\gamma)S^{32}$				
1926	$Ge^{74}(p,\gamma)As^{75}$			~15	
1931	$O^{18}(p,\gamma)F^{19}$	9.8		1.5	
1940	$Al^{27}(p,\gamma)Si^{28}$				
1945	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		40	
1972	$Ge^{74}(p,\gamma)As^{75}$			35	
1979	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	35	23	
1985	$P^{31}(p,\gamma)S^{32}$	10.77			
2000?	$Li^{7}(p,\gamma)Be^{8}$	19.0?, 16.1?			
2000	$C^{13}(p,\gamma)N^{14}$	5.10, 4.80		~20	
2010	$Mg^{24}(p,\gamma)Al^{25}$	3.77, 3.27		0.15	7.2 s; 3.3
2025	$C^{14}(p,\gamma)N^{15}$			18	
2026	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		120	
2026	$Al^{27}(p,\gamma)Si^{28}$				
2027	$P^{31}(p,\gamma)S^{32}$	10.81			
2074	$Ge^{74}(p,\gamma)As^{75}$			13.5	
2079	$C^{14}(p,\gamma)N^{15}$			55	
2083	$Al^{27}(p,\gamma)Si^{28}$				
2090	$Si^{28}(p,\gamma)P^{29}$	4.74		12	4.20 s; 4.0
2120	$C^{13}(p,\gamma)N^{14}$	5.10, 4.39	0.20	45	
2120	$P^{31}(p,\gamma)S^{32}$	10.90		5	
2130	$Li^{7}(p,\gamma)Be^{8}$	19.12, 16.21		400	
2135	$Ne^{20}(p,\gamma)Na^{21}$				
2161	$Ge^{74}(p,\gamma)As^{75}$			~15	22.8 s; 2.5
2180	$Al^{27}(p,\gamma)Si^{28}$				
2200	$Al^{27}(p,\gamma)Si^{28}$				
2210	$Ge^{74}(p,\gamma)As^{75}$			40	
2212	$Al^{27}(p,\gamma)Si^{28}$				
2282	$Al^{27}(p,\gamma)Si^{28}$				

TABLE A2-I (cont.)

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross-section (mb)	Resonance width (FWHM) (keV)	Half-life and β^+ energy (MeV)
2295	$Ge^{74}(p,\gamma)As^{75}$			27	
2315	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		85	
2320	$P^{31}(p,\gamma)S^{32}$	11.09		8	
2340	$P^{31}(p,\gamma)S^{32}$	11.11		8	
2342	$Ge^{74}(p,\gamma)As^{75}$			15	
2344	$Al^{27}(p,\gamma)Si^{28}$				
2350	$N^{14}(p,\gamma)O^{15}$	9.5?		14	2.03 min; 1.7
2400	$Mg^{24}(p,\gamma)Al^{25}$	3.65		0.3	7.2 s; 3.3
2440	$Ge^{74}(p,\gamma)As^{75}$			11	
2480	$N^{14}(p,\gamma)O^{15}$	9.7?		11	2.03 min; 1.7
2510	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		30	
2520?	$Si(p,\gamma)P$				
2528	$Ge^{74}(p,\gamma)As^{75}$			15	
2542	$Al^{27}(p,\gamma)Si^{28}$				
2543?	$Si(p,\gamma)P$				
2553?	$Si(p,\gamma)P$				
2558?	$Si(p,\gamma)P$				
2564	$Be^{9}(p,\gamma)B^{10}$	8.1, 0.7		39	
2564	$Be^{9}(p,\alpha\gamma)Li^{6}$	3.56		39	
2570?	$Si(p,\gamma)P$				
2575	$N^{14}(p,\gamma)O^{15}$	9.8?		1000	2.03 min; 1.7
2575?	$Si(p,\gamma)P$				
2593	$Ge^{74}(p,\gamma)As^{75}$			44	
2630	$B^{11}(p,\gamma)C^{12}$	13.94, 4.43, 2.14		300	
2630	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		90	
2664	$Ge^{74}(p,\gamma)As^{75}$			10	
2800	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		60	
3000	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	750	45	

APPENDIX 3

BIBLIOGRAPHY

1. Cross-sections for charged-particle reactions at higher energies

LANGE, J., MÜNZEL, H., Rep. KFK-767 (1968).

KELLER, K.A., LANGE, J., MÜNZEL, H., PFENNIG, G., in Landolt-Börnstein, New Series I/5, Springer Verlag (1973), Vol.a, Q-Values; Vol.b: Excitation Functions for Charged Particle Induced Nuclear Reactions; Vol.c: Systematics of Excitation Functions for Nuclear Reactions Induced by p, d, ^{3}He and α-Particles.

2. (p, γ) reactions

BUTLER, J.W., Rep. NRL-5282 (1959).

3. Detection limits and sensitivities for charged-particle reactions on light elements

MARKOWITZ, S.S., MAHONY, J.D., Anal. Chem. 34 (1962) 329.

RICCI, E., HAHN, R.L., Anal. Chem. 39 (1967) 794; 40 (1968) 54.

ENGELMAN, Ch., Isot. Radiat. Technol. 8 (1970) 118.

ENGELMAN, Ch., J. Radioanal. Chem. 7 (1971) 89, 281.

4. Compilations of charged-particle reaction cross-sections; Special topics concerning charged particles

JARMIE, N., SEAGRAVE, J.D., Rep. LA-2014 (1956) P-F.

SMITH, D.B. (Comp. and Ed.), Rep. LA-2424 (1961) Ne-Cr.

AJZENBERG-SELOVE, F., LAURITSEN, T., Nucl. Phys. 11 (1959) 1.

AJZENBERG-SELOVE, F., Rep. LAP-99 (1970).

AJZENBERG-SELOVE, F., Rep. LAP-100 (1971).

PHOTONUCLEAR CROSS-SECTIONS

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ABSTRACT: A compilation is given of about sixty (γ, n) cross-sections in the giant resonance region, which are sometimes complemented with cross-sections for other types of reactions. Special reference is taken to needs in activation analysis.

INTRODUCTION

Photonuclear absorption

The photonuclear absorption cross-section is comparatively small and has a maximum value of only a few millibarns per nucleon. If a photonuclear interaction takes place, the nucleus can be excited in a number of different ways, depending on the energy of the photon.

At low energies (10-25 MeV), the dominant feature of the photo-absorption cross-section is the giant resonance which occurs in all elements. Light nuclei have a resonance peak, at an energy around 22 MeV, which value decreases to about 13 MeV for heavy ones (Fig. 1).

The resonance width is about 4 MeV for spherical nuclei and increases to about 8 MeV for strongly deformed ones (Fig. 2). The energy dependence of the giant resonance absorption cross-section for medium and heavy nuclei

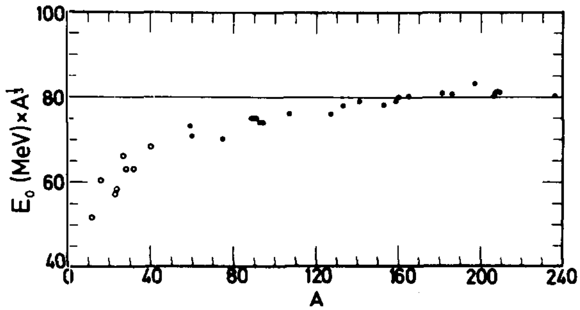


FIG. 1. Giant resonance energy times $A^{\frac{1}{3}}$ as a function of A (Ref. [1]). Data for light elements from total absorption experiments and for heavy elements from neutron yield.

has often been approximated by a Lorentz-shaped resonance line, with the width Γ:

$$\sigma(k) = \sigma_0 \frac{k^2\Gamma^2}{(k_0^2 - k^2)^2 + k^2\Gamma^2}$$

For deformed nuclei, the giant resonance splits into two main peaks. For light nuclei, the giant resonance shows considerably fine structure related mainly to the properties of individual levels but also to collective surface vibrations.

The giant resonance results primarily from electric dipole absorption and can be explained as a vibration of the groups of neutrons and protons confined in a nucleus with a rigid surface. The cross-section integrated over the resonance is of the order of the classical value of the dipole sum

$$\int_0^{E_\pi} \sigma dE = 0.06\ NZ/A \quad (\text{MeV}\cdot\text{barns})$$

where E_π is the meson production threshold and σ is the electric dipole absorption cross-section. Consequently, the integrated cross-section is approximately proportional to the mass number. In Fig. 3 the integrated cross-sections up to 30 MeV are given.

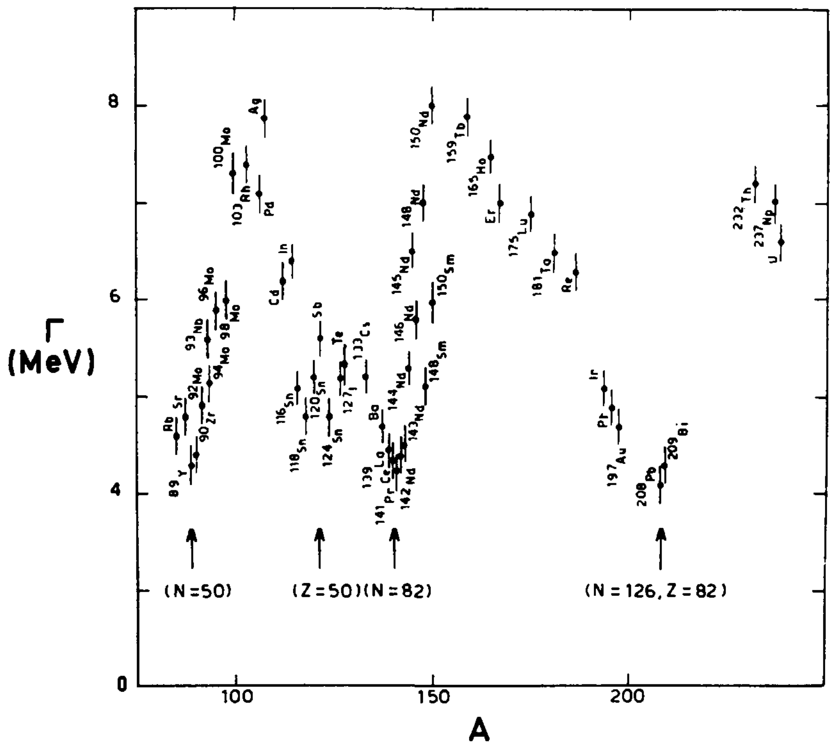


FIG. 2. Giant resonance width as a function of A (Ref. [2]).

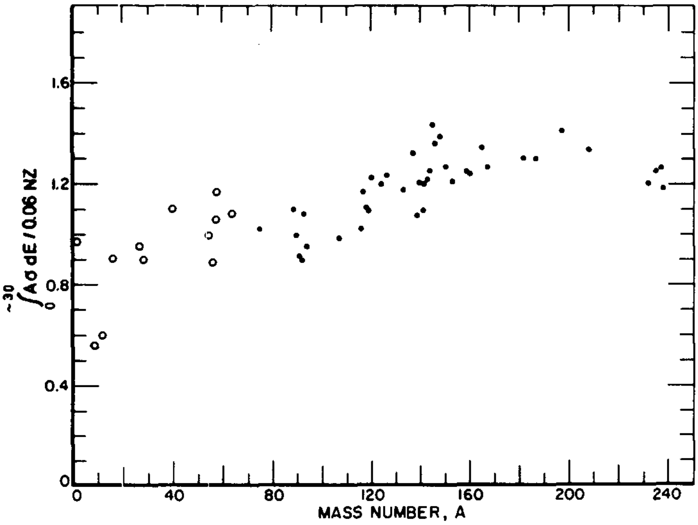


FIG.3. Integrated absorption cross-sections normalized to the classical dipole sum rule value. For more detailed information see Ref.[3].

In the energy region above the giant resonance, but below about 200 MeV, the photon mainly interacts with n-p clusters (quasi-deuterons) inside the nucleus. In this region the cross-section drops to small values. Thus the integrated cross-sections given in Fig.3 are expected to almost exhaust the dipole sum. New resonances appear in the cross-section curve when the photon energies are above the photomeson threshold at about 150 MeV (Fig.4). These resonances are related to the baryon resonances. The average photonuclear cross-section is about 0.30 mb per nucleon for photon energies between 300 MeV and 1000 MeV.

Nuclides produced in photonuclear reactions

In the giant resonance region, the most probable result of photonuclear absorption is the emission of a single neutron, but other processes must also be considered such as the emission of gamma rays, the emission of more than one neutron and, particularly for light nuclei, the emission of charged particles. Medium- and high-energy photon spallation yields are systematically treated in Ref. [4].

Bremsstrahlung spectrum

Since there exist no intense monochromatic photon sources, the bremsstrahlung beam obtained when electrons hit a target is used as photon source in almost all photoactivation studies. The energy spectrum of the photons in a bremsstrahlung beam from a thin target is well known and is shown in Fig.5.

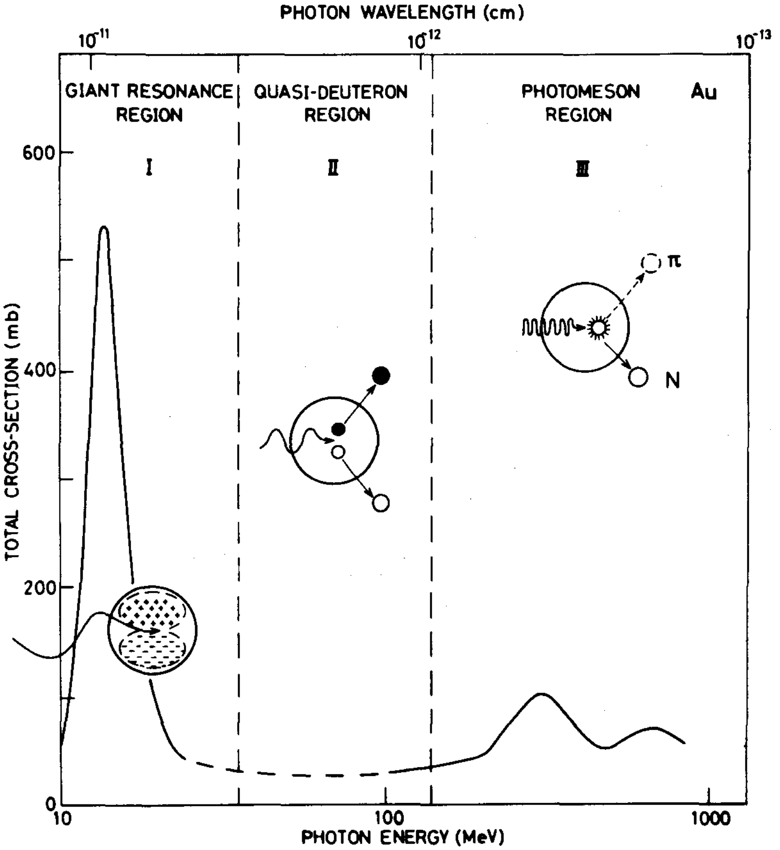


FIG. 4. Reaction mechanism and cross-section as a function of the photon wavelength and energy for ^{197}Au.

The spectra shown are calculated from the spectrum formulae given by Schiff [6]. The average angle of emission of the photons $\bar{\theta}$ is, for relativistic electrons,

$$\bar{\theta} = m_0c^2/k_0$$

k_0 being the maximum photon energy.

Bremsstrahlung activation yield

Let $n(k, k_0)dk$ be the number of photons with energies between k and k + dk per unit radiator thickness per second in a bremsstrahlung beam where k_0 is the maximum photon energy.

The energy content of the beam in the sample is then

$$U(k_0) = \int_0^{k_0} kn(k, k_0)f(k)dk$$

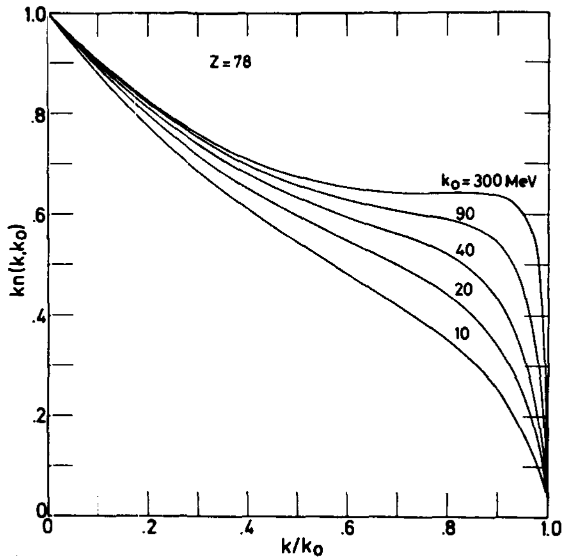


FIG. 5. Dependence of the bremsstrahlung spectrum shape on the electron kinetic energy for a platinum target normalized to one at zero energy (Ref.[5]).

where f(k) is a correction factor which accounts for the distortion of the bremsstrahlung spectrum by the effects of photon absorption in the machine target, in the walls of the accelerator chamber and in the sample.

We define the number of equivalent quanta Q by

$$Q = \frac{1}{k_0} U(k_0)$$

i.e. Q is the number of quanta with energy k_0 that have the same energy content as the bremsstrahlung beam and define the cross-section per equivalent quantum, σ_q, by

$$\sigma_q(k_0) = \frac{\int_0^{k_0} \sigma(k) n(k, k_0) f(k) dk}{Q}$$

The bremsstrahlung activation yield measured in monitor response units can be written

$$Y(k_0) = \frac{\int_0^{k_0} \sigma(k) n(k, k_0) f(k) dk}{UR(k_0)} = \frac{\sigma_q}{k_0 R(k_0)}$$

The monitor measures only some part of the energy content of the beam and thus $R(k_0)$ gives the sensitivity of the monitor for a k_0-bremsstrahlung beam.

While f(k) and $R(k_0)$ are quantities specific for the laboratory, $n(k, k_0)$ can be tabulated for a bremsstrahlung spectrum. The relation between the number of photons per MeV per incident electron per $g \cdot cm^{-1}$ of a radiator (Z, A) is

$$n(k, k_0) = \frac{N_A}{A} \sigma(k, k_0)_{brems}$$

$$= 32 \frac{N_A}{A} \frac{Z^2 r_e^2 \alpha}{k} \Phi(Z, k, k_0)$$

$$= 111.84 \frac{Z^2}{A} \frac{1}{k} \Phi(Z, k, k_0) \quad (MeV^{-1} \cdot g^{-1} \cdot cm^2)$$

where r_e is the classical electron radius
N_A is the Avogadro number
α is the fine structure constant.

In Tables I and II, $\Phi(Z, k, k_0)$ defined from the bremsstrahlung cross-section integrated over angles given by Schiff [6] has been used. The value of Z used in $\Phi(Z, k, k_0)$ was 78 (platinum) and the screening constant was taken to be 111.

$\int_0^{k_0} \Phi(k, k_0)dk$ is tabulated in Table I, $\Phi(k, k_0)$ is tabulated in Table II for different k_0 in the giant resonance region.

TABLE I. VALUES OF $\int_0^{k_0} \Phi(k, k_0)dk$ (Ref. [7])

k_0 (MeV)	$\int_0^{k_0} \Phi(k, k_0)dk$ (MeV)
10	03.55488
13	04.78641
16	06.04665
19	07.32788
22	08.62522
27	10.81470
32	13.02999
36	14.81454
44	18.41618
52	22.04727

TABLE II. VALUES OF $\Phi(k, k_0)$ (Ref. [7])

k (MeV)	$\Phi(k,k_o)$ (k_o=10MeV)	k (MeV)	$\Phi(k,k_o)$ (k_o=13MeV)	k (MeV)	$\Phi(k,k_o)$ (k_o=16MeV)
10	.02933	13	.02814	16	.02739
09	.16426	12	.16239	15	.16140
08	.22660	11	.22271	14	.22105
07	.27063	10	.26222	13	.25883
06	.30926	09	.29321	12	.28676
05	.34821	08	.32093	11	.30985
04	.39085	07	.34829	10	.33081
03	.43959	06	.37720	09	.35136
02	.49629	05	.40900	08	.37269
01	.56252	04	.44469	07	.39564
00	.64010	03	.48504	06	.42083
		02	.53068	05	.44875
		01	.58215	04	.47975
		00	.64010	03	.51414
				02	.55217
				01	.59406
				00	.64010

(MeV)	(k_o=19MeV)	(MeV)	(k_o=22MeV)	(MeV)	(k_o=27MeV)
19	.02687	22	.02649	27	.02604
18	.16080	21	.16040	26	.15997
17	.22024	20	.21981	25	.21949
16	.25731	19	.25661	24	.25620
15	.28386	18	.28250	23	.28170
14	.30476	17	.30229	22	.30068
13	.32262	16	.31852	21	.31563
12	.33907	15	.33275	20	.32805
11	.35519	14	.34601	19	.33891
10	.37176	13	.35905	18	.34891
09	.38935	12	.37239	17	.35855
08	.40838	11	.38643	16	.36820
07	.42918	10	.40146	15	.37813
06	.45198	09	.41772	14	.38855
05	.47700	08	.43539	13	.39964
04	.50438	07	.45461	12	.41151
03	.53426	06	.47548	11	.42428
02	.56676	05	.49812	10	.43803
01	.60200	04	.52258	09	.45283
00	.64010	03	.54895	08	.46873
		02	.57728	07	.48577
		01	.60764	06	.50401
		00	.64010	05	.52347
				04	.54418
				03	.56618
				02	.58948
				01	.61411
				00	.64010

This table is continued on the next page.

TABLE II (cont.)

k (MeV)	$\Phi(k,k_o)$ (k_o=32MeV)	k (MeV)	$\Phi(k,k_o)$ (k_o=36MeV)	k (MeV)	$\Phi(k,k_o)$ (k_o=44MeV)	k (MeV)	$\Phi(k,k_o)$ (k_o=52MeV)
32	.02573	36	.02554	44	.02527	52	.02508
31	.15970	34	.21935	42	.21938	50	.21943
30	.21938	32	.28178	40	.28224	48	.28273
29	.25619	30	.31479	38	.31534	46	.31613
28	.28163	28	.33550	36	.33553	44	.33631
27	.30037	26	.35057	34	.34931	42	.34967
26	.31483	24	.36335	32	.35990	40	.35936
25	.32647	22	.37568	30	.36909	38	.36713
24	.33625	20	.38869	28	.37797	36	.37402
23	.34483	18	.40308	26	.38720	34	.38070
22	.35270	16	.41931	24	.39725	32	.38761
21	.36020	14	.43771	22	.40841	30	.39504
20	.36759	12	.45849	20	.42090	28	.40322
19	.37508	10	.48182	18	.43488	26	.41229
18	.38283	8	.50782	16	.45046	24	.42236
17	.39096	6	.53657	14	.46772	22	.43352
16	.39958	4	.56816	12	.48674	20	.44583
15	.40875	2	.60265	10	.50757	18	.45936
14	.41854	0	.64010	8	.53025	16	.47412
13	.42902			6	.55482	14	.49017
12	.44021			4	.58129	12	.50753
11	.45216			2	.60971	10	.52621
10	.46490			0	.64010	8	.54623
09	.47846					6	.56762
08	.49285					4	.59039
07	.50810					2	.61454
06	.52423					0	.64010
05	.54124						
04	.55915						
03	.57799						
02	.59774						
01	.61844						
00	.64010						

Comments

In the following compilation, (γ, n) cross-section curves are given, which are sometimes complemented with cross-sections for other types of reactions. Preference has been given to monochromatic photon data when such are available. Estimates of non-tabulated cross-sections can be made from Figs 1, 2 and 3. When data for monochromatic photons are not available, continuous photon data have been used and the graphs are marked with "brems". For some nuclei equivalent data exist from several laboratories. They are then given without preference, for comparison. The separation energies of particles or groups of particles have been taken from Ref. [8] and are given in MeV. For further cross-section data and more detailed information, refer to the Photonuclear Data Index, Ref. [3], and the Photonuclear Data Center at NBS which offers a digital data library of cross-section data.

The survey of literature pertaining to this compilation was concluded in January 1974. Simultaneously with the compilation of the present cross-section data, B.L. Berman has compiled photonuclear cross-sections obtained with monoenergetic photons. To make our compilation as complete as possible, we have used results from Berman's atlas [9].

Example of how to determine the yield curve

Problem: We want to determine the (γ, n) yield curve for gold for 19 MeV bremsstrahlung.

Solution: Look at the page with the gold cross-section. We choose the upper figure, from which we get the $\sigma(k)$-value. From Table II we find k and $\Phi(k, k_0)$ and derive the following:

$k_0 = 19$ MeV

k (MeV)	$\Phi(k, k_0)$	$\sigma(k)$ (mb)	$\frac{\Phi(k, k_0)}{k}$ (mb · MeV^{-1})
8	0.40838	5.9	0.3012
9	0.38935	42.4	1.8343
10	0.37176	84.1	3.1265
11	0.35519	170.6	5.5087
12	0.33907	323.5	9.1408
13	0.32262	517.6	12.8452
14	0.30476	505.9	11.0127
15	0.28386	376.5	7.1249
16	0.25731	211.8	3.4061
17	0.22024	100.0	1.2955
18	0.16080	61.8	0.5521
19	0.02687	40.0	0.0566
			$\sum_i = 56.2046$

$$\sum_i \sigma(k_i) \frac{\Phi(k_i, k_0)}{k_i} = 56.2046$$

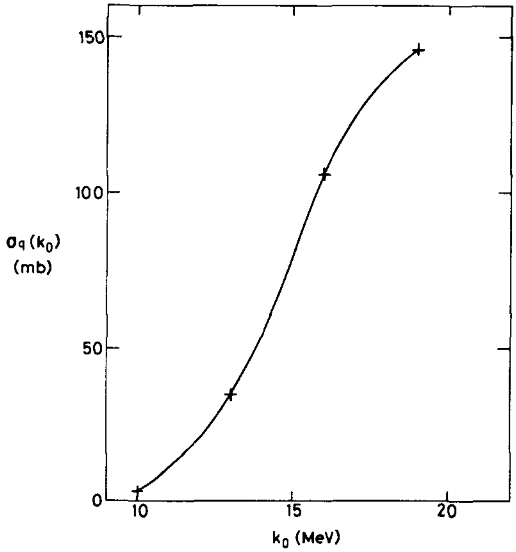


FIG. 6. $\sigma_q(k_0)$ as a function of k_0.

As

$$\int_0^{k_0} \sigma(k)\, \frac{\Phi(k, k_0)}{k}\, dk \simeq \sum_i \sigma(k_i) \cdot \frac{\Phi(k_i, k_0)}{k_i}\, \Delta k_i$$

and with the value of $\int_0^{k_0} \Phi(k, k_0) dk$ from Table I we get the cross-section per equivalent quantum

$$\sigma_q(k_0) = \int_0^{k_0} \sigma(k) \cdot \frac{\Phi(k, k_0)}{k}\, dk / k_0^{-1} \int_0^{k_0} \Phi(k, k_0) dk$$

$$= \frac{56.2046 \cdot 19}{7.32788} = 145.7 \text{ mb} \quad \text{if } f(k) = 1$$

In similar ways we get $\sigma_q(k_0)$ for other values of k_0:

k_0 = 16 MeV $\quad \sigma_q(k_0) = 39.9553 \cdot 16/6.04665 = 105.7$ mb

k_0 = 13 MeV $\quad \sigma_q(k_0) = 12.7755 \cdot 13/4.78641 = 34.7$ mb

k_0 = 10 MeV $\quad \sigma_q(k_0) = 1.1876 \cdot 10/3.55488 = 3.3$ mb

Figure 6 gives $\sigma_q(k_0)$ as a function of k_0.

REFERENCES TO INTRODUCTION

[1] HAYWARD, E., Photonuclear Reactions, NBS Monograph 118, Washington, D.C. (1970).
[2] CARLOS, P., BERGERE, R., BEIL, H., LEPRETRE, A., VEYSSIERE, A., Nuclear Physics A219 (1974) 61.
[3] FULLER, E.G., GERSTENBERG, H.M., VANDER MOLEN, H., DUNN, T.C., Photonuclear Reaction Data, NBS Special Publication 380, Washington, D.C. (1973).
[4] JONSSON, G.G., LINDGREN, K., Physica Scripta 7 (1973) 49.
[5] KOCH, H.W., MOTZ, J.W., Rev. Mod. Phys. 31 (1959) 920.
[6] SCHIFF, L.I., Phys. Rev. 83 (1951) 252.
[7] PENFOLD, A.S., LEISS, J.E., Analysis of Photo Cross Sections, Physics Research Laboratory, University of Illinois (1958).
[8] WAPSTRA, A.H., GOVE, N.B., Nuclear Data Tables 9 (1971).
[9] BERMAN, B.L., Atlas of Photoneutron Cross Sections obtained with Monoenergetic Photons, Rep. UCRL-74622, Lawrence Livermore Laboratory, California (1973).

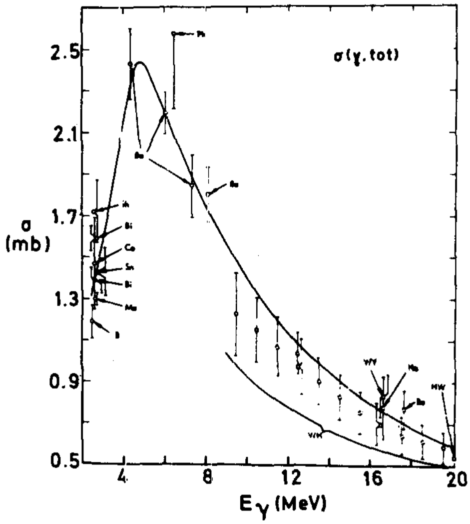
GRAPHS OF CROSS-SECTIONS

Symbols

Z	atomic number
A	nuclear mass number
G	photon
N	neutron
P	proton
fis	fission
tot	total photon absorption
Γ	Lorentz line width
P_0	proton ground-state transition
brems	bremsstrahlung
mono	monoenergetic
Compt scatt	Compton scattering
$\sigma(\gamma, \text{Tr.})$	$\sigma(\gamma, n) + \sigma(\gamma, pn) + \sigma(\gamma, 2n) + \ldots$

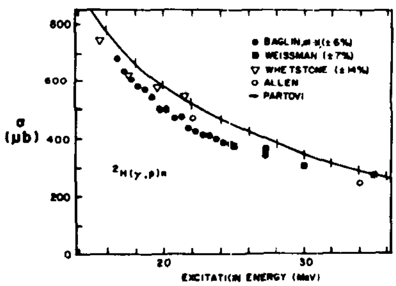
CONTENTS LIST OF GRAPHS

DEUTERIUM



Data point designations — see reference

Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 323
G. Breit



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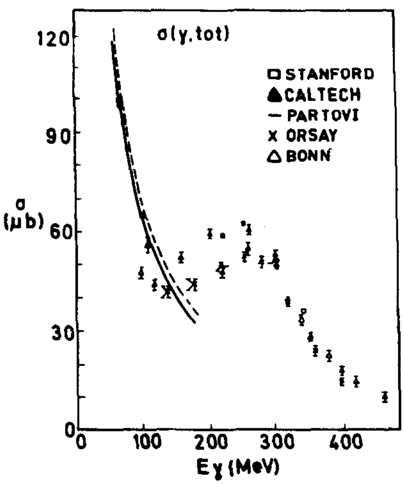
J. E.E. Baglin



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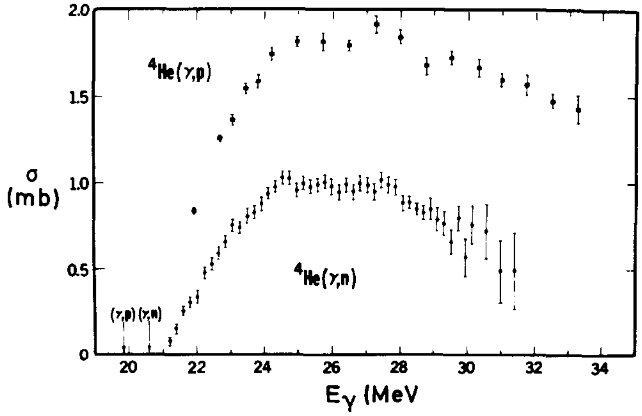
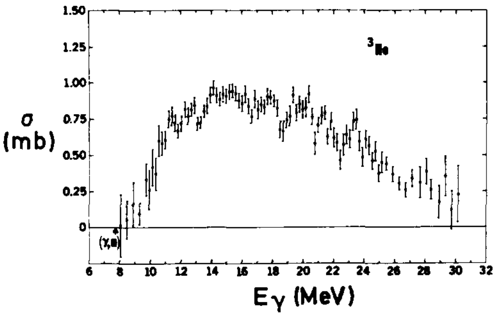
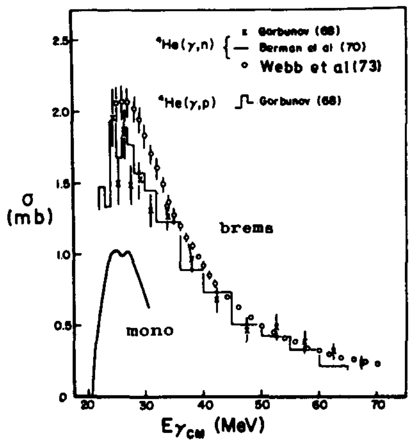
Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 363
E. B. Dally

HELIUM



^{4}He(γ,p) Nucl. Phys. A148 (1970), 211, Meyerhof et al.
Ref: Phys. Rev. C4 (1971) 723, B.L.Berman et al.



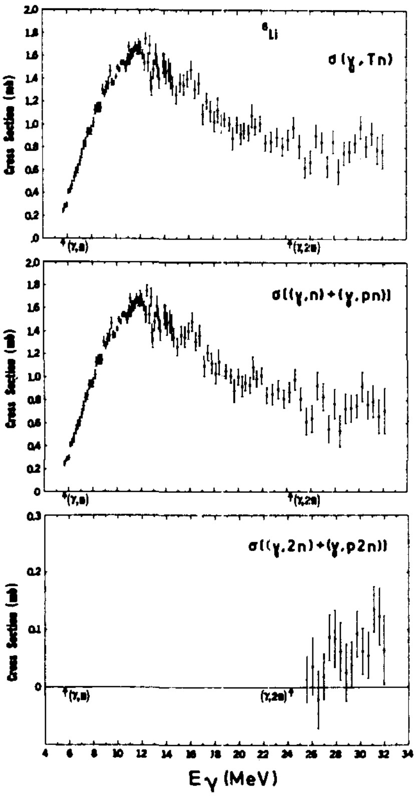


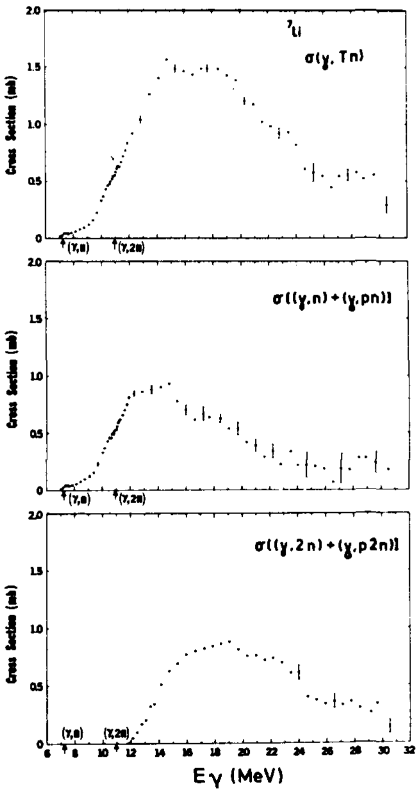
Ref: Phys. Rev. Lett. 24 (1970) 1594, B. L. Berman et al.

Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 149 D. V. Webb et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
2	4	100.0	20.6	19.8	28.3	26.1	28.3

LITHIUM



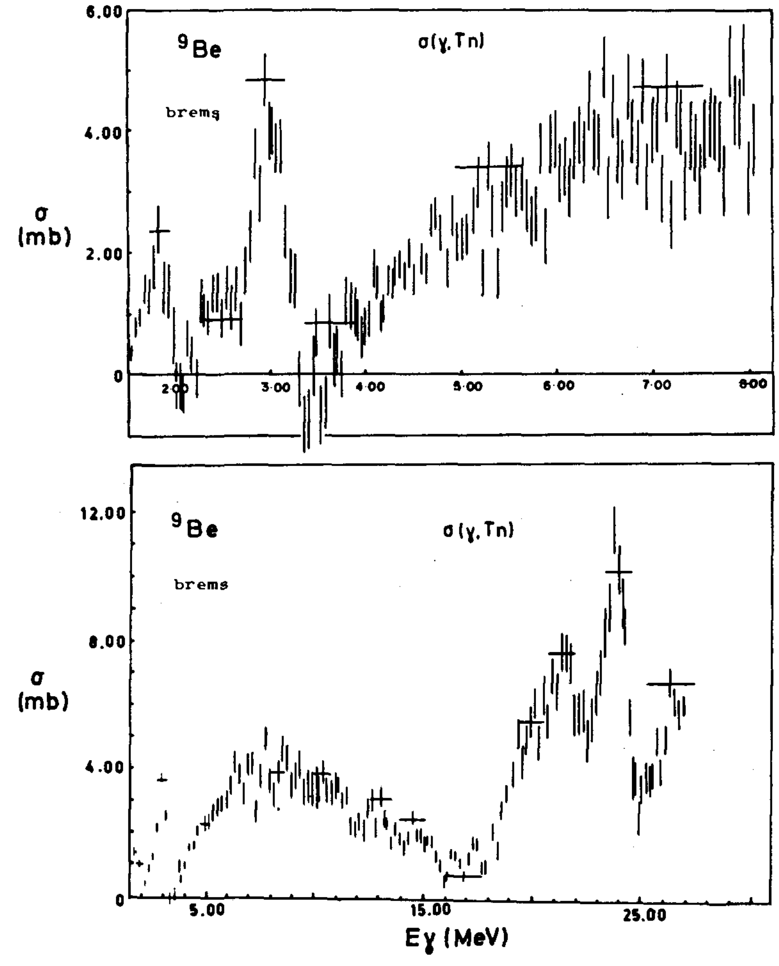


Ref: Phys. Rev. Lett. 15 (1965) 727
B. L. Berman et al.

Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 175
R. L. Bramblett et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
3	6	7.4	5.7	4.6	27.2	3.7	26.4
	7	92.6	7.3	10.0	12.9	11.8	33.5

BERYLLIUM

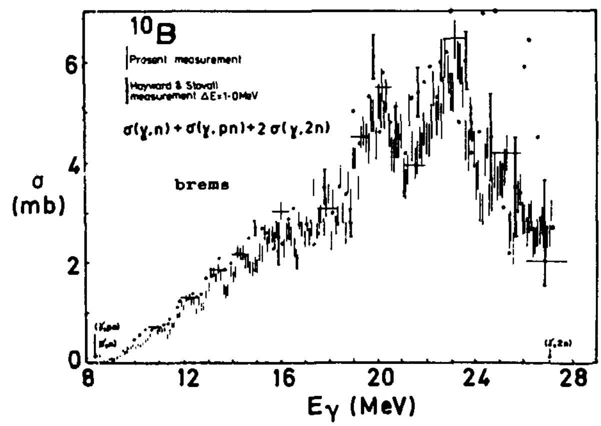


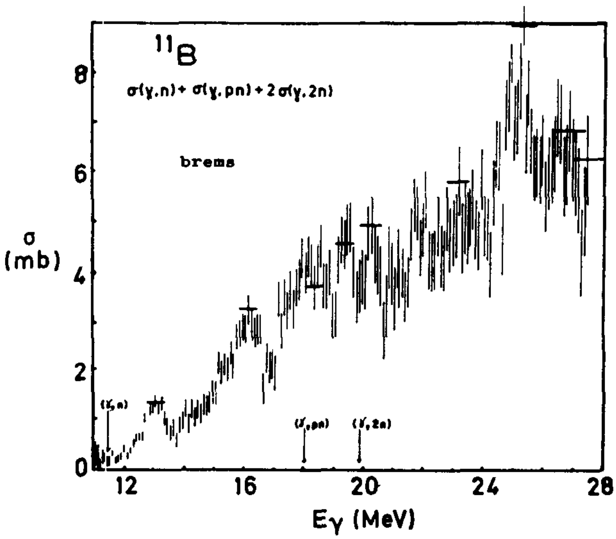
Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 151
R. J. Hughes et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
4	9	100.0	1.7	16.9	20.6	18.9	29.3

See total cross-sections for the nuclear photoeffect.

BORON



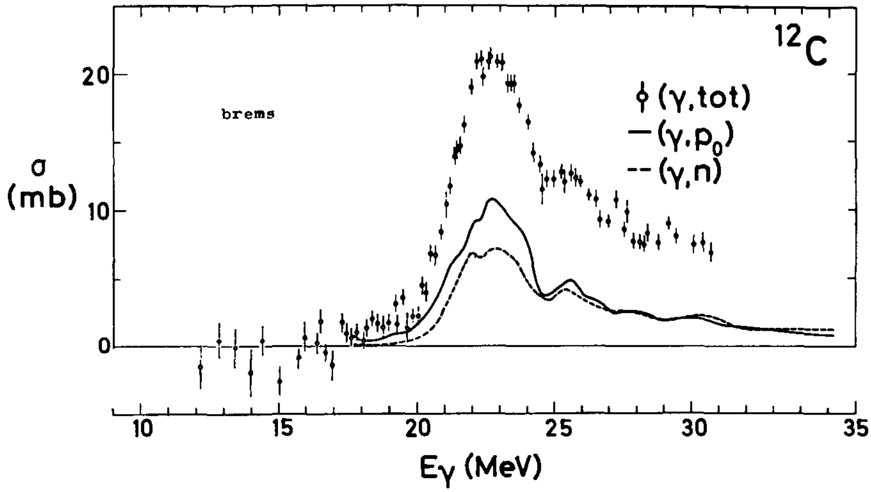


Ref: Nucl. Phys. A215 (1973) 147
R. I. Hughes and E. G. Muirhead

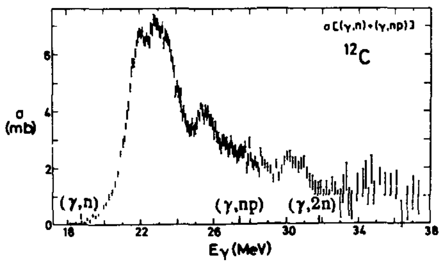
Z	A	ABUND	G, N	G, P	G,2N	G,NP	G,2P
5	10	19.6	8.4	6.6	27.0	8.3	23.5
	11	80.4	11.5	11.2	19.9	18.0	30.9

For (γ,p) cross-section data see
Sov. J. Nucl. Phys. 11 (1970) 4, I. Sorokin et al.

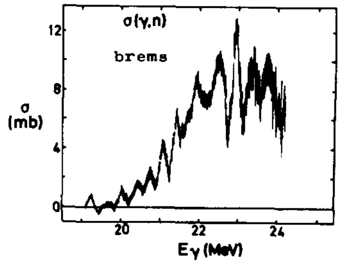
CARBON



Ref:	(γ,tot)	Nucl. Phys. A128 (1969) 426,	N. Bezić et al(fig)
	(γ,po)	Nucl. Phys. 58 (1964) 122,	R. G. Allas et al.
	(γ,n)	Phys. Rev. 143 (1966) 790,	S. C. Fultz et al.



Ref: Phys. Rev. 143 (1966)790 S. C. Fultz et al.

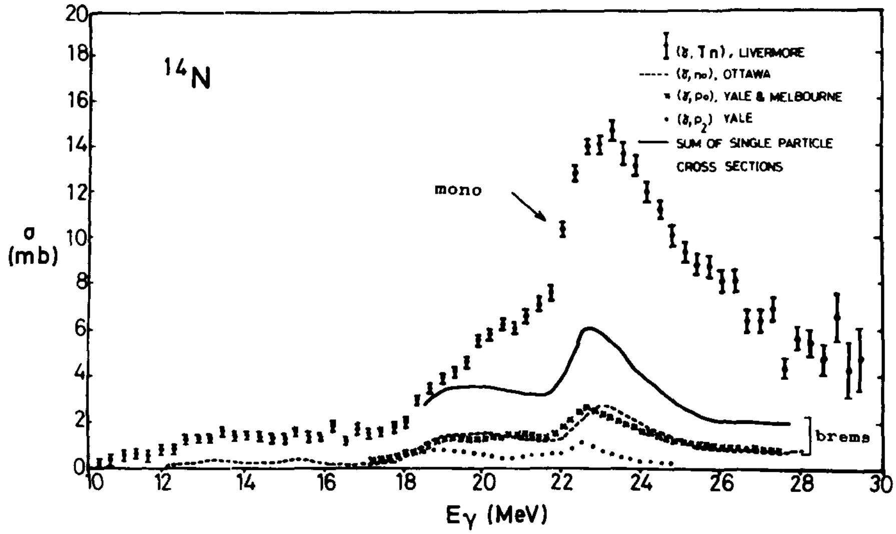


Ref: Sov. J. Nucl. Phys. 14 (1972) 142 B. S. Ishkhànov et al.

Z	A	ABUND	G, N	G, P	G,2N	G,NP	G,2P
6	12	98.9	18.7	16.0	31.8	27.4	27.2
	13	1.1	4.9	17.5	23.7	20.9	31.6

See total cross-sections for the nuclear photoeffect.

NITROGEN

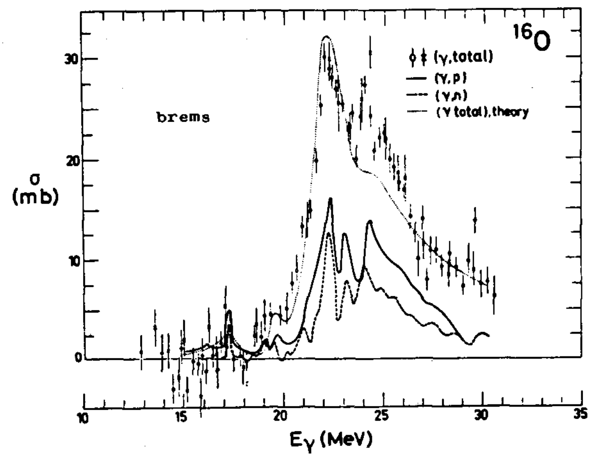


(γ,Tn) Phys. Rev. C2 (1970) 2318
B. L. Berman et al.

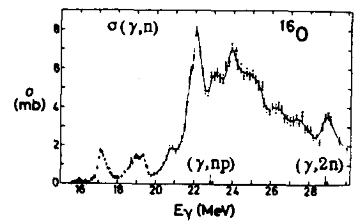
Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 727
J. M. Dixon

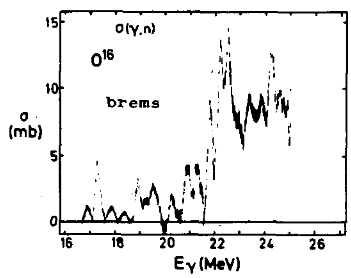
Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
7	14	99.6	10.6	7.6	30.6	12.5	25.1
	15	0.4	10.8	10.2	21.4	18.4	31.0

OXYGEN



Ref: (γ,tot) Nucl. Phys. A128 (1969) 426, N. Bezić et al. (fig)
(γ,p) Phys. Rev. Lett. 15(1965)367, R. C. Morrison et al
(γ,n) Phys. Rev. 143 (1966) 712, B. C. Cook et al.
(γ,tot)theory Nucl. Phys. A95(1967)271, B. Buck et al.





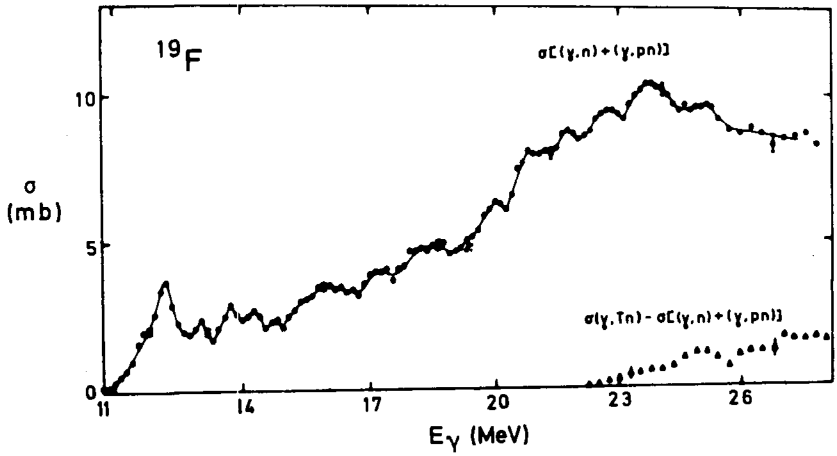
Ref: Phys. Rev. 133 (1964)B869
R. L. Bramblett et al.

Sov. J. Nucl. Phys. 12 (1971)484
B. S. Ishkhanov et al.

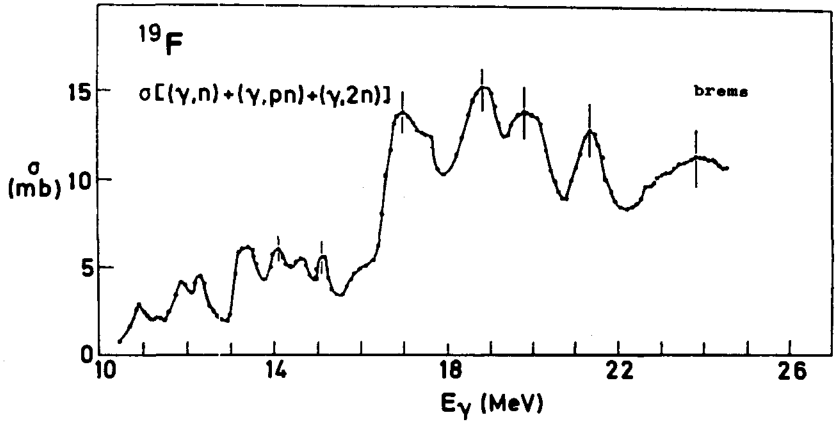
Z	A	ABUND	G, N	G, P	G,2N	G,NP	G,2P
8	16	99.8	15.7	12.1	28.9	23.0	22.3

See total cross-sections for the nuclear photoeffect.

FLUORINE



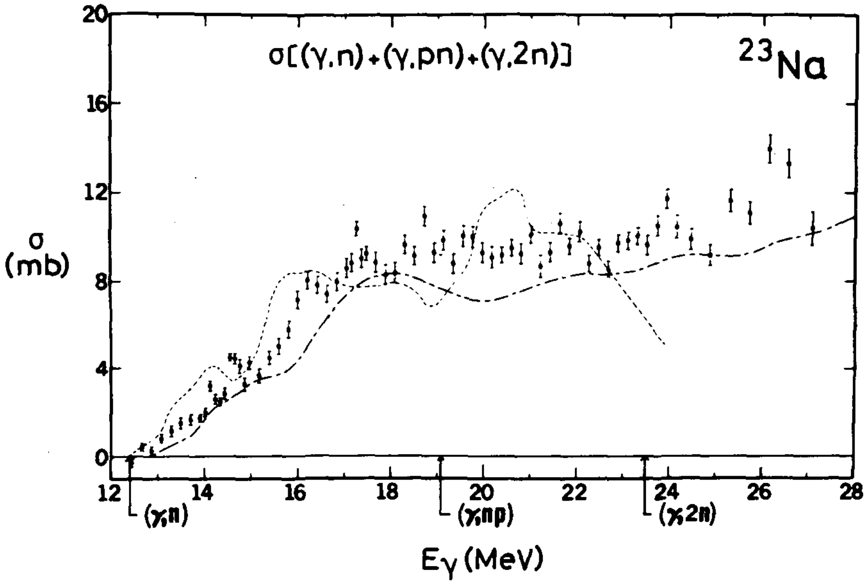
Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 525
R. Bergère et al.



Ref: Z. Physik <u>261</u> (1973) 125, D. Catană et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
9	19	100.0	10.4	8.0	19.6	16.0	23.9

SODIUM



Total photoneutron cross-section.

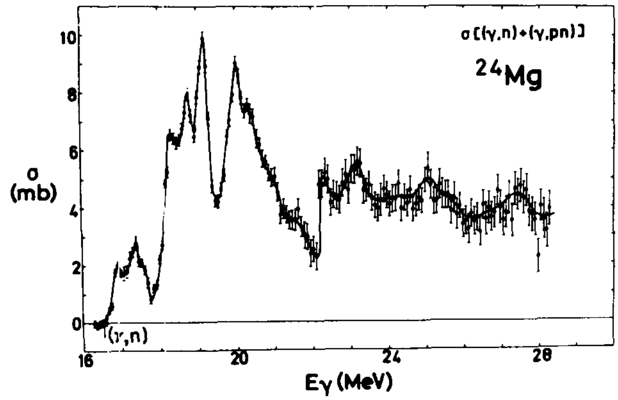
Ref: Plotted points:
R. A. Alvarez et al.
Phys. Rev. C4 (1971) 1673

Dash-dotted curve:
D. S. Fielder et al.
Proc. of the Int. Conf. on Nucl. Phys.
Paris 1964, page 1025

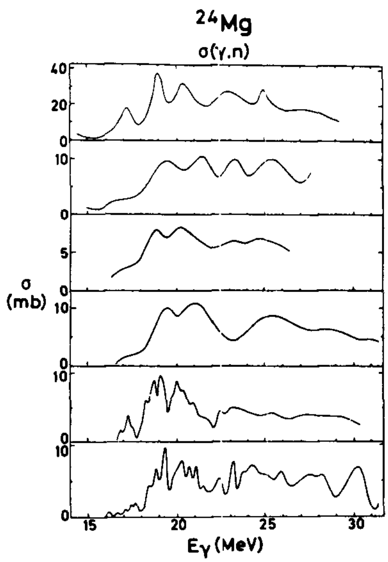
Dashed curve:
K. Sato
J. Phys. Soc. Japan 18 (1963) 1353

Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
11	23	100.0	12.4	8.8	23.5	19.2	24.1

MAGNESIUM



Ref: Phys. Rev. C4 (1971) 149, 1673 ^{24,25,26}Mg Fultz et al.



Dolbilkin et al. (γ, total)
Nucl. Phys. 72 (1965) 137

Min & Whitehead(brems)
Phys. Rev. 137 (1965) B301

Miller et al. (mono)
J. de Phys. 27 (1966) 8

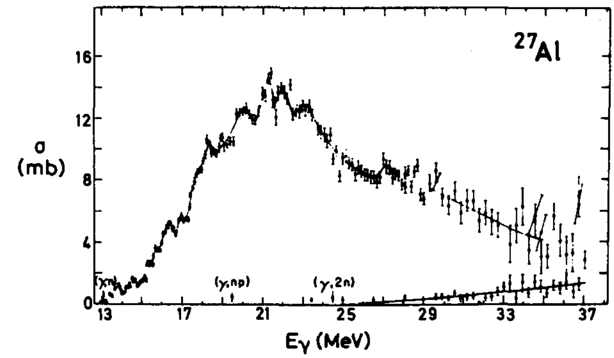
Anderson et al. (brems)
Nucl. Phys. A127 (1969) 474

Fultz et al. (mono)
Phys. Rev. C4 (1971) 149

Webb et al. (brems)
Nucl. Phys. A159 (1970) 81 (fig)

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
12	24	78.7	16.5	11.7	29.7	24.1	20.5
	25	10.1	7.3	12.1	23.9	19.0	22.6
	26	11.2	11.1	14.1	18.4	23.1	24.8

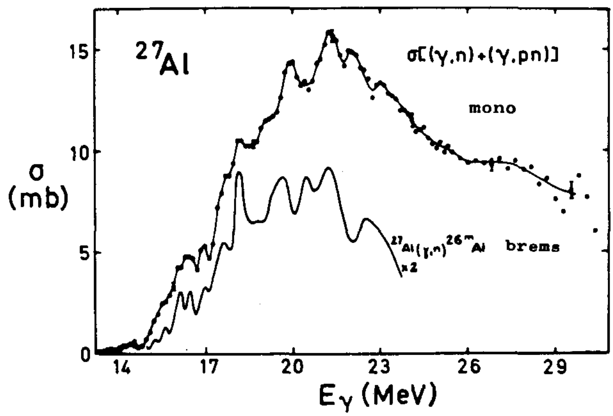
ALUMINIUM



Upper curve $\sigma[(\gamma,n) + (\gamma,pn) + 2(\gamma,2n)]$

Lower curve $\sigma(\gamma,2n)$

Ref: Phys. Rev. 143 (1966) 790, S. C. Fultz et al.



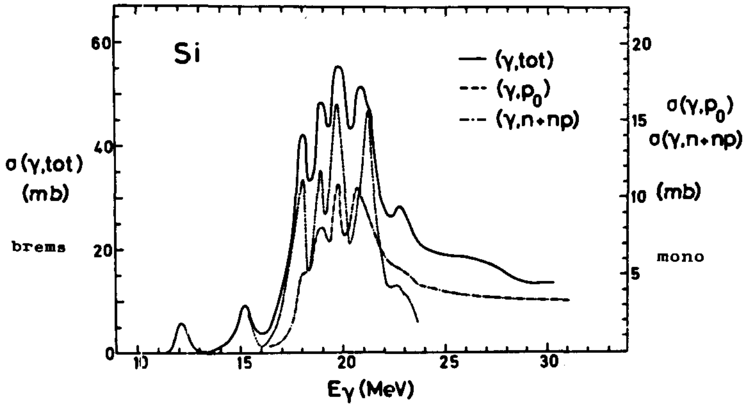
$^{27}Al(\gamma,n)^{26}Al^{m}$ Nucl. Phys. 64 (1965) 486, M. N. Thompson et al.

Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 525
R. Bergère et al.

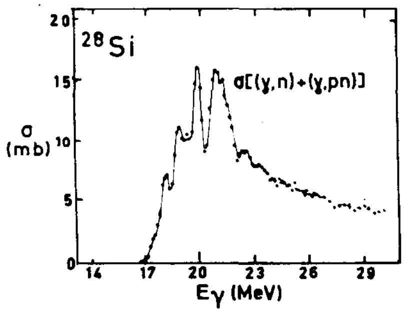
Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
13	27	100.0	13.1	8.3	24.4	19.4	22.4

See total cross-sections for the nuclear photoeffect.

SILICON



Ref: (γ,tot)	Nucl. Phys. A117 (1968) 124,	N. Bezić et al. (fig)
(γ,p_0)	Nucl. Phys. 65 (1965) 577,	P. P. Singh et al.
$(\gamma,n+np)$	Phys. Lett. 6 (1963) 213,	J. T. Caldwell et al.

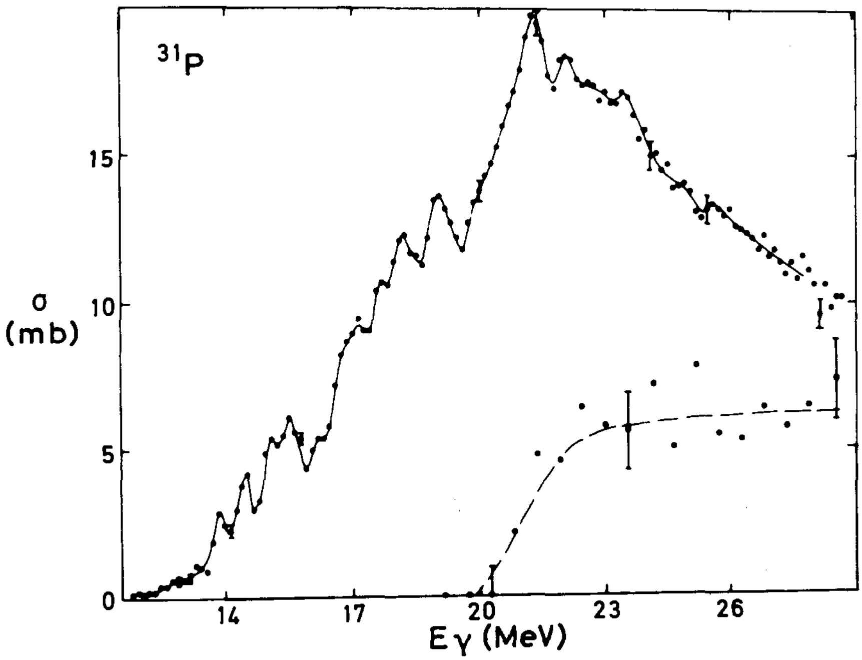


Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 525
R. Bergère et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2p
14	28	92.2	17.2	11.6	30.5	24.6	19.9
	29	4.7	8.5	12.3	25.7	20.1	21.9
	30	3.1	10.6	13.5	19.1	22.9	24.0

See total cross-sections for the nuclear photoeffect.

PHOSPHORUS

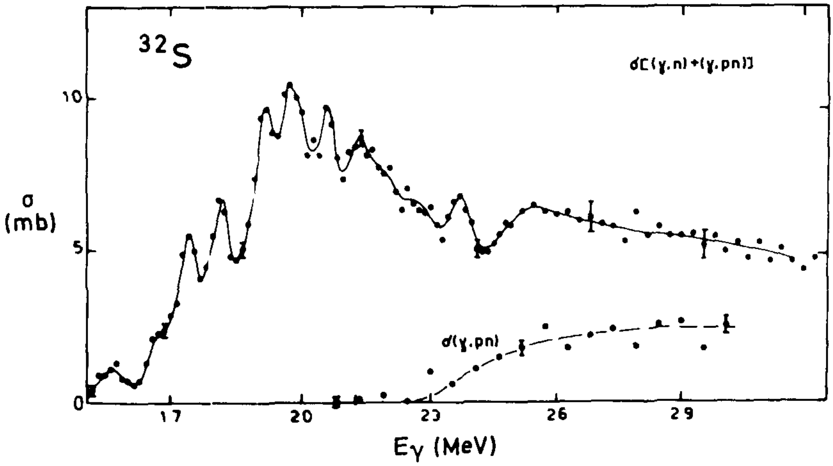


Top curve represents $\sigma(\gamma,n) + \sigma(\gamma,pn)$
Lower curve represents $\sigma(\gamma,pn)$

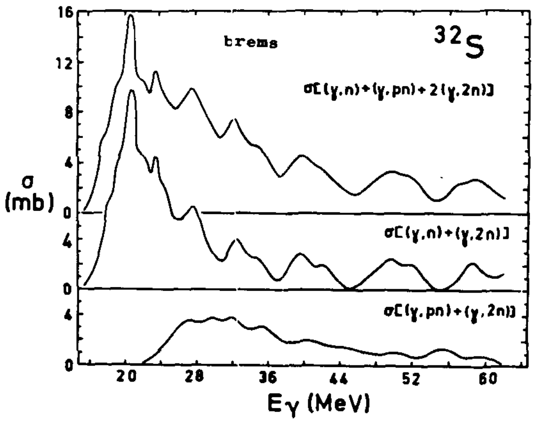
Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 525
R. Bergère et al.

Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
15	31	100.0	12.3	7.3	23.6	17.9	20.8

SULPHUR



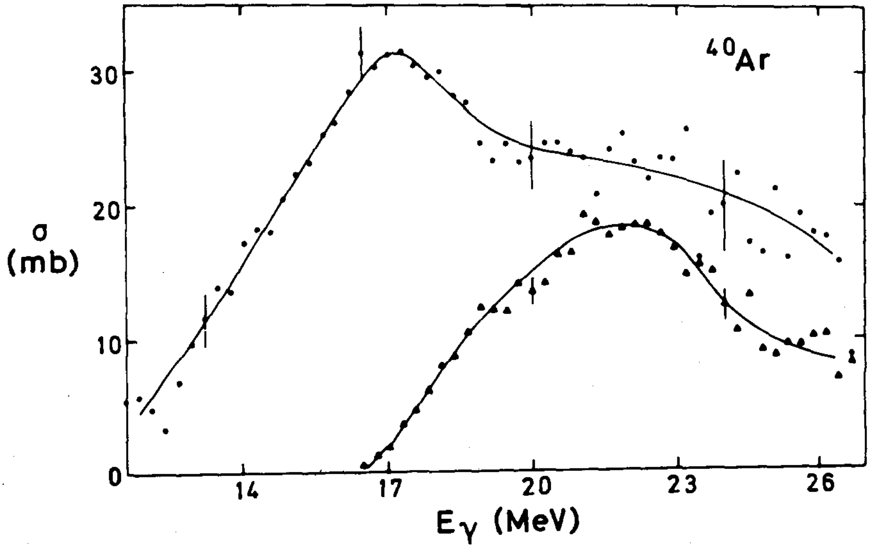
Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 525
R. Bergère et al.



Ref:
Nucl. Phys. A156 (1970) 74
D. W. Anderson et al.

Z	A	ABUND	G, N	G, P	G,2N	G,NP	G,2P
16	32	95.0	15.1	8.9	28.1	21.2	16.2
	34	4.2	11.4	10.9	20.1	21.0	20.4
	other	0.8					

ARGON

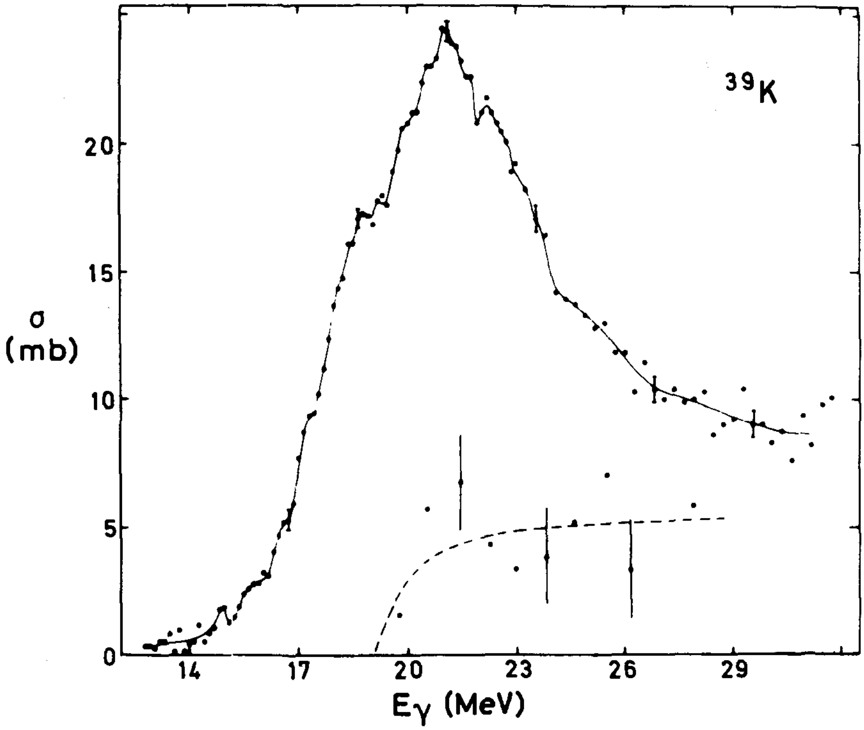


Top curve represents $\sigma(\gamma,n) + \sigma(\gamma,pn) + \sigma(\gamma,2n)$
Lower curve represents $\sigma(\gamma,2n)$

Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 525
R. Bergère et al.

Z	A	ABUND	G,N	G, P	G,2N	G,NP	G,2P
18	40	99.6	9.9	12.5	16.5	20.6	22.8
	other	0.4					

POTASSIUM



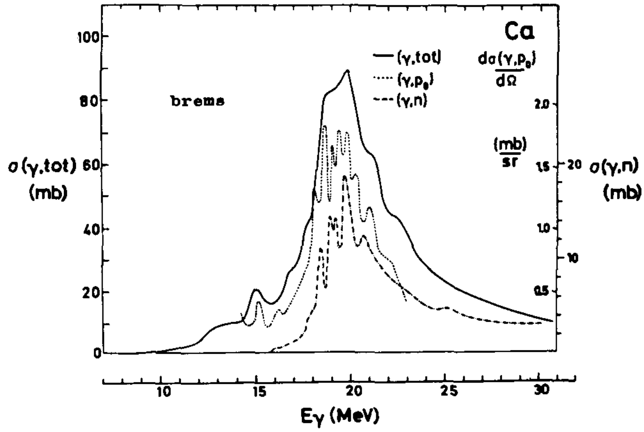
Top curve represents $\sigma(\gamma,n) + \sigma(\gamma,pn)$

Lower curve represents $\sigma(\gamma,2n)$

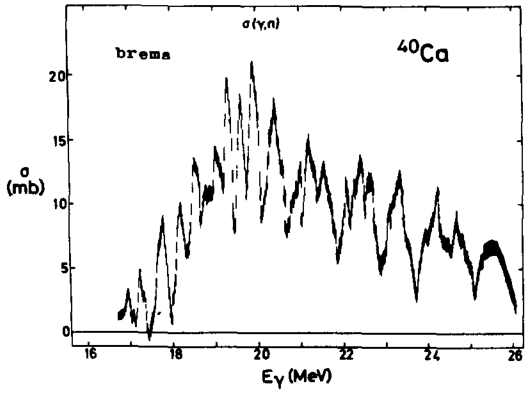
Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 525
R. Bergère et al.

Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
19	39	93.1	13.1	6.4	25.2	18.2	16.6
	41	6.9	10.1	7.8	17.9	17.7	20.3

CALCIUM



Ref: (γ,tot) Nucl. Phys. A117 (1968) 124, N. Bezić et al. (fig)
(γ,n) Nucl. Phys. 54 (1964) 549, J. E. E. Baglin et al.
(γ,p_o) Phys. Rev. 135 (1964) B365, J. C. Hafele

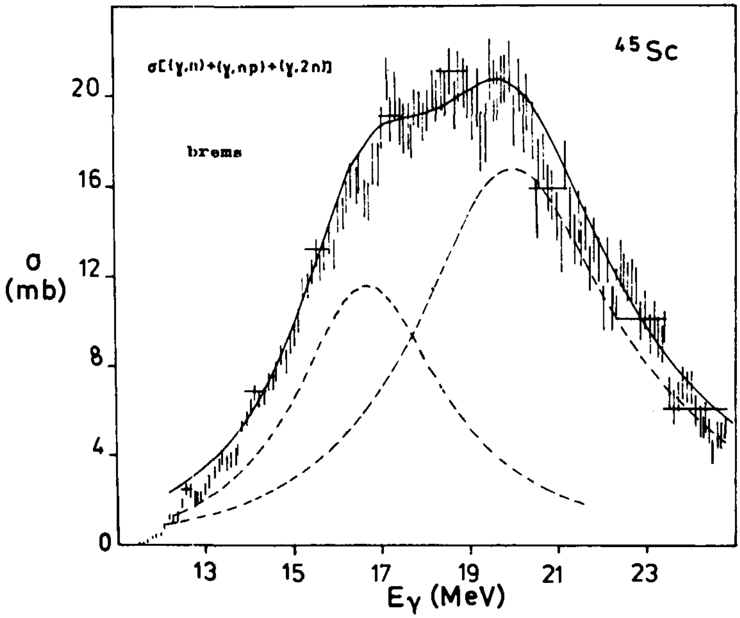


Ref: Sov. J. Nucl. Phys. 13 (1971) 655, B. S. Ishkhanov et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
20	40	97.0	15.6	8.3	29.0	21.4	14.7
	44	2.1	11.1	12.2	19.1	21.8	21.6
	other	0.9					

See total cross-sections for the nuclear photoeffect.

SCANDIUM

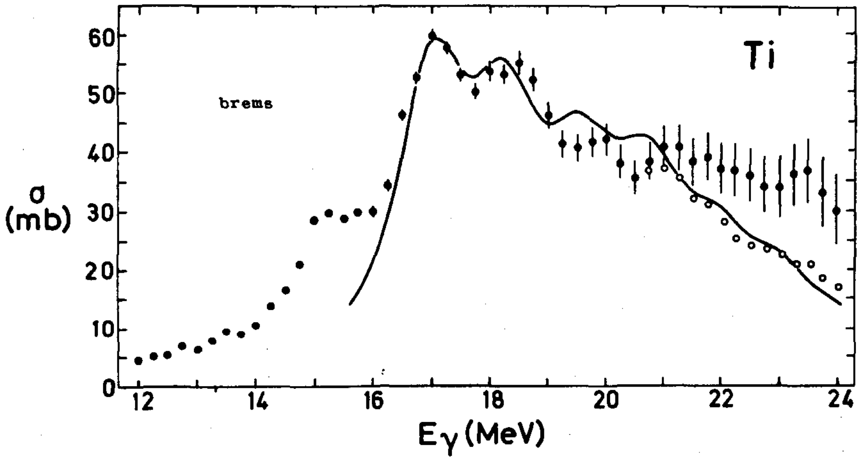


The smooth curve represents the Danos model fit which is the sum of the two dashed Lorentz curves.

Ref: Nucl. Phys. A205 (1973) 139
R. H. Sambell and B. M. Spicer

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
21	45	100.0	11.3	6.9	21.0	18.0	19.1

TITANIUM



$\sigma(\gamma,n) + 2\sigma(\gamma,2n) + \sigma(\gamma,np)$

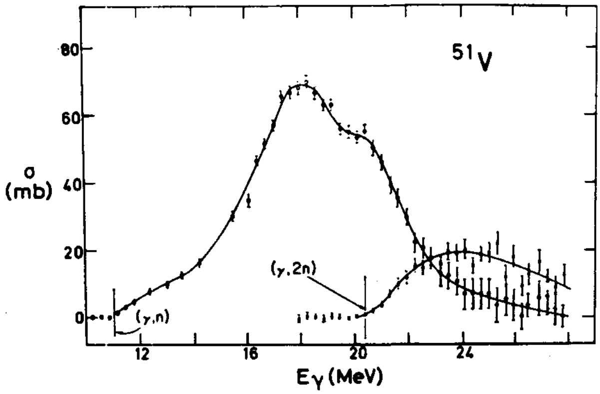
The solid curve is calculated.

Open circles represent the (γ,Tn) cross-section corrected for neutron multiplicity.

Ref: Nuovo Cimento 48B (1967) 460
S. Costa, F. Ferrero, C. Manfredotti, L. Pasqualini, G. Piragina and H. Arenhövel

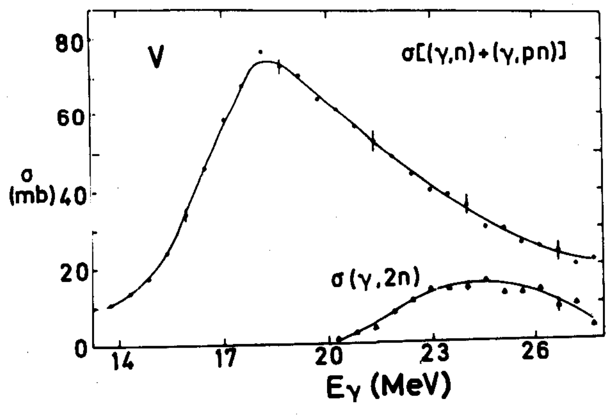
Z	A	ABUND	G, N	G, P	G,2N	G,NP	G,2P
22	46	8.0	13.2	10.4	22.7	21.7	17.2
	47	7.3	8.9	10.5	22.1	19.2	18.7
	48	73.9	11.6	11.4	20.5	22.1	19.9
	49	5.5	8.1	11.4	19.8	19.6	20.8
	50	5.3	10.9	12.2	19.1	22.3	21.8

VANADIUM



Top curve represents σ[(γ,n) + (γ,pn)]
Lower curve represents σ[(γ,2n)+3(γ,3n)]

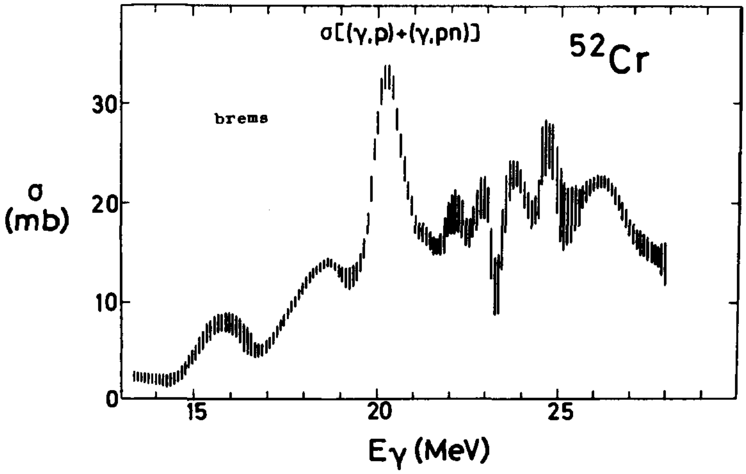
Ref: Phys. Rev. 128 (1962) 2345, S. C. Fultz et al.



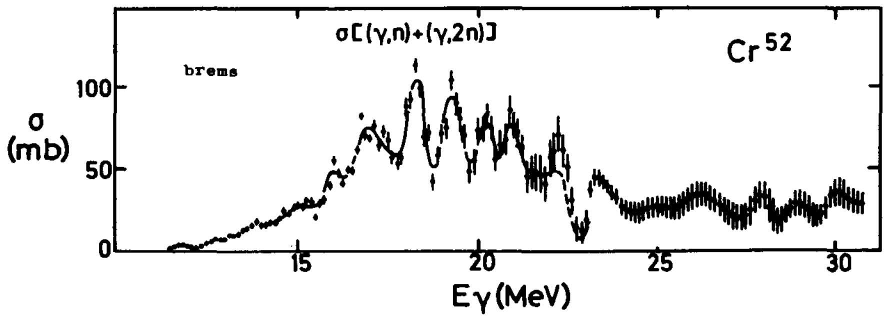
Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 525
R. Bergère et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
23	50	0.2	9.3	7.9	20.9	16.1	19.3
	51	99.8	11.1	8.1	20.4	19.0	20.2

CHROMIUM



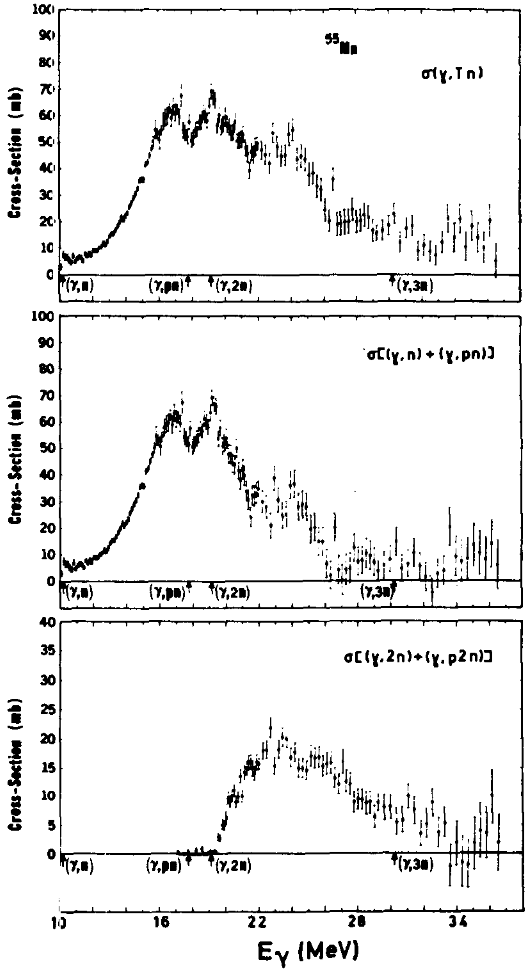
Ref: Sov. J. Nucl. Phys. 11 (1970) 272
B. S. Ishkhanov et al.



Ref: Bull. Acad. Sci. USSR-Phys. 33 (1969) 1588
B. I. Goryachev et al.

Z	A	ABUND	G, N	G, P	G,2N	G,NP	G,2P
24	50	4.3	12.9	9.6	23.6	21.1	16.3
	52	83.8	12.0	10.5	21.3	21.6	18.6
	53	9.5	7.9	11.1	20.0	18.4	20.1
	54	2.4	9.7	12.4	17.7	20.9	22.0

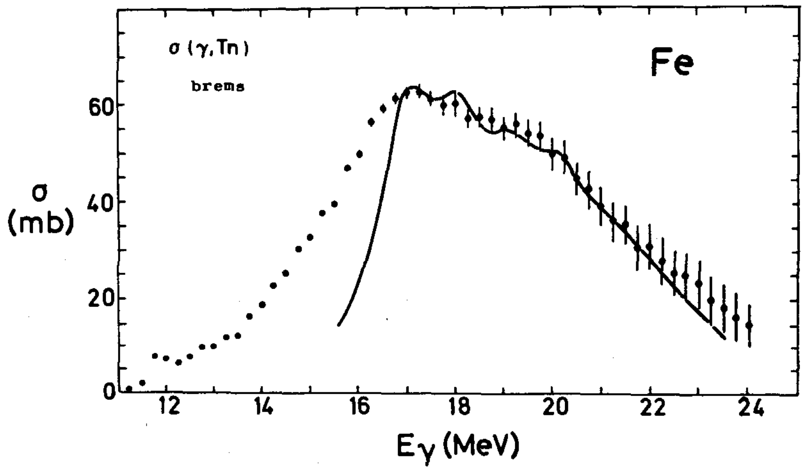
MANGANESE



Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 545
R. A. Alvarez et al.

Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
25	55	100.0	10.2	8.1	19.2	17.8	20.4

IRON

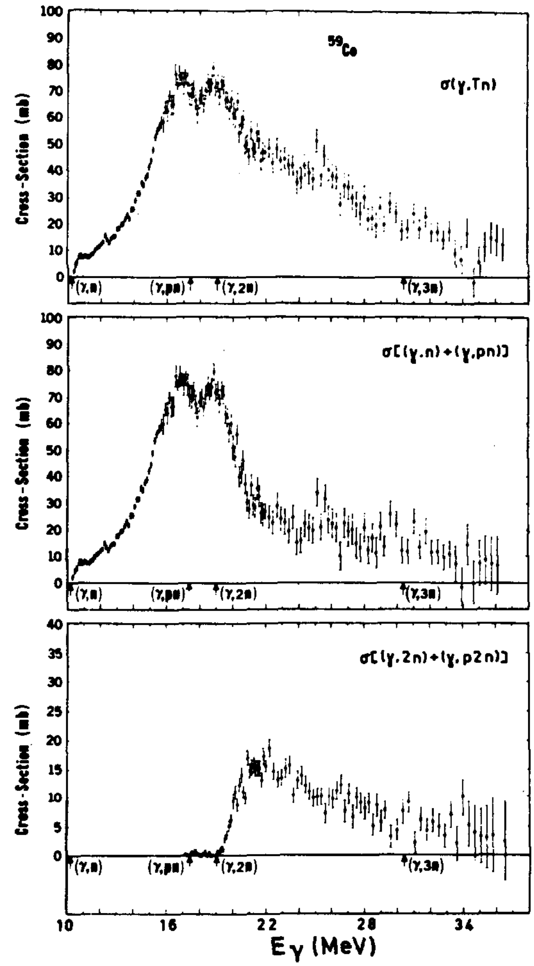


The solid curve is calculated.

Ref: Nuovo Cimento 51B (1967) 199
S. Costa, F. Ferrero, C. Manfredotti, L. Pasqualini, G. Piragino and H. Arenhövel

Z	A	ABUND	G, N	G, P	G,2N	G,NP	G,2P
26	54	5.8	13.4	8.9	24.1	20.9	15.4
	56	91.7	11.2	10.2	20.5	20.4	18.3
	57	2.2	7.6	10.6	18.8	17.8	19.6
	other	0.3					

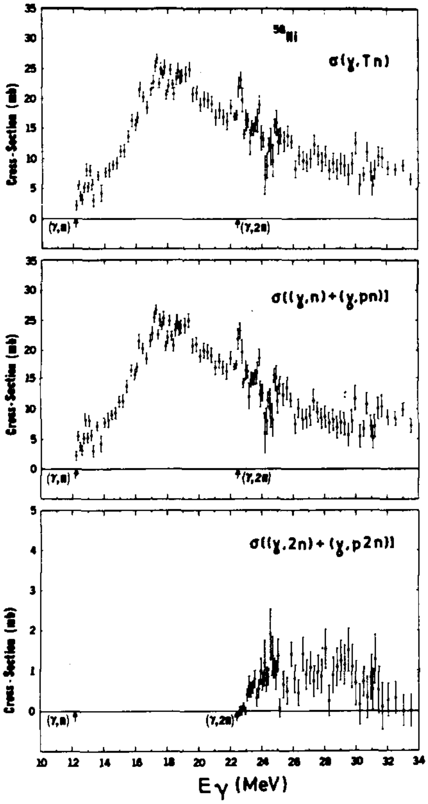
COBALT



Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 547
R. A. Alvarez et al.

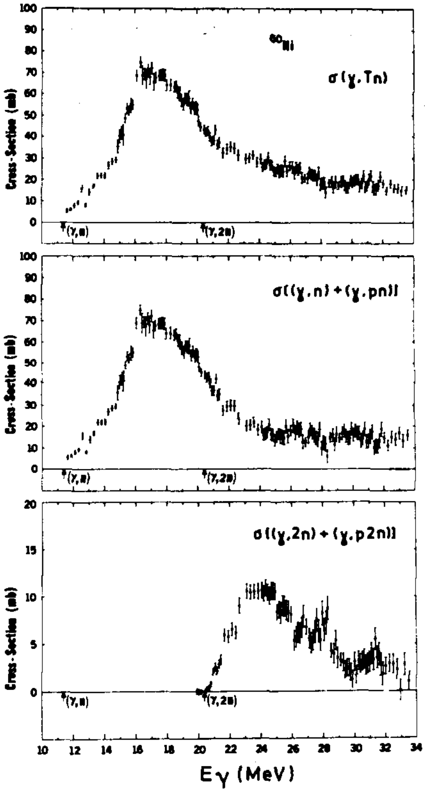
Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2p
27	59	100.0	10.5	7.4	19.0	17.4	19.2

NICKEL



Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 549

S. C. Fultz et al.

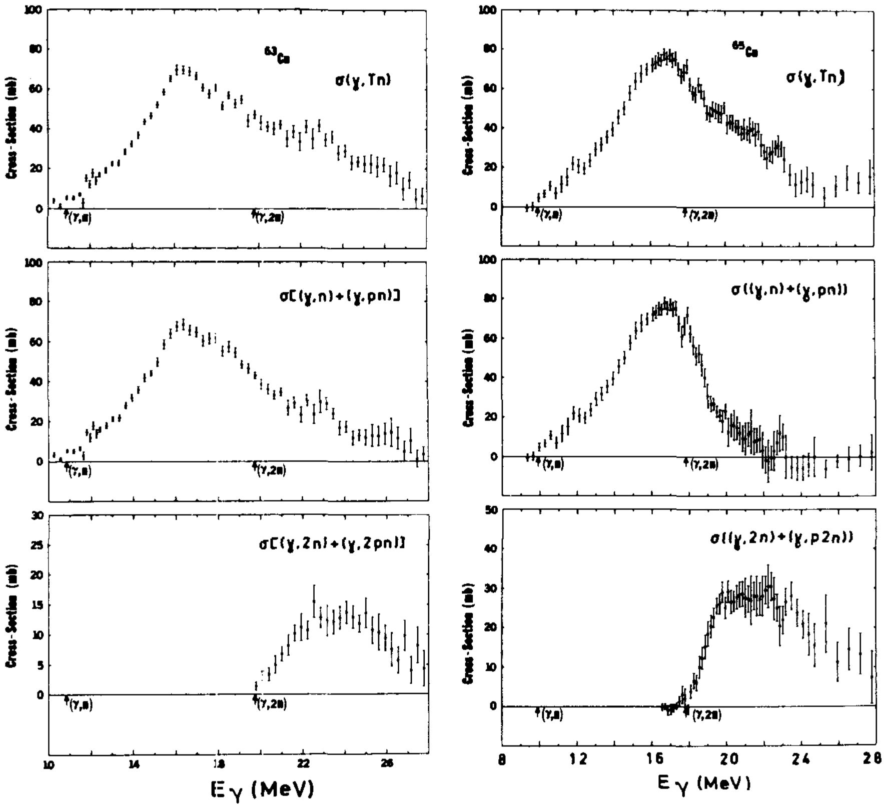


Ref: Proc. Int. Conf. Photonuclear Reactions and Applications (1973) Asilomar, page 551

S. C. Fultz et al.

Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
28	58	67.9	12.2	8.2	22.5	19.6	14.2
	60	26.2	11.4	9.5	20.4	20.0	16.9
	61	1.2	7.8	9.9	19.2	17.4	18.1
	62	3.6	10.6	11.1	18.4	20.5	19.9
	64	1.1	9.7	12.5	16.5	20.9	—

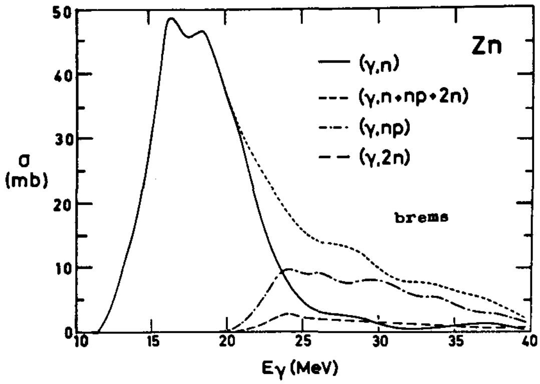
COPPER



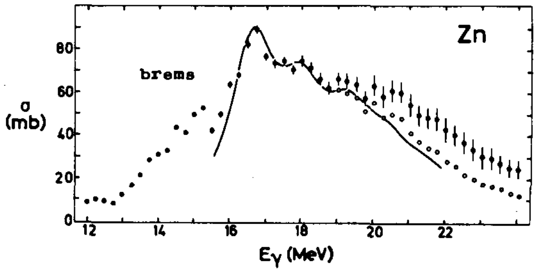
Ref: Phys. Rev. 133 (1964) B1149, S. C. Fultz et al.

Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
29	63	69.1	10.9	6.1	19.7	16.7	17.2
	65	30.9	9.9	7.4	17.8	17.1	20.0

ZINC



Ref: Phys. Rev. Lett. 25 (1970) 685, B. C. Cook et al.



σ[(γ,n) + 2(γ,2n) + (γ,np)]

Solid curve is calculated

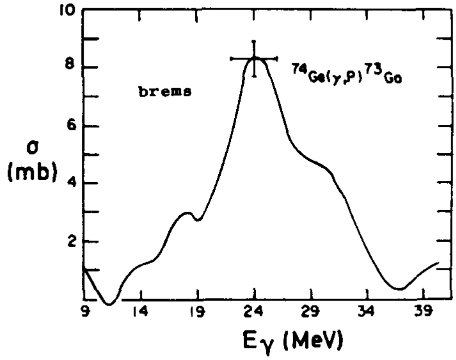
Open circles give the (γ,Tn) cross-section corrected for neutron multiplicity

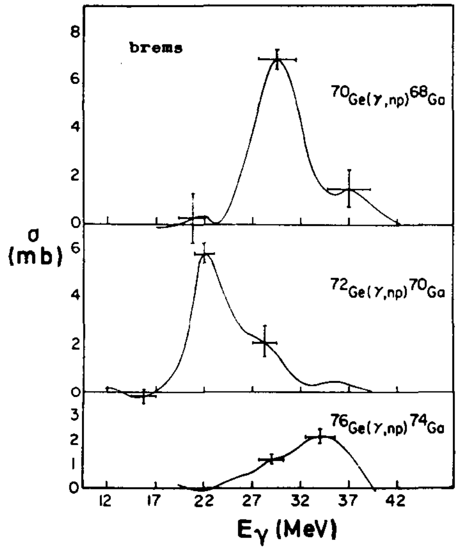
Ref: Nuovo Cimento 48B (1967) 460, S. Costa et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
30	64	48.9	11.9	7.7	21.0	18.6	13.8
	66	27.8	11.1	8.9	19.0	18.8	16.4
	67	4.1	7.1	8.9	18.1	16.0	17.3
	68	18.6	10.2	10.0	17.3	19.1	18.5
	other	0.6					

For (γ,p) see Nucl. Phys. A213 (1973) 388, G. E. Clark et al.

GERMANIUM

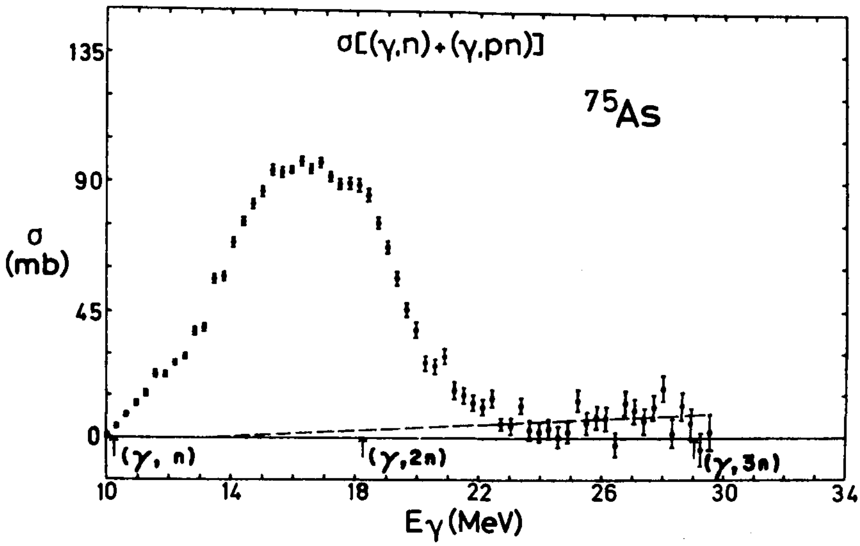




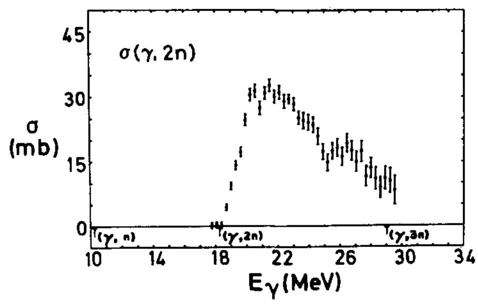
Ref: Nucl. Phys. A213 (1973) 371, J. J. McCarthy et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
32	70	20.5	11.5	8.5	20.0	18.8	15.1
	72	27.4	10.7	9.7	18.2	19.0	17.6
	73	7.8	6.8	10.0	17.5	16.5	18.5
	74	36.5	10.2	11.0	17.0	20.2	19.9
	76	7.8	9.4	12.0	15.9	20.7	–

ARSENIC



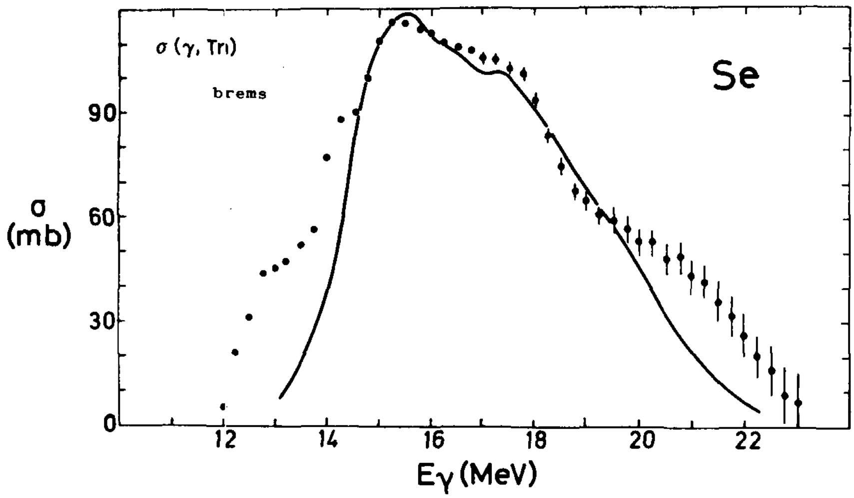
Dashed curve: estimated maximum systematic error owing to bremsstrahlung normalization.



Ref: Phys. Rev. 177 (1969) 1745
B. L. Berman, R. L. Bramblett, J. T. Caldwell, H. S. Davis, M. A. Kelly and S. C. Fultz

Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
33	75	100.0	10.2	6.9	18.2	17.1	17.9

SELENIUM

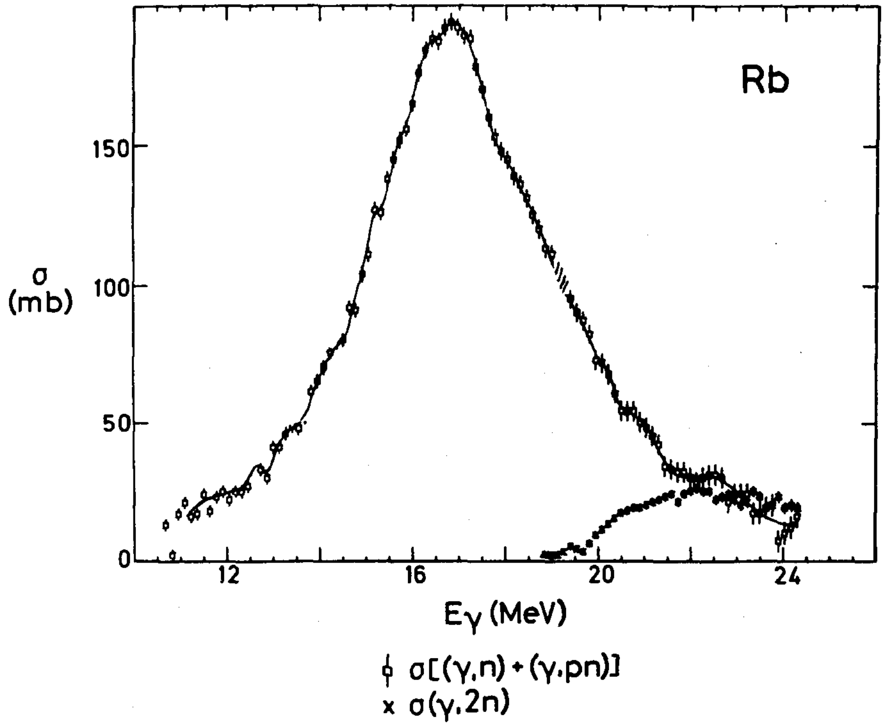


The solid curve is calculated.

Ref: Nuovo Cimento 51B (1967) 199
S. Costa, F. Ferrero, C. Manfredotti, L. Pasqualini, G. Piragino and H. Arenhövel

Z	A	ABUND	G, N	G, P	G,2N	G,NP	G,2P
34	76	9.0	11.1	9.5	19.2	19.8	16.4
	77	7.6	7.4	9.6	18.6	16.9	17.3
	78	23.5	10.5	10.4	17.9	20.1	18.4
	80	49.8	9.9	11.4	16.9	20.4	20.6
	82	9.2	9.3	12.3	16.0	21.2	-
	other	0.9					

RUBIDIUM

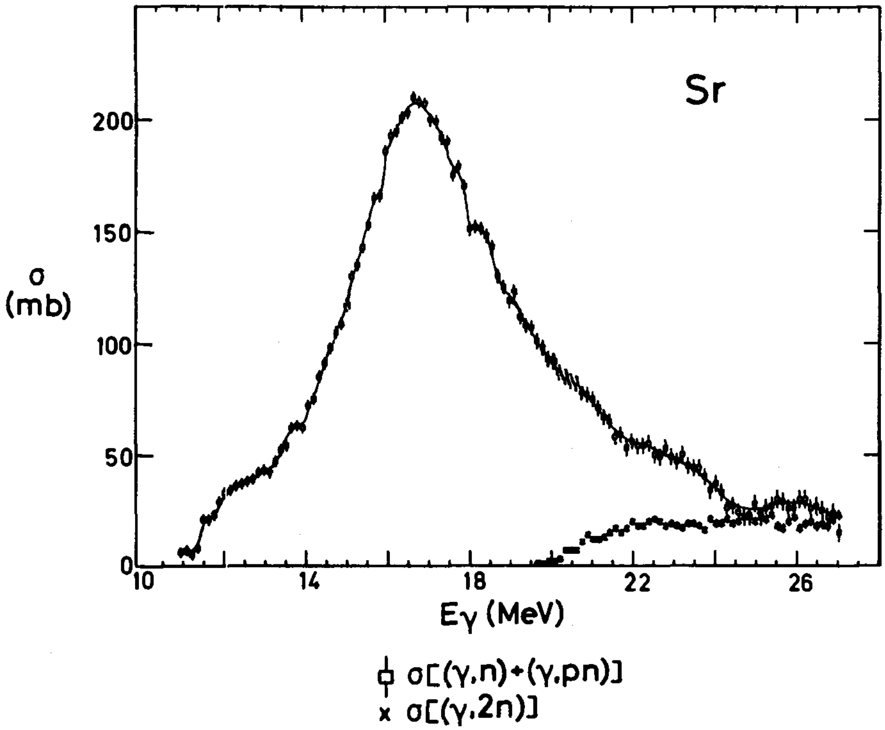


See compilation for giant dipole resonance in A ≈ 90 nuclei.

Ref: Nucl. Phys. A175 (1971) 609
A. Leprêtre, H. Beil, R. Bergère, P. Carlos, A. Veyssière and M. Sugawara

Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
37	85	72.2	10.5	7.0	19.4-	17.5	17.7
	87	27.8	9.9	8.6	18.6	18.5	20.5

STRONTIUM

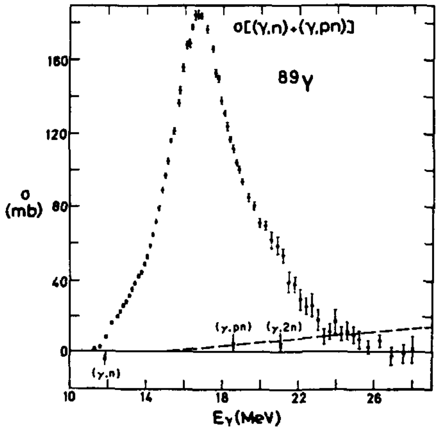


See compilation for giant dipole resonance in A ~ 90 nuclei.

Ref: Nucl. Phys. 175 (1971) 609
A. Leprêtre, H. Beil, R. Bergère, P. Carlos,
A. Veyssière and M. Sugawara

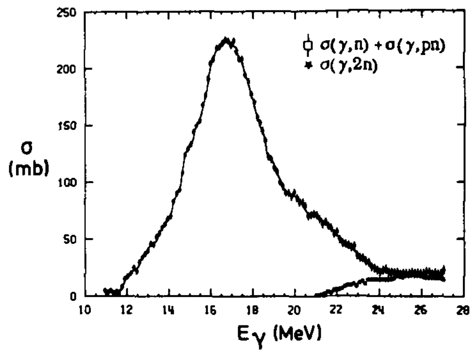
Z	A	ABUND	G, N	G, P	G,2N	G,NP	G,2P
38	86	9.9	11.5	9.6	20.0	20.1	16.6
	87	7.0	8.4	9.4	19.9	18.1	18.0
	88	82.6	11.1	10.6	19.5	20.5	19.2
	other	0.5					

YTTRIUM



Dashed curve: estimated maximum systematic error owing to bremsstrahlung normalization.

Ref: Phys. Rev. 162 (1967) 1098
B. L. Berman et al.

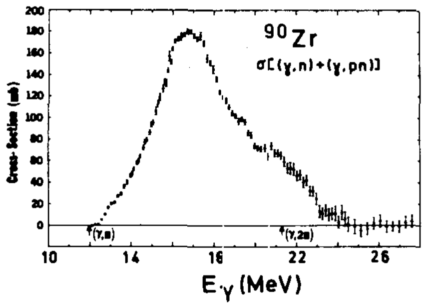


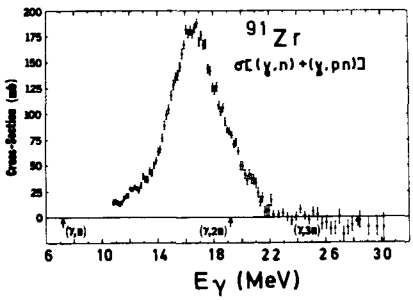
Ref: Nucl. Phys. 175 (1971) 609, A. Leprêtre et al.

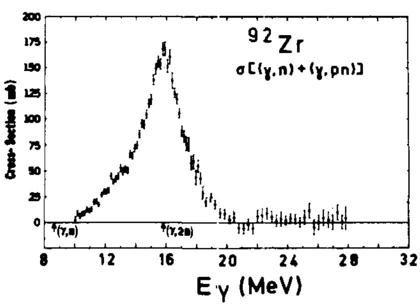
Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
39	89	100.0	11.5	7.1	20.8	18.2	17.7

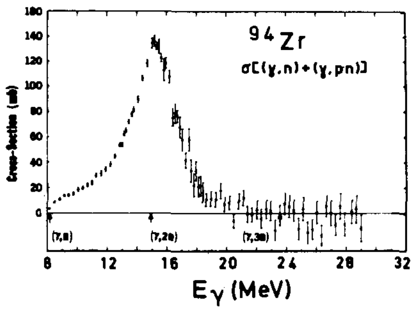
See compilation for giant dipole resonance in A ≈ 90 nuclei.

ZIRCONIUM







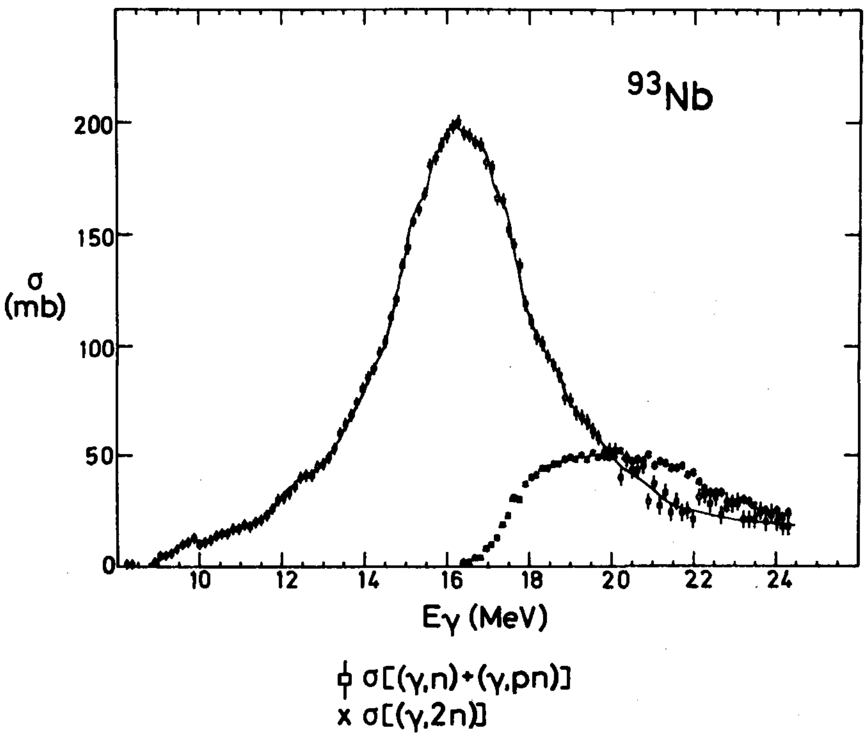


Ref: Phys. Rev. 162 (1967) 1098, B. L. Berman et al.

Z	A	ABUND	G, N	G,P	G,2N	G,NP	G,2P
40	90	51.5	12.0	8.4	21.3	19.8	15.4
	91	11.2	7.2	8.7	19.2	15.6	16.3
	92	17.1	8.6	9.4	15.8	17.3	17.1
	94	17.4	8.2	10.3	14.9	17.8	18.9
	96	2.8	7.8	11.5	14.3	18.5	21.2

See compilation for giant dipole resonance in A = 90 nuclei.

NIOBIUM

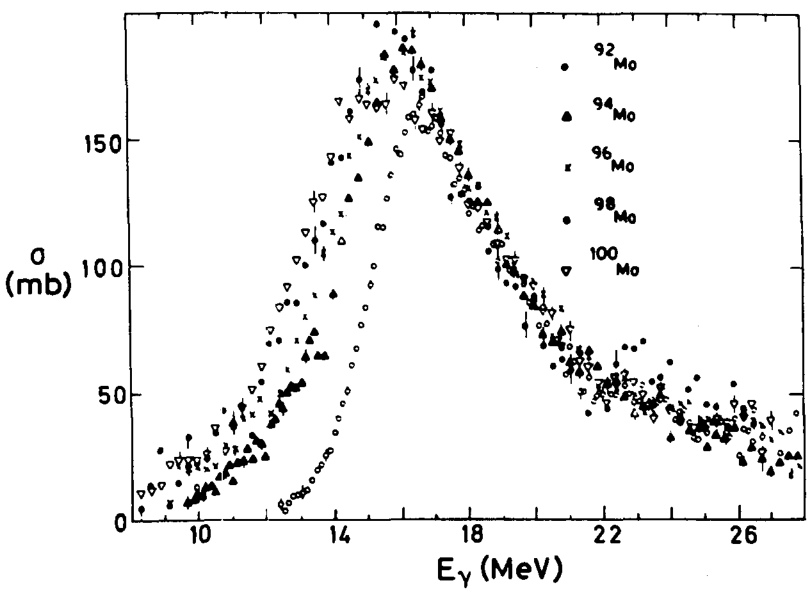


Ref: Nucl. Phys. 175 (1971) 609
A. Leprêtre, H. Beil, R Bergère, P. Carlos, A. Veyssière and M. Sugawara

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
41	93	100.0	8.8	6.0	16.7	14.7	15.4

See compilation for giant dipole resonance in A ≈ 90 nuclei.

MOLYBDENUM



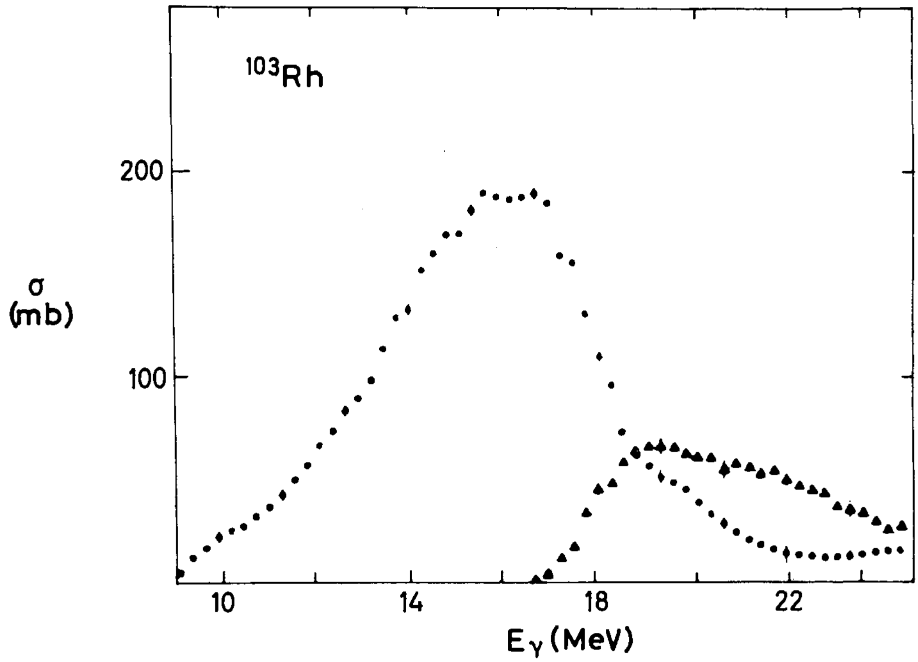
Experimental total photoneutron cross-section

σ[(γ,n) + (γ,pn) + (γ,2n)] for Mo isotopes

Ref: Nucl. Phys. A129 (1974) 61, P. Carlos et al.

Z	A	ABUND	G.N	G,P	G,2N	G,NP	G,2P
42	92	15.8	12.7	7.5	22.8	19.5	12.6
	94	9.1	9.7	8.5	17.7	17.3	14.5
	95	15.7	7.4	8.6	17.0	15.9	15.1
	96	16.5	9.2	9.3	16.5	17.8	16.1
	97	9.5	6.8	9.2	16.0	16.1	16.5
	98	23.8	8.6	9.8	15.5	17.9	17.3
	100	9.6	8.3	10.6	14.2	18.0	19.5

RHODIUM



Top curve represents $\sigma[(\gamma,n) + (\gamma,pn)]$

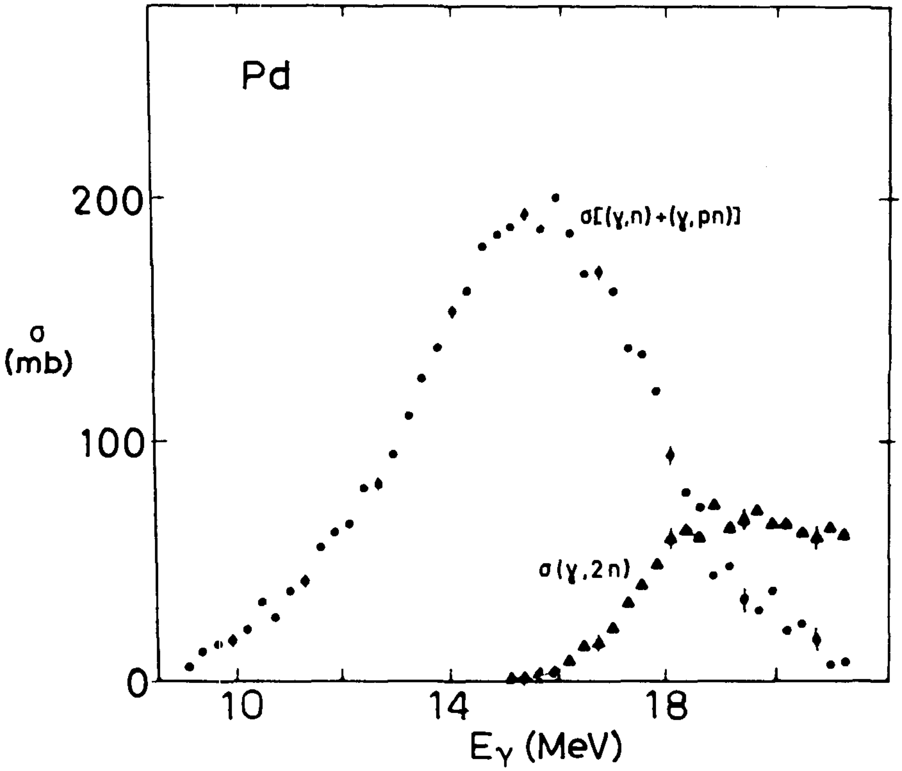
Lower curve represents $\sigma(\gamma,2n)$

Ref: Nucl. Phys. A219 (1974) 39
A. Leprêtre et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
45	103	100.0	9.3	6.2	16.8	15.4	16.3

See giant dipole resonance in 103 ≤ A ≤ 133 nuclei.

PALLADIUM

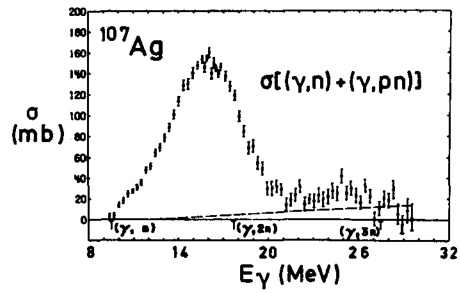


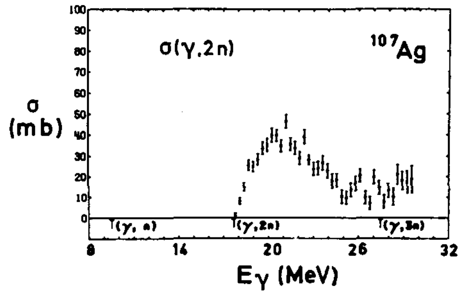
Ref: Nucl. Phys. A219 (1974) 39, A. Leprêtre et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
46	102	1.0	10.6	7.8	18.9	17.7	13.3
	104	11.0	10.0	8.7	17.6	18.0	14.9
	105	22.2	7.1	8.8	17.1	15.8	15.7
	106	27.3	9.6	9.3	16.6	18.3	16.4
	108	26.7	9.2	10.0	15.8	18.5	17.8
	110	11.8	8.8	10.5	15.0	18.7	19.2

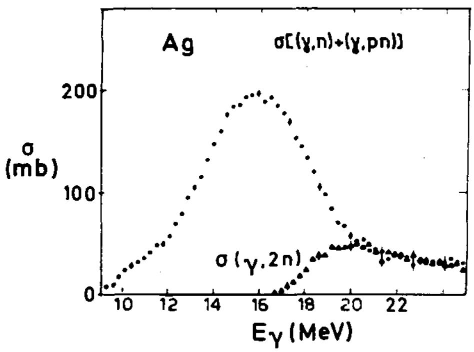
See giant dipole resonance in 103 ≤ A ≤ 133 nuclei.

SILVER

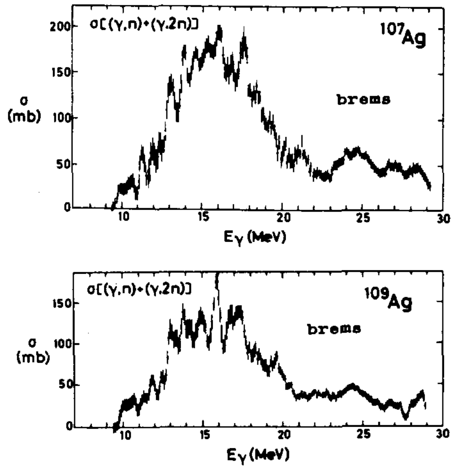




Ref: Phys. Rev. 177 (1969) 1745, B.L. Berman et al.



Ref: Nucl. Phys. A219 (1974) 39
A. Leprêtre et al.

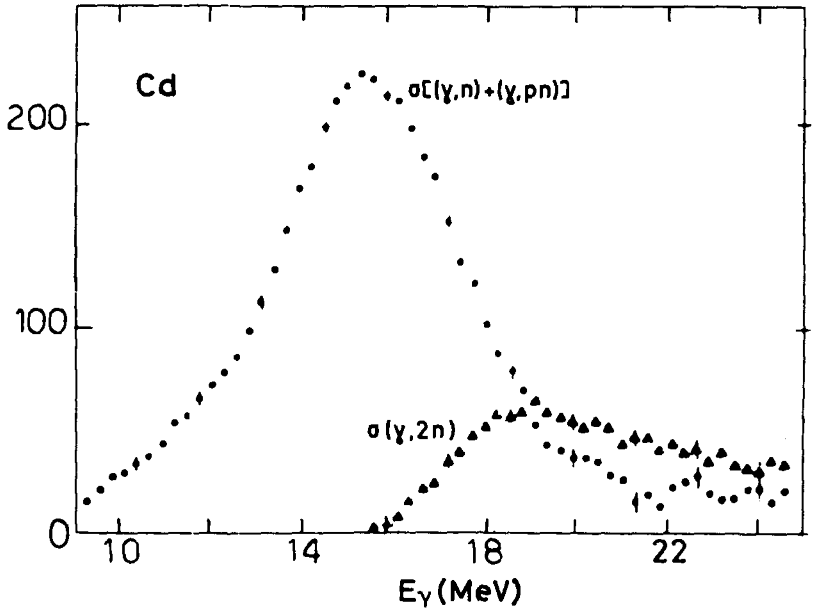


Ref: Bull. Acad. Sci. USSR 33 (1969) 1889
B. S. Ishkhanov et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
47	107	51.4	9.6	5.8	17.5	15.4	15.1
	109	48.6	9.2	6.5	16.5	15.7	16.4

See giant dipole resonance in $103 \leq A \leq 133$ nuclei.

CADMIUM

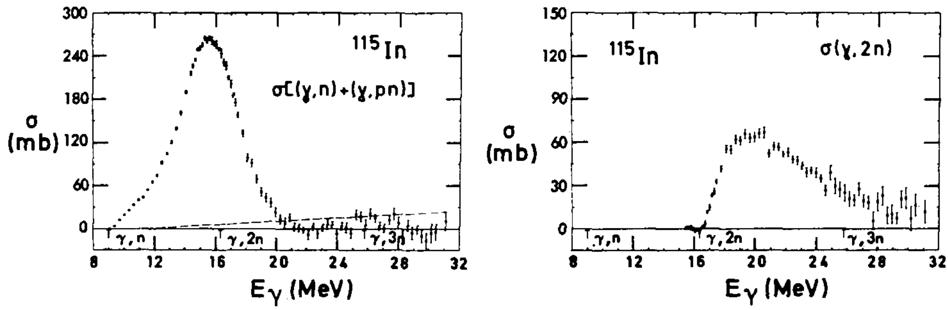


Ref: Nucl. Phys. A219 (1974) 39, A. Leprêtre et al.

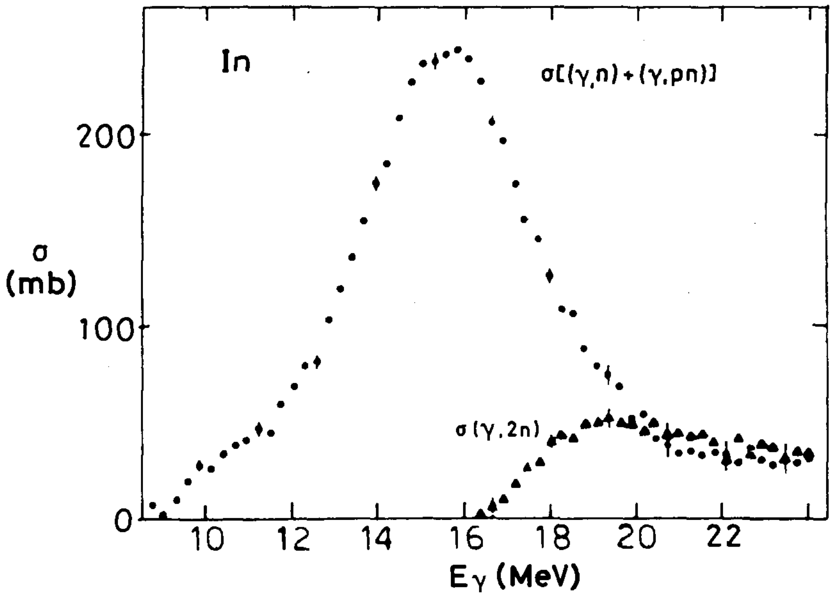
Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
48	110	12.4	9.9	8.9	17.2	18.1	15.4
	111	12.8	7.0	9.1	16.9	15.9	16.2
	112	24.1	9.4	9.6	16.4	18.5	16.8
	113	12.3	6.5	9.8	15.9	16.2	17.6
	114	28.9	9.0	10.3	15.6	18.8	18.3
	116	7.6	8.7	11.1	14.8	19.1	—
	other	1.9					

See giant dipole resonance in $103 \le A \le 133$ nuclei.

INDIUM



Ref: Phys. Rev. 186 (1969) 1255, S.C. Fultz et al.

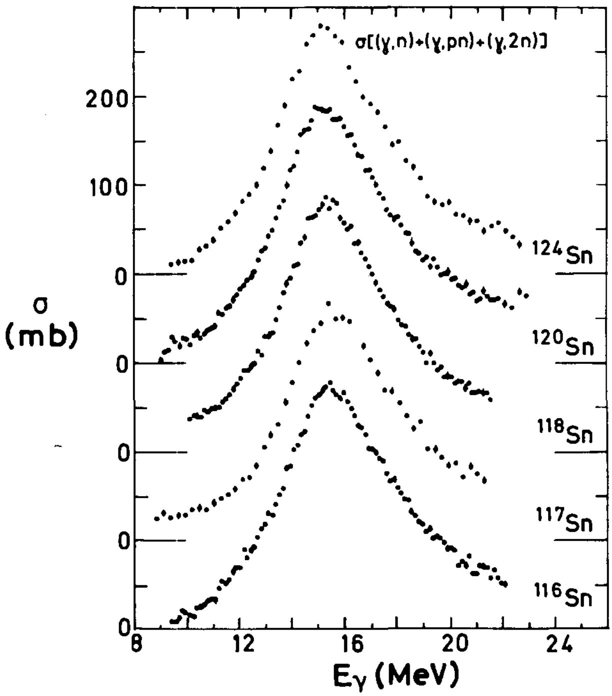


Ref: Nucl. Phys. A219 (1974) 39, A. Leprêtre et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
49	113	4.3	9.4	6.1	17.1	15.5	15.7
	115	95.7	9.0	6.8	16.3	15.9	17.1

See giant dipole resonance in 103 ≤ A ≤ 133 nuclei.

TIN

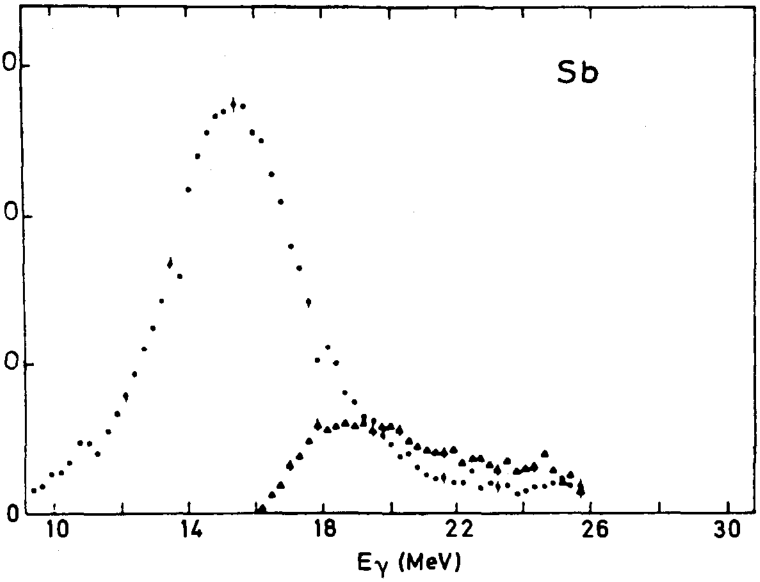


Ref: Nucl. Phys. A219 (1974) 61, P. Carlos et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
50	112	1.0	10.8	7.5	19.0	17.6	12.9
	116	14.3	9.6	9.3	17.1	18.3	16.1
	117	7.6	6.9	9.4	16.5	16.2	16.9
	118	24.0	9.3	10.0	16.3	18.8	17.5
	119	8.6	6.5	9.9	15.8	16.5	18.2
	120	32.9	9.1	10.7	15.6	19.0	19.0
	122	4.7	8.8	11.4	15.0	19.8	-
	124	5.9	8.5	12.1	14.4	20.4	-
	other	1.0					

See also: Phys. Rev. 186 (1969) 1255, S.C. Fultz et al.

ANTIMONY



Top curve represents σ[(γ,n) + (γ,pn)]

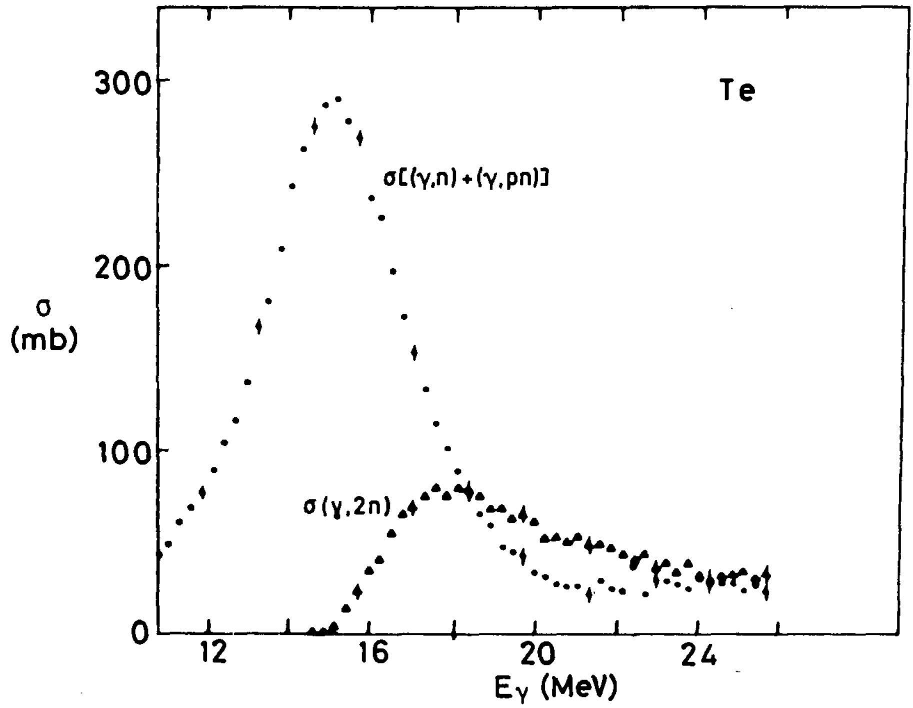
Lower curve represents σ(γ,2n)

Ref: Nucl. Phys. A219 (1974) 39, A. Leprêtre et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
51	121	57.2	9.2	5.8	16.3	14.9	16.5
	123	42.8	9.0	6.6	15.8	15.4	18.0

See giant dipole resonance in 103 ≤ A ≤ 133 nuclei.

TELLURIUM

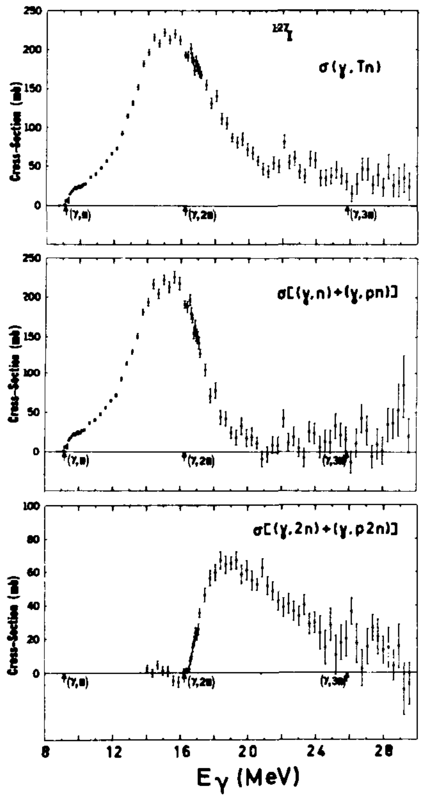


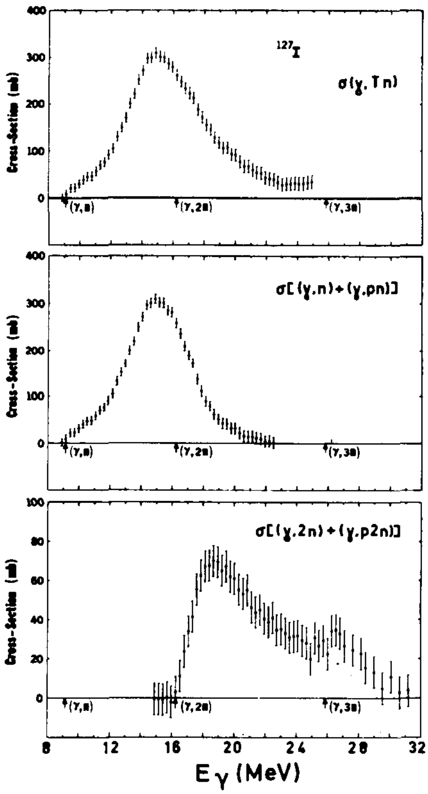
Ref: Nucl. Phys. A219 (1974) 39, A. Leprêtre et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
52	122	2.5	9.8	8.0	17.0	17.3	13.8
	124	4.6	9.4	8.6	16.4	17.5	15.2
	125	7.0	6.6	8.7	16.0	15.2	15.8
	126	18.7	9.1	9.1	15.7	17.8	16.4
	128	31.8	8.8	9.6	15.1	18.0	17.6
	130	34.5	8.4	10.0	14.5	18.0	18.5
	other	0.9					

See giant dipole resonance in 103 ≤ A ≤ 133 nuclei.

IODINE



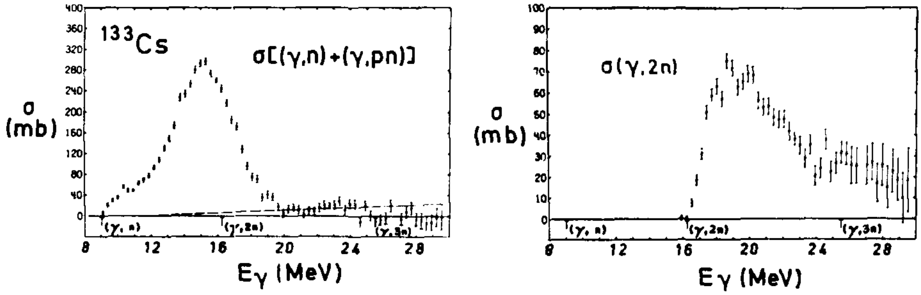


Ref: Phys. Rev. 148 (1966) 1198
R. L. Bramblett et al.

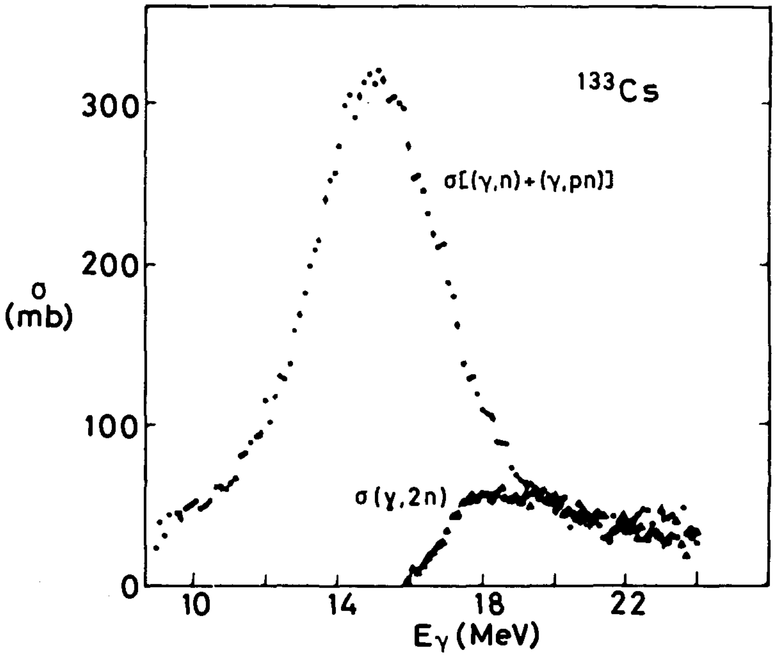
Ref: Nucl. Phys. A133 (1969) 417
R. Bergère et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
53	127	100.0	9.1	6.2	16.2	15.3	15.3

CAESIUM



Ref: Phys. Rev. 177 (1969) 1745, B.L. Berman et al.

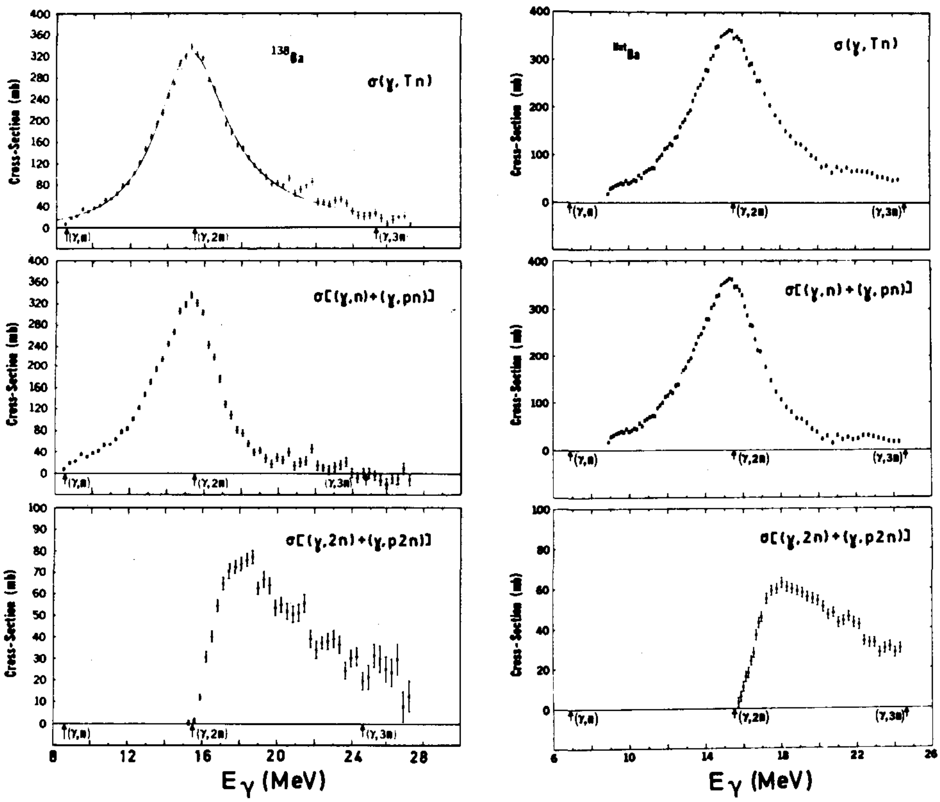


Ref: Nucl. Phys. A219 (1974) 39, A. Leprêtre et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
55	133	100.0	9.0	6.1	16.2	15.0	15.2

See giant dipole resonance in $103 \leq A \leq 133$ nuclei.

BARIUM



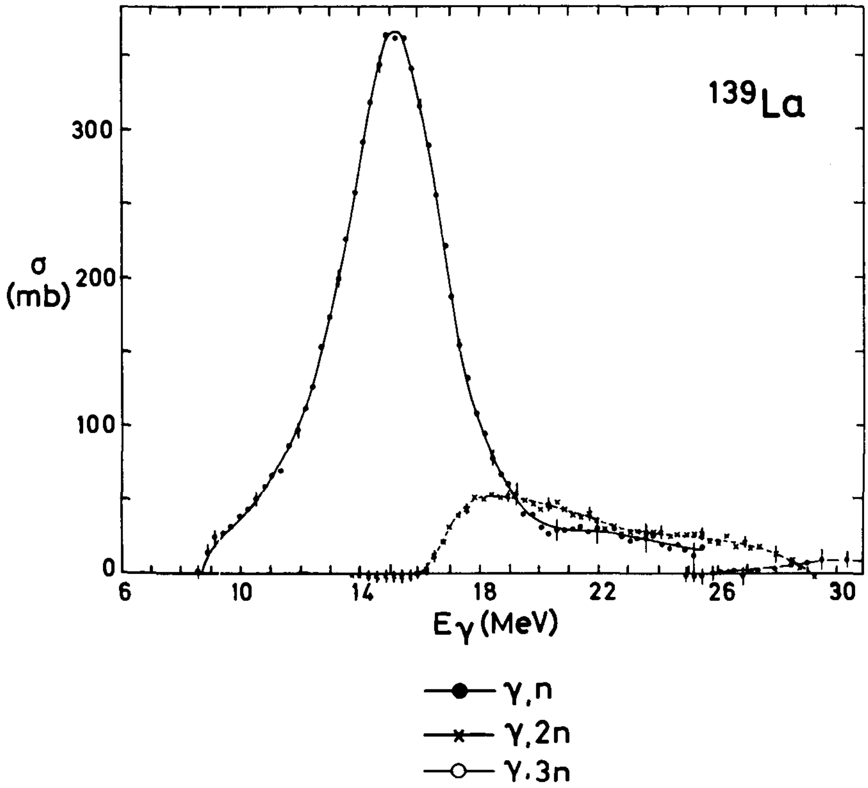
Ref: Phys. Rev. C2 (1970) 2318
B. L. Berman et al.

Ref: Nucl. Phys. A172 (1971) 426
H. Beil et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2p
56	134	2.4	9.5	8.2	16.7	17.1	14.3
	135	6.6	7.0	8.3	16.4	15.1	14.8
	136	7.8	9.1	8.5	16.1	17.4	15.4
	137	11.3	6.9	8.7	16.0	15.4	15.8
	138	71.7	8.6	9.0	15.5	17.3	16.4
	other	0.2					

See compilation for giant dipole resonance in N = 82 nuclei.

LANTHANUM

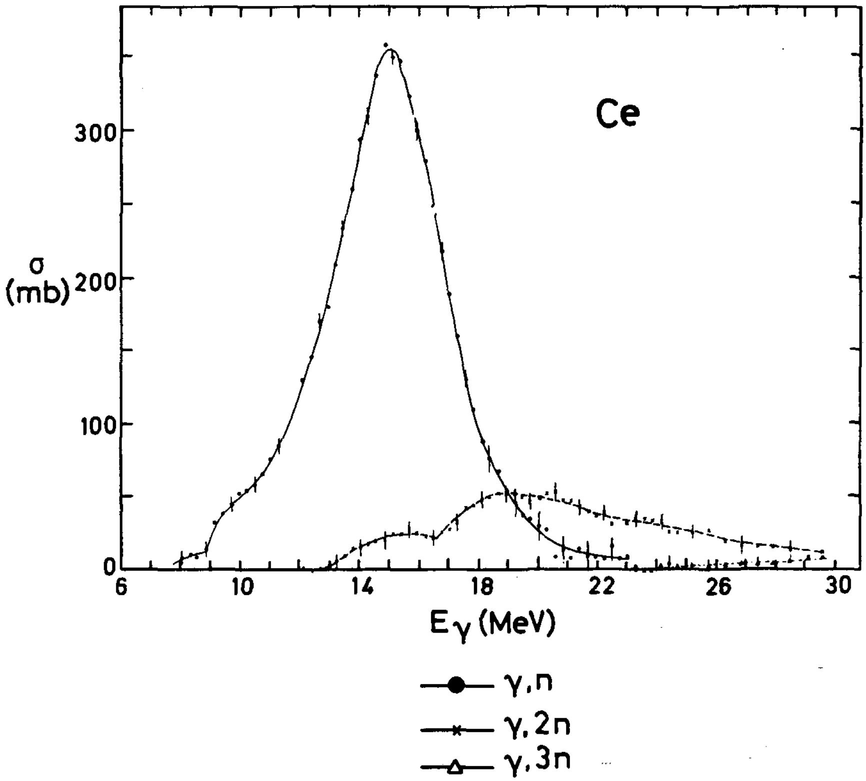


Ref: Nucl. Phys. A121 (1968) 463
R. Bergère, H. Beil and A. Veyssière

See compilation for giant dipole resonance in N = 82 nuclei.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
57	139	99.9	8.8	6.2	16.1	14.8	15.2
	other	0.1					

CERIUM

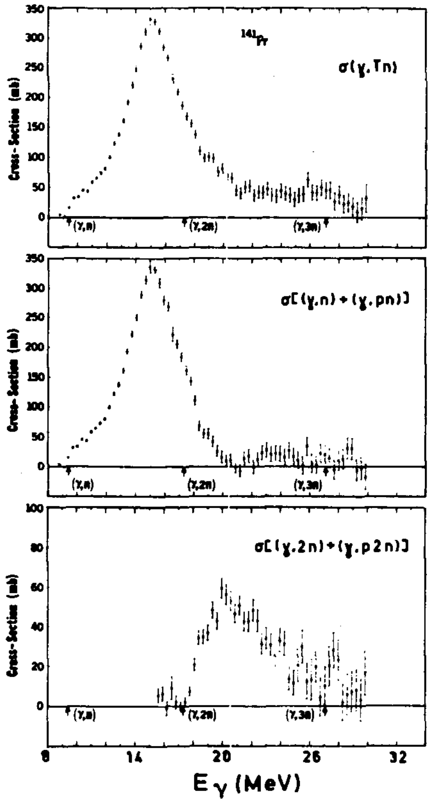


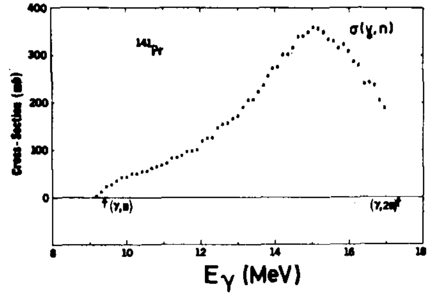
Ref: Nucl. Phys. A133 (1969) 417
R. Bergère, H. Beil, P. Carlos and A. Veyssière

See compilation for giant dipole resonance in N = 82 nuclei.

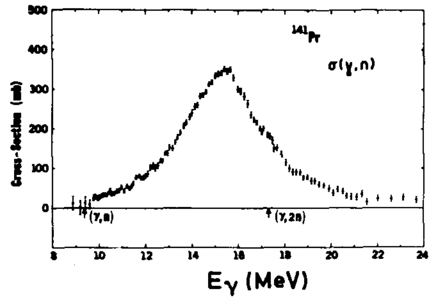
Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
58	140	88.5	9.2	8.1	16.7	16.9	14.3
	142	11.1	7.2	8.8	12.6	15.6	15.8
	other	0.4					

PRASEODYMIUM





Ref: Nucl. Phys. A172 (1971) 426
H. Beil et al.



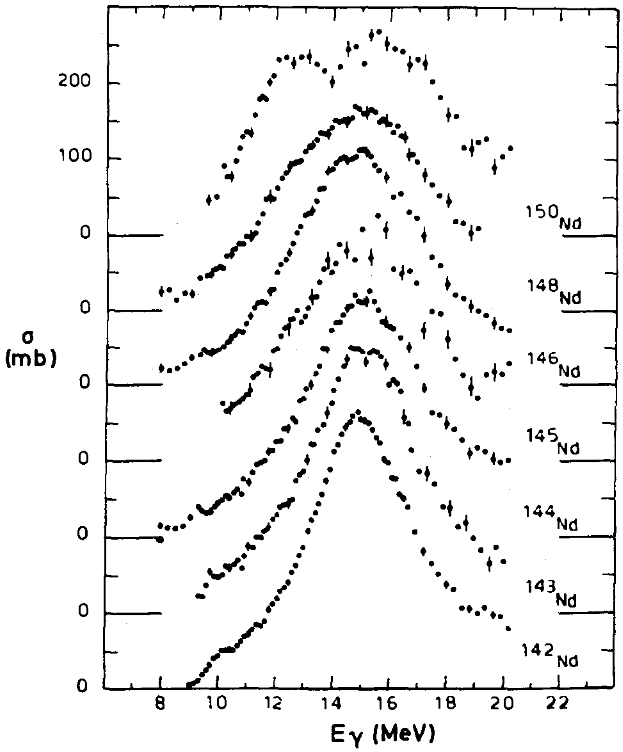
Ref: Phys. Rev. 148 (1966) 1198
R. L. Bramblett et al.

Ref: Phys. Rev. C2 (1970) 1129
R. E. Sund et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
59	141	100.0	9.4	5.2	17.3	14.4	13.3

See compilation for giant dipole resonance in N = 82 nuclei.

NEODYMIUM



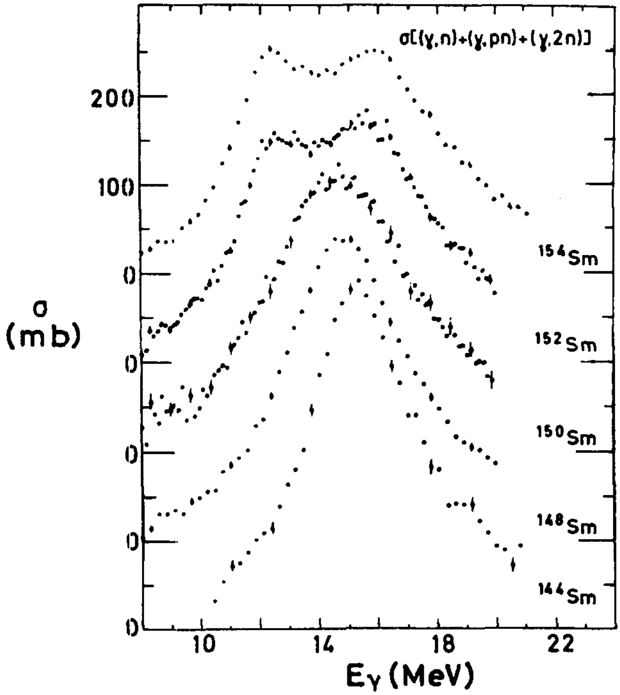
$\sigma[(\gamma,n) + (\gamma,pn) + (\gamma,2n)]$

Ref: Nucl. Phys. A219 (1974) 61, P. Carlos et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
60	142	27.1	9.8	7.2	17.9	16.6	12.5
	143	12.2	6.1	7.5	15.9	13.4	13.1
	144	23.9	7.8	8.0	13.9	15.3	13.8
	145	8.3	5.7	8.0	13.6	13.7	14.4
	146	17.2	7.6	8.6	13.3	15.5	15.1
	148	5.7	7.3	9.2	12.6	15.9	16.2
	150	5.6	7.4	9.6	12.4	16.5	17.6

See compilation for giant dipole resonance in N = 82 nuclei.

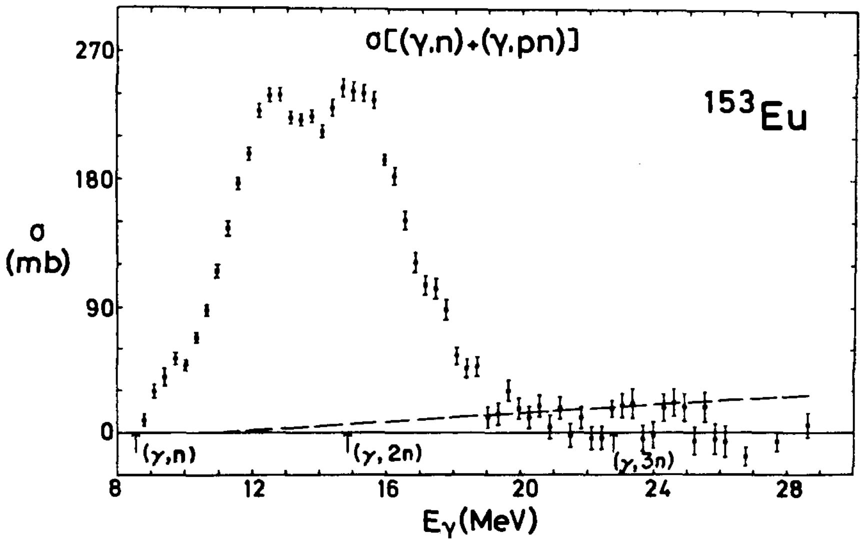
SAMARIUM



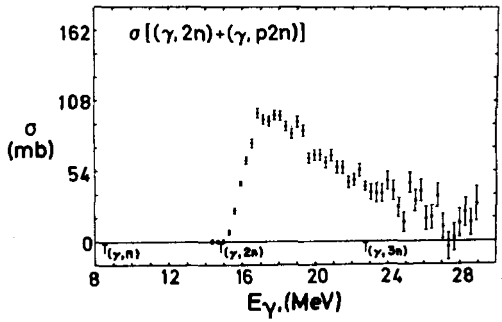
Ref: Nucl. Phys. <u>A219</u> (1974) 61, P. Carlos et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
62	144	3.1	10.6	6.3	19.0	16.2	10.6
	147	15.0	6.4	7.1	14.8	13.4	12.4
	148	11.3	8.1	7.6	14.5	15.3	13.0
	149	13.8	5.9	7.6	14.0	13.5	13.6
	150	7.4	8.0	8.3	13.9	15.5	14.2
	152	26.7	8.3	8.7	13.9	16.6	15.7
	154	22.7	8.0	9.0	13.8	16.5	16.9

EUROPIUM



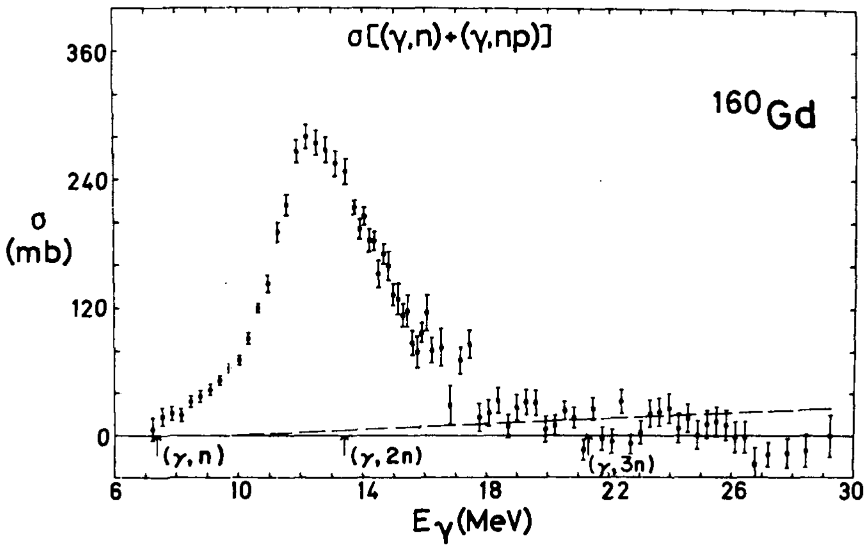
Dashed curve: estimated maximum systematic error owing to bremsstrahlung normalization.



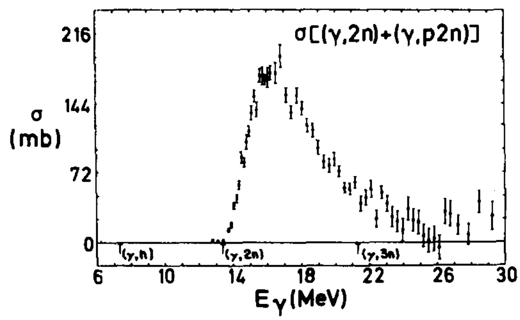
Ref: Phys. Rev. 185 (1969) 1576, B. L. Berman et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
63	151	47.8	8.0	4.9	14.4	12.9	13.2
	153	52.2	8.6	5.9	14.9	14.2	14.6

GADOLINIUM



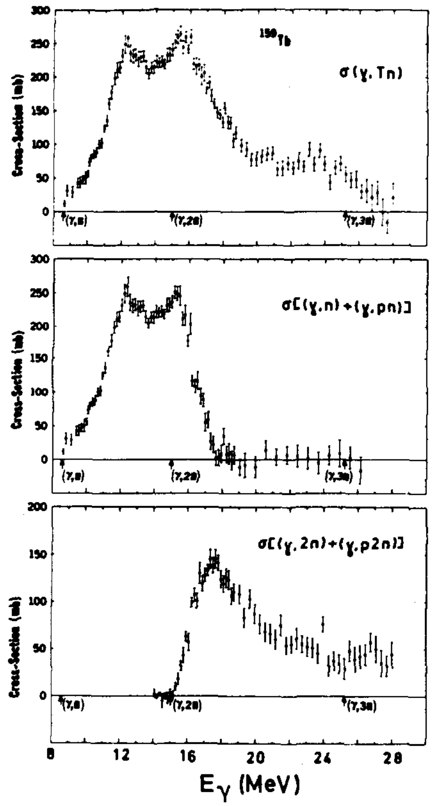
Dashed curve: estimated maximum systematic error owing to bremsstrahlung normalization.

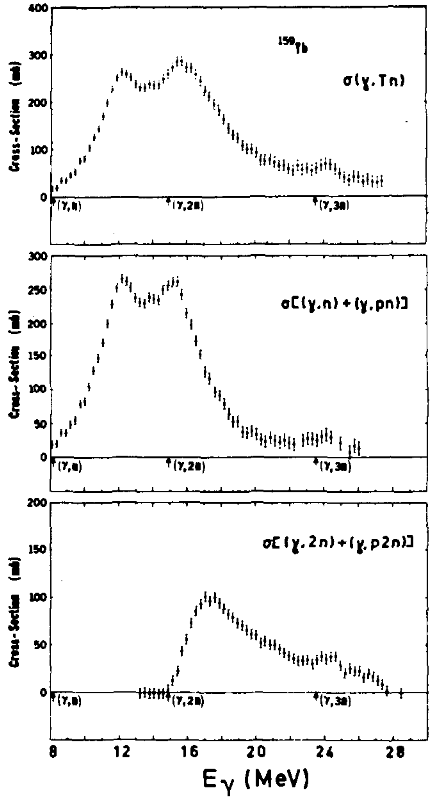


Ref: Phys. Rev. 185 (1969) 1576, B. L. Berman et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
64	154	2.1	8.7	7.6	15.1	16.2	13.5
	155	14.7	6.4	7.6	15.1	14.1	14.1
	156	20.5	8.5	8.0	15.0	16.2	14.7
	157	15.7	6.4	8.0	14.9	14.4	15.2
	158	24.9	7.9	8.5	14.3	16.0	15.9
	160	21.9	7.5	9.3	13.4	16.0	-
	other	0.2					

TERBIUM



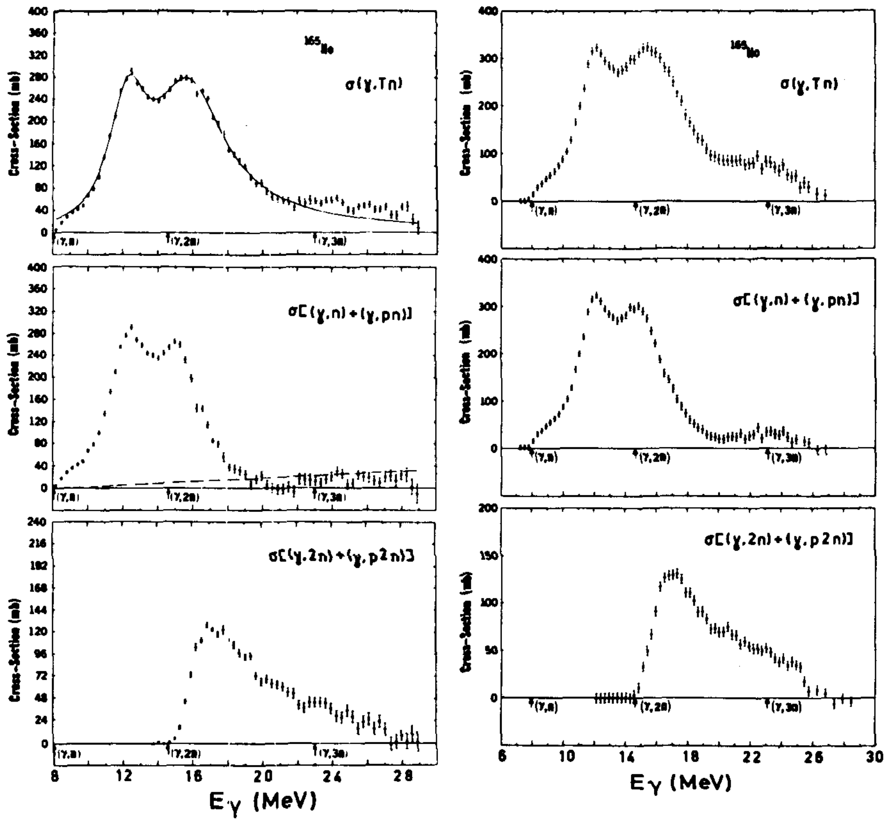


Ref: Phys. Rev. 133 (1964) B869
R. L. Bramblett et al.

Ref: Nucl. Phys. A121 (1968) 463
R. Bergère et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
65	159	100.0	8.1	6.1	14.9	14.0	14.6

HOLMIUM

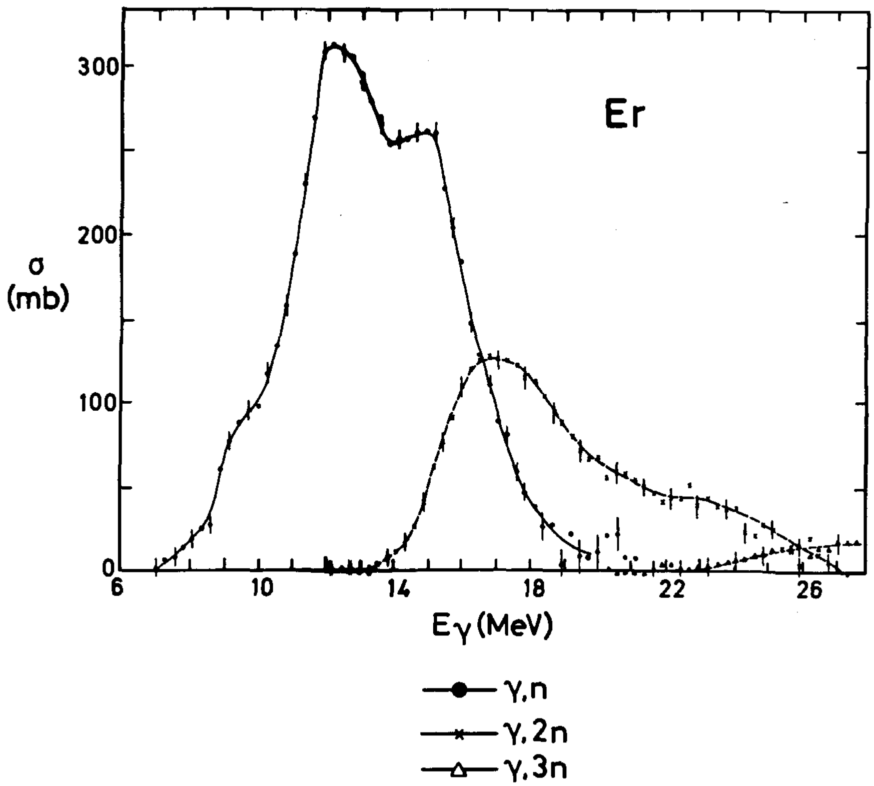


Ref: Nucl. Phys. A121 (1968) 463
R. Bergère et al.

Ref: Phys. Rev. 185 (1969) 1576
B. L. Berman et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
67	165	100.0	8.0	6.2	14.7	13.9	14.8

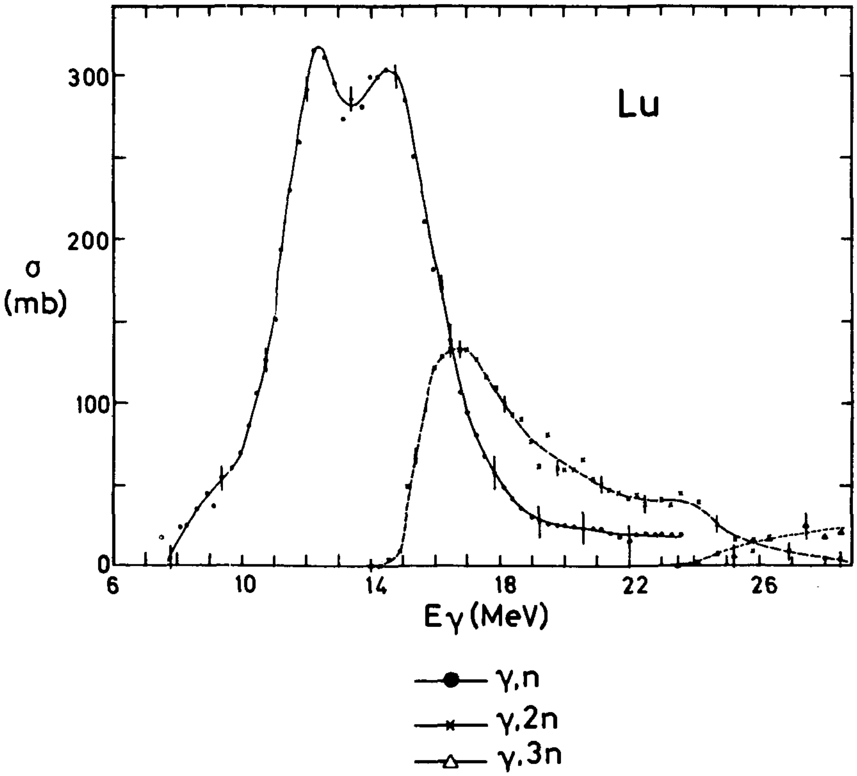
ERBIUM



Ref: Nucl. Phys. A133 (1969) 417
R. Bergère, H. Beil, P. Carlos and A. Veyssière

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
68	164	1.6	8.9	6.9	15.8	15.3	12.3
	166	33.4	8.5	7.3	15.1	15.3	13.5
	167	22.9	6.4	7.5	14.9	13.8	14.3
	168	27.1	7.8	8.0	14.2	15.3	15.0
	170	14.9	7.3	8.6	13.3	15.3	-
	other	0.1					

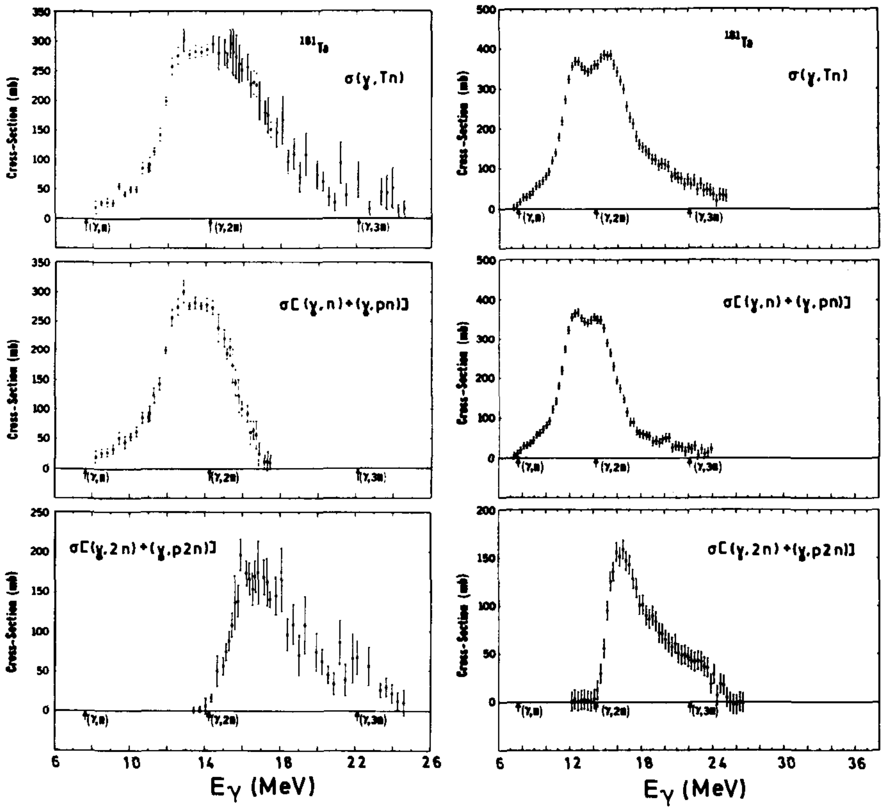
LUTETIUM



Ref: Nucl. Phys. A 133 (1969) 417
R. Bergère, H. Beil, P. Carlos and A. Veyssière

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
71	175	97.4	7.7	5.5	14.4	13.0	13.5
	176	2.6	6.3	6.0	14.0	11.8	14.1

TANTALUM

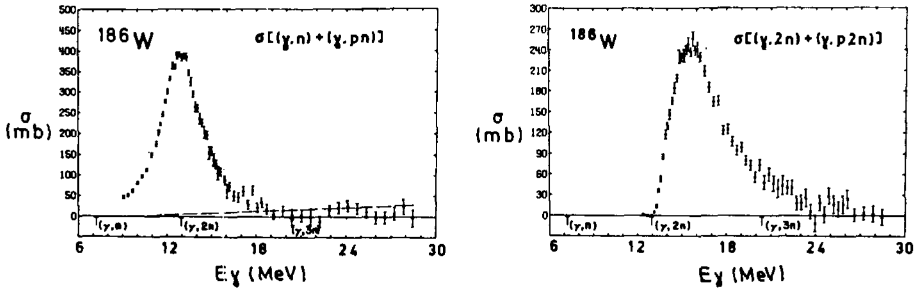


Ref: Phys. Rev. 129 (1963) 2723
R. L. Bramblett et al.

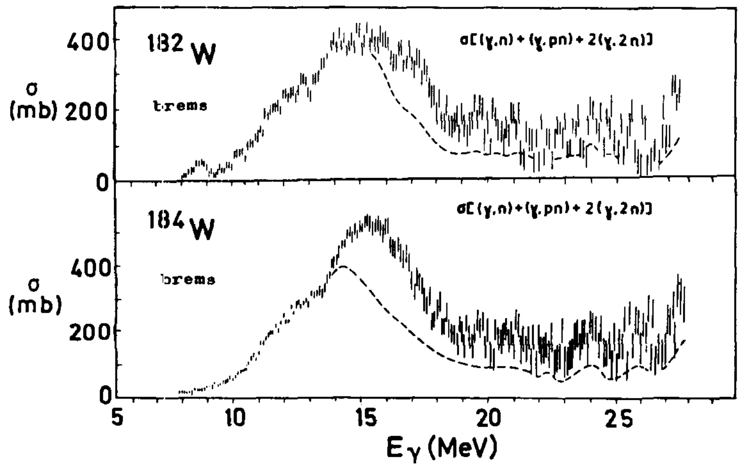
Ref: Nucl. Phys. A121 (1968) 463
R. Bergère et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
73	181	100.0	7.6	5.9	14.2	13.3	13.9

TUNGSTEN



Ref: Phys. Rev. 185 (1969) 1576, B.L. Berman et al.

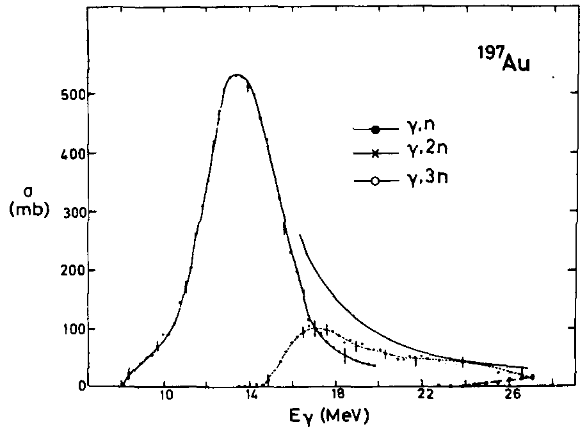


Dashed curves show the cross-sections corrected for multiplicity

Ref: Sov. J. Nucl. Phys. 17 (1973) 1, Yu. I. Sorokin et al.

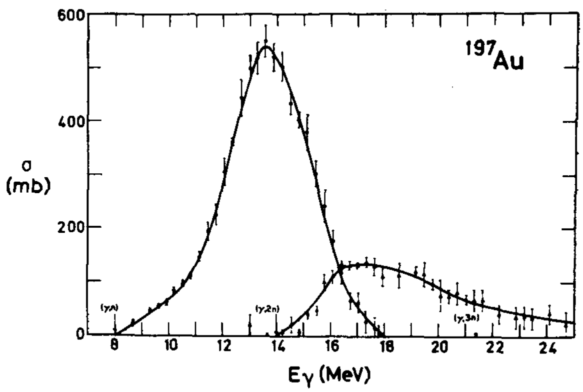
Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
74	182	26.4	8.1	7.1	14.7	14.7	13.0
	183	14.4	6.2	7.2	14.2	13.3	13.5
	184	30.6	7.4	7.7	13.6	14.6	14.3
	186	28.4	7.2	8.4	13.0	15.2	–
	other	0.2					

GOLD



The solid line is a Lorentz line.

Ref: Nucl. Phys. A159 (1970) 561, A.Veyssière et al.

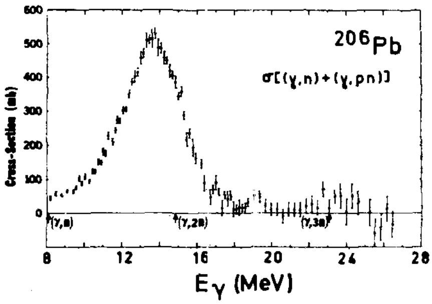


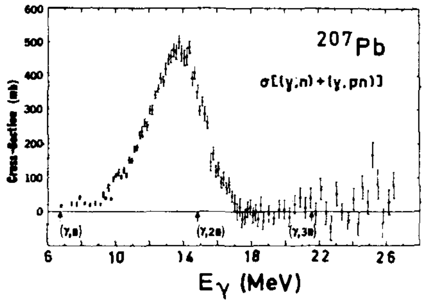
Upper curve: σ(γ,n) + σ(γ,np)
Lower curve: σ(γ,2n) + 3σ(γ,3n).

Ref: Phys. Rev. 127 (1962)1273 , S.C. Fultz et al.

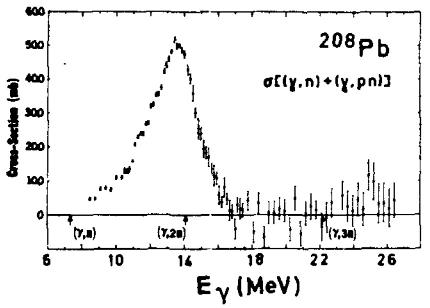
Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
79	197	100.0	8.1	5.8	14.7	13.7	13.9

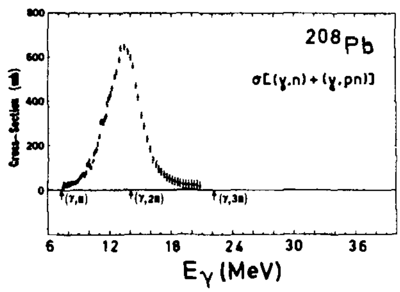
LEAD





Ref: Phys. Rev. 136 (1964) B126, R.R. Harvey et al.



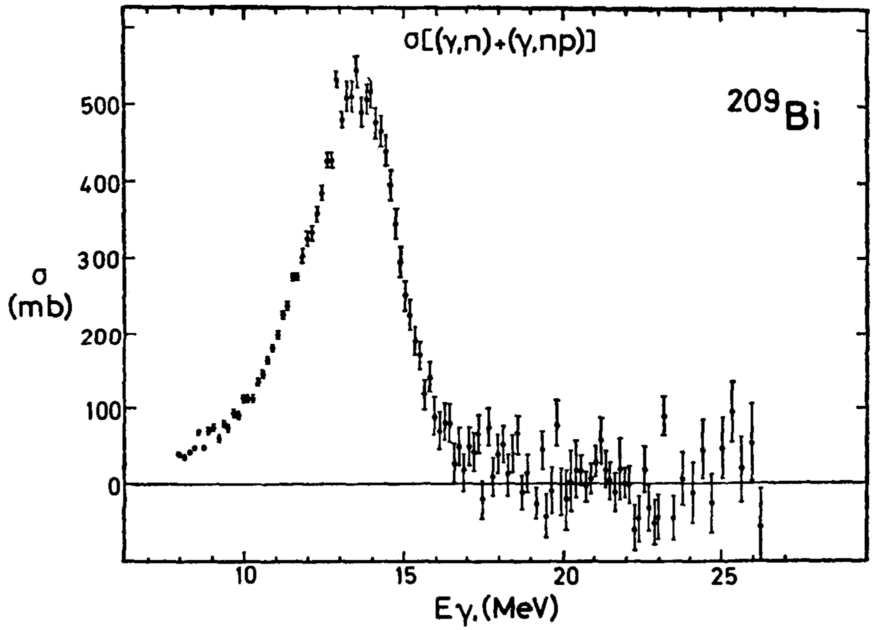


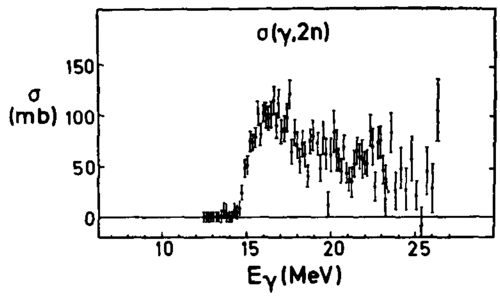
Ref: Phys. Rev. 136 (1964) B126
R.R. Harvey et al.

Ref: Nucl. Phys. A159 (1970) 561
A. Veyssière et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
82	204	1.5	8.4	6.6	15.2	14.4	12.3
	206	23.6	8.1	7.3	14.8	14.8	13.7
	207	22.6	6.7	7.5	14.8	14.0	14.7
	208	52.3	7.4	8.0	14.1	14.9	15.4

BISMUTH

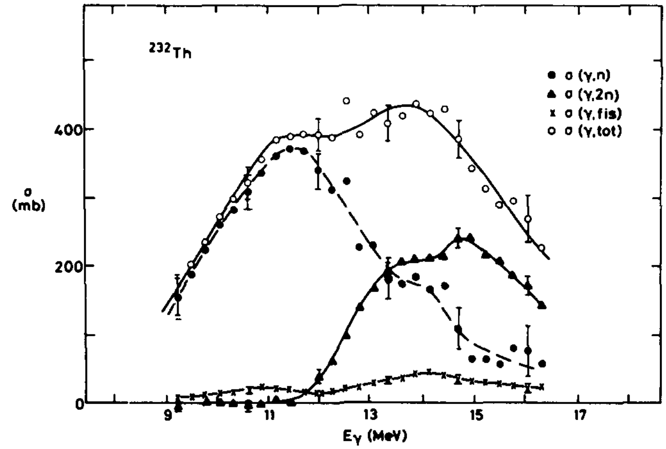




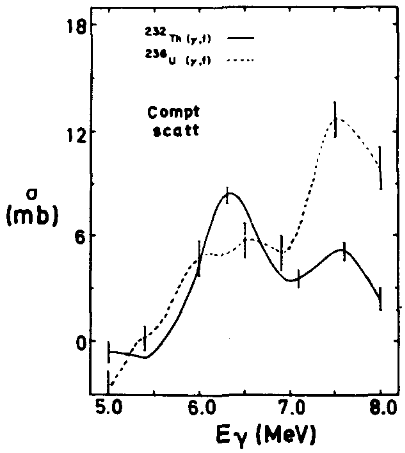
Ref: Phys. Rev. 136 (1964) B126
R. R. Harvey et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
83	209	100.0	7.5	3.8	14.4	11.1	11.8

THORIUM



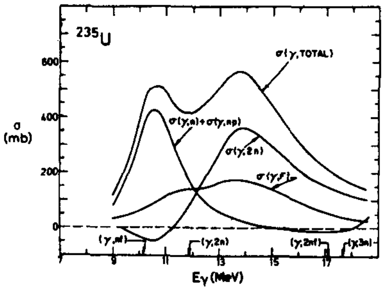
Ref: Nucl. Phys. <u>A199</u> (1973) 45, A.Veyssière et al.



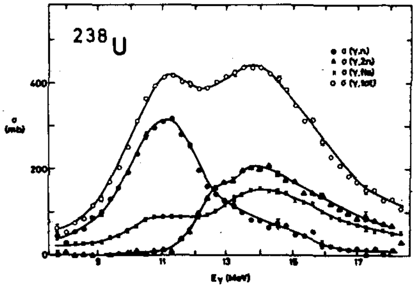
Ref: Nucl. Phys. <u>A206</u> (1973) 593, M.V.Yester et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
90	232	100.0	6.4	7.8	11.6	13.7	13.7

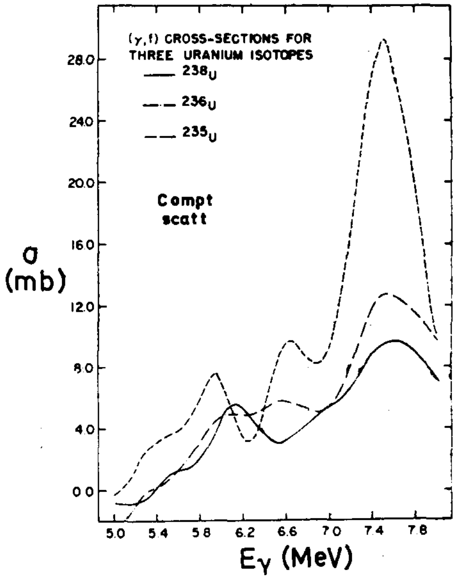
URANIUM



Ref: Phys. Rev. 133 (1964)B676
C.D.Bowman et al.



Ref: Nucl. Phys. A199(1973)45
A.Veyssière et al.

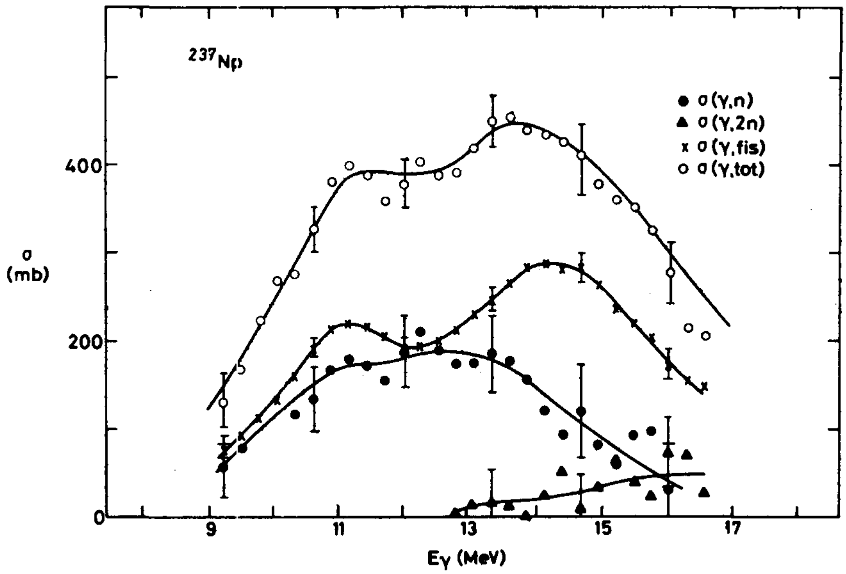


^{236}U: Nucl. Phys. A206 (1973) 593, M.V. Yester et al.

Ref: Nucl. Phys. A212 (1973) 221, R.A. Anderl et al.

Z	A	ABUND	G,N	G,P	G,2N	G,NP	G,2P
92	235	0.7	5.3	6.7	12.1	11.9	12.4
	238	99.3	6.1	7.7	11.3	13.6	–

NEPTUNIUM

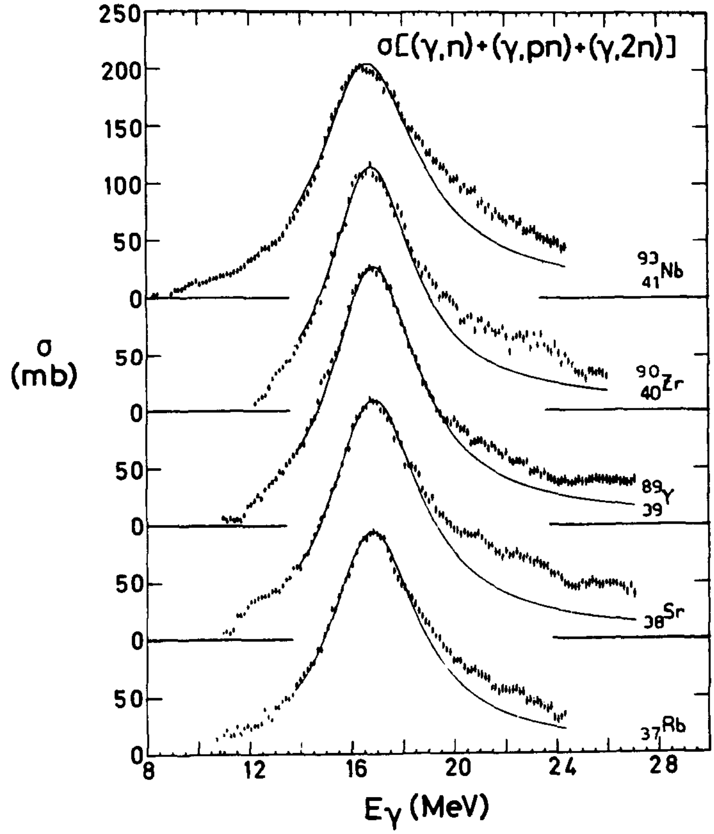


Ref: Nucl. Phys. A199 (1973) 45

A. Veyssière, H. Beil, R. Bergère, P. Carlos, A. Lepretre and K. Kernbath

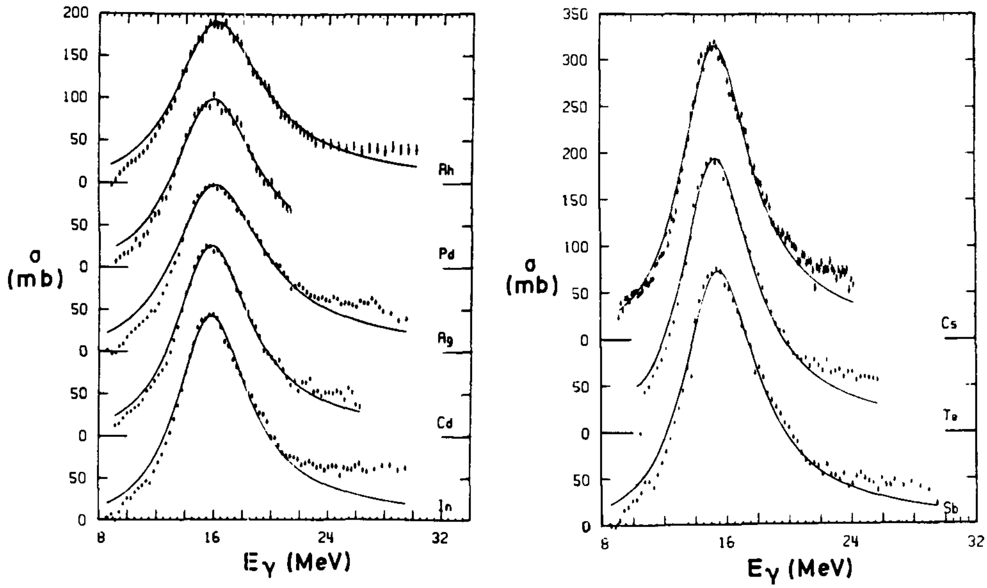
Z	A	ABUND	G,N	G,P	G,2N	G, NP	G,2P
93	237	–	6.6	4.9	12.3	11.4	12.0

Giant dipole resonance in A≃90 nuclei

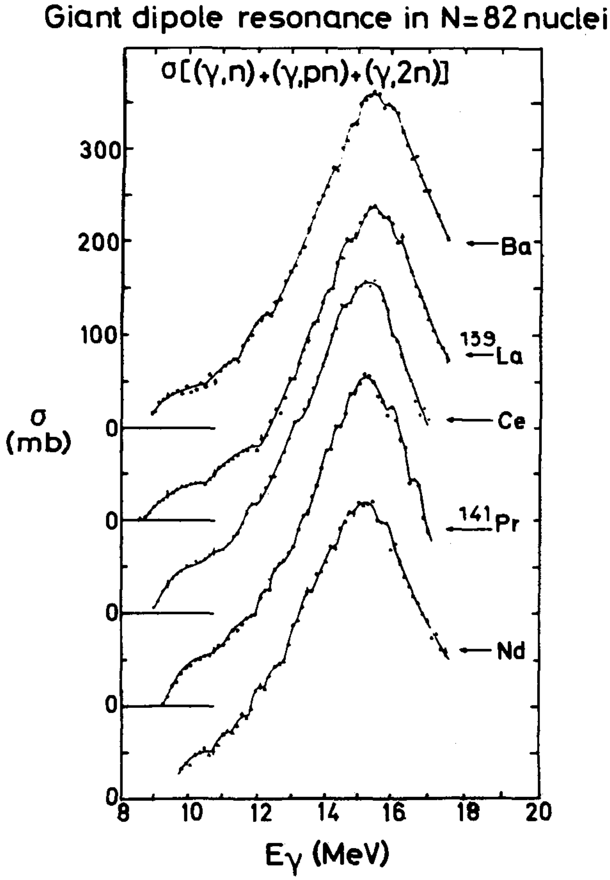


Ref: Nucl. Phys. A 175 (1971) 609
A. Leprêtre et al.

Giant dipole resonance in 103≤A≤133 nuclei

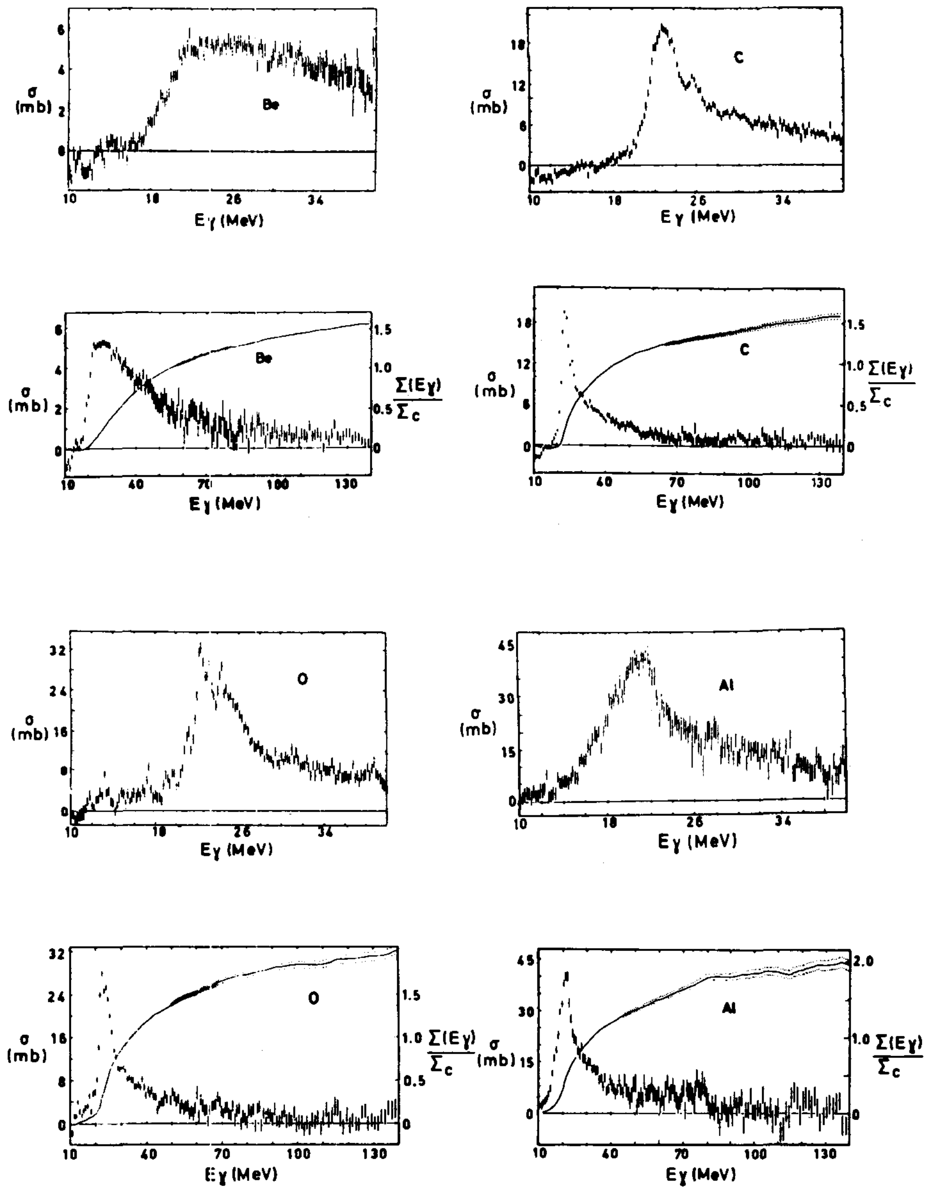


Ref: Nucl. Phys. A219 (1974) 39, A. Leprêtre et al.



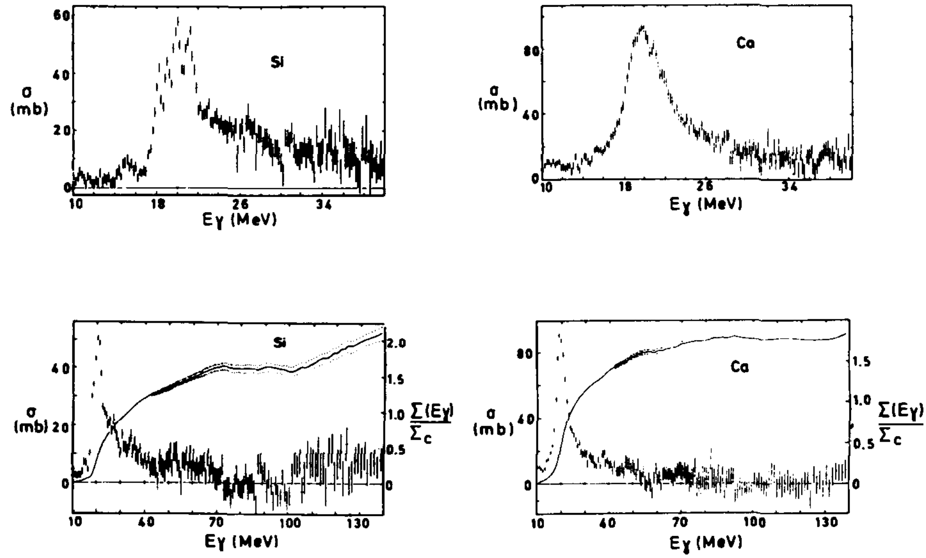
Ref: Nucl. Phys. A172 (1971) 426
H. Beil et al.

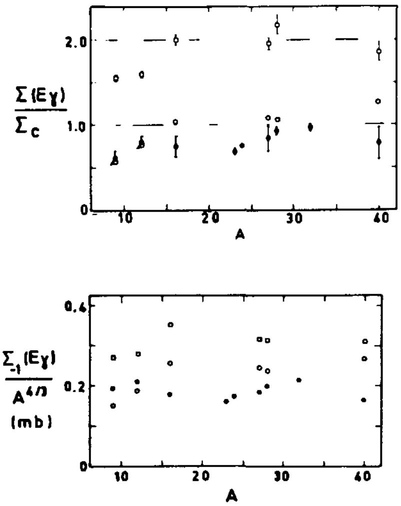
Total photonuclear absorption: σ_{tot}



(See also next page)

Total photonuclear absorption: σ_{tot}
(cont.)





$$\Sigma_c = \frac{60\,NZ}{A}$$

$$\Sigma(E\gamma) = \int_{10}^{E\gamma} \sigma(\hat{E}\gamma)\, d\hat{E}\gamma$$

$$\Sigma_{-1}(E\gamma) = \int_{10}^{E\gamma} \sigma(\hat{E}\gamma)\, \frac{d\hat{E}\gamma}{\hat{E}\gamma}$$

● $E\gamma = 35$ MeV NBS

○ $E\gamma = 35$ MeV Ahrens et al

□ $E\gamma = 140$ MeV Ahrens et al

Ref: Nuclear structure studies using electron scattering and photoreaction
Sendai Conf. 1972, page 213, J. Ahrens et al.

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