International Atomic Energy Agency

INDC(CPR)-16
Distr.: L

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

COMPILATION OF MEASUREMENTS AND EVALUATIONS OF NUCLEAR ACTIVATION CROSS SECTIONS FOR NUCLEAR DATA APPLICATIONS

By

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August 1989

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

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CNDC-89014

August 1989

Abstract

The cross-sections of fifty-eight reactions of interest for nuclear technology applications have been measured by the activation method in our laboratory. For the same reactions compilations and evaluations of available neutron activation cross-sections have been made. Table 1 lists all of the reactions included in the present work.

A brief description of experimental measurements for activation cross-sections is given. The evaluation procedure is described. The collected data were modified as needed to account fo recent revisions in nuclear constants and standard cross-sections.

For each reaction, the data measured by ourselves and our evaluations are listed in Tables 3 and 4 respectively. A graphical intercomparison with available experimental data is given. References can be found for each investigated reaction.

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January 1990

90-00593

Contents

1 Introduction

The neutron activation cross sections are very useful in nuclear technology applications and nuclear theory investigation. As developing of nuclear technology and nuclear engineering, more accurate data are required.

The cross sections at about 14 MeV are of strong interest for fusion facilities. One of pressing needs for nuclear data in the field is dosimetry applications. Nowadays, neutron production from plasma is of reality, which makes the nuclear data have special useness to monitor plasma temperature and to assess D-T fuel "burn" rates during the containment intervals. Of concern for blanket design purposes are tritium breeding cross sections and neutron multiplier cross sections for energies of about 14 MeV and below. Of longer-range concern are such matters as radiation damage by energetic neutrons and long-lived activation of fusion reactor structure. These are important matters which will affect the longevity and service of facilities and decommissioning procedures.

Meanwhile, the accurate neutron activation cross section is one of the important factors to understand and to select suitable materials for reactors.

The other application of activation cross sections is that some reactions can be used as threshold detectors to measure neutron spectra of reactors or some neutron fields, which may provide significant information for reactor shielding calculations and for other purposes.

There are some more conventional applications of activation data, such as neutron activation analysis, isotope production, medical technology, oil well logging, and mineral exploration and so on.

Many kinds of cross sections have been measured and published, and several sets of evaluated results have been given by some laboratories [Ref. 1-3]. But among them, there are large discrepancies. Therefore, which datum is selected is a difficult problem for users. In this case, a decision was made to measure and evaluate some reactions in our lab so as to check and improve the existing data and to publish more reliable and accurate results. We think that the evaluations of existing data including our own results are quite necessary.

Since 1970, we have begun to collect and measure the activation cross sections for some elements or isotopes, which are mainly used as structure materials of reactors, indicators for dosimetry monitors, and standard cross sections. In the late of 1970s, we have begun to make evaluations for some reactions.

Up to now, we have measured, compiled and evaluated fifty eight reactions, which are listed in Table 1. For each reaction, our measured and evaluated data are summarized in Tables 3 and 4 respectively, and ploted in figures.

In sections II and III, simple procedures for measuring and evaluating are described. Some information for several reactions is given in the last section.

Table.1 List of reactions measured and associated parameters

Fig. No.	Reaction	Exp. Neutron Energy Range (MeV)	Exp. Point	Isotopic Abundance (%)	Activity	E_γ (keV)	Branching ratio(%)	Half-life
1	^{24}Mg(n,p)^{24}Na	8.50-18.3	37	78.99	^{24}Na	1368	99.993	15.02 h
2	^{27}Al(n,α)^{24}Na	12.2-18	11	100				
3	^{45}Sc(n,2n)^{44m}Sc	13.2-18.3	12	100	^{44m}Sc	271	86.6	2.44 d
4	^{44g}Sc	14.6-18.3	5		^{44g}Sc	1157	99.9	3.93 h
5	$^{44m+g}$Sc	14.6-18.3	5					
6	^{46}Ti(n,p)^{46}Sc	4.5-18	10	8.0	^{46}Sc	889,1121	100	83.83 d
7	^{47}Ti(n,p)^{47}Sc	8.50	1	7.3	^{47}Sc	159.4	68	3.341 d
8	^{48}Ti(n,p)^{48}Sc	5-18	15	73.8	^{48}Sc	984	100	43.7 h
9	^{51}V(n,α)^{48}Sc	8.50-18	12	99.75				
10	^{55}Mn(n,2n)^{54}Mn	12.4-18.3	15	100	^{54}Mn	834.8	99.975	312.2 d
11	^{54}Fe(n,p)^{54}Mn	8.50-17.2	25	5.8				
12	^{54}Fe(n,α)^{51}Cr	8.50-18.3	22		^{51}Cr	320	9.85	27.70 d
13	^{56}Fe(n,p)^{56}Mn	12.8-18.3	25	91.72	^{56}Mn	847	98.9	2.578 h
14	^{59}Co(n,2n)^{58}Co	12.5-18.3	20/9	100	^{58}Co	810	99.44	70.91 d
15	^{59}Co(n,p)^{59}Fe	13.6-17.8	8		^{59}Fe	1099	56.5	44.496 d
16	^{59}Co(n,α)^{56}Mn	12.5-18.3	20/6					
17	^{58}Ni(n,2n)^{57}Ni	12.8-18.3	13	68.27	^{57}Ni	1377	77.9	1.503 d
18	^{58}Ni(n,p)^{58}Co	8.50-17.8	10					
19	^{58}Ni(n,x)^{57}Co	12.8-18.3	13		^{57}Co	122	85.5	271.2 d
20	^{60}Ni(n,p)^{60}Co	~14	2	26.10	^{60}Co	1173	99.89	5.271 y
21	^{62}Ni(n,α)^{59}Fe	~14	2	3.59				
22	^{63}Cu(n,α)^{60}Co	12.8-17.7	7	69.17				
23	^{66}Zn(n,2n)^{65}Zn	12.8-17.7	9	27.9	^{65}Zn	1116	50.57	244.1 d
24	^{67}Zn(n,p)^{67}Cu	12.8-17.7	6	4.1	^{67}Cu	185	47	61.9 h
25	^{70}Zn(n,2n)^{69m}Zn	12.8-17.7	5	0.6	^{69m}Zn	439	94.8	13.76 h
26	^{85}Rb(n,2n)^{84m}Rb	12.5-17.5	11	72.165	^{84m}Rb	248	63	20.5 m
27	^{85}Rb(n,2n)$^{84m+g}$Rb	12.5-17.5	11		^{84g}Rb	881	67.9	32.87 d
28	^{85}Rb(n,p)^{85m}Kr	13.5-14.8	6		^{85m}Kr	151	76.1	4.48 h
29	^{85}Rb(n,α)^{82}Br	13.5-14.8	6		^{82}Br	776	83.3	35.3 h
30	^{87}Rb(n,2n)^{86}Rb	13.5-14.8	6	27.835	^{86}Rb	1078.8	8.8	18.82 d
31	^{87}Rb(n,p)^{87}Kr	13.5-14.8	6		^{87}Kr	403	48.3	76 m
32	^{89}Y(n,2n)^{88}Y	12.8-18	13	100	^{88}Y	898	92.7	106.6 d
33	^{90}Zr(n,2n)^{89}Zr	12.4-18.3	25	51.45	^{89}Zr	909	99.01	78.43 h
34	^{96}Zr(n,2n)^{95}Zr	12.8-17.7	7	2.80	^{95}Zr	724,756	44.2,54.5	64.02 d
35	^{93}Nb(n,2n)^{92m}Nb	12.8-18.3	14	100	^{92m}Nb	934	99.0	10.15 d
36	^{93}Nb(n,α)^{90m}Y	8.50-18	8		^{90m}Y	480	91.7	3.19 h
37	^{113}In(n,2n)^{112m}In	~14	1	4.3	^{112m}In	155.5	12.8	20.9 m
38	^{113}In(n,n')^{113m}In	8.50-14.8	9		^{113m}In	391	64.89	1.65 h
39	^{115}In(n,2n)^{114m}In	11.4-18	11/18	95.7	^{114m}In	191	15.7	49.51 d
40	^{115}In(n,n')^{115m}In	0.88-14.8	53		^{115m}In	336	45.9	4.486 h

Table.1 (Continued)

Fig. No.	Reaction	Exp. Neutron Energy Range (MeV)	Exp. Point	Isotopic Abundance (%)	Activity	E_γ (keV)	Branching ratio(%)	Half-life
41	^{115}In(n,γ)^{116m}In	0.144,0.565	2		^{116m}In	4πβ		54.2 m
42	^{115}In(n,p)^{115}Cd	~14	3		^{115}Cd	527	27.5	53.38 h
43	^{115}In(n,α)^{112}Ag	~14	2		^{112}Ag	617	42.5	3.14 h
44	^{127}I(n,2n)^{126}I	11.4-18	10	100	^{126}I	389	34.1	13.0 d
45	^{136}Ce(n,2n)^{135}Ce	13.5-14.8	8	0.19	^{135}Ce	265.3	42.1	17.76 h
46	^{138}Ce(n,2n)^{137m}Ce	~14	1	0.25	^{137m}Ce	254.3	10.96	34.4 d
47	^{140}Ce(n,2n)^{139}Ce	12.4-18.3	23	88.48	^{139}Ce	165.8	79.9	137.2 d
48	^{140}Ce(n,p)^{140}La	13.5-14.8	8		^{140}La	487.1	45.9	40.27 h
49	^{142}Ce(n,2n)^{141}Ce	12.4-18.3	23	11.08	^{141}Ce	145.4	48.4	32.55 d
50	^{169}Tm(n,2n)^{168}Tm	12.4-18.3	16	100	^{168}Tm	198	50.3	93.1 d
51	^{169}Tm(n,3n)^{167}Tm	15-18.2	9		^{167}Tm	208	41.1	9.25 d
52	^{181}Ta(n,2n)^{180m}Ta	8.50-18.3	34	99.988	^{180m}Ta	93.3,103	4.27,0.79	8.152 h
53	^{181}Ta(n,p)^{181}Hf	12.8-18.3	18		^{181}Hf	482	80.6	42.4 d
54	Pt(n,x)^{195m}Pt	0.144-17.76	39	100	^{195m}Pt	98.8	11.11	4.02 d
55	^{198}Pt(n,2n)^{197}Pt	8.50	1	7.2	^{197}Pt	191	3.5	18.3 h
56	^{197}Au(n,2n)^{196}Au	9.41-18.2	17/7	100	^{196}Au	356	87.6	6.18 d
57	^{197}Au(n,3n)^{195}Au	16-18.2	4		^{195}Au	99.8	9.347	183 d
58	^{204}Pb(n,2n)^{203}Pb	9.4-15	12	1.4	^{203}Pb	279	80.1	52.05 h

Table 2 Standard Cross Section Used in Our Lab.

En(MeV)	Cross Section (mb)		
	^{27}Al(n,α)^{24}Na	^{56}Fe(n,p)^{56}Mn	^{93}Nb(n,2n)^{92m}Nb
13.2	126.3±4.2		444.0±10.0
13.25		116.6±1.3	
13.4	125.9±4.1		447.4±8.9
13.5		116.9±1.2	
13.6	125.1±2.9		450.7±7.4
13.75		116.4±1.2	
13.8	123.9±2.9		453.5±6.0
14.0	122.3±2.2	115.2±1.1	455.8±5.0
14.2	120.3±1.9	113.8±1.0	457.6±4.5
14.4	118.2±1.9	111.8±1.0	458.7±4.5
14.6	115.8±1.6	109.5±1.0	459.1±4.9
14.8	113.2±1.1	106.9±1.0	458.6±5.6
15.0	110.3±1.5	103.9±1.0	457.0±7.0

2 Brief description of measurements

The investigation is comprised of three parts: data compilation, data measurement, and data evaluation.

Since 1970, the neutron activation cross sections of some nuclides, which are summarized in Table 1,have been measured by means of activation method in our lab. Table 1 gives relevant information for our investigation. The first column lists the number of figures, in which our evaluated curves and measured results are shown together with collected data. The second column represents the reactions studied in present work. The measured neutron energy region and energy points are given in columns three and four. The isotopic abundance for each target element is listed in column five. The product nuclides, the characteristic γ-ray energies and the branching ratios as well as the half-lives of the residual nuclides are tabulated in columns six, seven, eight, and nine respectively.

The neutron sources used in our measurements were as follows: D(d,n) and T(d,n) reactions were used in neutron energy ranges of 2-3 MeV and 13-15 MeV at Cockcroft-Walton accelerator. Li(p,n), T(p,n), D(d,n), and T(d,n) reactions were used as neutron sources in 0.1-5.5MeV and 12-18MeV energy regions at Van de Graaff accelerator. And D(d,n) reaction provide neutrons of 6-11.4 MeV at Cyclotron.

Neutron flux was determined using various methods in the whole measured energy range. Such as proportional counters filled with hydrogen or methane were used for neutrons below 2 MeV energy; proton associated particle method for about 3 MeV neutrons; proton recoil semiconductor and semiconductor telescope for about 1.5-5.5 MeV neutrons; proton recoil scintillation telescope for 5-18 MeV neutrons; α associated particle method for about 14 MeV neutrons; and a calibrated long counter for 0.1-14 MeV neutrons. The standard cross sections were used in very wide measured region if suitable standard reaction was selected. The values of standard cross sections used in our lab are listed in Table 2. In order to check and improve the accuracy of neutron flux, we participated in the second international intercomparison of neutron flux organized by BIPM, 1982 to 1985, and got quite satisfactory results [Ref. 4].

For most of the reactions, the cross sections were measured in two steps: relative measurement and absolute measurement.

The absolute measurements were usually carried out at Cockcroft-Walton accelerator using 200 KeV deuteron beam bombarding T-Ti target, and 14.61 MeV of neutron energy was used for earlier published data. After considering the effect of oxide layer at the surface of T-Ti target, the neutron energy was modified to 14.58 MeV for the same deuteron beam energy. In the recent years, more reasonable averaged distance was used instead of the distance from the center of target to the center of sample in earlier experiments.These would induce a little change for our data. In present work, all of the earlier data were adjusted for the effects of distance and neutron energy.In order to get good energy resolution,the distance between target and sample in question was as large as possible. Neutron flux can be determined by α associated particle method or standard cross sections of $^{27}Al(n,\alpha)$, $^{56}Fe(n,p)$, or $^{93}Nb(n,2n)^{92m}Nb$ reaction. The sample holder was as light as it could be to reduce the effects of scattered neutrons.

The relative measurements were performed in the energy region of 12-18 MeV at Van de Graaff accelerator or in the region of 13-15 MeV at Cockcroft-Walton accelerator. A group of samples was placed at variant angles of ring sample holder to irradiation. The relatively measured curve was normalized to the cross section value obtained in the absolute measurement at 14.58 MeV. The reactions measured in this way were $^{90}Zr(n,2n)$, $^{27}Al(n,\alpha)$, $^{56}Fe(n,p)$, $^{93}Nb(n,2n)^{92m}Nb$, and $^{115}In(n,2n)^{114m}In$, ect. [Ref.5-9].

For some reactions, all the cross sections were measured relative to standard cross sections in the whole measured energy range. Therefore, the excitation function can be obtained directly. The reactions of $Pt(n,x)^{195m}Pt$, $^{197}Au(n,2n)$ and $^{169}Tm(n,2n)$ [Ref.10-12] etc were fulfiled in this way.Throughout the irradiations, the neutron flux as a function of irradiation time was recorded continually. It was used to make correction for the influnce of neutron flux fluctuation.

The samples in question were usually natural metal plates,which were machined to disks or slips, or oxide powder, which was pressed into pills. The purity of them, in general, was better than 99.9%.

The activities of the residual nuclides investigated were counted by Ge(Li) or NaI(Tl) detector. Their efficiencies were calibrated quite carefully using a set of standard point γ-ray sources. The corrections were made for the effects of γ-ray cascade in the detectors and γ-ray selfabsorption in the samples, as well as for the efficiency change owing to the size of the sample.

Special arrangements were made for the reactions with low threshold to reduce the effects of low energy neutrons, which came from D(d,n) self build-up neutron source in the target assembly. Even so, the corrections of scattered neutrons by target materials, sample holder and sample itself, and of neutron flux attenuation due to target and sample were calculated for each reaction using a Monte Carlo program. As an example, Fig. I shows the relation of low energy neutrons scattered by target assembly with angles, where the samples were placed. The effects of both attenuated and scattered neutrons by target assembly and sample as a function of angles are drawn in Fig. II.The calculations were carried out for Ce(n,2n) reaction under the following conditions: 0.3 mm in thickness of Cu target tube with a diameter of 20 mm, 7 mm in radius and 0.3 mm in thickness of Mo target backing. $T(d,n)^4He$ reaction was used to produce neutrons. The results show that there is a big influnce at about 90°. Therefore, no sample was mounted at about 90° when the irradiation was made. The relation of contribution from low energy neutrons with reaction Q values at 8.5 MeV and 14 MeV incident neutrons are plotted in Fig.III, which shows that the larger the contribution, the lower the reaction Q value.

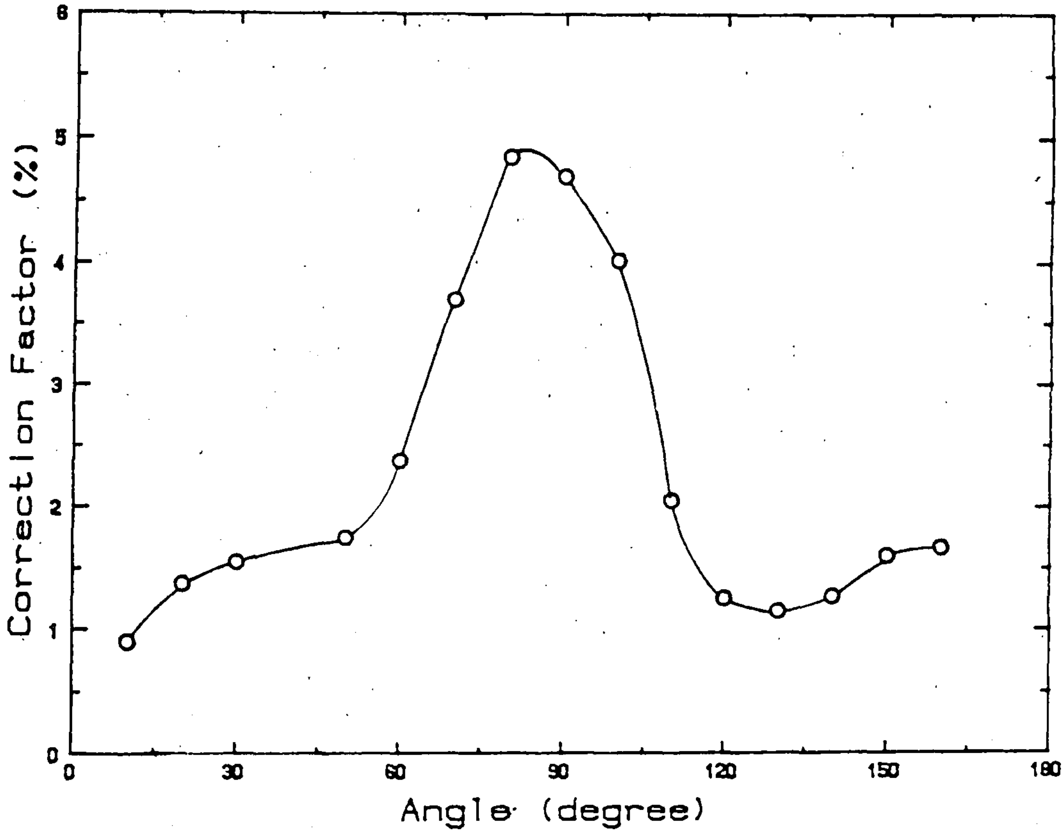

Fig.I Correction Factor of Scattered Neutrons Induced by Target Assemble for Ce(n,2n)Ce Reaction

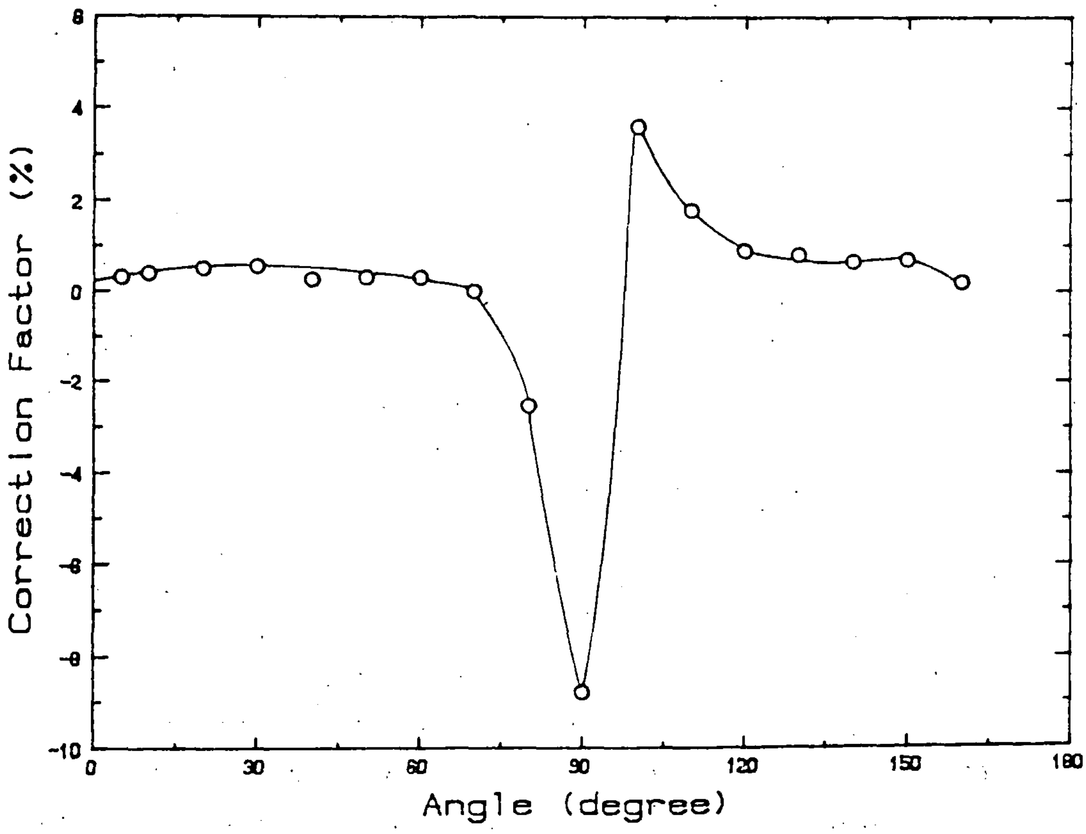

Fig.II Correction Factor of Scattered and Attenuated Neutrons Induced by Target Assemble for Ce(n,2n)Ce Reaction

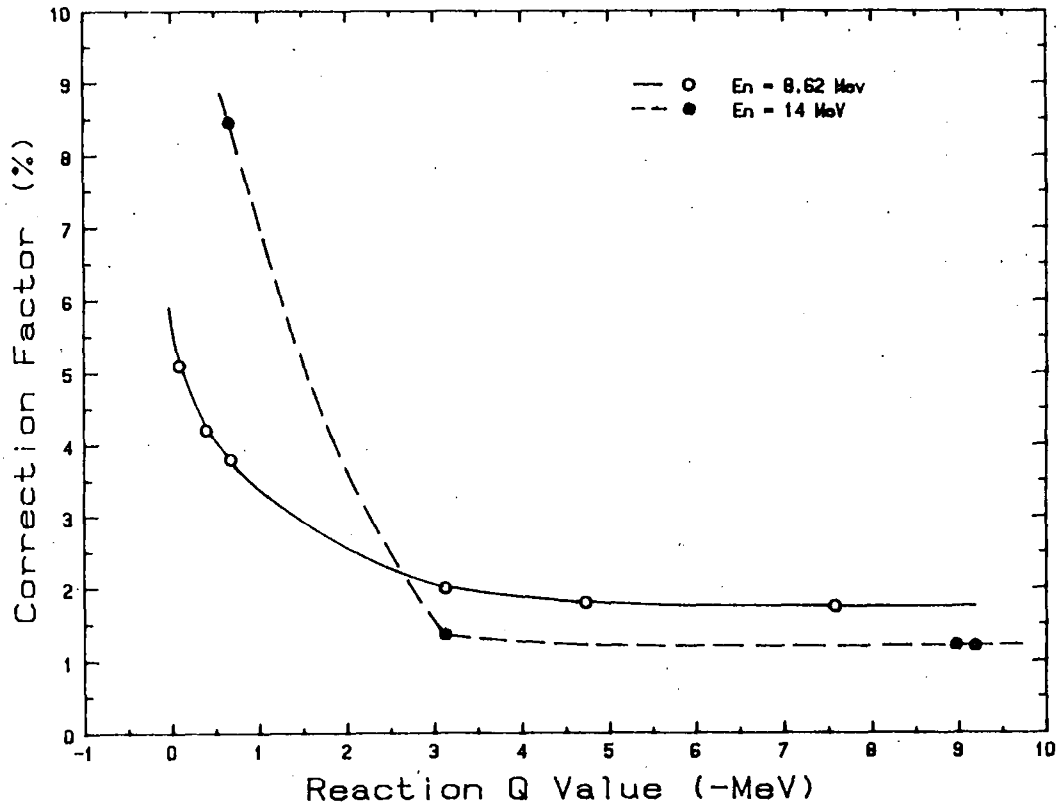

Fig.III Relation between Correction of Scattered Neutrons and Reaction Q Value

In our earlier measurements, the corrections for low energy neutrons mentioned above were done in a simple way-a quartet integration, which didn't give satisfactory results. So some modifications were made for earlier published data.

Our measured data for each reaction are listed in Table 3 in an order of atomic number of elements.

3 Outline of evaluation procedure

The compilations of data were usually based on CINDA [Ref.13] and BNL-325 [Ref.14] of reference guidances.

Once our measurements were finished, the evaluations were made for most of the reactions using a program of spline function fitting for multi-set data [Ref.15], or using a program of orthogonal polynomial fit for data sets [Ref.16].

In recent years, the knowlodge of nuclear constants and standard cross sections was improved. Prior to evaluation, therefore, the essential step was to analyze the compiled experimental data and to adjust them to be consistant with more accurate standard cross sections and with the latest values of nuclear constants, which were usually taken from "Table of isotopes" [Ref.17] and "Table of radioactive isotopes" [Ref.18]. Table 2 lists our standard cross sections of $^{27}Al(n,\alpha)^{24}Na$, $^{56}Fe(n,p)^{56}Mn$ and $^{93}Nb(n,2n)^{92m}Nb$ reactions in the neutron energy range of 13-15 MeV.

The evaluations were done in different way for different reaction. For some reactions, the compiled data were modified according to the data at 14.7 MeV, including decay parameters, abundances of isotopes, standard cross sections and ect. Then, the evaluation was made first at 14.7 MeV, which was used to normalize the adjusted excitation functions of various authors. Finally, the whole evaluation was performed using the adjusted and normalized excitation function curves in the neutron energy range from threshold to about 20 MeV, through several times of iterations, which depended on χ^2 values. For example, ^{27}Al(n,α) and ^{58}Ni(n,p) reactions were done in this way.

For some reactions, after similar adjustments mentioned above were finished for collected data, the evaluations were performed directly in the energy region of threshold-20 MeV. The recommended curves were obtained through some interations, which also relied on χ^2 values. The reactions of ^{90}Zr(n,2n), ^{58}Ni(n,2n) and ect, were evaluated in this way. Present work gave evaluated curves from threshold to about 20 MeV for twenty-eight reactions in Table 1.

Since the measurements were concentrated on about 14 MeV for ^{113}In(n,n') ^{113m}In reaction, the evaluation was finished only in energies around 14 MeV.

Some data were rejected during the evaluation if not enough information was provided to modify them, which were apparently discrepant with most of the data. Here we assume that the coincident majority of the data are right. There were tremendous differences for some adjusted data. Usually, this kind of results was cancelled or enlarged errors were assigned to them. That means, their weight factors were decreased in the evaluation because of their poor accuracy. Larger error of the data was corresponding to smaller weight factor.

For some reactions, only a few data were found, and their coincidence was poor. Therefore, in order to get recommended excitation function, the systematic model [Ref.19] was employed for the following six reactions: ^{60}Ni(n,p)^{60}Co, ^{66}Zn(n,2n)^{65}Zn, ^{67}Zn(n,p)^{67}Cu, ^{70}Zn(n,2n)^{69m}Zn, ^{96}Zr(n,2n)^{95}Zr, and ^{198}Pt(n,2n) ^{197}Pt. And the MUP2R program for model calculation [Ref.20] was used to obtain excitation functions of ^{85}Rb(n,2n)^{84}Rb, and ^{87}Rb(n,2n)^{86}Rb reactions.

Eye guide curves were drawn for the reactions of ^{58}Ni(n,x)^{57}Co, ^{62}Ni(n,α) ^{59}Fe, ^{93}Nb(n,α)^{90m}Y, ^{113}In(n,2n)^{112m}In, ^{181}Ta(n,p)^{181}Hf, and ^{204}Pb(n,2n)^{203}Pb.

No way can be used to get any evaluation because the existing data were highly incoincident. The pictures just display the data collected for fifteen reactions, such as ^{24}Mg(n,p)^{24}Na and ^{47}Ti(n,p)^{47}Sc and so on.

Some reactions, which were evaluated several years ago, were checked and modified in present work so as to include the data published recently.

The evaluated errors depended on measuring errors and fitting errors. The recommended data are summarized in Table 4 and plotted in figures together with compiled results without adjustment. There is an addition diagram at about 14 MeV for some reactions since it is difficult to show so many sets of data clearly in one picture.

4 Simple explanation for some reactions

In this section, explanations are given for following reactions.

(1) $^{24}Mg(n,p)^{24}Na$

The reaction was measured in many labs. The results show that there are many large fluctuations in the cross sections in energy region of 12-14 MeV. That is, the cross sections display a lot of small peaks, and the peak positions were different for different author's data. Fig. 1 details the appearance of the cross section values for the reaction in neutron energy range of 12-14 MeV. It is very difficult to determine the right positions of the small peaks, and to make evaluation. Therefore, no recommended datum was given in present work.

(2) $^{27}Al(n,\alpha)^{24}Na$

The reaction is quit suitable to be used as standard cross section and threshold detector due to the appropriate half-life of 15.02 h, simple decay scheme, and 100% branch ratios of 1.37 and 2.75 MeV gamma rays of residue ^{24}Na, as well as high purity of sample. Therefore, many labs have been interested in measuring it, and quite a number of data have been published since 1950.

The preliminary evaluation was performed in 1978 by Ma Hongchang [Ref. Al:2]. In his work, thirty-seven references were compiled. Among them, twenty papers gave the values at about 14 MeV, and the excitation function was measured in the rest of the papers. The collected data were fitted using the pragram of orthogonal polynomials. The evaluated cross section at 14.8 MeV was 114.0±1.12 mb. Reference [Al: 2] described the detail informantion for the data treatment.

In present work, it was checked and modified to include the latest data. The whole excitation curve was reevaluated, and the cross section at 14.8 MeV was revised to 113.2±1.3 mb. For comparison, the evaluated results of ENDF/B-V, S.Tagesem [Ref. Al: 3-4], and present work as well as our measured data [Ref. Al: 1] are plotted in Fig.2. The data of ENDF/B-V and present work fall into agreement at neutron energy below 12.5 MeV. But the latter is a little bit lower in energy region of 12-17 MeV since the data of ENDF/B-V didn't include our measured results.

(3) $^{45}Sc(n,2n)^{44}Sc$

Fig. 5 shows ten data sets [Ref. Sc: 3,4,5,11,12,15-19]. Among them, three labs measured the excitation curve. R.I.Prestwood and Ma Hongchang gave coincident results. L.R.Veeser measured it using large liquid scintillation detector to count two outgoing neutrons. And his data, which were rejected for evaluation, were 20% higher than the other two sets of data at energy above 15 MeV. Present recommended values are listed in Table 4.

(4) $^{46}Ti(n,p)^{46}Sc$

Several reaction channels may produce the same activity of ^{46}Sc for Ti element having five isotopic components of ^{46}Ti, ^{47}Ti, ^{48}Ti, ^{49}Ti and ^{50}Ti. Therefore, the activities of ^{46}Sc are produced through following reactions: $^{46}Ti(n,p)$, $^{47}Ti(n,pn)$, $^{47}Ti(n,d)$ and $^{48}Ti(n,t)$. Of these, (n,p) of ^{46}Ti and (n,np) and (n,d) of ^{47}Ti are significant for ^{46}Sc production.

For calculating the cross sections, the number of nuclides in sample was determined using 8.0% abundance of ^{46}Ti [Ref. 21]. The cross sections of $^{46}Ti(n,p)^{46}Sc$ were the sum of $^{46}Ti(n,p)$, $^{47}Ti(n,np)$ and $^{47}Ti(n,d)$ reactions.

Seven data sets [Ref. Ti:4,5,7,13-15,20] were collected for evaluation. Our measured and evaluated results are listed in Tables 3 and 4 respectively, and plotted in Fig. 6 together with the compiled data without any adjustment.

(5) $^{51}V(n,\alpha)^{48}Sc$

In present work, sixteen data sets [Ref. V: 1-16] were collected. The earlier data were three times as large as present results. Because the $^{51}V(n,\alpha)$ reaction is usually used as a threshold detector and the cross section is a significant factor to determine the mechanic performance of V alloy, which is important structure material of reactors, the large scattering of the data was noted by many labs, and new precise measurements have been carried out since 1973. After analyzing the published data, we thought that some measurements involved systematic or personal mistakes. Therefore, they were rejected in the evaluation. Our evaluation was mainly based on the latest accurate data, which were more coincident from each other. The evaluated data were given in neutron energy region of 6 to 19.6 MeV. All compiled data are plotted in Fig. 9, which shows how large the discrepances of the data are!

(6) $^{54}Fe(n,p)^{54}Mn$

Twelve compiled data sets[Ref. Fe: 4-8,10-12,14,17,19,20] are represented in Fig. 11. It is clear that our results are much higher than that of Smith and Paulsen at about 8 MeV, and the difference between ours and Paulsen's is small in high energy region. The evaluated results of BOSPOR [Ref. Fe: 18] (dash line), and of present work agree well in neutron energies from threshold to 11 MeV. But when the energy is over 11 MeV, our data are lower than that of BOSPOR. Present evaluated values are tabulated in Table 4.

(7) $^{56}Fe(n,p)^{56}Mn$

The decay of ^{56}Mn is favorable for used as standard cross section and threshold detector.

The evaluation of $^{56}Fe(n,p)^{56}Mn$ reaction was originally produced in 1977 in our lab. Thirty-four literatures distributed in a period of 1952-1977 were compiled and adjusted as requirement to obtain the optimum evaluated results. The detail information about how to deal with the collected data was given in reference [Ref. Fe: 15].

The reaction was reevaluated in present work. the cross section of 14.8 MeV was modified to 106.9±1.0 mb from 106.8±1.9 mb. Fig. 13 plots only the results of ENDF/B-V [Ref. Fe: 16] and present evaluated curve as well as our measured data [Ref. Fe:13] for comparison. The values of ENDF/B-V are lower than that of present evaluation in the whole energy region, and the difference between them is 4.5% at 14.8 MeV neutron energy.

(8) $^{59}Co(n,2n)^{58}Co$

Cobalt is a useful material for the reactors. Many labs, therefore, were and are interested in measuring the cross sections of the reaction. And sixteen data sets [Ref. Co:4,9,12,15,19,20,27,29-32,36-39,43] were obtained. Of them, Paulsen gave out the widest measured energy region from 12.63 to 19.59 MeV. So his data should be used if the whole excitation function was evaluated.But because the data of Paulsen were much lower than that of the majority including ours, before using Paulsen's data to evaluate, we need to normalize them by a factor evaluating value at 14.7 MeV.

The collected data at about 14 MeV, which didn't include Paulsen's value,were modified to 14.7 MeV according to the curve shape measured by us. And they were adjusted as the latest standard cross sections and decay parameters. The adjusted data at 14.7 MeV were fitted by the program of orthogonal polynormial, and a value of 772.1±9.3 mb were obtained at 14.7 MeV.

Since Jeronymo [Ref. Co: 9] used thicker samples, which induced a large correction for scattered neutrons, and Okumura [Ref. Co: 19] took incorrect decay scheme, their data were cancelled in present work. The evaluated excitation curve was given first in region of 10.9-20 MeV. Then, the data in energy region between threshold to 12 MeV were obtained through fitting the evaluated data by using theoretical calculation values. Fig. 14 shows present results, ENDF/B-V and three compiled data. It indicates that our evaluated curve is a little different from ENDF/B-V [Ref. Co: 44].

(9) $^{59}Co(n,p)^{59}Fe$

Our search of the literatures provided thirteen sets of data [Ref. Co:4,8,9,16,28,29,32,36-38,41-43] for the reaction. But most of them focused on about 14 MeV. Besides us only Smith and Jeronymo measured the data in wider energy region. Fig.15 displays the curves of present evaluated and BOSPOR as well. The shapes of the two curves are very similar. However, there is a shift of ~2 MeV between the two curves.

(10) $^{59}Co(n,\alpha)^{56}Mn$

Fig.16(a) illustrates nine sets of data [Ref. Co: 6,7,9-11,26,33,34,43] for the excitation curve measurements, and Fig. 16(b) shows other fourteen data [Ref. Co: 1,3-5,13,14,21,25,34-36,38,42,43] measured at about 14 MeV. In recent years, some authors (Ghoral, Huang, Li [Ref. Co: 33,34,43]) reported the cross sections having higher values, which made present evaluation higher than that of BOSPOR (dash line) in energies of 12-18 MeV.

(11) $^{58}Ni(n,2n)^{57}Ni$

Natural Ni is a important structure material for reactors, and the evaluation is very useful for reactor engineering. However, the data evaluation for the reaction is complicated due to branching ratios of β^+ and gamma rays, which were counted in order to determine the ^{57}Ni activity. The decay parameters of the ^{57}Ni were largely modified in recent years. Now $I\beta^+$=0.40, I_{511keV}=0.80 and $I_{1370keV}$= 0.779 are exhibited in references of Table of Isotopes [17] and Table of Radioactive Isotopes [18]. Before that, different values were used, for example, $I\beta^+$=0.467, I_{511keV}=0.936 and $I_{1370keV}$=0.86. That means, the cross sections will be increased by 15% for 511 keV γ- ray or β^+ measurements, or enlarged by 10% if the activity of ^{57}Ni was determined using 1370 keV γ- ray. However, it was very difficult to make correction for branching ratios because some references didn't offer sufficient information. Therefore,we still kept the previous decay constants in present evaluation, that is, $I\beta^+$=0.467, I_{511keV}=0.934 and $I_{1370keV}$=0.86. But other adjustments for the compiled data were made wherever necessary.The evaluated results are listed in Table 4 and plotted in Figs. 17(a) and (b) with the other compiled data [Ref. Ni: 1-4,6-12,13,15,16,18,19,21,24,25,30,34].

In our cross section calculations, $I_{1370keV}$=0.86 and 0.6788 abundance of ^{58}Ni were used. So, the previous cross sections were normalized by a factor of 67.88/68.72=0.988. The normalized data were employed in the evaluation. Table 3 lists our revised results, which were modified for abundance factor of 0.988 and branching ratio factor of 0.860/0.779=1.104.

(12) $^{58}Ni(n,p)^{58}Co$

Fig.18 plots eight sets of data [Ref. Ni: 5,14,17,23,25,33,36,38], including three groups of results measured in our lab. Our data are much higher than that of Smith and Vonach at about 8 MeV,and a little higher than Paulsen's data.Present evaluation is in good agreement with the data of IAEA-NDS-48 at energy below 5 MeV, far higher in energy region of 6-13 MeV, and lower than that of IAEA-NDS-48 when energy is over 13 MeV.

(13) $^{58}Ni(n,x)^{57}Co$

$^{58}Ni(n,x)^{57}Co$ contains the contributions of (n,np),(n,pn) and (n,d) reactions on ^{58}Ni nuclide. Since the ratio of (n,d)/(n,np) is about 0.2 at 14 MeV, the cross sections of ^{58}Ni(n,x)^{57}Co mainly come from the contribution of ^{58}Ni(n,np) reaction.

Eight data sets [Ref. Ni: 4,6,7,13,15,16,19,25] were compiled, and among them seven measurements centred on about 14 MeV neutron energy. Only our lab measured the excitation function in energies of 12-18 MeV. It isn't easy for us to make an evaluation for the reaction. Present work only gives eye guide curve.

(14) ^{60}Ni(n,p)^{60}Co

Eleven sets of data [Ref. Ni:12,19,20,22,26,28,32,35-38] are shown in Fig.20. Except Paulsen and Vonach, all the measurements were finished at about 14 MeV. Li and Wang gave out coincident results. But the discrepancy between Paulsen's data and Li's is as much as 20%. A systematic calculation is given in Table 4.

(15) ^{63}Cu(n, α)^{60}Co

Copper is a significant material of magnetic coil for fusion reactor. Therefore, the cross sections of ^{63}Cu(n, α)^{60}Co reaction are very interesting for understanding irradiation damage and the material performance under exposure to intense neutron flux. Since ^{60}Co has a half-life of 5.27 years, the activity of ^{60}Co is also an important factor for waste treatment and maintenance of facility.

We collected eleven data stes [Ref. Cu: 1-11],which are shown in fig.22. Lu's data agree with Wang's. They are about 50% higher than that of Paulsen, who measured the whole curve. No evaluation can be made for this reaction owing to big discrepancies among the data.

(16) ^{67}Zn(n,p)^{67}Cu

Fig. 24 indicats that our measurements [Ref. Zn: 19] gave out very different shape from the curve calculated using the systematic model of (n,p) reaction. It appears to be reasonable since the calculated curve only includes the cross section of ^{67}Zn(n,p)^{67}Cu reaction and the measured activities of ^{67}Cu are induced through the reactions of ^{67}Zn(n,p)^{67}Cu and ^{68}Zn(n,np), (n,d). That means, the cross sections of ^{67}Zn(n,p)^{67}Cu reaction are determined by the contributions of ^{67}Zn(n,p)^{67}Cu and ^{68}Zn(n,np), (n,d). The later has a great effect on the total cross section due to big abundance of ^{68}Zn 18.8%, which is much higher than 4.1% of ^{67}Zn [Ref. 21]. The effects of (n,np), (n,d) on ^{68}Zn are greater and greater with the increase of energy when the energy is over their thresholds (~10 MeV). This causes the considerable scattering of the cross sections.

Six data points [Ref.Zn:1-3,5,13,15] were collected. Five of them were around 14 MeV. The differences among the data are as big as three times. No evaluation is given except systematic calculation.

(17) ^{70}Zn(n,2n)^{69m}Zn

Thirty-one data points were compiled from leteratures, corresponding to seven distinct experiments [Ref. Zn: 7-10,14,17,19]. Among them, only Santry's data span the entire energy range from threshold to 20 MeV. These data, including our own, exhibited a high degree of inconsistancy.

The product of ^{69m}Zn was yielded by $^{70}Zn(n,2n)^{69m}Zn$ and $^{68}Zn(n,\gamma)^{69m}Zn$ reactions. The isotope of ^{68}Zn has an abundance of 18.57%, which is much larger than 0.62% of ^{70}Zn. This makes the measurements of cross sections quite complicated.

For each energy point, the activities of ^{69m}Zn were produced not only by incident neutrons investigated through the two reactions mentioned above, but also by low energy neutrons of background and scattered as well as the neutrons of D-D self build-up target mainly through $^{68}Zn(n,\gamma)$ reaction. The effects of low energy neutrons are different for different energy region. The large the effects, the lower the energy. The order of the magnidute of the low energy neutrons depends on the experimental arrangement and the experimental hall dimension. So it is difficult to make correction for the effects.Maybe this is the reason why the data were so inconsistant. And it was very difficult to obtain an evaluated curve using reported data. The curve shown in Fig. 25 was calculated by the systematic model of (n,2n) reaction, and the results are lower than that of Santry. This situation is reasonable since the measured cross sections consist of the contribution of the two reactions : $^{70}Zn(n,2n)^{69m}Zn$ and $^{68}Zn(n,\gamma)^{69m}Zn$.

(18) $^{96}Zr(n,2n)^{95}Zr$

The cross section of $^{96}Zr(n,2n)^{95}Zr$ reaction is very important as Zr is a cladding material for reactor fuel.Eight data [Ref.Zr:7,11,12,15,16,20-22] focused on 14 MeV were available. Only in our lab, a littel wider measured energy region was given from about 12 to 18 MeV. Therefore, it is quite difficult to get an evaluated curve. The curve, which is coincident with our measured results, was calculated using the systematic model of (n,2n) reaction in an energy range from threshold to 20 MeV, and it is used to replace excitation function evaluation. Fig. 34 shows the calculated curve and available data.

(19) $^{93}Nb(n,\alpha)^{90m}Y$

Thirteen references were compiled for the reaction [Ref.Nb: 1,3,8,9,13,14,17, 20-22,24-26,28,29] besides ours.The experiments of Mannan, Wolfle and present work cover wider energy regions. However,no measurement was finished in energy range of 9-13 MeV owing to the lack of suitable neutron source in our lab. Present work didn't make evaluation for the reaction since not enough data can be used. We sketched an eye guide curve through these points.

(20) $^{115}In(n,2n)^{114m}In$

Elemental indium has two stable isotopes: ^{113}In (4.3%) and ^{115}In (95.75%).The reactions of $^{113}In(n,\gamma)$ and $^{115}In(n,2n)$ need to be considered for ^{114m}In production. $^{115}In(n,2n)$ is dominant because of the high abundance of ^{115}In.

$^{113}In(n,\gamma)$ reaction, which has small cross sections for fast neutrons, is produced mainly by low energy background and scattered neutrons.Fifteen sets of data were collected, including our two. There is a considerable scattereing among the cross section values. Since the activities were determined usually using NaI(Tl) detector with a poor energy resolution for earlier experiments, it is difficult to take away the effect of adjacent γ rays, and this effect made the cross sections inconsistent. Nowadays, the activity measurements are improved by using Ge(Li) detector and more coincident results are published.

Present evaluation was finished at 14.7 MeV first, and then, the data of Menlov, Prestwood Lu and Ke Wei [Ref. 10,5,26,47] were normalized by the value at 14.7 MeV. The whole evaluated results are given in Table 4 and represented in Figs. 39(a) and (b).

(21) $^{115}In(n,n')^{115m}In$

The excitation function of $^{115}In(n,n')^{115m}In$ reaction covers considerable wider energy range from threshold of 0.3 MeV to about 20 MeV.So it is an excellent neutron indicator for neutron dosimetry monitor and spectrum measurements.

Twenty-four available data sets [Ref. In:1,7,9-11,14,16,18,20-22,24,28,31-35, 37,40-43,46] are plotted in Figs. 40(a) and (b), which indicate poor consistency of the data, especially in about 14 MeV region.

There are two reasons causing the data scattering. The first, part of the primary neutrons from D-T or D-D reaction,which is usually used as neutron source, is scattered through target backing and assembly, including the target-cooling system and beam tube, producing a small low energy component in the neutron field, and there is other part of low energy neutrons from (D-D) self build-up target in the target diaphragm. This kind of neutrons has a small effect on the reactions with high threshold, but has a large influnce on $^{115}In(n,n')^{115m}In$ reaction. Even in the condition of well-designed experiments, the activaties may be increased by several percent due to the effect of low energy neutrons. The second, there is an apparent presence of structures in the excitation curve in energy region of 2-6 MeV, which makes the measurements complicated. The positions of the structures, which depend on the energy resolution of the experiment, weren't coincident.

After analizing the collected data, we found that only Nagel, Ryves and present work [Ref. In: 9,41,46] corrected the effects of the low energy neutrons. The three data were used to make an evaluation at about 14 MeV. The evaluation is summarized in Table 4 and plotted in Figs. 40(a) and (b). It appears to adequately represent the general energy dependence of the reaction.

(22) $^{181}Ta(n,2n)^{180m}Ta$

The excitation function of the reaction has low threshold and smooth shape. Therefore, it is an excellent threshold detector.

Fig.52(a) shows that the available data for the reaction are divided into three groups according to their values. The data of Brzosko [Ref.Ta:12], for example,are the highest one, the data of Ryves and ours [Ref.Ta:17,20] are located at middle, and the others [Ref.Ta:6,10] belong to low value group.

During the experimental measurements, we found that the values of the cross sections measured at different labs depended on their use of decay scheme. Three different decay schemes can be found, that is, Brown's, Gallaghor's, and Ryves' [Ref.Ta:1,7,17]. If the available data at 14 MeV were normalized using these decay schemes respectively, the results showed that Ryves' decay scheme made the data of authors coincident very well within experiment error range except the results of Brzosko, which were higher than others.That means, Ryves' decay scheme is the best one. So, prior to evaluation of the reaction, the available data were adjusted regarding the branch ratio of Ryves' decay scheme besides the other necessary improvements of the data. Owing to only one available cross section value of 8.50 MeV in low energy range [Ref.Ta:20], the evaluation was finished in energy region of 12-20 MeV first. Then the theoretic calculation was used to fit the evaluated data so as to get the partial curve from threshold to 12 MeV. The evaluation of the reaction was fulfilled by Yao Lisan [Ref.Ta:21] of Lanzhou university.

Present evaluation, which quite differs from Bychkov's results [Ref.Ta:18], was made mainly based on the data of Ryves and ours as well as the shape of Prestwood [Ref.Ta:6]. Present evaluation appears to describe the cross sections of ^{181}Ta(n,2n)^{180m}Ta reaction better.

(23) Pt(n,x)^{195m}Pt

The activities of ^{195m}Pt are produced through three reactions of ^{194}Pt(n,γ)^{195m}Pt, ^{195}Pt(n,n')^{195m}Pt and ^{196}Pt(n,2n)^{195m}Pt. Each reaction has its own main energy region for producing ^{195m}Pt activities. For example, the contribution of ^{194}Pt(n,γ)^{195m}Pt reaction is in low energies, ^{195}Pt(n,n')^{195m}Pt in 1-5 MeV, while ^{196}Pt(n,2n)^{195m}Pt at energy above 6 MeV.

Since the energy region covered by Pt(n,x)^{195m}Pt is quite wider.In principle, no threshold exists for ^{195m}Pt production.Therefore, Pt(n,x) reaction is favorable for dosimetry applications. Unfortunitely, besides our own measurements [Ref. Pt: 7], only one energy point of 14.4 MeV was found [Ref.Pt:3].The data are summarized in Table 3 and plotted in Fig.54. In our work, there was just one measurement of 8.50 MeV in energy region from 6 MeV to 12 MeV [Ref.Pt:8] due to the lack of suitable neutron source. The cross section value at 8.50 MeV is much lower than that at two sides. This forms a so-called cross section valley at abont 8 MeV because the cross sections of ^{195}Pt(n,n')^{195m}Pt reaction is falling down, and the reaction of ^{196}Pt(n,2n)^{195m}Pt is just begining to produce in this energy region. The valley of the cross sections makes the measurement and evaluation complicated. More data were required to obtain a good evaluated curve for Pt(n,x)^{195m}Pt reaction. No evaluation was made for the reaction in present work.

(24) ^{204}Pb(n,2n)^{203}Pb

Pb element is a main material for dosimetry pretection and its nuclear data are very useful for nuclear engineering. However, only ^{204}Pb(n,2n)^{203}Pb reaction can be measured using activation technique. The latest data reported by Iwasaki and Kobayashi [Ref.Pb:13,14] are about 20% lower than that recommended by BOSPOR [Ref.Pb:11] and JENDL-2 [Ref.Pb:12], which are represented in Fig.58 by point line and dash line respectively. The differences made us to measure the reaction. We want to check whether the cross section has a lower tendency with the improvement of measurement technology. The reaction was measured in energy range of 9.4-15 MeV in our lab, and our values don't suppot the lower cross sections. It is about 15% higher than that of Iwasaki and Kobayashi at about 14 MeV.

Since there are large discrepancies among fourteen compiled sets of data [Ref.Pb:1-10,13-16], no evaluation was given in present work. Only eye guide curve is drawn in Fig.58. The curve is consistent with the results of BOSPOR at energy below 13 MeV, and a little lower when energy is over 13 MeV. While, the data of JEND-2 are different from present curve at energies below 12 MeV and above 14 MeV.

5 Summation

Fifty-eight reactions of Table 1 were investigated in present work. Most of the existing data for each reaction were compiled and analized for the evaluation. The reactions concerned were sorted into four categories. Twenty-nine reactions fall in category 1. The recommended values in the energy region of threshold-20 MeV were given for these reactions except ^{113}In(n,n')^{113m}In reaction, for which the evaluation was given only in energies around 14 MeV. The evaluations are reasonable representatives for their excitation functions. Therefore, our work provides reliable recommended data along with fitting errors for the twenty-nine reactions to users. The calculated results produced by use of the systematic model or the theoretic model for eight reactions fall in category 2. The results appear to be adequate description for the cross sections of the eight reactions. Six excitation curves drawn by eye guide belong to category 3. The recommended data for the reactions belonging to categories 2 and 3 were only references for users. After more coincident measured results were obtained, the reliable evaluations will be yielded. The rest of the reactions of Table 1 fall in category 4. No any evaluations were finished for the fifteen reactions. For these, the pictures only show the available data of literatures. Most of the reactions of category 4 are gas-producing reactions, such as (n, α), and (n,p) reactions. Some of the reactions have the highest cross section values in energy region of 8-12 MeV. But there are few data published in this range owing to lack of suitable neutron sources, and the existing data represent high degree of inconsistence. Therefore, further experiments should be focused on the reactions of category 4 and on the reactions having shor-of-data range of 8-12 MeV.

Acknowlodgements

This work was entrusted and supported by The Chinese Nuclear Data Centre, especially by Cai Dunjiu and Zhou Delin.

We would like to thank Wang Dahai, Cui Yunfeng, Ma Hongchang, Li Jizhou, Huang Jianzhou, Fan Peiguo, Xia Yijun, Chen Baolin, Ke Wei, Li Tingyan, Teng Dan, Yu Baosheng Zhou Enchen and Li Jingwen for their participating part of the measurements or making some evaluations. Thanks are also due to Zhou Shuhua for providing IBM personal computer, and to Chang Jin and Zhao Zhixiang for some calculations using systematic model, as well as to Wang Yongchang and Yao Lisan for providing some data of Ni and Cu and evaluation for Ta. We are indebted to Liu Tingjin for his useful discussions in some evaluations. We greatly appreciate Tang Hongqing for his carefully reading the manuscript and giving a lot interesting suggestions.

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Table 3 Digital cross section data measured

$^{24}Mg(n,p)^{24}Na$

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
8.50±0.27	131±9	13.80±0.10	197.2±6.4	15.88±0.27	149.0±6.6
12.18±0.10	166.0±7.3	13.95±0.22	200.0±8.8	15.92±0.27	150.8±6.6
12.37±0.14	187.1±8.2	14.05±0.18	197.5±8.7	16.44±0.24	141.4±6.2
12.49±0.11	203.7±8.9	14.08±0.10	197.2±6.4	16.52±0.30	137.2±6.0
12.63±0.15	187.8±8.2	14.17±0.22	194.0±8.5	16.76±0.31	135.2±5.9
12.67±0.11	215.2±9.4	14.29±0.27	190.7±8.4	16.95±0.27	126.1±5.5
12.96±0.21	189.8±8.3	14.36±0.15	192.7±6.3	17.25±0.22	122.9±5.4
13.01±0.15	195.6±8.6	14.58±0.20	183.0±5.2	17.54±0.21	114.0±5.0
13.15±0.20	192.9±8.5	14.77±0.25	176.7±5.8	17.91±0.21	109.5±4.8
13.17±0.17	191.2±8.4	14.82±0.26	175.6±5.0	18.03±0.15	110.5±4.0
13.24±0.14	205.6±9.0	14.99±0.23	168.2±7.4	18.26±0.18	108.4±4.8
13.35±0.21	199.9±8.8	15.33±0.25	163.8±7.2		
13.57±0.13	210.0±6.9	15.64±0.29	155.9±6.8		

$^{27}Al(n,\alpha)^{24}Na$

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
12.23±0.14	118.2±5.1	13.68±0.35	124.2±3.3	16.05±0.43	91.8±4.0
12.79±0.29	120.8±5.3	14.36±0.15	119.1±3.2	17.18±0.38	71.2±3.1
13.41±0.16	124.9±3.3	14.58±0.21	115.8±3.0	17.97±0.27	61.0±2.6
13.56±0.13	126.1±3.3	14.77±0.25	114.2±3.0		

En(MeV)	$^{45}Sc(n,2n)^{44m}Sc$ σ(mb)	$^{45}Sc(n,2n)^{44g}Sc$ σ(mb)	$^{45}Sc(n,2n)^{44m+g}Sc$ σ(mb)
13.15±0.18	42.86±2.64		
13.55±0.18	53.84±3.31		
13.79±0.18	91.30±4.84		
14.07±0.14	108.0±5.3		
14.36±0.22	124.4±6.1		
14.58±0.28	129.3±6.2	185.2±9.4	314.5±11.3
14.84±0.38	133.6±6.6		
15.64±0.25	149.9±9.2		
16.03±0.38		234.7±14.8	388.2±17.6

(Continued)

16.76±0.32	160.0±9.6	251.3±15.7	411.4±18.5
16.95±0.19	161.4±9.9		
17.54±0.16		279.5±17.8	444.1±20.5
17.91±0.18	166.5±10.2		
18.26±0.15	157.8±10.3	288.5±19.5	446.2±22.1

En(MeV)	$^{46}Ti(n,p)^{46}Sc$* σ(mb)	$^{48}Ti(n,p)^{48}Sc$ σ(mb)	$^{51}V(n,\alpha)^{48}Sc$ σ(mb)	$^{47}Ti(n,p)^{47}Sc$ σ(mb)
4.5±0.1	44±7			
5.0±0.1	68±11	0.1		
6.3±0.4		2.5±0.2		
7.6±0.6		10.8±0.6		
8.50±0.27	241±16	16.8±1.1	16.1±0.11	99.7±7.0
10.0±0.6		27.2±3.5		
11.4±0.8		43.1±5.5	5.3±0.7	
12.23±0.14	288.5±20.4	50.2±3.2	10.0±0.6	
12.79±0.29	297.6±19.8	53.6±3.5	11.3±0.7	
13.41±0.16			13.0±0.7	
13.68±0.35	282.0±13.9	58.7±3.1	13.9±0.7	
14.38±0.15		61.3±3.4	15.8±0.8	
14.58±0.21	284.7±14.0	62.8±3.2	16.6±0.9	
14.77±0.25		63.4±3.7	17.1±0.9	
16.05±0.43	283.9±17.1	57.1±3.6	19.0±1.2	
17.18±0.38	271.3±16.3	50.2±3.1	20.0±1.3	
17.97±0.27	292.7±17.7	45.4±2.9	19.4±1.3	

* $^{46}Ti(n,p)+^{47}Ti(n,np)$

$^{55}Mn(n,2n)^{54}Mn$

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
12.37±0.20	442±23	14.44±0.15	806±32	14.98±0.25	855±34
13.15±0.30	605±32	14.58±0.20	812.9±28.9	15.64±0.50	883±48
13.52±0.16	662±26	14.73±0.21	814±32	16.95±0.50	896±47
13.80±0.13	693±28	14.85±0.25	830.5±29.5	17.91±0.40	885±47
14.29±0.35	780±41	14.90±0.25	841±34	18.26±0.23	881±46

(Continued)

En(MeV)	$^{54}Fe(n,p)^{54}Mn$ σ (mb)	$^{54}Fe(n,\alpha)^{51}Cr$ σ (mb)	En(MeV)	$^{54}Fe(n,p)^{54}Mn$ σ (mb)	$^{54}Fe(n,\alpha)^{51}Cr$ σ (mb)
8.50±0.27	571.3±38.0	43.2±3.7	14.73±0.25	301±11	89.9±4.6
12.37±0.26	466±22	72.0±4.2	14.83±0.26	284±11	93.8±4.8
12.86±0.30	432±21	78.5±4.5	14.90±0.25	288±11	
12.96±0.35	435±21	80.6±4.7	14.97±0.25	282±11	
13.14±0.40	420±20		15.33±0.45	249±12	89.5±5.2
13.50±0.13	379±14		15.37±0.50	246±12	88.8±5.1
13.53±0.13	393±15	86.5±4.4	15.64±0.50	253±12	86.3±5.0
13.57±0.47	377±18	87.6±5.1	16.45±0.40	228±11	86.0±5.0
13.77±0.10	360±14	88.7±4.5	16.95±0.35	200±10	83.2±4.8
13.95±0.40	359±17		17.18±0.35	181±9	
14.29±0.50	332±16	89.4±5.1	17.25±0.22		80.3±4.6
14.42±0.15	316±12		17.54±0.21		76.2±4.4
14.45±0.15	316±12	90.5±4.6	17.91±0.21		71.5±4.1
14.58±0.20	311±11	90.2±4.5	18.01±0.20		71.9±4.2
14.71±0.20	301±11		18.23±0.18		69.5±4.0

$^{56}Fe(n,p)^{56}Mn$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
12.79±0.29	112.7±4.6	13.64±0.31	114.3±4.7	14.66±0.16	107.5±3.1
12.86±0.21	112.9±4.6	13.68±0.35	114.2±4.7	14.84±0.18	105.2±3.1
12.98±0.18	116.6±4.8	13.78±0.11	114.0±3.3	14.90±0.18	104.8±3.1
13.53±0.11	112.9±3.3	14.39±0.13	109.8±3.2	15.27±0.30	95.1±3.9
13.62±0.25	114.3±4.7	14.58±0.20	108.3±2.7	15.68±0.36	91.1±3.7
16.04±0.32	83.3±3.4	16.77±0.28	74.1±3.0	17.97±0.27	59.3±2.4
16.05±0.43	85.3±3.5	17.18±0.38	69.3±2.7	18.26±0.21	58.5±2.4
16.56±0.29	77.2±3.1	17.30±0.26	67.5±2.7		
16.63±0.33	76.3±3.1	17.54±0.22	66.9±2.7		

En(MeV)	$^{59}Co(n,2n)^{58}Co$ σ (mb)	$^{59}Co(n,\alpha)^{56}Mn$ σ (mb)	En(MeV)	$^{59}Co(n,2n)^{58}Co$ σ (mb)	$^{59}Co(n,\alpha)^{56}Mn$ σ (mb)
12.49±0.15	435±20	26.2±1.1	14.58±0.25	789±29	30.2±0.9
12.81±0.29	506±24	26.4±1.1	14.77±0.25	789±29	29.8±1.0

(Continued)

12.88±0.21	573±27	27.8±1.2	14.83±0.26	808±29	30.5±1.0
13.35±0.27	605±28	28.4±1.2	15.09±0.34	810±38	27.8±1.2
13.65±0.31	694±32	29.1±1.2	15.69±0.36	856±40	27.1±1.1
13.69±0.35	676±31	28.8±1.2	16.08±0.40	859±40	26.7±1.1
13.80±0.10	653±24	28.9±0.9	16.65±0.33	859±40	22.6±1.0
14.08±0.10	715±28	29.4±0.9	17.20±0.38	875±41	21.1±0.9
14.17±0.32	766±36	29.9±1.3	17.55±0.22	890±41	19.5±0.9
14.36±0.15	769±28	30.3±1.0	18.26±0.21	890±41	16.8±0.7

* measured in 1981

En(MeV)	$^{59}Co(n,2n)^{58}Co$ σ(mb)	$^{59}Co(n,p)^{59}Fe$ σ(mb)	$^{59}Co(n,\alpha)^{56}Mn$ σ(mb)
12.84±0.30	490±47		
13.60±0.13	640±27	55.3±2.6	
13.74±0.11	649±27	51.7±2.7	32.0±1.6
14.60±0.22	761±37	48.3±2.4	30.4±1.6
14.72±0.26	764±43	45.7±2.2	31.3±1.9
14.81±0.30	816±52	47.8±2.4	
15.37±0.44	804±53	44.2±2.2	
16.42±0.60			25.8±2.9
17.04±0.17	913±50	35.5±2.2	23.4±1.4
17.77±0.18	918±63	31.4±2.0	20.0±1.4

* measured in 1988

En(MeV)	$^{58}Ni(n,x)^{57}Co$ σ(mb)	$^{58}Ni(n,2n)^{57}Co$ σ(mb)	En(MeV)	$^{58}Ni(n,x)^{57}Co$ σ(mb)	$^{58}Ni(n,2n)^{57}Co$ σ(mb)
12.79±0.29	350±22	3.8±0.5	16.63±0.33	644±42	71.2±2.4
12.86±0.21	336±24	3.9±0.5	17.18±0.38	668±43	75.1±2.5
13.64±0.31	430±27	18.0±1.3	17.30±0.26	675±45	76.6±2.6
13.68±0.35	464±28	20.5±0.9	17.54±0.22	677±45	80.0±2.7
14.58±0.20	528±28	39.9±1.0	17.97±0.27	648±44	78.0±2.7
15.68±0.36	594±40	61.8±3.0	18.26±0.21	658±46	83.3±2.9
16.05±0.43	623±41	65.6±2.2			

(Continued)

En(MeV)	$^{58}Ni(n,p)^{58}Co$ σ(mb)	$^{60}Ni(n,p)^{60}Co$ σ(mb)	$^{62}Ni(n,\alpha)^{59}Fe$ σ(mb)
8.50±0.27*	689±47		
13.60±0.13	461±16		
14.09±0.14	366±12	162±8	20.1±1.3
14.58±0.20**	341±11		
14.60±0.22	331±17		
14.77±0.28	285±17	142±5	25.0±1.7
14.81±0.30	290±18		
15.37±0.44	260±18		
16.42±0.60	199±13		
17.77±0.18	166±9		

* 1985 ** 1977

En(MeV)	$^{63}Cu(n,\alpha)^{60}Co$ σ(mb)	$^{66}Zn(n,2n)^{65}Zn$ σ(mb)	$^{67}Zn(n,p)^{67}Cu$ σ(mb)	$^{70}Zn(n,2n)^{69m}Zn$ σ(mb)
12.82±0.45	68.9±2.9	274±7	38.6±1.1	395±9
14.09±0.12	56.7±1.7	588±13	56.8±1.5	564±13
14.47±0.17	54.3±1.6	618±20	73.9±2.0	
14.58±0.17	54.4±1.6	746±16		671±16
14.78±0.35		739±24		
14.80±0.19	52.2±1.5	766±17	76.2±2.2	
16.86±0.96	37.1±1.2	772±26	130±5	644±23
17.63±0.21	31.2±1.0	793±26	165±6	651±22
17.69±0.25		820±28		

En(MeV)	$^{85}Rb(n,2n)^{84m}Rb$ σ(mb)	$^{85}Rb(n,2n)^{84m+g}Rb$ σ(mb)	$^{85}Rb(n,p)^{85m}Kr$ σ(mb)
12.49±0.11	238±9	652±26	
13.47±0.10	339±8	845±28	4.06±0.13
13.74±0.21	372±15	912±34	
13.83±0.07	387±12	940±29	4.28±0.14
14.43±0.10	442±14	1084±33	4.33±0.14
14.58±0.12	460±13	1106±31	4.38±0.13
14.70±0.14	470±15	1128±34	4.40±0.14
14.80±0.15	478±15	1138±35	4.38±0.14
16.02±0.22	566±23	1287±48	
17.12±0.13	600±24	1343±50	
17.54±0.15	607±25	1373±50	

(Continued)

En(MeV)	$^{85}Rb(n,\alpha)^{82}Br$ σ (mb)	$^{87}Rb(n,p)^{87}Kr$ σ (mb)	$^{87}Rb(n,2n)^{86}Rb$ σ (mb)
13.47±0.10	4.11±0.14	6.72±0.27	1049±39
13.83±0.07	4.75±0.17	8.19±0.33	1073±40
14.43±0.10	5.73±0.20	9.47±0.39	1199±44
14.58±0.12	5.88±0.21	10.2±0.3	1215±36
14.70±0.14	5.93±0.21	11.0±0.5	1233±46
14.80±0.15	6.15±0.22	10.4±0.4	1252±46

$^{89}Y(n,2n)^{88}Y$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
12.81±0.13	381±22	14.58±0.21	1018±34	16.63±0.30	1257±64
13.51±0.16	702±30	14.70±0.23	1048±52	17.20±0.28	1270±68
13.65±0.20	746±40	14.96±0.06	1076±48	18.00±0.30	1287±66
13.69±0.22	755±41	15.68±0.31	1156±60		
14.09±0.07	899±39	16.08±0.33	1204±62		

$^{90}Zr(n,2n)^{89}Zr$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
12.37±0.06	41.5±1.7	14.35±0.13	722.7±29.7	17.12±0.16	1139±47
12.49±0.07	65.0±2.7	14.58±0.17	774.2±21.9	17.18±0.18	1165±48
12.79±0.09	153.0±6.3	14.77±0.18	856.7±31.2	17.43±0.18	1153±47
12.86±0.09	183.4±7.5	14.80±0.19	877.8±36.0	17.52±0.15	1187±49
13.35±0.11	379.4±15.6	15.33±0.15	891.9±36.6	17.76±0.18	1177±48
13.58±0.15	452.7±18.6	15.65±0.17	971.1±39.9	18.12±0.17	1216±50
13.81±0.06	542.2±22.3	16.02±0.16	1033±42	18.24±0.17	1216±50
13.95±0.12	585.2±24.0	16.45±0.18	1097±45		
14.05±0.15	609.6±25.0	16.63±0.16	1098±45		

$^{96}Zr(n,2n)^{95}Zr$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
12.82±0.45	1426±31	14.80±0.19	1594±32	17.69±0.25	1220±41
14.09±0.12	1499±34	16.86±0.96	1299±42		
14.60±0.30	1514±31	17.63±0.21	1170±36		

(Continued)

En(MeV)	$^{93}Nb(n,2n)^{92m}Nb$ σ(mb)	$^{93}Nb(n,\alpha)^{90m}Y$ σ(mb)	En(MeV)	$^{93}Nb(n,2n)^{92m}Nb$ σ(mb)	$^{93}Nb(n,\alpha)^{90m}Y$ σ(mb)
8.50±0.27		0.79±0.16	16.05±0.31	429±17	
12.79±0.16	434±17		16.65±0.34	420±17	5.59±0.51
12.87±0.10	448±18	4.15±0.39	17.18±0.30	413±16	
13.66±0.10	470±19	5.41±0.42	17.31±0.31	408±16	5.31±0.38
13.69±0.32	452±18		17.55±0.21	405±16	4.92±0.68
14.58±0.20	457±11		17.97±0.24	395±16	
14.60±0.30	457±18	5.68±0.36	18.24±0.16	388±16	
15.69±0.33	439±18	5.58±0.48			

$^{113}In(n,2n)^{112m}In$

En(MeV)	σ(mb)
14.4±0.3	1095±47

$^{115}In(n,\gamma)^{116m}In$

En(MeV)	σ(mb)
0.144±0.010	237.5±8.6
0.565±0.010	167.5±5.8

$^{115}In(n,p)^{115}Cd$

En(MeV)	σ(mb)
14.1±0.3	3.3±1.4
14.5±0.3	4.15±0.50
14.8±0.3	3.25±0.50

$^{115}In(n,\alpha)^{112}Ag$

En(MeV)	σ(mb)
14.1±0.3	2.28±0.07
14.8±0.3	2.75±0.07

$^{113}In(n,n')^{113m}In$

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
8.50±0.27	229±17	14.10±0.30	51.5±1.9	14.58±0.15	51.0±1.9
13.54±0.11	63.4±2.4	14.31±0.13	54.3±2.1	14.78±0.15	44.8±1.7
13.72±0.05	62.2±2.3	14.50±0.30	51.1±2.4	14.80±0.30	49.7±1.8

(Continued)

$^{115}In(n,2n)^{114m}In$

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
11.4±0.8	749±96	13.7±0.2	1258±84	16.1±0.5	1333±101
12.2±0.2	1125±86	14.3±0.3	1331±89	17.2±0.5	1315±101
12.8±0.3	1163±88	14.6±0.3	1359±91	18.0±0.4	1304±100
13.4±0.2	1198±80	14.8±0.3	1354±90		

* measured by NaI(Tl) (1975)

$^{115}In(n,2n)^{114m}In$

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
12.18±0.20	868±33	13.35±0.24	1200±46	14.78±0.30	1274±49
12.37±0.20	954±37	13.54±0.21	1217±47	15.09±0.25	1343±52
12.43±0.31	1025±39	13.72±0.23	1257±48	15.98±0.30	1283±49
12.63±0.21	1037±40	13.80±0.22	1257±49	16.69±0.35	1309±50
12.82±0.25	1066±41	14.30±0.28	1251±48	17.43±0.35	1257±50
12.96±0.23	1106±42	14.57±0.23	1296±31	17.90±0.20	1290±50

* measured by Ge(Li) (1986)

$^{115}In(n,n')^{115m}In$

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
0.88±0.04	30.4±1.6	2.50±0.08	324.1±18.9	4.17±0.22	308.6±18.0
1.00±0.04	65.2±3.4	2.61±0.08	341.5±19.9	4.50±0.20	303.7±15.2
1.19±0.34	101.9±5.3	2.73±0.14	352.5±20.6	4.55±0.22	325.7±19.0
1.40±0.34	139.5±7.3	2.81±0.27	346.6±20.2	4.91±0.22	332.8±19.4
1.43±0.34	139.0±7.3	2.84±0.25	350.0±17.5	5.22±0.22	308.6±18.0
1.70±0.02	193.3±11.3	2.95±0.37	332.4±19.4	5.30±0.14	322.5±16.1
1.80±0.05	214.0±12.5	3.00±0.42	330.1±19.2	5.46±0.12	275.6±16.1
1.89±0.06	228.2±13.3	3.13±0.13	320.3±18.7	5.65±0.10	336.0±16.8
1.94±0.05	236.1±13.8	3.35±0.16	299.5±17.5	8.50±0.27	297±27
2.04±0.08	266.3±15.5	3.56±0.20	297.3±17.3	13.54±0.11	67.2±2.5
2.05±0.05	255.6±14.9	3.75±0.23	301.5±17.6	13.72±0.05	64.1±2.3
2.12±0.15	297.7±17.4	3.78±0.20	277.3±16.2	14.10±0.30	54.4±2.0
2.18±0.31	286.4±16.7	3.80±0.30	295.5±14.8	14.31±0.13	55.1±2.0
2.23±0.09	316.7±18.5	3.91±0.26	292.9±17.1	14.50±0.30	54.3±2.9
2.24±0.08	320.9±18.7	4.03±0.28	289.1±16.9	14.58±0.15	53.8±2.0
2.33±0.07	306.6±17.9	4.11±0.29	290.0±16.9	14.78±0.15	50.8±1.9
2.41±0.02	338.9±19.8	4.13±0.11	303.7±17.6	14.80±0.30	50.8±1.8
2.46±0.12	353.3±20.6	4.14±0.30	303.3±15.2		

(Continued)

$^{127}I(n,2n)^{128}I$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
11.4±0.8	894±116	14.36±0.15	1619±67	17.18±0.38	1665±93
12.23±0.14	1407±79	14.58±0.21	1632±68	17.97±0.27	1624±94
12.79±0.29	1508±87	14.77±0.25	1637±68		
13.68±0.35	1594±66	16.05±0.43	1707±94		

En(MeV)	$^{136}Ce(n,2n)^{135}Ce$ σ (mb)	$^{140}Ce(n,p)^{140}La$ σ (mb)	$^{138}Ce(n,2n)^{137m}Ce$ σ (mb)
13.50±0.19	1138±56	5.28±0.35	
13.77±0.13	1202±48	5.83±0.34	
14.01±0.09	1210±45	6.05±0.34	
14.07±0.16	1244±39	6.28±0.33	925±68
14.30±0.18	1303±48	6.74±0.34	
14.50±0.25	1330±57	7.05±0.43	
14.68±0.29	1315±64	7.47±0.49	
14.82±0.30	1361±74	7.62±0.54	

En(MeV)	$^{140}Ce(n,2n)^{139}Ce$ σ (mb)	$^{142}Ce(n,2n)^{141}Ce$ σ (mb)	En(MeV)	$^{140}Ce(n,2n)^{139}Ce$ σ (mb)	$^{142}Ce(n,2n)^{141}Ce$ σ (mb)
12.37±0.15	1531±81	1996±110	14.59±0.16	1766±44	1981±57
12.72±0.17	1597±80	2089±109	14.68±0.29	1771±80	1974±93
13.10±0.16	1602±77	2093±105	14.82±0.30	1804±90	1994±106
13.35±0.24	1693±76	1963±92	15.14±0.34	1751±74	1878±83
13.50±0.19	1643±74	2019±95	15.64±0.34	1811±78	1793±81
13.54±0.16	1659±73	1940±89	16.10±0.34	1833±88	1745±87
13.77±0.13	1703±60	2061±78	16.45±0.34	1876±84	1629±77
14.01±0.09	1726±55	2017±73	16.79±0.34	1856±98	1560±86
14.17±0.20	1740±71	2043±88	17.25±0.38	1839±106	1379±75
14.30±0.18	1734±55	1990±72	17.48±0.34	1811±99	1256±72
14.50±0.25	1766±67	1979±81	18.23±0.20	1838±105	963±57
14.55±0.26	1794±75	2071±91			

(Continued)

$^{169}Tm(n,2n)^{168}Tm$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
12.37±0.27	1850±89	14.59±0.10	1966±75	17.35±0.26	1738±84
12.60±0.29	1905±92	15.09±0.33	1958±95	17.53±0.22	1582±77
13.01±0.23	1935±94	15.64±0.35	1924±93	17.91±0.27	1451±70
13.15±0.31	2050±99	16.02±0.34	1967±95	18.21±0.22	1364±66
13.74±0.36	1973±96	16.63±0.33	1945±94		
14.29±0.32	1973±96	16.95±0.41	1787±87		

$^{169}Tm(n,3n)^{167}Tm$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
15.09±0.33	4.9±0.5	16.63±0.33	106±6	17.53±0.22	346±17
15.64±0.35	13.2±1.1	16.95±0.41	185±9	17.91±0.27	460±22
16.02±0.34	22.5±1.7	17.35±0.26	276±13	18.21±0.22	603±29

$^{181}Ta(n,2n)^{180m}Ta$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
8.50±0.22	243±18	14.16±0.32	1276±50	16.63±0.33	971±38
12.32±0.22	1286±50	14.47±0.13	1241±33	16.95±0.41	882±34
12.37±0.27	1234±48	14.59±0.10	1239±30	17.12±0.28	834±32
12.49±0.28	1287±50	14.75±0.15	1240±33	17.25±0.38	782±30
12.87±0.29	1312±51	15.09±0.33	1183±46	17.30±0.26	808±31
12.96±0.31	1261±49	15.35±0.40	1165±45	17.43±0.24	744±29
13.01±0.23	1303±51	15.56±0.34	1186±46	17.56±0.22	727±28
13.54±0.11	1292±35	15.66±0.35	1166±45	17.76±0.29	683±27
13.67±0.31	1291±50	15.92±0.42	1118±44	18.00±0.27	604±24
13.79±0.10	1288±35	16.02±0.34	1108±43	18.25±0.21	578±23
13.97±0.37	1287±50	16.10±0.43	1071±42		
14.04±0.38	1278±50	16.46±0.34	976±38		

(Continued)

$^{181}Ta(n,p)^{181}Hf$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
12.80±0.17	2.08±0.13	14.45±0.15	3.66±0.16	16.45±0.20	5.47±0.31
12.86±0.18	2.19±0.13	14.58±0.20	3.96±0.17	17.18±0.19	5.85±0.32
13.53±0.13	2.47±0.11	14.73±0.25	4.19±0.18	17.25±0.18	5.86±0.32
13.70±0.28	3.43±0.19	14.83±0.26	4.33±0.19	17.54±0.17	6.12±0.35
13.77±0.10	2.88±0.13	15.35±0.27	4.71±0.26	18.01±0.10	5.90±0.34
13.95±0.21	2.97±0.16	16.10±0.25	5.25±0.30	18.23±0.18	5.59±0.31

$Pt(n,x)^{195m}Pt$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
0.144±0.040	6.16±0.52	4.11±0.26	328±23	14.33±0.13	431±16
0.329±0.114	6.32±0.40	4.37±0.22	319±22	14.35±0.13	410±14
0.565±0.123	8.28±0.46	5.13±0.20	333±19	14.60±0.21	407±13
0.653±0.132	12.3±1.3	5.19±0.18	346±22	14.64±0.21	428±14
0.677±0.110	10.7±0.7	5.53±0.21	355±17	14.77±0.25	438±18
0.776±0.053	11.3±1.1	5.59±0.17	382±18	14.82±0.26	420±14
1.01±0.16	38.6±2.3	8.50±0.27	246±17	15.56±0.34	438±34
1.03±0.07	41.0±2.5	12.99±0.18	422±25	15.71±0.33	452±33
1.39±0.17	104±6	13.62±0.11	422±17	15.78±0.35	464±29
2.84±0.26	248±16	13.72±0.27	418±14	16.75±0.27	444±32
2.87±0.39	220±14	13.74±0.27	411±32	17.22±0.30	433±17
2.94±0.41	240±16	13.76±0.29	410±24	17.35±0.31	417±33
4.07±0.30	347±34	13.83±0.09	418±17	17.76±0.24	403±24

$^{197}Au(n,2n)^{196}Au^{*}$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
9.41	6.35	11.04	1677	12.49	1948	13.20	2058	14.10	2102	16.05	2102
9.67	1160	12.10	1861	13.02	2080	13.60	2043	14.40	2129	17.09	1916
10.34	1353	12.12	1932	13.05	2067	14.03	2034	14.80	2026		

* 1968 Data normalized at 14.4 MeV to 2129 mb.

(Continued)

$^{197}Au(n,2n)^{196}Au$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
12.78	2075±118	14.60	2129±95	17.18	1925±110	18.23	1589±50
13.68	2127±120	16.05	2059±116	17.97	1640±93		

$^{197}Au(n,3n)^{195}Au$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
16.05	29.6±6.3	17.18	244±22	17.97	523±38	18.32	731±55

$^{204}Pb(n,2n)^{203}Pb$

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
9.41±0.45	332±14	13.05±0.20	2029±93	14.4 ±0.2	2047±73
10.34±0.40	832±30	13.4 ±0.2	1921±69	14.49±0.40	2054±45
11.04±0.35	1255±44	13.6 ±0.2	1931±70	14.58±0.16	2018±43
12.12±0.35	1753±90	14.1 ±0.2	1998±72	14.8 ±0.2	2008±72

$^{198}Pt(n,2n)^{197}Pt$

En(MeV)	σ (mb)
8.50±0.27	554±39

Table 4 Present Recommended Values

$^{27}Al(n,\alpha)^{24}Na$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
6.0	1.34±0.06	10.0	90.0±2.6	13.4	125.9±4.1	14.5	117.1±1.6	16.5	86.6±2.2
6.5	7.06±0.19	10.5	98.9±2.9	13.6	125.1±2.9	14.6	115.8±1.6	17.0	78.7±2.0
7.0	14.9±0.3	11.0	107.3±3.2	13.8	123.9±2.9	14.7	114.5±1.1	17.5	71.1±1.1
7.5	27.8±0.6	11.5	115.0±4.2	14.0	122.3±2.8	14.8	113.2±1.1	18.0	63.7±1.6
8.0	43.2±0.8	12.0	121.2±4.3	14.1	121.4±2.2	14.9	111.8±1.6	18.5	56.2±1.5
8.5	57.7±1.6	12.5	125.5±4.3	14.2	120.3±1.9	15.0	110.3±1.5	19.0	49.0±1.5
9.0	70.1±2.1	13.0	126.4±4.2	14.3	119.3±1.9	15.5	102.6±2.5	19.5	42.3±1.6
9.5	80.7±2.4	13.2	126.3±4.2	14.4	118.2±1.9	16.0	94.6±2.3	20.0	37.5±1.5

En(MeV)	$^{45}Sc(n,2n)^{44m}Sc$ (E) σ(mb)	$^{46}Sc(n,2n)^{44g}Sc$ (E) σ(mb)	$^{45}Sc(n,2n)^{44m+g}Sc$ (E) σ(mb)
11.57	0	0	0
12.0	2.2±0.2	5.9±0.6	8.1±0.7
12.5	12±1	15±2	27±3
13.0	36±3	42±4	78±6
13.4	62±3	75±6	137±8
13.8	91±3	113±6	204±9
14.2	114±4	148±7	262±10
14.6	132±5	177±8	308±13
15.0	144±6	200±10	344±16
15.4	152±6	218±136	370±19
15.8	157±7	233±15	390±22
16.2	160±8	246±18	405±25
16.6	162±8	256±18	418±26
17.0	163±8	267±18	429±26
17.4	164±8	276±18	440±26
17.8	165±8	286±21	451±28
18.0	166±8	290±22	456±30
19.0	168±9	303±33	471±42
20.0	167±10	282±45	448±55
21.0	161±10		

∻ (E): Evaluated. (S): Systematic calculation.

(G): Eye guide. (T): Theoretical calculation.

(Continued)

$^{46}Ti(n,p)^{46}Sc$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
3.6	12.8±2.5	6.8	162±13	10.0	266±27	13.2	294±9	16.4	290±12
4.0	23.9±1.4	7.2	181±16	10.4	273±27	13.6	295±8	16.8	289±14
4.4	40.0±2.0	7.6	197±18	10.8	278±28	14.0	295±8	17.2	288±18
4.8	59.2±2.4	8.0	212±20	11.2	283±28	14.4	295±8	17.6	287±23
5.2	80.0±3.2	8.4	226±22	11.6	287±29	14.8	294±8	18.0	286±23
5.6	101±4	8.8	238±23	12.0	290±29	15.2	293±9	18.4	286±23
6.0	123±6	9.2	248±25	12.4	292±13	15.6	292±9	18.8	285±23
6.4	143±9	9.6	258±26	12.8	293±11	16.0	291±10		

$^{48}Ti(n,p)^{48}Sc$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
5.0	0.088±0.009	8.5	16.6±0.83	12.0	48.0±3.4	14.6	62.9±0.6	17.5	48.3±2.9
5.5	0.447±0.045	9.0	20.2±1.0	12.5	52.8±3.2	14.8	62.6±0.6	18.0	45.1±2.7
6.0	1.71±0.12	9.5	24.0±1.2	13.0	57.0±3.4	15.0	62.3±0.9	18.5	42.2±2.5
6.5	3.48±0.26	10.0	28.2±1.4	13.5	60.2±3.1	15.5	60.4±1.8	19.0	40.2±2.4
7.0	6.25±0.49	10.5	32.8±1.6	14.0	62.4±2.0	16.0	57.7±2.3	19.5	37.5±2.2
7.5	9.64±0.52	11.0	37.8±1.9	14.2	62.7±0.6	16.5	54.8±2.7	20.0	35.7±2.2
8.0	13.2±0.66	11.5	42.9±2.5	14.4	62.9±0.6	17.0	51.6±3.1		

$^{51}V(n,\alpha)^{48}Sc$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
6.0	0.1±0.1	9.5	2.84±0.20	12.6	11.04±0.53	15.4	18.57±0.61	18.2	19.52±0.94
6.5	0.25±0.12	10.0	3.80±0.27	13.0	12.34±0.48	15.8	19.24±0.69	18.6	18.80±0.90
7.0	0.45±0.15	10.5	4.90±0.34	13.4	13.57±0.43	16.2	19.76±0.77	19.0	17.82±0.94
7.5	0.65±0.13	11.0	6.20±0.43	13.8	14.74±0.41	16.6	20.12±0.84	19.4	16.56±1.16
8.0	1.00±0.10	11.4	7.30±0.51	14.2	15.84±0.43	17.0	20.28±0.91		
8.5	1.55±0.11	11.8	8.55±0.52	14.6	16.86±0.49	17.4	20.25±0.95		
9.0	2.09±0.15	12.2	9.68±0.53	15.0	17.77±0.55	17.8	20.01±0.96		

(Continued)

$^{55}Mn(n,2n)^{54}Mn$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
10.5	9±1	12.5	476±20	14.5	812±15	16.5	912±74	18.5	877±88
11.0	100±8	13.0	586±20	15.0	855±19	17.0	912±69	19.0	853±85
11.5	222±10	13.5	679±19	15.5	884±36	17.5	906±64	19.5	825±83
12.0	353±15	14.0	754±18	16.0	903±60	18.0	894±78	20.0	790±79

$^{54}Fe(n,p)^{54}Mn$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
2.0	14.4±1.02	5.5	449.3±31.9	10.0	587.0±88.1	14.0	348.3±10.4	17.5	175.9±6.2
2.5	64.8±4.6	6.0	498.8±35.4	10.5	586.7±88.0	14.5	315.5±9.5	18.0	160.3±5.6
3.0	143.4±10.2	6.5	523.8±37.2	11.0	561.4±84.2	15.0	285.8±8.6	18.5	146.4±5.1
3.5	214.7±15.2	7.0	543.1±81.5	12.0	516.7±77.5	15.5	259.0±9.1	19.0	134.1±4.7
4.0	280.0±19.9	8.5	577.1±86.6	12.5	468.7±23.4	16.0	234.8±8.2	19.5	123.3±4.3
4.5	340.5±24.2	9.0	582.5±87.4	13.0	424.5±21.2	16.5	213.0±7.4	20.0	113.9±4.0
5.0	396.7±28.2	9.5	585.7±87.8	13.5	384.5±19.2	17.0	193.5±6.8		

$^{54}Fe(n,\alpha)^{51}Cr$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
4.0	0	8.0	33.8±1.3	12.0	71.4±3.2	14.7	91.5±2.1	18.0	71.6±2.4
4.5	0.9±0.5	8.5	38.6±1.4	12.5	76.2±3.3	14.8	91.3±2.1	18.5	65.6±3.0
5.0	4.7±1.5	9.0	43.3±1.6	13.0	80.9±3.5	15.0	91.0±2.4	19.0	58.9±4.0
5.5	8.8±1.5	9.5	47.9±2.8	13.5	85.8±3.8	15.5	90.2±2.3	19.5	51.8±5.2
6.0	14.1±2.8	10.0	52.6±3.0	14.0	88.9±3.0	16.0	88.2±2.4	20.0	44.0±4.4
6.5	19.3±1.1	10.5	57.4±3.1	14.2	89.6±2.4	16.5	85.3±2.4		
7.0	24.3±1.2	11.0	62.0±3.2	14.4	90.3±2.2	17.0	81.6±2.4		
7.5	29.2±1.2	11.5	66.7±3.4	14.6	91.6±2.1	17.5	76.9±2.4		

(Continued)

$^{56}Fe(n,p)^{56}Mn$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
4.0	0.007±0.002	8.0	46.1±1.2	12.0	106.6±2.5	14.4	111.8±1.0	16.0	87.4±1.3
4.5	0.162±0.014	8.5	53.1±1.6	12.5	112.3±1.7	14.5	110.7±1.0	16.5	79.8±1.2
5.0	1.18±0.05	9.0	59.3±2.3	13.0	115.8±1.5	14.6	109.5±1.0	17.0	73.0±1.4
5.5	5.07±0.14	9.5	65.8±2.6	13.5	116.9±1.2	14.7	108.2±1.0	17.5	67.2±1.5
6.0	13.6±0.4	10.0	73.3±2.8	14.0	115.2±1.1	14.8	106.9±1.0	18.0	61.8±1.7
6.5	22.8±0.6	10.5	81.9±3.1	14.1	114.5±1.0	14.9	105.3±1.0	18.5	57.1±2.3
7.0	30.6±0.9	11.0	91.0±3.6	14.2	113.8±1.0	15.0	103.9±1.0	19.0	53.3±2.8
7.5	38.3±1.1	11.5	99.5±3.5	14.3	112.8±1.0	15.5	95.8±1.1	19.5	50.7±3.6

$^{59}Co(n,2n)^{58}Co$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
10.91	20±6	13.0	549±8	14.7	772±9	16.5	867±16	19.0	852±60
11.0	46±14	13.5	631±9	14.8	780±12	17.0	875±16	19.5	834±59
11.5	184±15	14.0	699±11	15.0	796±12	17.5	877±16	20.0	814±58
12.0	314±20	14.2	722±11	15.5	829±15	18.0	874±16		
12.5	435±6	14.5	753±12	16.0	852±15	18.5	865±16		

$^{59}Co(n,p)^{59}Fe$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
4.0	5.01±0.40	9.0	37.2±7.4	13.0	54.8±1.6	14.8	46.5±1.3	17.5	31.6±1.9
4.5	6.01±0.48	10.0	45.7±9.1	13.5	52.7±1.6	15.0	45.5±1.4	18.0	28.7±1.7
5.0	7.96±0.64	11.0	54.3±10.9	14.0	50.4±1.5	15.5	42.9±2.6	19.0	22.6±4.5
6.0	13.7±1.1	11.5	58.6±11.7	14.2	49.5±1.5	16.0	40.2±2.4	20.0	16.4±3.3
7.0	20.9±1.7	12.0	58.5±11.7	14.5	48.0±1.4	16.5	37.4±2.2		
8.0	28.8±5.8	12.5	56.7±1.7	14.7	47.0±1.3	17.0	34.5±2.1		

$^{59}Co(n,\alpha)^{56}Mn$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
5.02	0.144±0.022	9.0	12.5±1.0	13.0	28.9±0.8	14.7	31.1±0.7	17.0	22.7±0.7
6.0	1.06±0.11	10.0	16.5±1.4	13.6	30.5±0.7	15.0	30.7±0.8	18.0	17.8±0.7
7.0	3.53±0.17	11.0	20.2±1.2	14.0	31.1±0.8	15.4	29.7±0.8	19.0	13.9±0.9
8.0	7.59±0.26	12.0	24.6±1.0	14.4	31.4±0.8	16.0	27.4±0.9	20.0	11.0±1.1

(Continued)

$^{58}Ni(n,2n)^{57}Ni$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
13.0	2.75±0.6	15.0	42.0±0.8	18.0	76.0±1.0	22.0	94.5±2.2	25.0	93.5±3.0
13.4	11.3±0.7	15.4	49.5±0.7	19.0	82.0±1.2	23.0	96.0±2.6	26.0	89.0±3.0
14.0	23.6±0.8	16.0	58.5±0.8	20.0	87.5±1.5	23.5	96.1±2.8	27.0	81.0±3.1
14.4	31.3±0.7	17.0	67.8±0.9	21.0	91.5±1.9	24.0	96.0±2.9	28.0	69.0±3.5

$^{58}Ni(n,p)^{58}Co$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
0.5	0.02±0.02	4.0	344.6±5.7	7.0	627.9±20.9	12.0	630.6±25.2	16.0	222.6±8.9
1.5	16.4±0.4	4.5	415.9±6.9	8.0	657.4±21.9	13.0	492.4±13.1	17.0	168.1±6.7
2.0	62.7±1.6	5.0	477.0±7.9	9.155	675.0±67.5	14.0	381.4±10.2	18.0	126.6±5.1
3.0	176.0±4.4	5.5	528.1±17.6	10.17	684.0±68.4	14.7	316.8±5.7	19.0	96.3±9.6
3.5	263.8±4.4	6.0	569.8±19.0	11.19	678.0±67.8	15.0	292.8±7.8	20.0	75.6±7.6

$^{58}Ni(n,x)^{57}Co$ (G)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
12.90	342.9	13.93	466.1	14.96	543.1	16.00	604.8	17.03	652.1	18.06	648.0
13.16	384.4	14.19	490.0	15.22	558.0	16.25	619.4	17.29	657.3		
13.42	415.6	14.45	510.6	15.48	573.5	16.51	632.5	17.54	658.8		
13.67	441.6	14.71	527.8	15.73	589.3	16.77	643.6	17/80	655.9		

$^{60}Ni(n,p)^{60}Co$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
1.00	0	5.00	12.4	9.00	126	13.00	136	17.00	69.1
2.00	0.20	6.00	36.3	10.00	134	14.00	122	18.00	62.2
3.00	0.57	7.00	83.2	11.00	138	15.00	97.1	19.00	57.8
4.00	3.40	8.00	112	12.00	139	16.00	80.5	20.00	55.0

(Continued)

$^{62}Ni(n,\alpha)^{59}Fe$ (G)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
5.0	0	8.0	2.5±0.31	12.0	18.0±3.6	14.5	23.1±1.1	17.0	18.2±3.6
6.5	0.46±0.057	9.0	4.7±0.94	13.0	21.1±4.2	15.0	22.9±1.1	18.0	13.4±2.7
7.0	0.93±0.12	10.0	8.9±1.8	13.5	22.2±4.4	15.5	22.4±4.5	19.0	7.4±1.5
7.5	1.6±2.0	11.0	13.7±2.7	14.0	22.8±1.1	16.0	21.4±4.3		

$^{66}Zn(n,2n)^{65}Zn$ (S)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
11.06	0	12.4	205	14.0	570	15.6	767	18.2	872	19.8	889
11.4	7.7	12.8	306	14.4	637	16.0	795	18.6	878	20.0	889
11.6	31.0	13.2	403	14.8	690	17.4	854	19.0	882		
12.0	108	13.6	492	15.2	733	17.8	864	19.4	886		

$^{67}Zn(n,p)^{67}Cu$ (S)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
2.00	1.4	6.00	25.7	10.0	46.0	12.6	46.5	16.0	32.2	20.0	21.8
3.00	3.1	7.00	37.2	11.0	46.6	13.0	46.2	17.0	27.4		
4.00	6.6	8.00	42.2	11.6	46.8	14.0	44.3	18.0	24.6		
5.00	13.6	9.00	44.7	12.0	46.7	15.0	39.6	19.0	22.8		

$^{70}Zn(n,2n)^{69m}Zn$ (S)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
9.40	30.6	10.98	340	12.56	508	14.15	609	16.00	657	18.00	630
9.79	131	11.38	388	12.96	541	14.54	624	16.40	660	18.40	608
10.19	214	11.77	432	13.36	568	15.00	640	16.80	662	19.00	565
10.58	283	12.17	472	13.75	591	15.40	648	17.40	653	20.00	482

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	$^{85}Rb(n,2n)^{84m+g}Rb$ (T)	$^{87}Rb(n,2n)^{86m+g}Rb$ (T)		$^{85}Rb(n,2n)^{84m+g}Rb$ (T)	$^{87}Rb(n,2n)^{86m+g}Rb$ (T)
En(MeV)	σ(mb)	σ(mb)	En(MeV)	σ(mb)	σ(mb)
12.49	554	803	14.70	1040	1200
13.47	823	1028	14.80	1050	1211
13.74	891	1073	16.02	1143	1320
13.83	910	1088	17.12	1204	1389
14.43	1008	1170	17.54	1223	1412
14.58	1026	1187			

$^{89}Y(n,2n)^{88}Y$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
11.79	15.3±15.3	15.20	1110±14	18.76	1264±20	22.25	1167±26	25.74	869±38
12.27	220±14	15.80	1160±14	19.35	1264±19	22.83	1130±28	26.32	803±40
12.85	465±14	16.40	1195±16	19.93	1257±19	23.42	1088±31	26.90	732±44
13.43	697±13	17.02	1223±18	20.51	1244±20	24.00	1041±33	27.49	658±50
14.01	888±12	17.60	1244±19	21.09	1224±21	24.58	988±35		
14.60	1026±14	18.18	1258±20	21.67	1199±23	25.16	931±36		

$^{90}Zr(n,2n)^{89}Zr$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
12.0	0	13.4	387.1±9.8	14.8	822.1±66.0	16.6	1093±82	18.6	1220±40
12.2	15.20±1.84	13.8	530.0±32.7	15.0	862.9±67.3	17.0	1133±24	19.0	1232±42
12.6	93.62±2.60	14.2	653.7±27.3	15.4	934.3±35.4	17.4	1169±27	19.4	1236±46
13.0	233.9±7.6	14.4	727.9±28.9	15.8	994.8±26.0	17.8	1188±32	19.6	1236±45
13.2	310.8±8.2	14.6	777.2±28.4	16.2	1047±21	18.2	1203±37	20.0	1231±50

$^{96}Zr(n,2n)^{95}Zr$ (S)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
7.854	0	9.20	443	11.2	1146	13.6	1436	15.6	1465	18.0	1077
8.20	34.2	9.60	624	11.6	1224	14.0	1456	16.0	1435	18.4	988
8.40	93.1	9.80	709	12.0	1288	14.4	1472	16.4	1388	18.8	902
8.60	170	10.0	788	12.4	1338	14.8	1478	16.8	1325	19.2	819
8.80	257	10.4	930	12.8	1378	15.0	1479	17.2	1249	19.6	742
9.00	349	10.8	1048	13.2	1410	15.2	1477	17.6	1165	20.0	671

(Continued)

$^{93}Nb(n,2n)^{92m}Nb$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
9.0	2.31±0.68	11.4	340±8	13.8	453.5±6.0	15.0	457±7	17.2	407±11
9.4	10.3±0.1	11.8	382±17	14.0	455.8±5.0	15.2	455±7	17.6	397±11
9.8	51.9±2.7	12.2	410±15	14.2	457.6±4.5	15.4	452±8	18.0	388±15
10.2	124±4	12.6	428±13	14.4	458.7±4.5	16.0	437±10	18.4	378±28
10.6	206±9	13.0	439±12	14.6	459.1±4.9	16.4	426±11	18.8	370±48
11.0	281±15	13.6	450.7±7.4	14.8	458.6±5.6	16.8	417±12	19.2	361±60

$^{93}Nb(n,\alpha)^{90m}Y$ (G)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
8.0	0.40	10.5	2.12	12.5	3.72	14.0	4.91	15.5	5.46	17.0	5.18
9.0	1.03	11.0	2.51	13.0	4.13	14.5	5.18	16.0	5.46	17.6	4.81
10.0	1.74	12.0	3.33	13.5	4.55	15.0	5.36	16.5	5.36		

$^{113}In(n,2n)^{112m}In$ (G)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
12.7	863	13.2	981	13.8	1075	14.4	1126	15.0	1144	16.5	1101
12.8	890	13.4	1017	14.0	1096	14.6	1136	15.5	1140	17.0	1076
13.0	938	13.6	1048	14.2	1113	14.8	1142	16.0	1124	18.0	1040

$^{113}In(n,n')^{113m}In$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
13.5	62.0±2.5	13.8	59.6±2.3	14.1	57.2±1.8	14.4	54.3±1.7	14.7	50.5±1.5
13.6	61.2±2.4	13.9	58.8±2.0	14.2	56.3±1.8	14.5	53.1±1.7	14.8	47.6±1.5
13.7	60.4±2.4	14.0	58.0±1.8	14.3	55.3±1.7	14.6	51.9±1.6	15.0	46.0±1.5

(Continued)

^{115}In(n,2n)^{114m}In (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
9.4	14.9±3.0	11.6	790±79	14.0	1243±37	15.2	1308±39	17.5	1219±120
9.6	96±19	12.0	896±90	14.2	1261±25	15.4	1309±39	18.0	1184±118
10.0	253±38	12.4	991±74	14.4	1276±25	15.6	1309±65	18.5	1150±115
10.4	403±60	12.8	1073±54	14.6	1288±26	16.0	1301±65	19.0	1123±112
10.8	542±81	13.2	1142±57	14.8	1297±26	16.5	1282±64	19.5	1107±111
11.2	672±100	13.6	1199±36	15.0	1303±39	17.0	1253±63	20.0	1103±110

^{115}In(n,n')^{115m}In (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
0.4	1.22±0.44	2.8	334±4	5.4	334±4	7.8	301±4	13.4	68.9±2.1
0.6	4.83±0.42	3.0	332±5	5.6	337±5	8.2	298±3	13.8	59.3±1.6
0.8	23.5±0.5	3.4	317±4	5.8	338±6	8.6	292±4	14.2	54.5±1.3
1.2	90.0±1.2	3.8	299±5	6.0	337±7	9.2	276±4	14.6	52.7±1.4
1.6	176±2	4.0	294±5	6.4	329±6	10.0	245±3	15.6	51.7±2.5
2.0	259±3	4.2	294±5	6.8	317±5	11.0	196±5	16.6	51.5±4.6
2.4	315±3	4.6	306±4	7.0	312±5	12.0	140±4	17.6	51.6±6.5
2.6	329±4	5.0	322±5	7.4	305±5	13.0	84.9±2.4	19.2	50.8±6.1

^{127}I(n,2n)^{126}I (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
9.0	0	11.2	950±52	13.6	1627±42	15.9	1709±41	17.7	1659±60
9.2	2±0.6	11.6	1181±56	14.0	1652±33	16.1	1711±41	18.1	1622±63
9.4	45±2	11.8	1274±54	14.3	1670±26	16.3	1711±42	18.5	1572±64
9.8	81±3	12.0	1352±51	14.7	1684±29	16.5	1709±44	18.9	1507±65
10.0	176±30	12.4	1468±45	15.1	1694±36	16.7	1706±46	19.3	1427±72
10.4	413±33	12.8	1544±44	15.5	1703±39	16.9	1701±48	19.7	1330±97
10.8	682±42	13.2	1593±46	15.7	1707±40	17.3	1685±54	19.9	1275±117

(Continued)

$^{140}Ce(n,2n)^{139}Ce$ (E)

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
9.4	16±4	11.6	1159±91	14.0	1729±45	16.6	1855±70	18.0	1839±72
9.6	78±15	12.0	1312±92	14.4	1767±46	17.0	1863±71	18.4	1795±81
10.0	277±28	12.4	1437±91	14.8	1793±47	17.2	1865±71	18.8	1728±89
10.4	519±52	12.8	1535±64	15.2	1803±47	17.4	1865±71	19.2	1641±82
10.8	758±76	13.2	1616±61	15.8	1835±68	17.6	1862±71	19.6	1540±77
11.2	974±97	13.6	1679±51	16.2	1849±70	17.8	1853±70	20.0	1431±71

$^{169}Tm(n,2n)^{168}Tm$ (E)

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
8.4	60±40	10.8	1644±44	13.2	1995±69	15.6	2011±73	18.0	1521±46
8.8	317±18	11.2	1745±42	13.6	2014±41	16.0	1977±73	18.4	1401±29
9.2	674±25	11.6	1817±38	14.0	2025±41	16.4	1914±46	18.8	1278±29
9.6	1016±34	12.0	1872±35	14.4	2032±45	16.8	1834±46	19.2	1156±29
10.0	1293±41	12.4	1918±71	14.8	2032±45	17.2	1741±46	19.6	1038±29
10.4	1499±45	12.8	1959±70	15.2	2025±74	17.6	1635±46	20.0	928±28

$^{169}Tm(n,3n)^{167}Tm$ (E)

En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)	En(MeV)	σ (mb)
15.0	3.14±0.31	17.4	320±20	20.0	1195±50	23.0	1570±66	26.0	1623±68
15.4	8.83±0.70	17.8	467±20	20.5	1282±54	23.5	1615±68	26.5	1580±67
15.8	15.4±1.2	18.2	624±25	21.0	1344±56	24.0	1640±69	27.0	1520±64
16.2	41.5±2.8	18.6	779±33	21.5	1392±59	24.5	1662±70	28.0	1420±60
16.6	99.7±6.7	19.0	923±39	22.0	1460±62	25.0	1650±70		
17.0	194±13	19.5	1076±45	22.5	1525±64	25.5	1646±70		

(Continued)

$^{181}Ta(n,2n)^{180m}Ta$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
7.676	0	10.4	980±78	13.0	1322±61	14.8	1260±50	17.6	740±51
8.0	56±11	10.8	1091±76	13.2	1333±61	15.2	1221±50	18.0	640±53
8.4	230±39	11.2	1177±77	13.4	1322±61	15.6	1169±49	18.4	555±46
8.8	372±56	11.6	1238±71	13.6	1319±61	16.0	1104±51	18.8	485±57
9.2	525±68	12.0	1279±64	14.0	1309±58	16.4	1027±51	19.2	430±63
9.6	686±76	12.4	1305±65	14.4	1298±53	16.8	939±52	19.6	390±63
10.0	842±78	12.8	1318±66	14.6	1276±51	17.2	841±51	20.0	380±74

$^{181}Ta(n,p)^{181}Hf$ (G)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
3.00	0.097	6.00	0.456	9.00	1.191	12.00	2.41	15.00	4.05	18.00	6.00
3.50	0.132	6.50	0.544	9.50	1.359	12.50	2.65	15.50	4.35	18.50	6.35
4.00	0.204	7.00	0.648	10.00	1.544	13.00	2.91	16.00	4.67	19.00	6.70
4.50	0.251	7.50	0.765	10.50	1.739	13.50	3.18	16.50	4.99	19.50	7.03
5.00	0.298	8.00	0.895	11.00	1.949	14.00	3.46	17.00	5.32	20.00	7.28
5.50	0.369	8.50	1.036	11.50	2.17	14.50	3.75	17.50	5.65		

$^{198}Pt(n,2n)^{197}Pt$ (S)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
7.556	0	9.8	1333	12.2	2059	14.4	2201	16.8	1580	19.2	797
7.8	34	10.2	1530	12.6	2107	14.8	2166	17.2	1429	19.6	707
8.2	241	10.6	1691	13.0	2144	15.2	2097	17.6	1282	20.0	629
8.6	526	11.0	1818	13.4	2174	15.6	1997	18.0	1143		
9.0	823	11.4	1919	13.8	2196	16.0	1872	18.4	1015		
9.4	1096	11.8	1998	14.2	2206	16.4	1730	18.8	899		

(Continued)

$^{197}Au(n,2n)^{196}Au$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
8.4	27.8±2.0	10.8	1531±77	13.2	2074±43	15.6	2116±77	18.0	1716±111
8.8	223±16	11.2	1690±84	13.6	2103±42	16.0	2087±97	18.4	1596±104
9.2	502±35	11.6	1816±91	14.0	2123±41	16.4	2044±102	18.8	1464±100
9.6	801±50	12.0	1908±95	14.4	2135±40	16.8	1986±99	19.2	1323±93
10.0	1082±70	12.4	1980±87	14.8	2138±41	17.2	1912±96	19.6	1177±82
10.4	1328±80	12.8	2034±60	15.2	2132±58	17.6	1822±100	20.0	1033±72

$^{197}Au(n,3n)^{195}Au$ (E)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
16.0	20±3	18.2	576±43	21.0	1457±120	24.0	1977±198	27.0	1765±132
16.2	50±7	18.6	706±53	21.5	1585±140	24.5	1997±200	27.5	1651±124
16.6	127±15	19.0	839±63	22.0	1699±85	25.0	1995±140	28.0	1513±113
17.0	221±22	19.5	1003±75	22.5	1797±180	25.5	1971±140		
17.4	330±25	20.0	1163±87	23.0	1876±188	26.0	1925±100		
17.8	450±34	20.5	1315±98	23.5	1937±194	26.5	1857±139		

$^{204}Pb(n,2n)^{203}Pb$ (G)

En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)	En(MeV)	σ(mb)
8.8	21	10.5	1003	12.5	1791	14.5	2032	16.5	2047	18.5	1703
9.0	90	11.0	1255	13.0	1909	15.0	2050	17.0	1983	19.0	1580
9.5	374	11.5	1458	13.5	1963	15.5	2064	17.5	1910	19.5	1394
10.0	702	12.0	1649	14.0	2004	16.0	2070	18.0	1805	20.0	1197

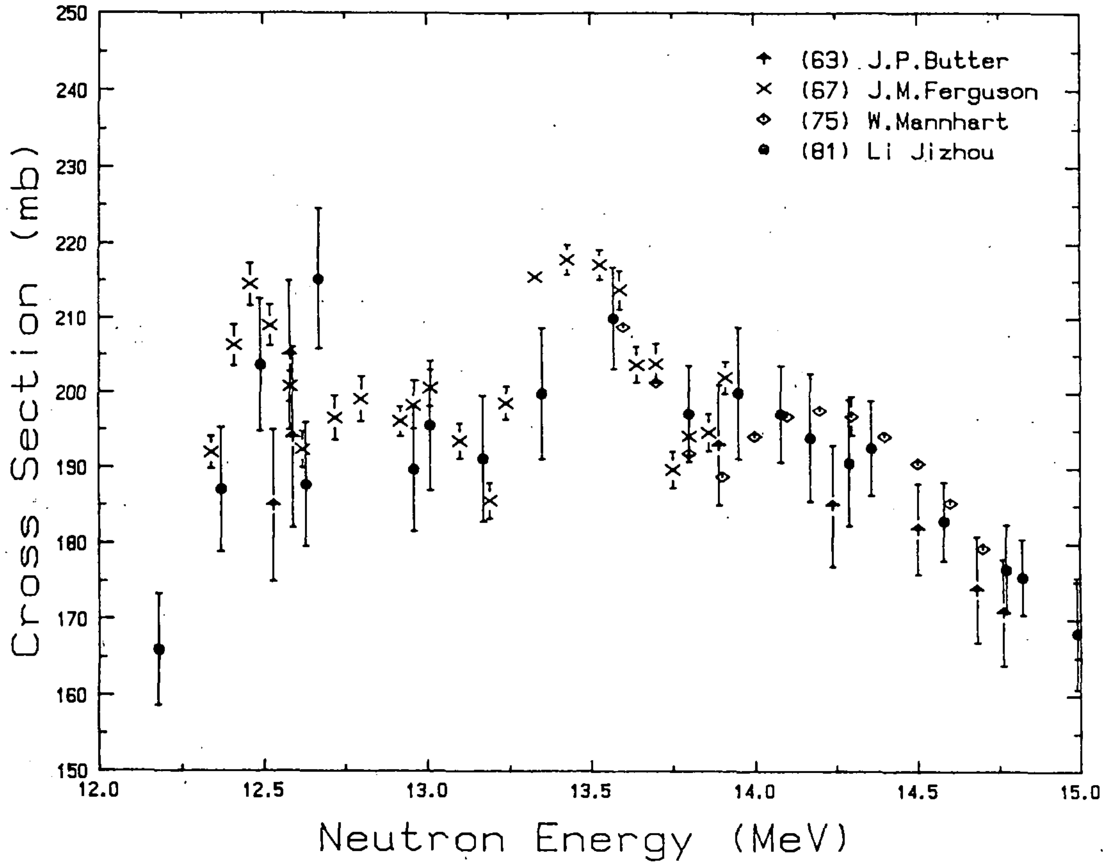

Fig.1 Mg-24(n,p)Na-24

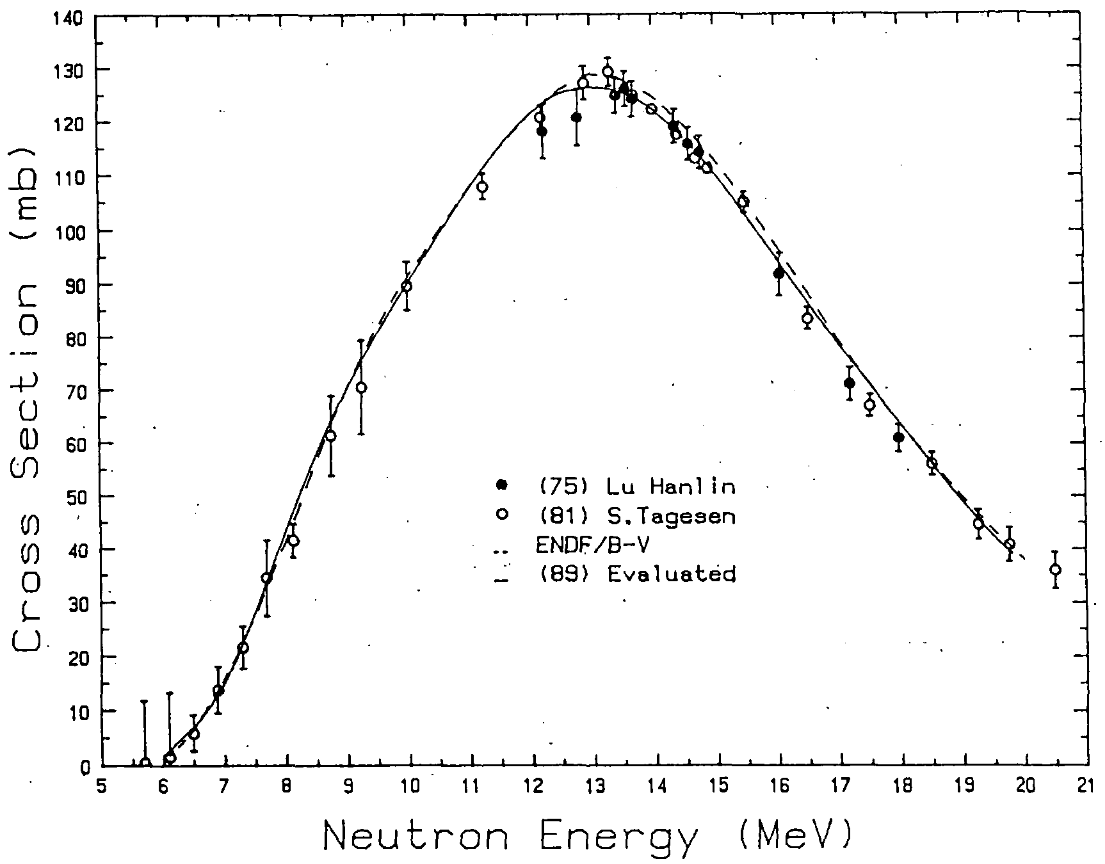

Fig.2 Al-27(n,a)Na-24

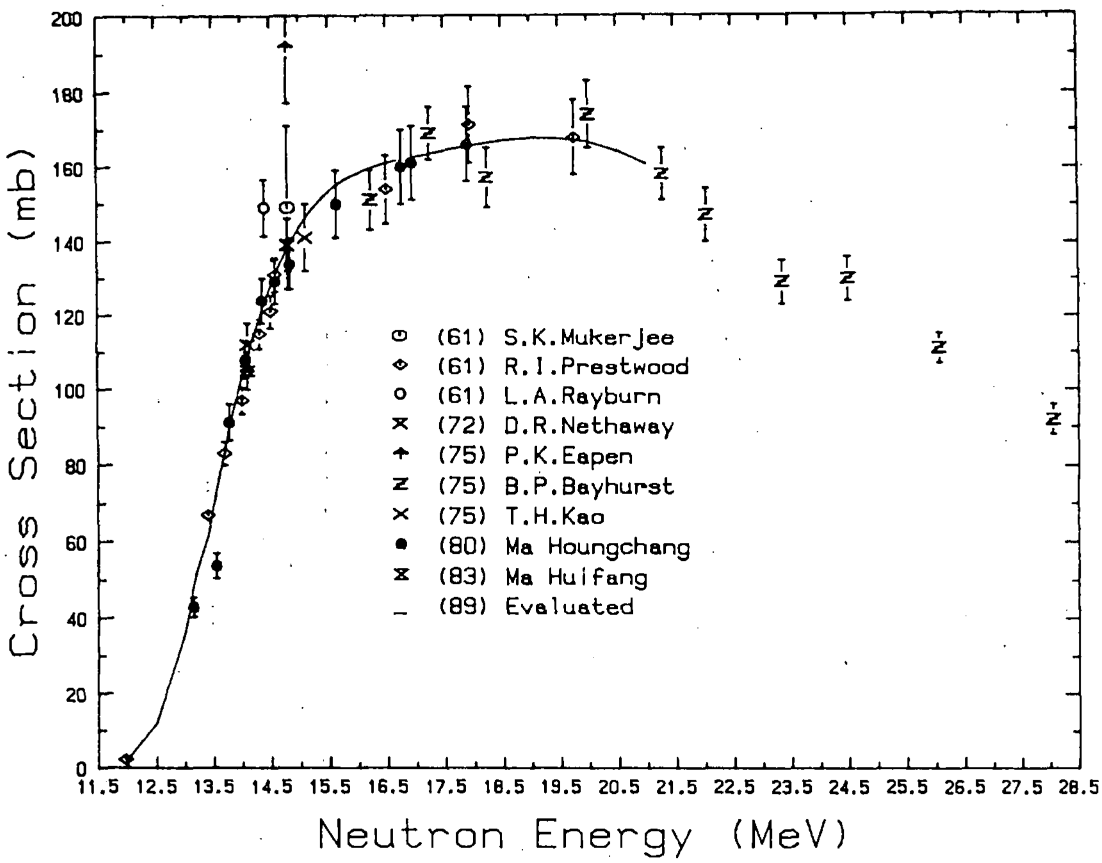

Fig.3 Sc-45(n,2n)Sc-44m

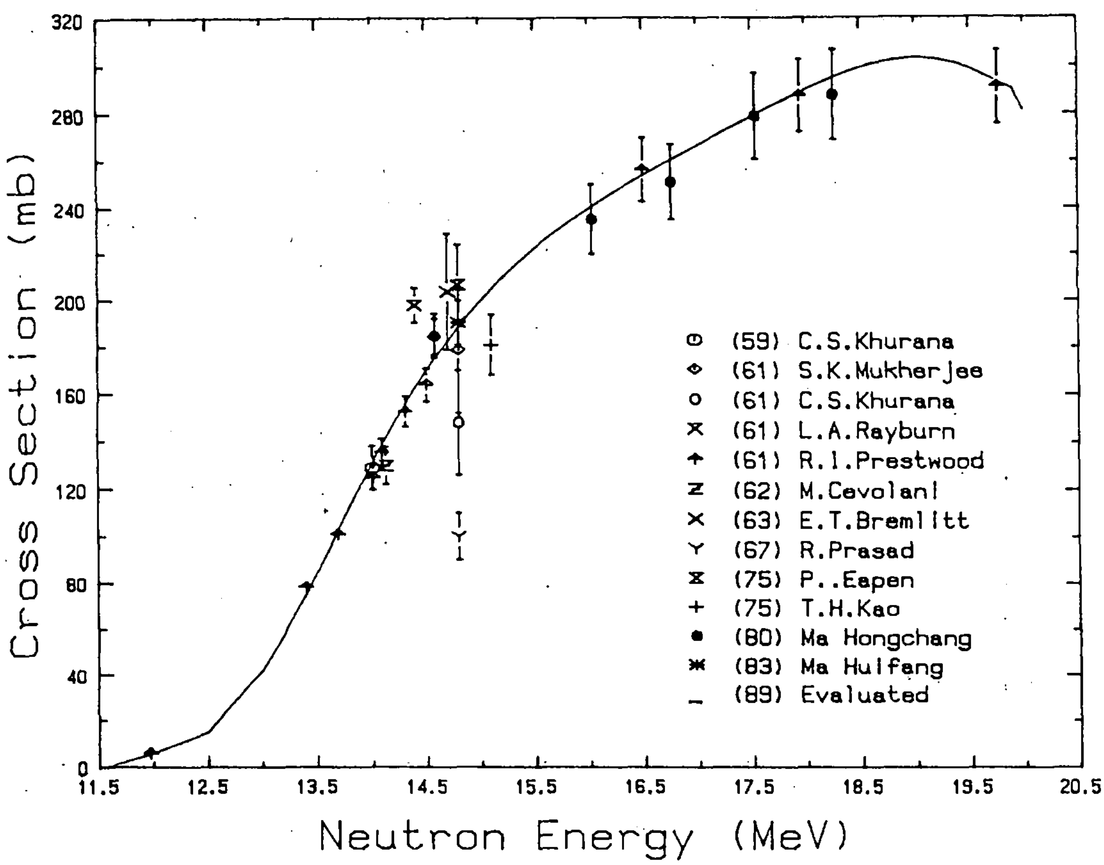

Fig.4 Sc-45(n,2n)Sc-44g

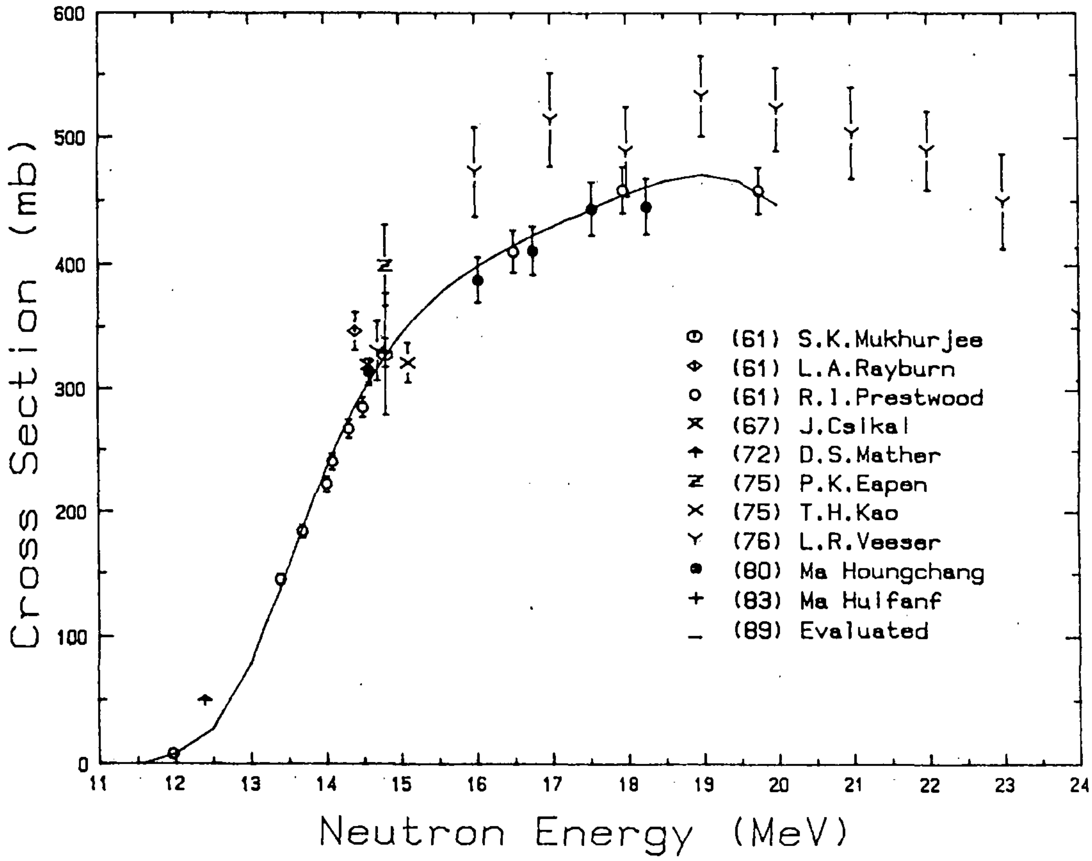

Fig.5 Sc-45(n,2n)Sc-44

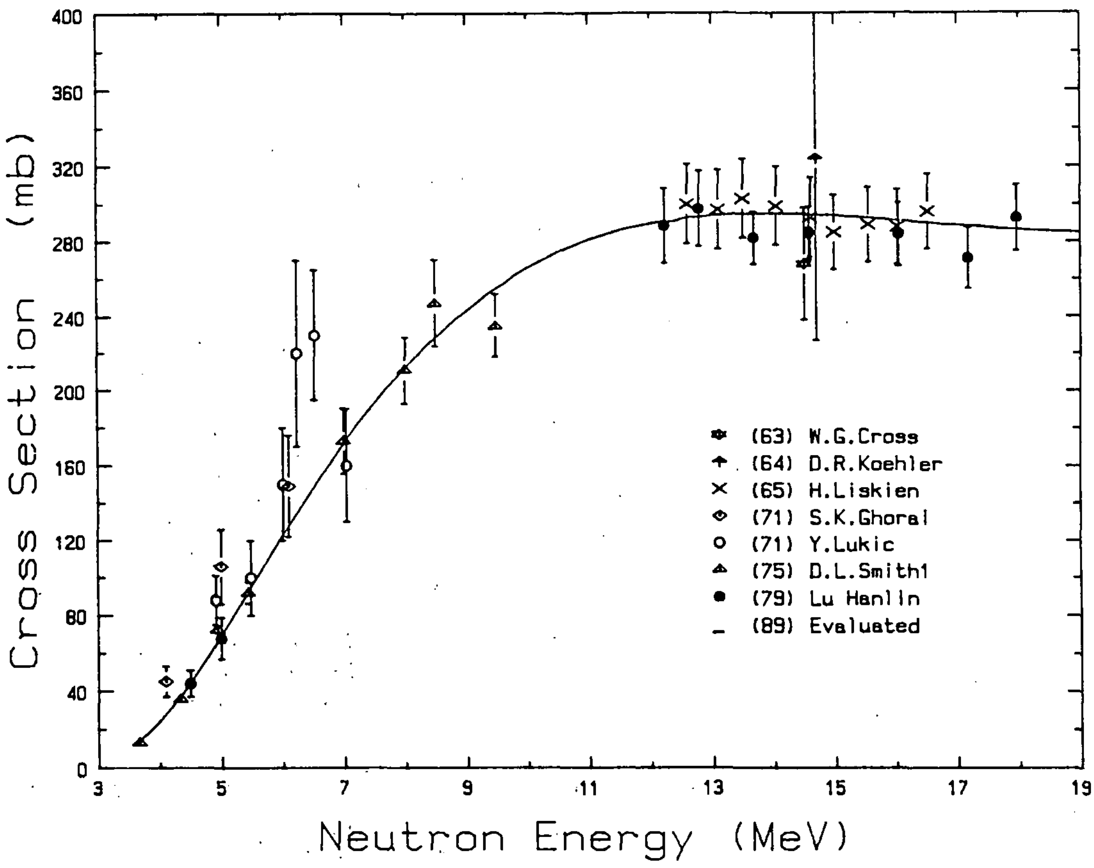

Fig.6 Ti-46(n,p)Sc-46

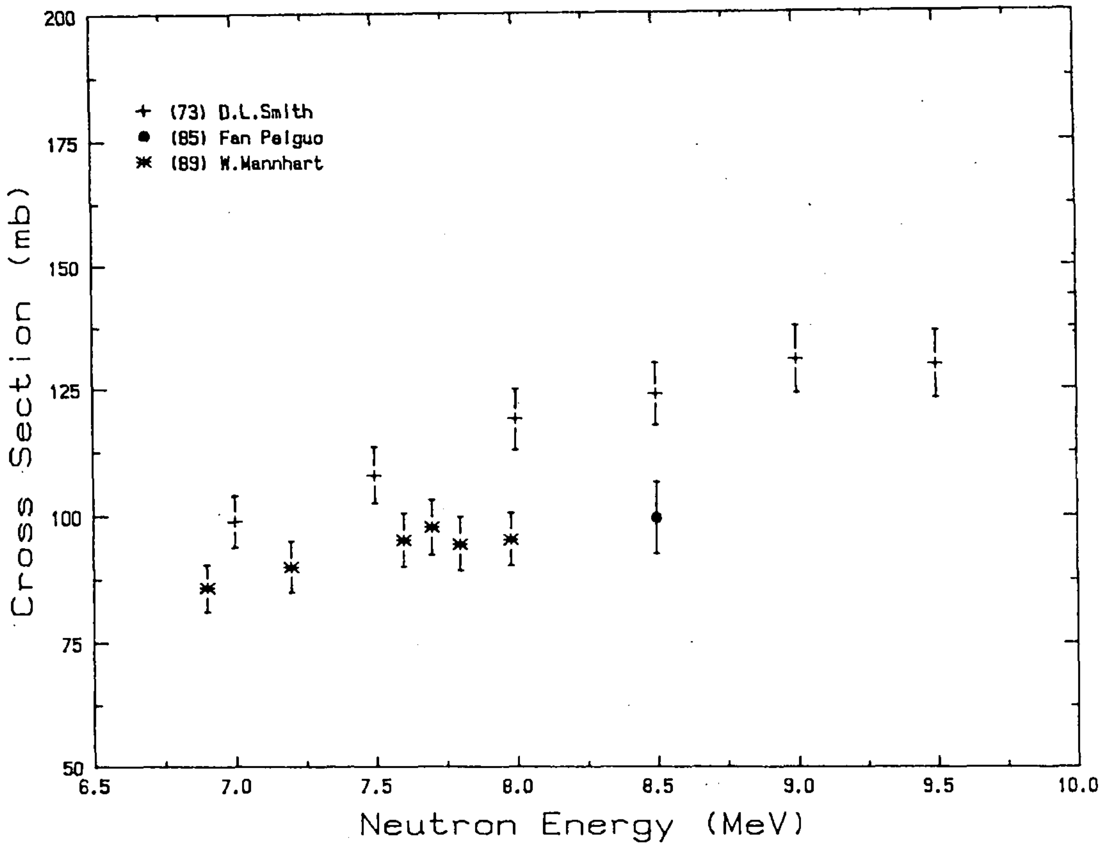

Fig.7 Ti-47(n,p)Sc-47

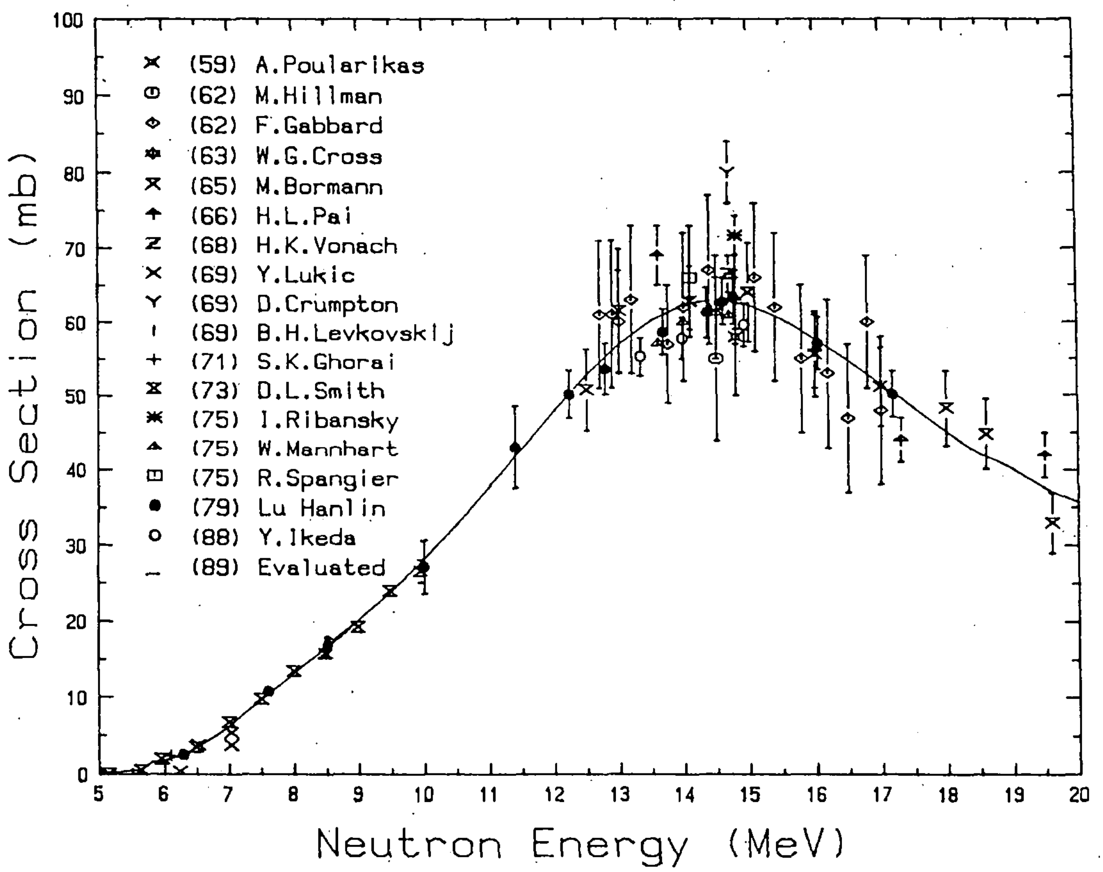

Fig.8 Ti-48(n,p)Sc-48

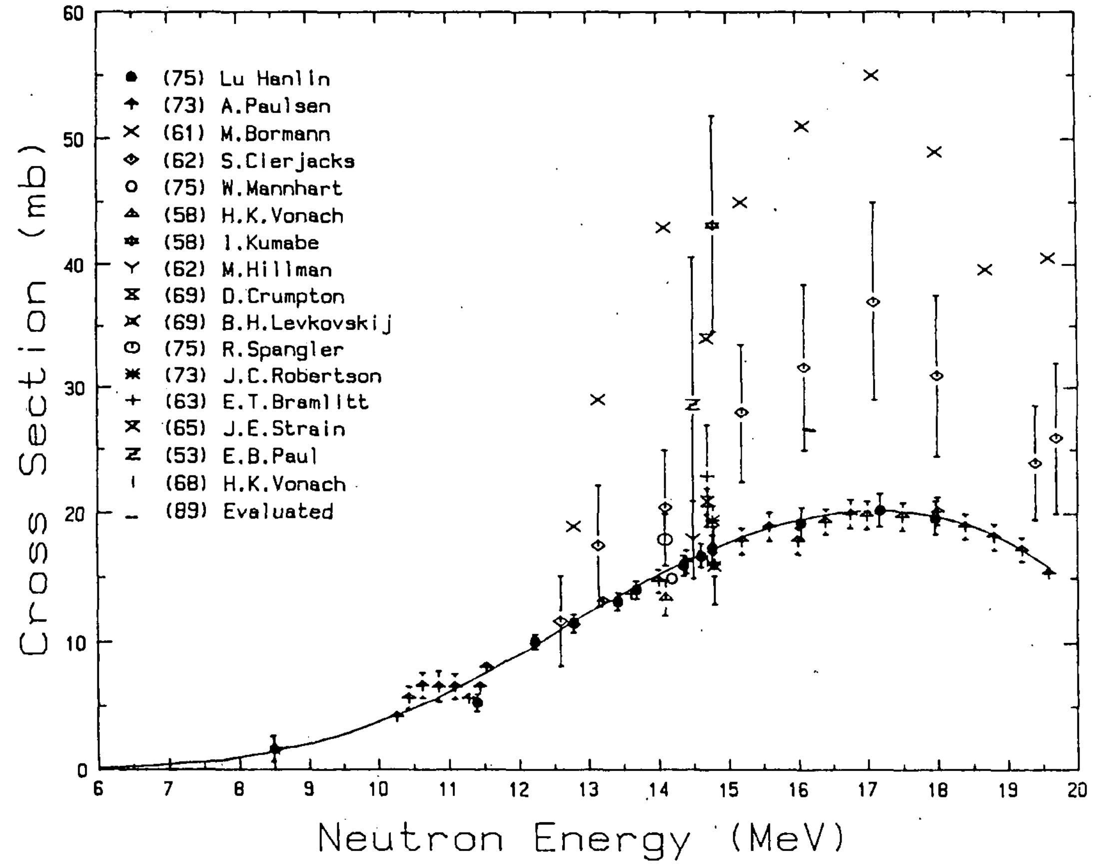

Fig. 9 V-51(n,a)Sc-48

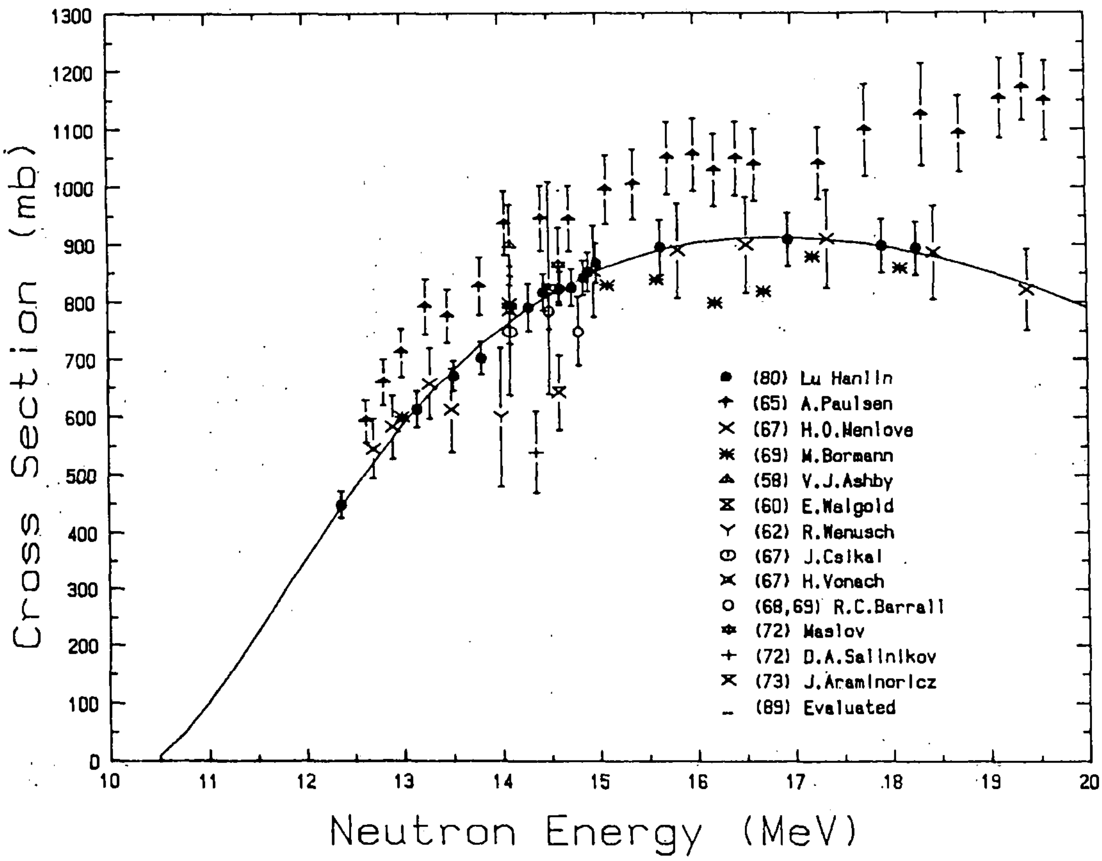

Fig.10 Mn-55(n,2n)Mn-54

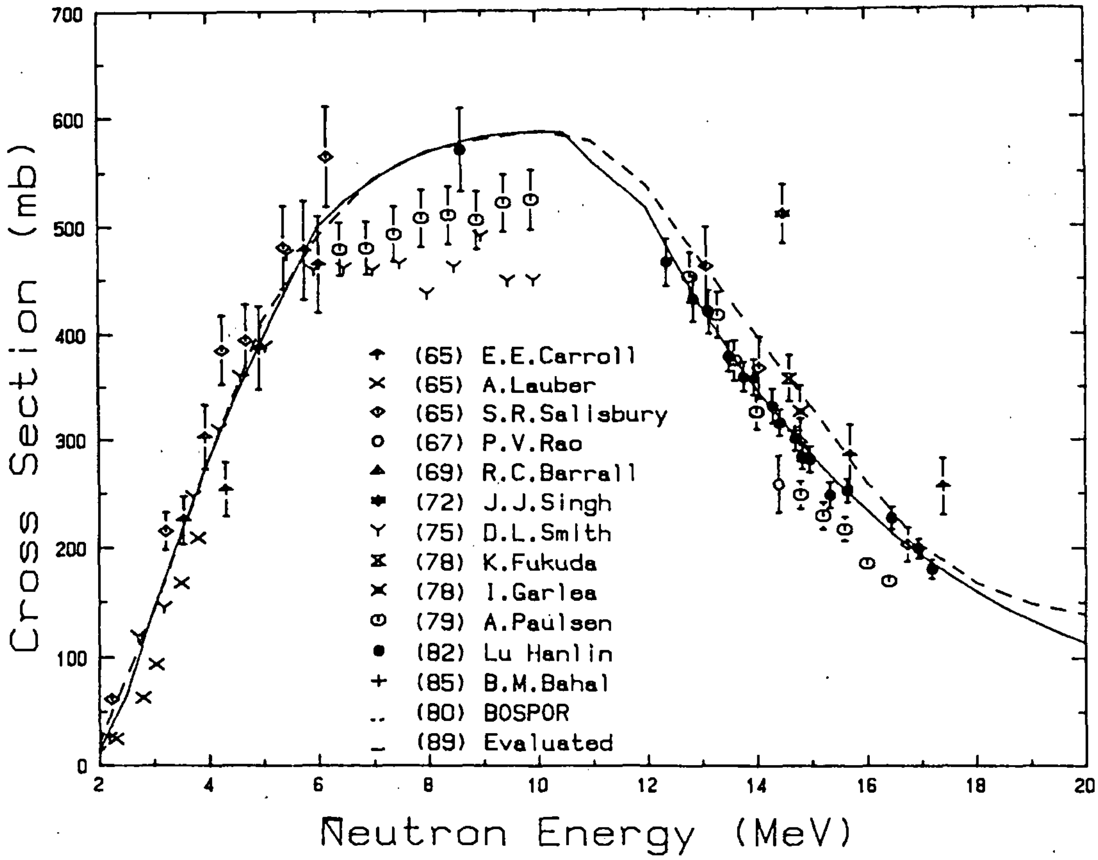

Fig. 11 Fe-54(n,p)Mn-54

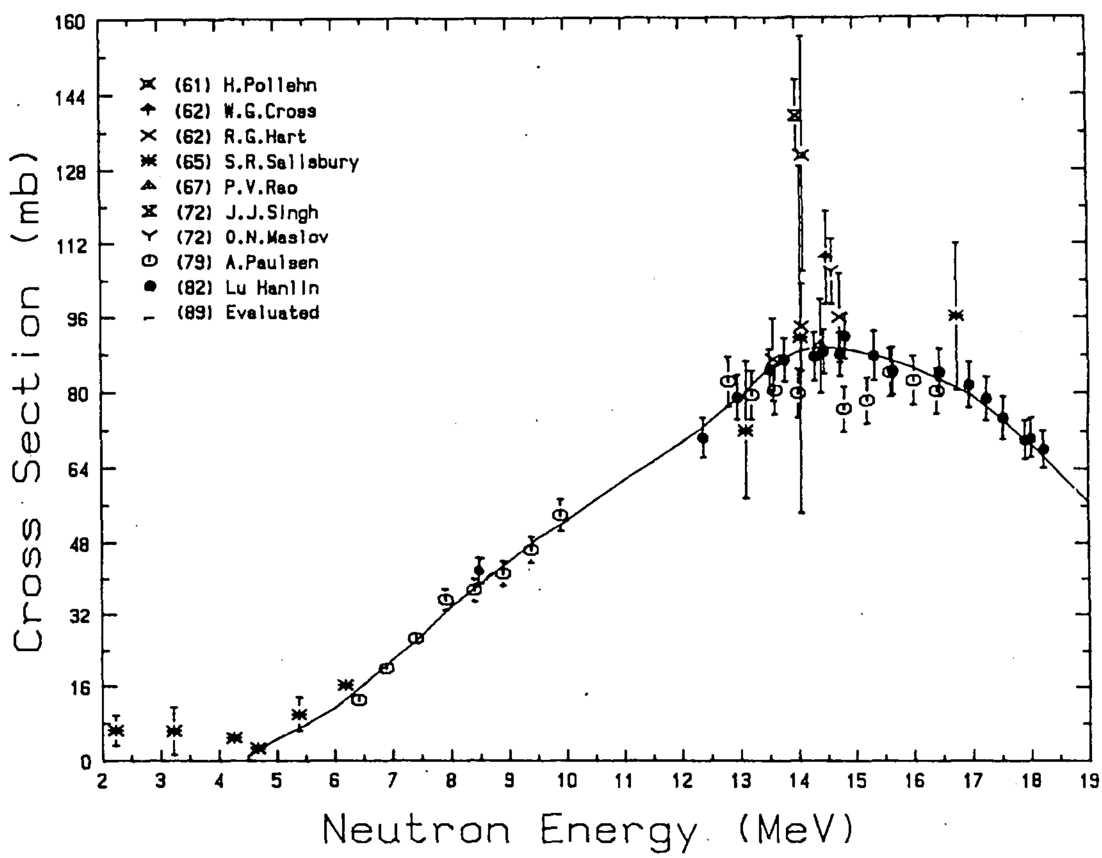

Fig.12 Fe-54(n,a)Cr-51

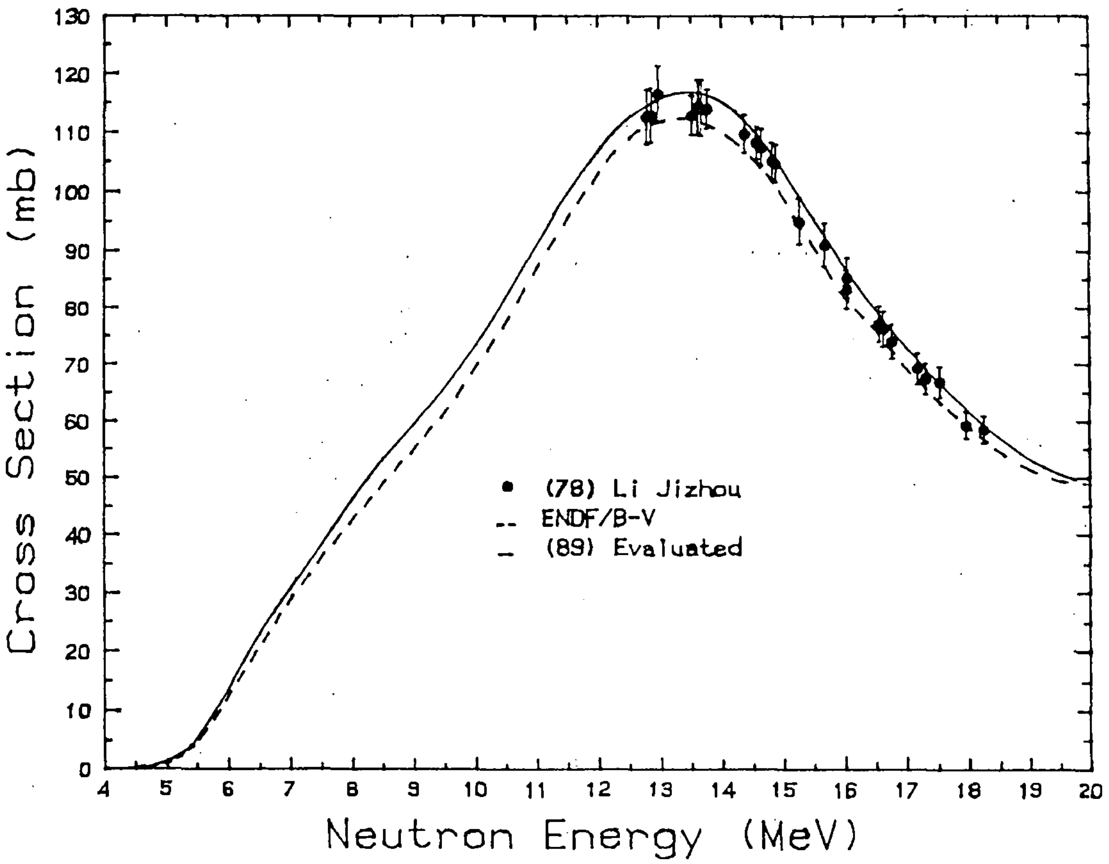

Fig.13 Fe-56(n,p)Mn-56

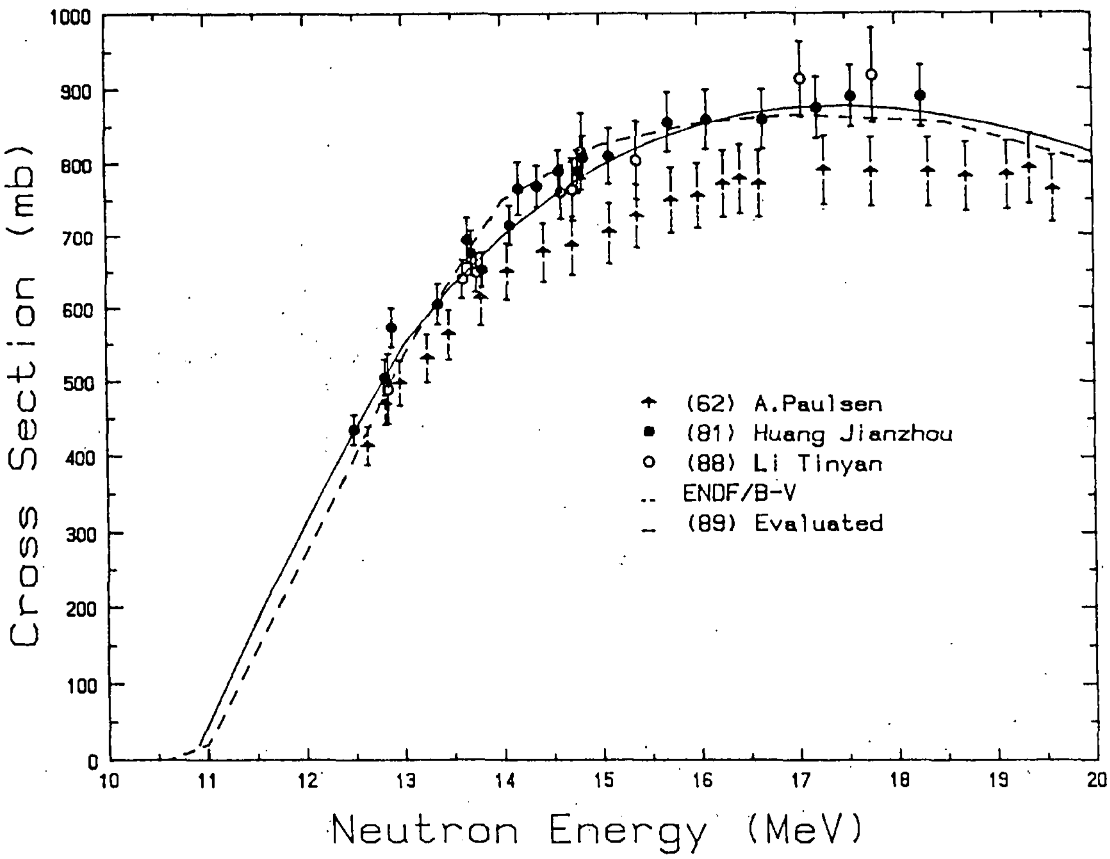

Fig.14 Co-59(n,2n)Co-58

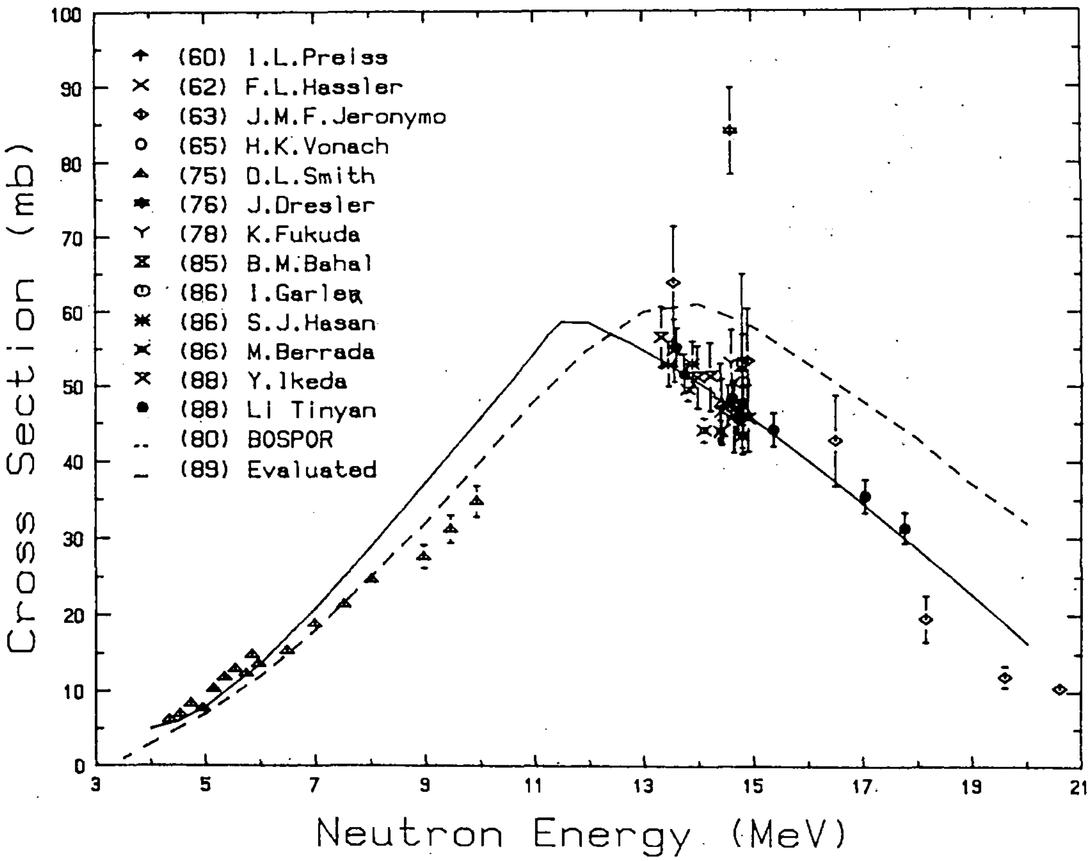

Fig.15 Co-59(n,p)Fe-59

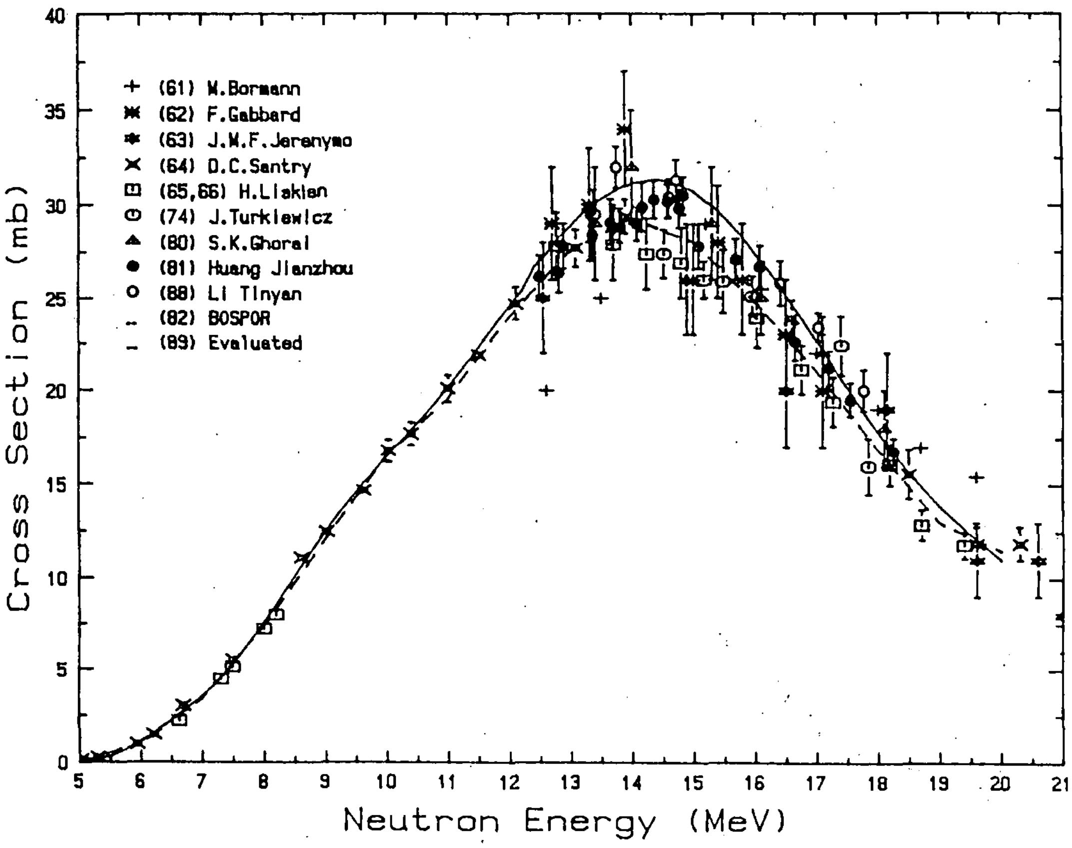

Fig.16(a) Co-59(n,a)Mn-56

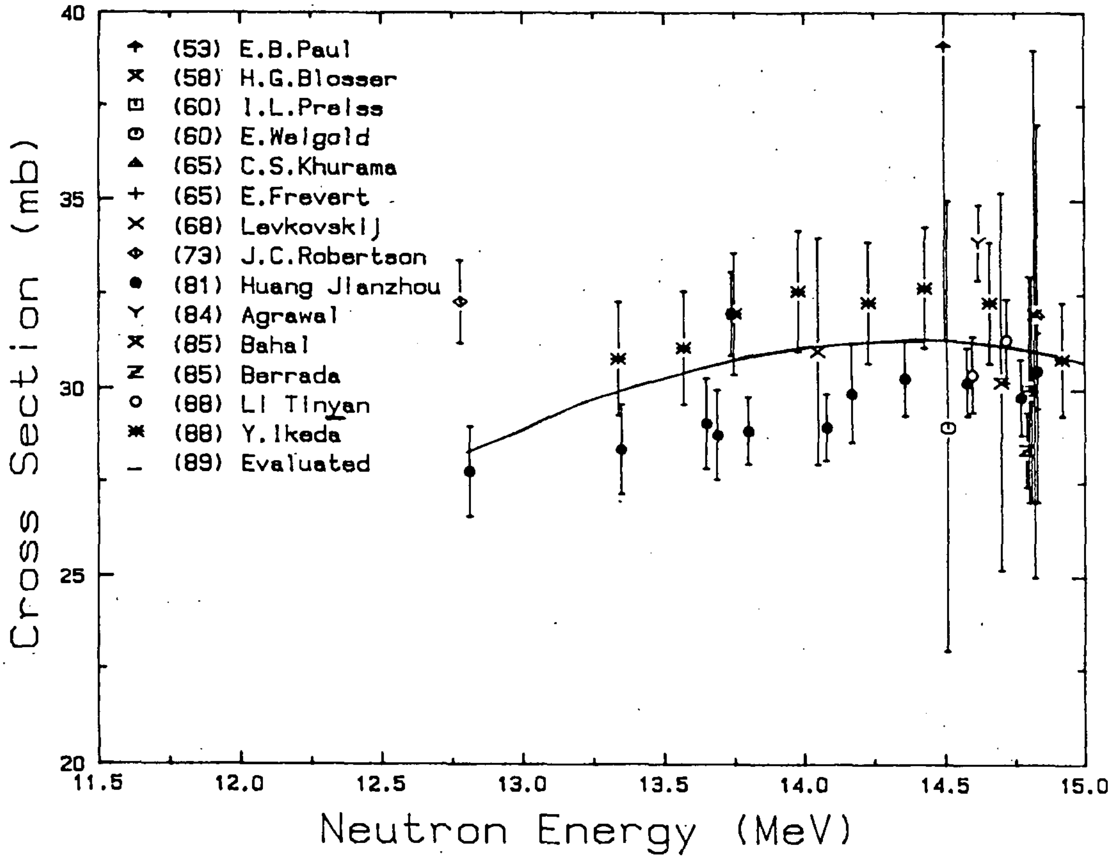

Fig.16(b) Co-59(n,a)Mn-56

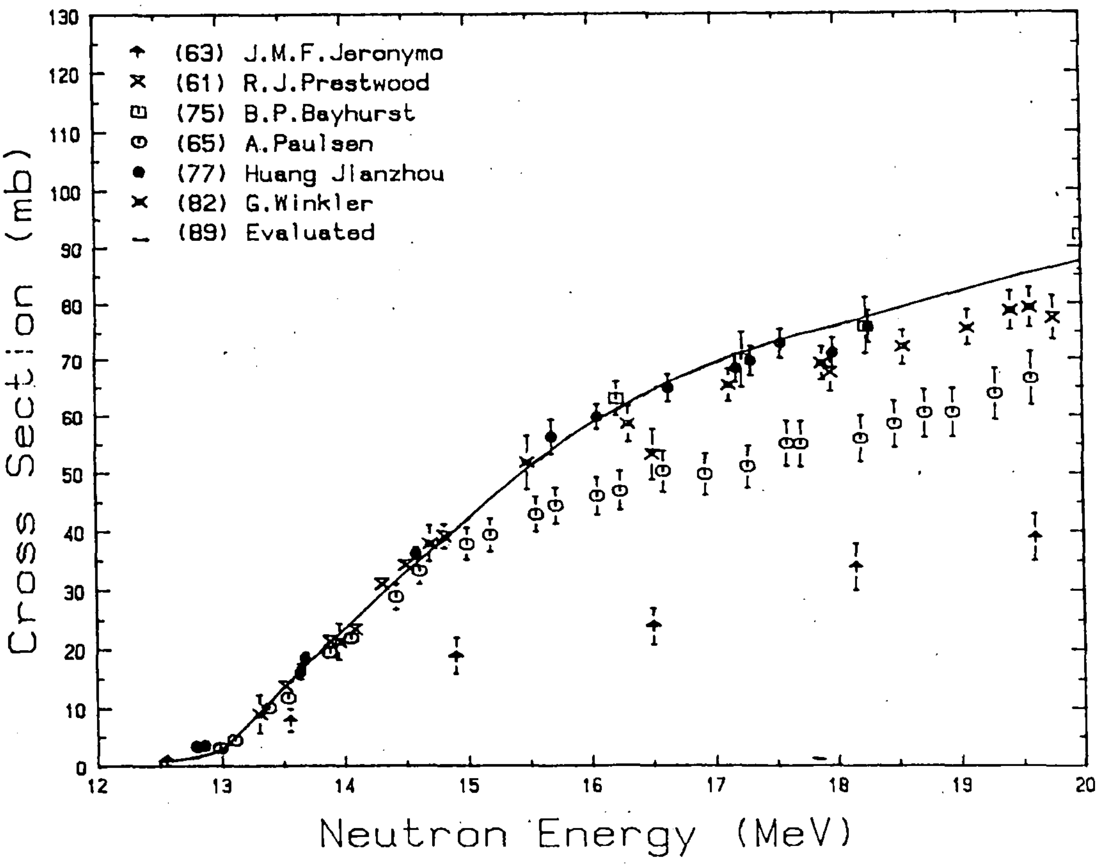

Fig.17(a) Ni-58(n,2n)Ni-57

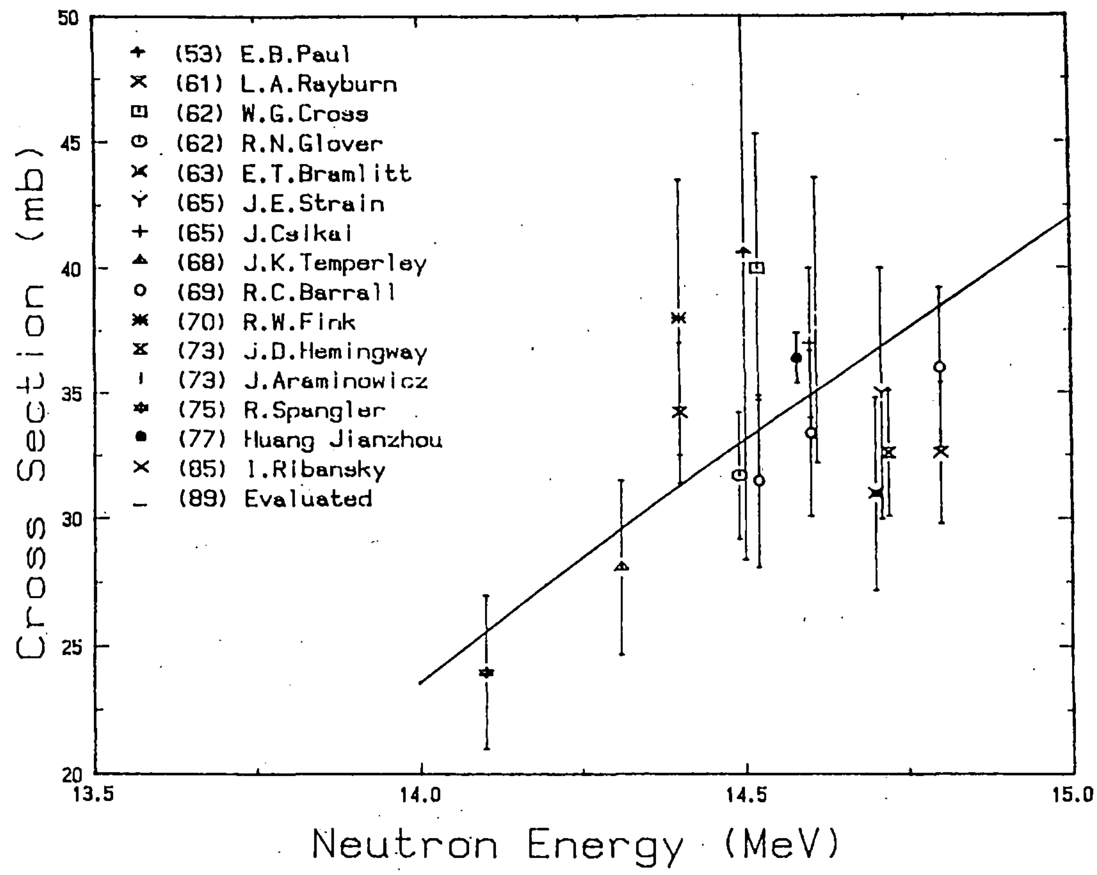

Fig.17(b) Ni-58(n,2n)Ni-57

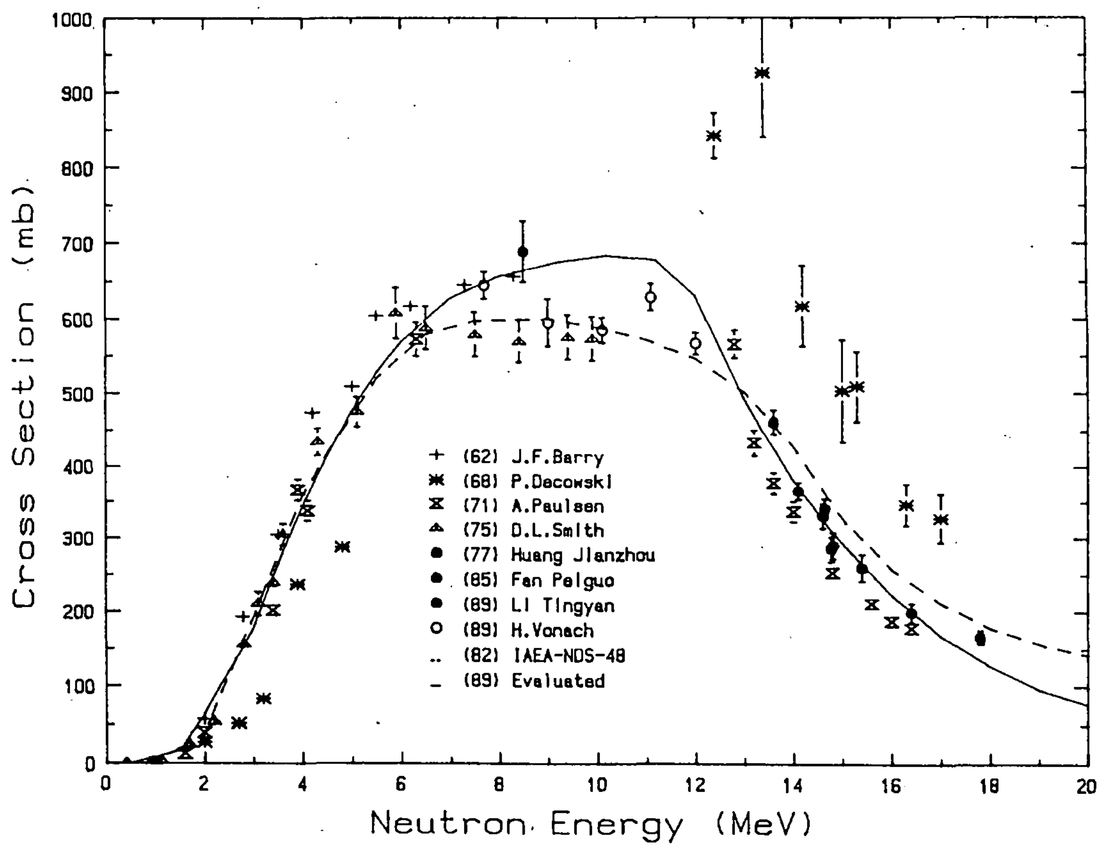

Fig.18 Ni-58(n,p)Co-58

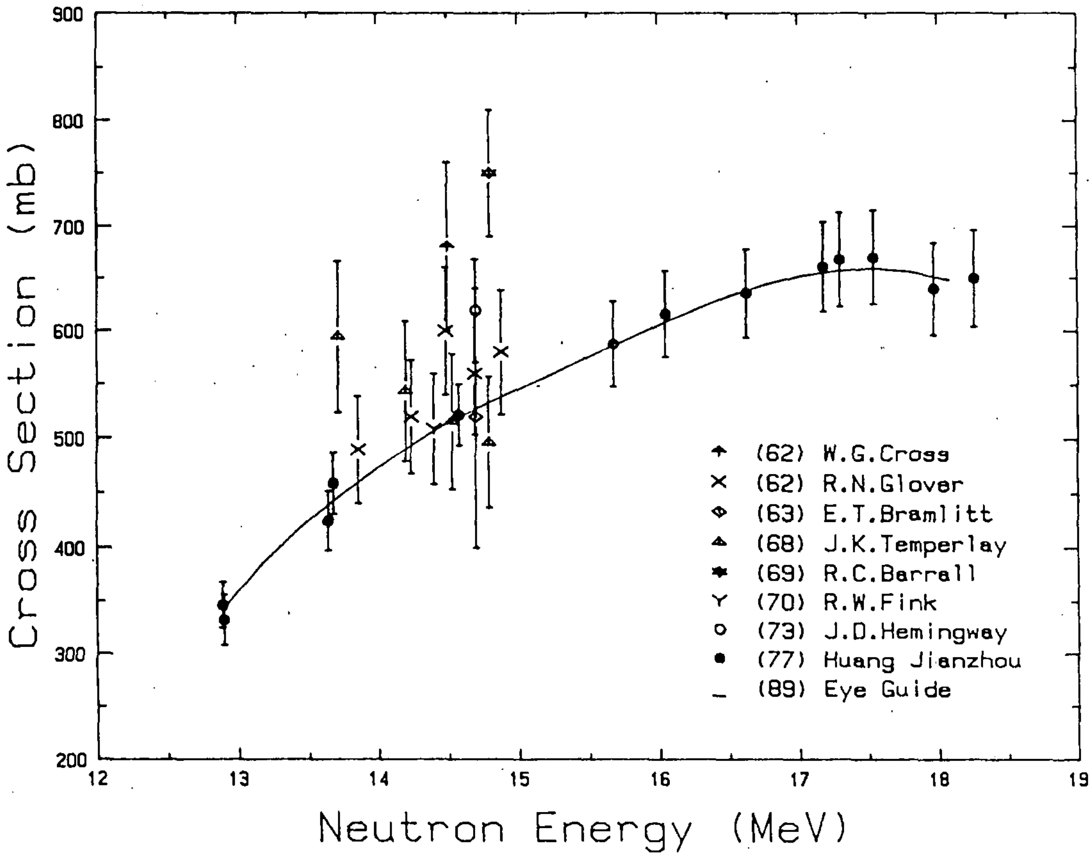

Fig.19 Ni-58(n,x)Co-57

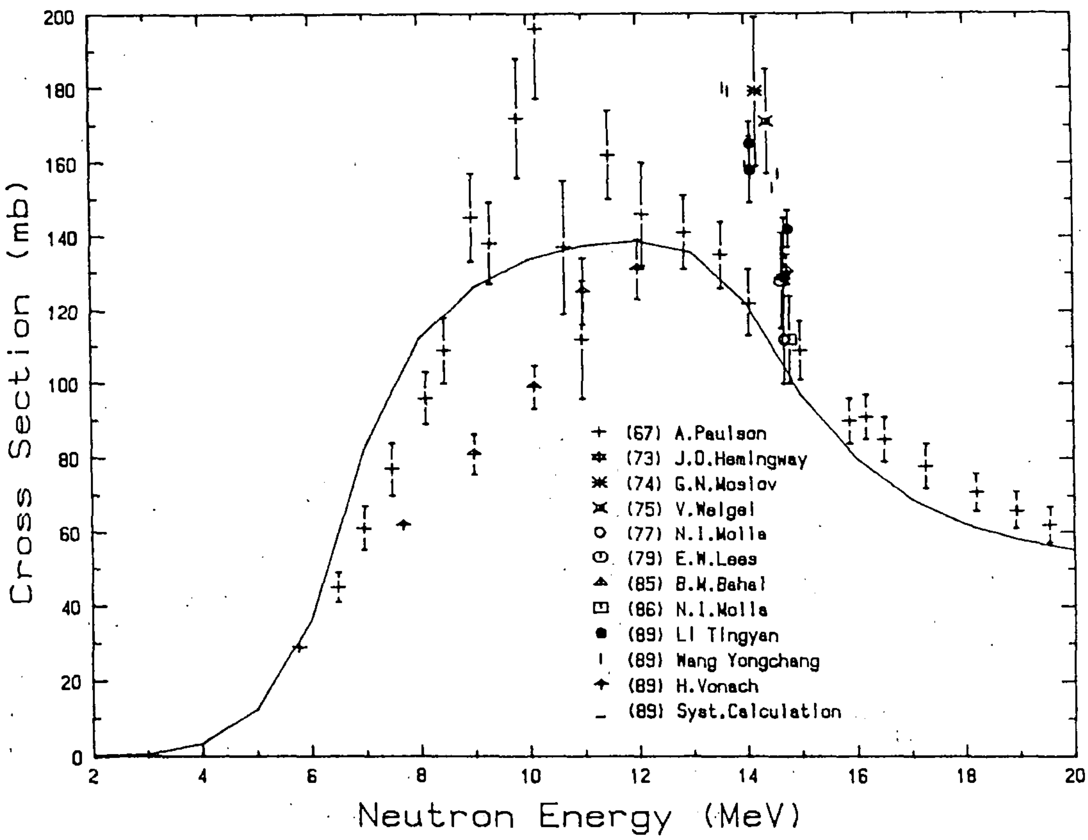

Fig.20 NI-60(n,p)Co-60

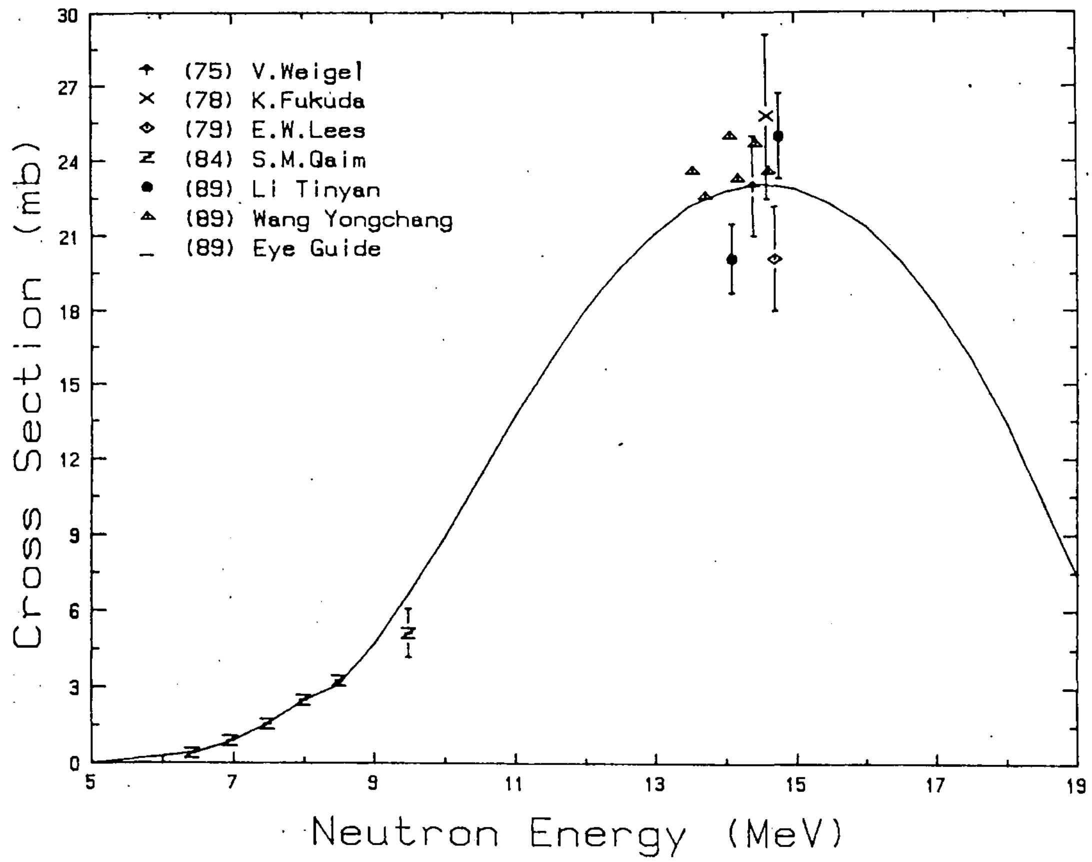

Fig. 21 Ni-62(n,a)Fe-59

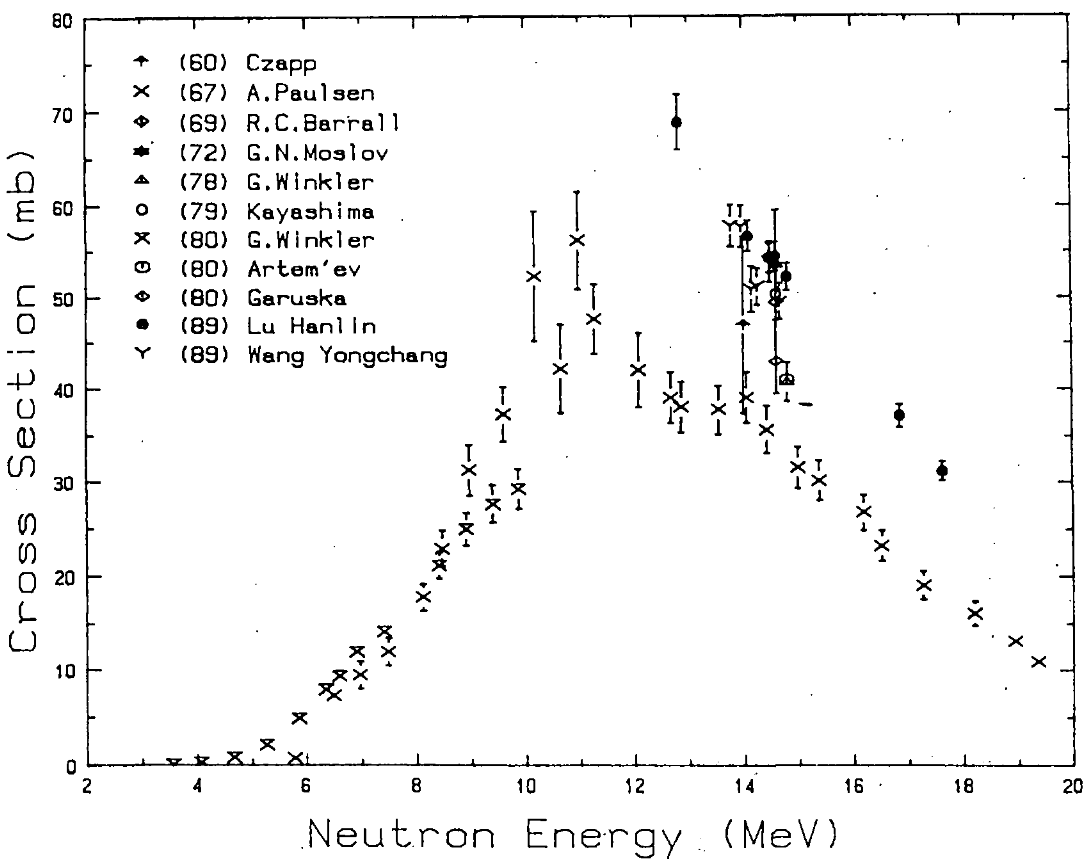

Fig. 22 Cu-63(n,a)Co-60

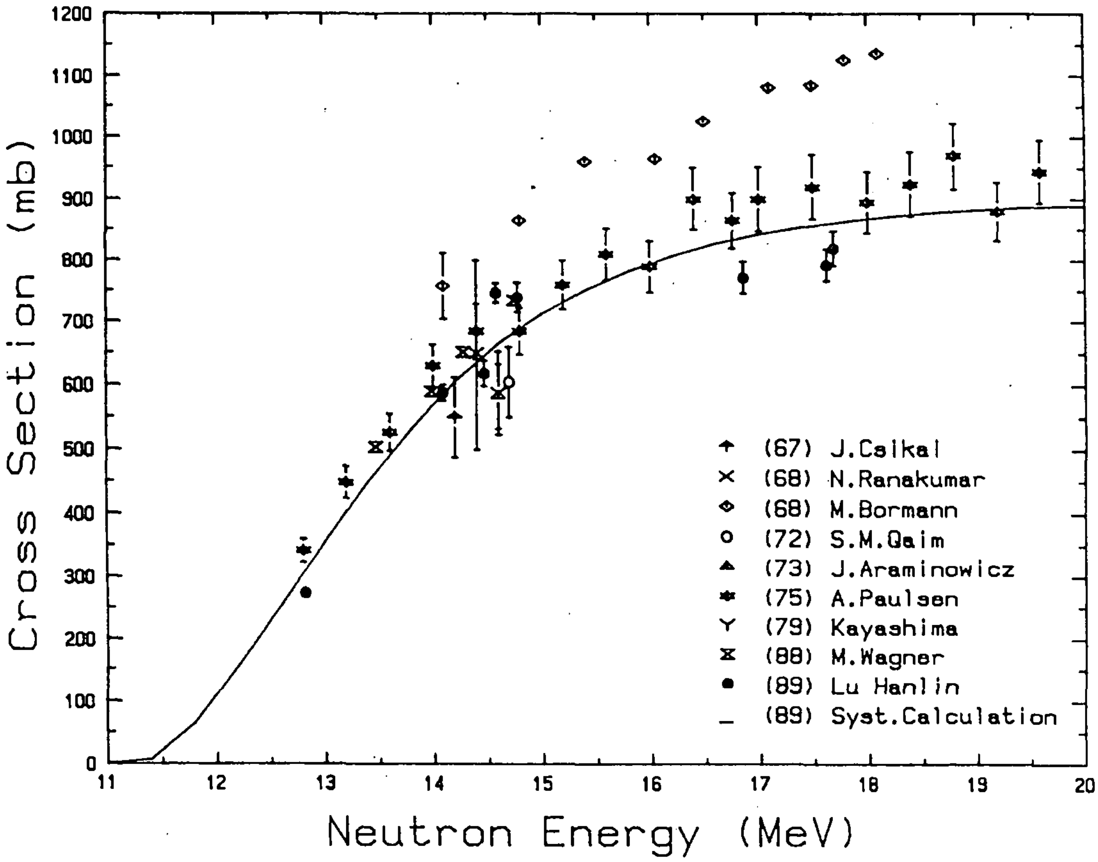

Fig.23 Zn-66(n,2n)Zn-65

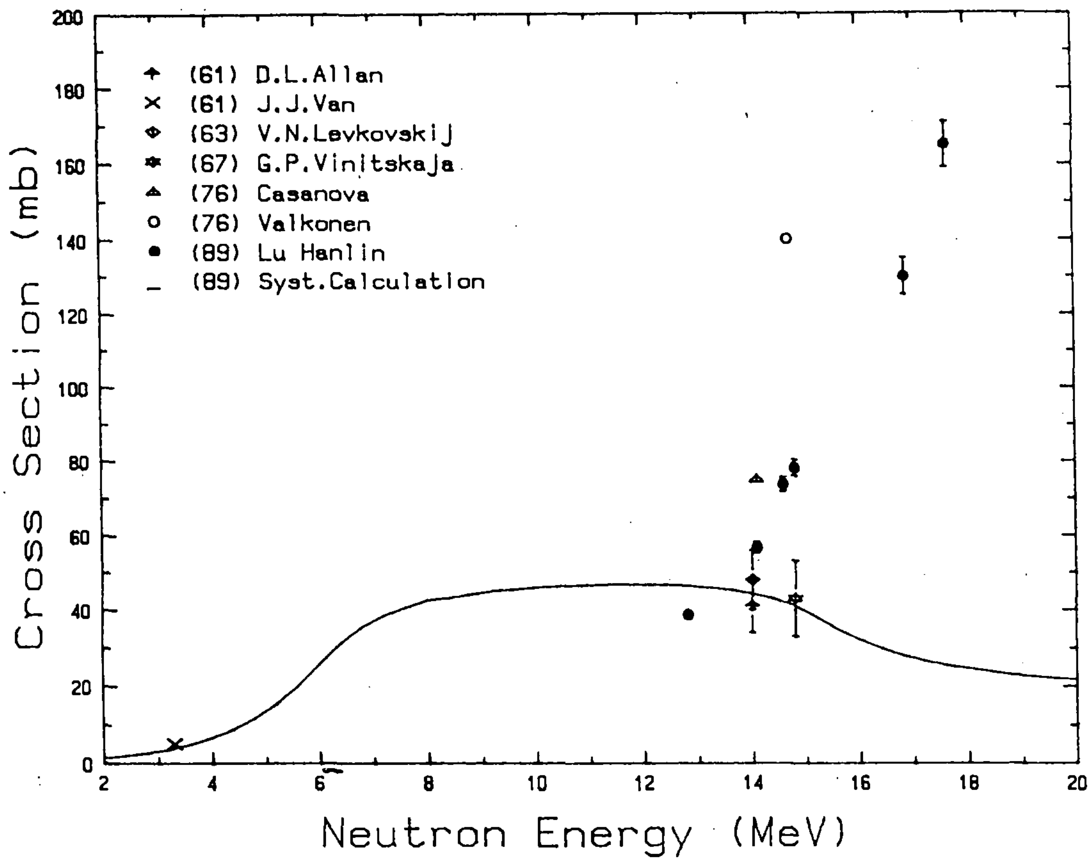

Fig.24 Zn-67(n,p)Cu-67

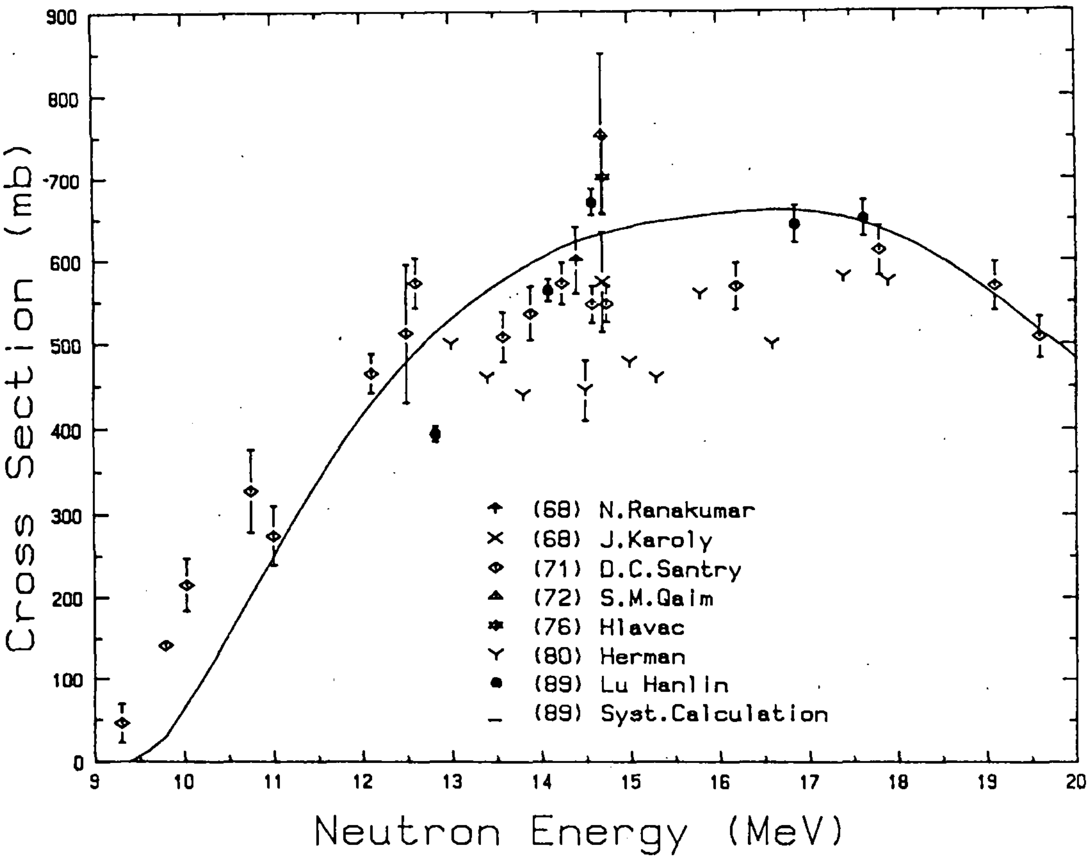

Fig.25 Zn-70(n,2n)Zn-69m

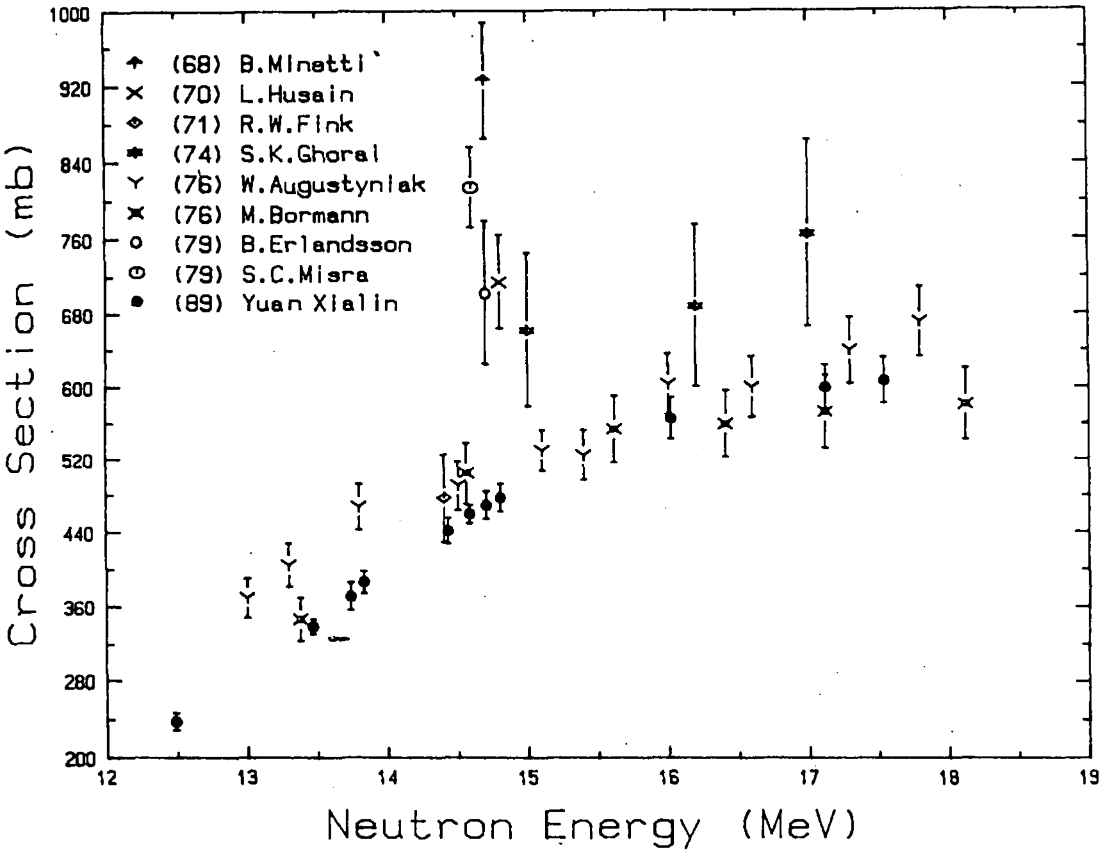

Fig.26 Rb-85(n,2n)Rb-84m

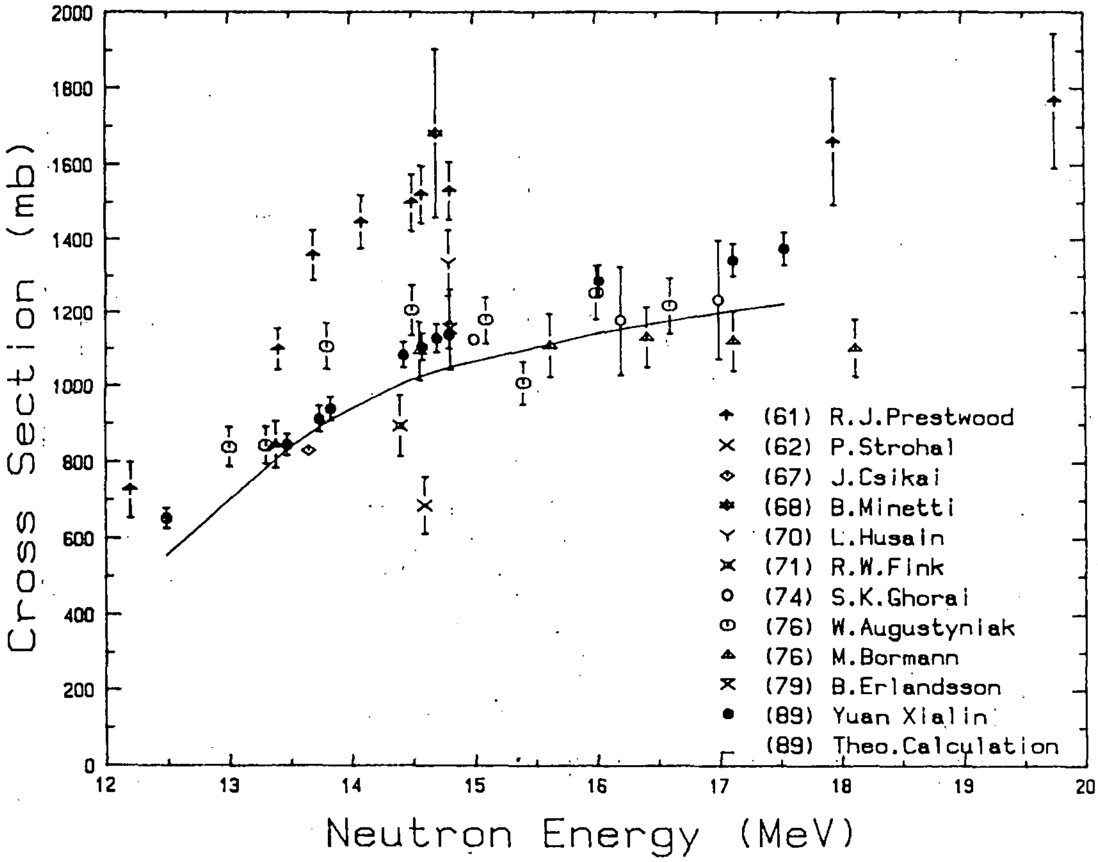

Fig. 27 Rb-85(n,2n)Rb-84

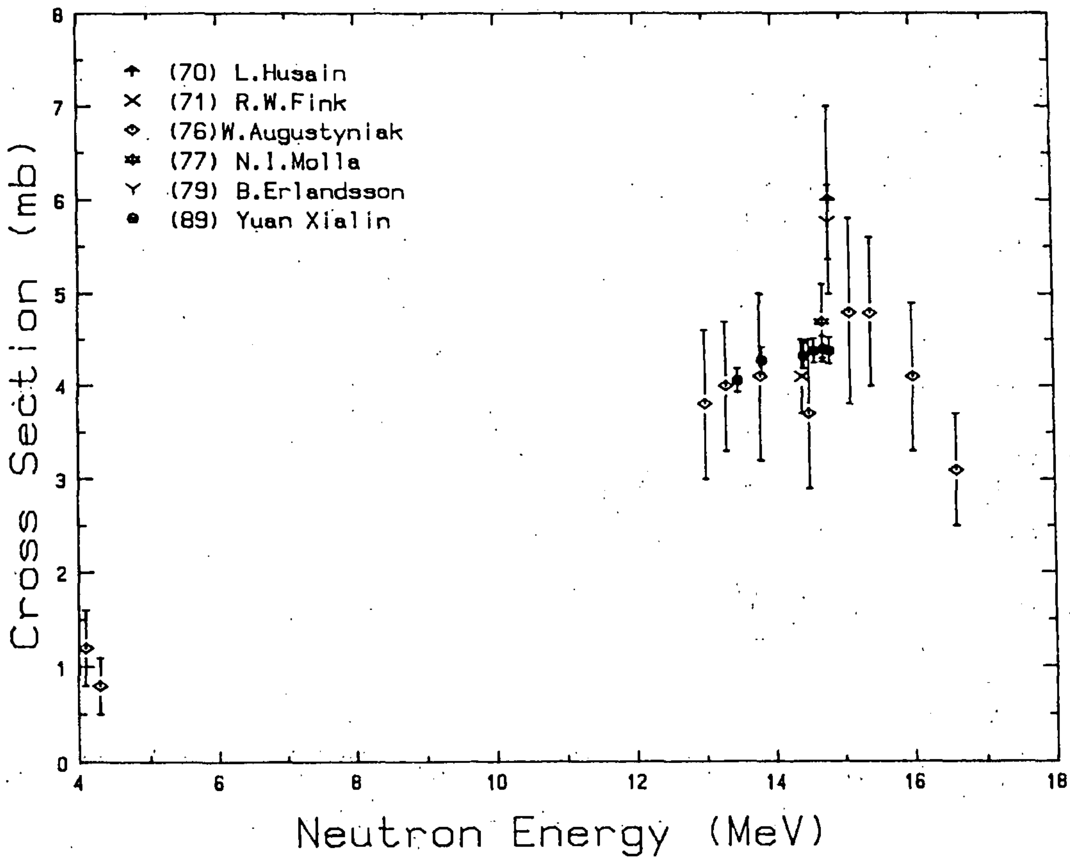

Fig. 28 Rb-85(n,p)Kr-85m

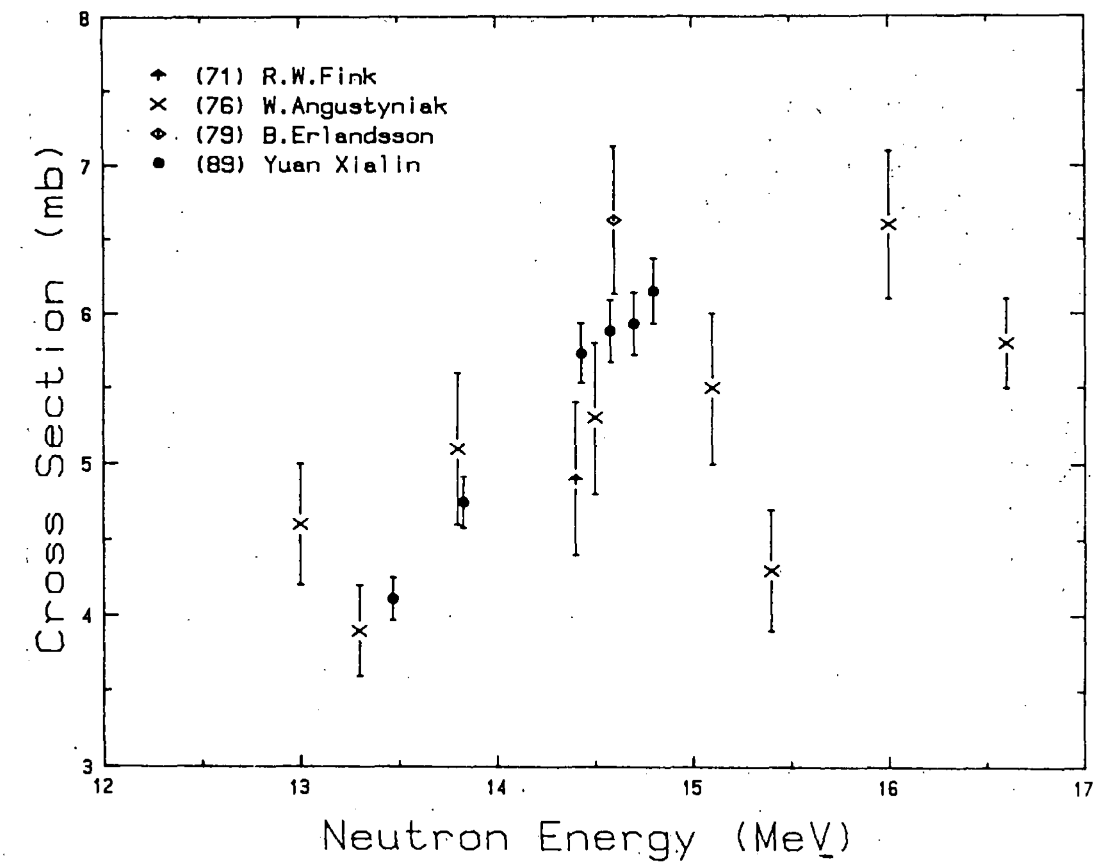

Fig. 29 Rb-85(n,a)Br-82

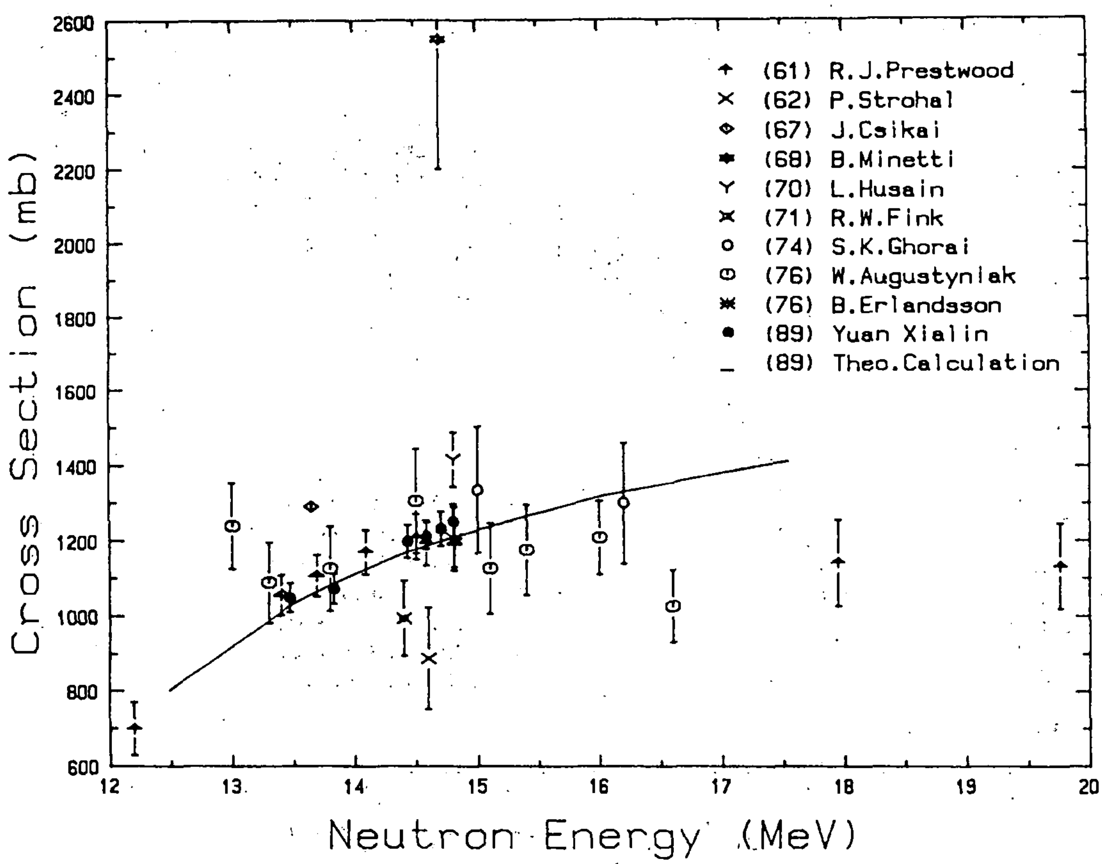

Fig. 30 Rb-87(n,2n)Rb-86

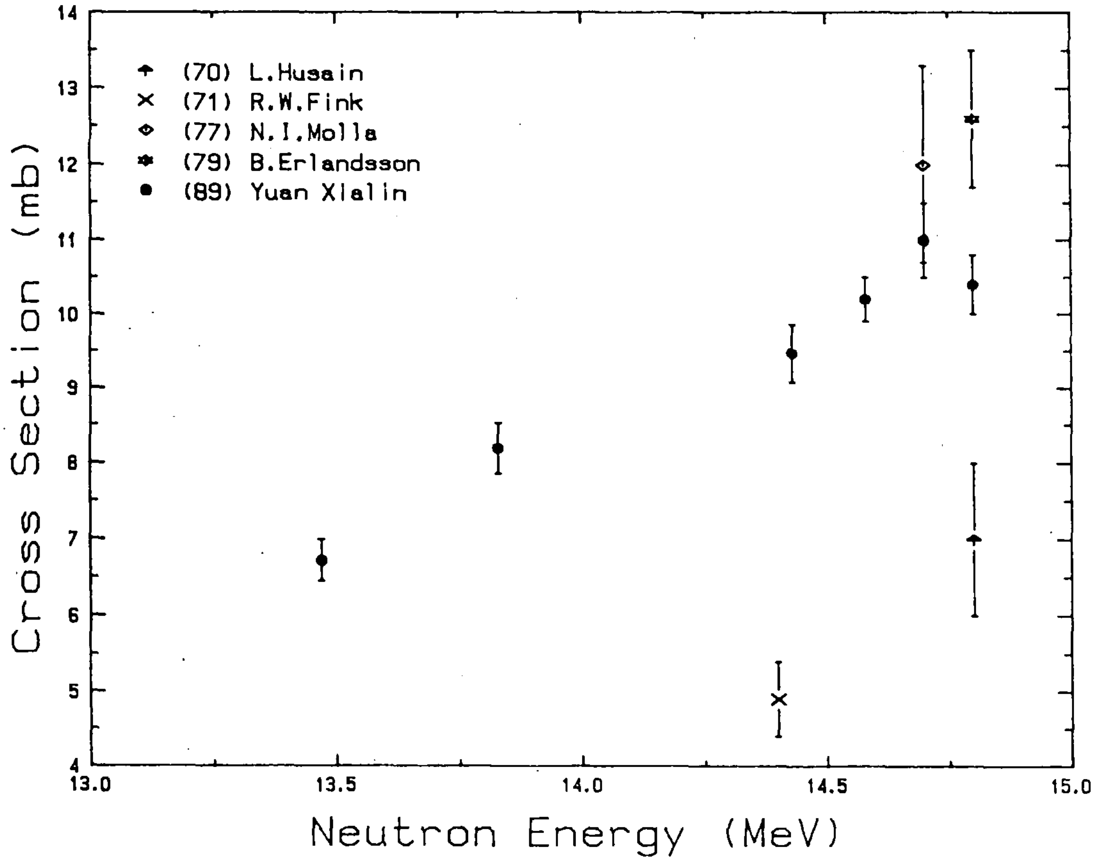

Fig. 31 Rb-87(n,p)Kr-87

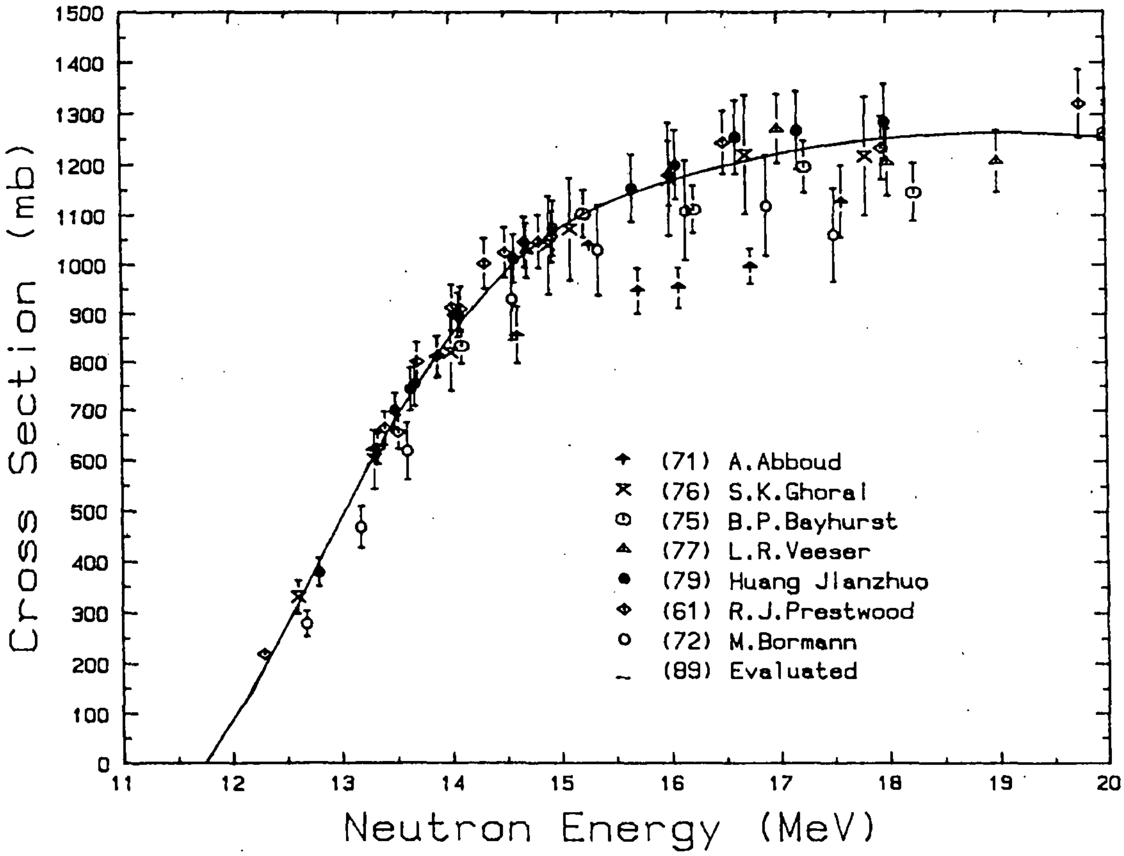

Fig. 32(a) Y-89(n,2n)Y-88

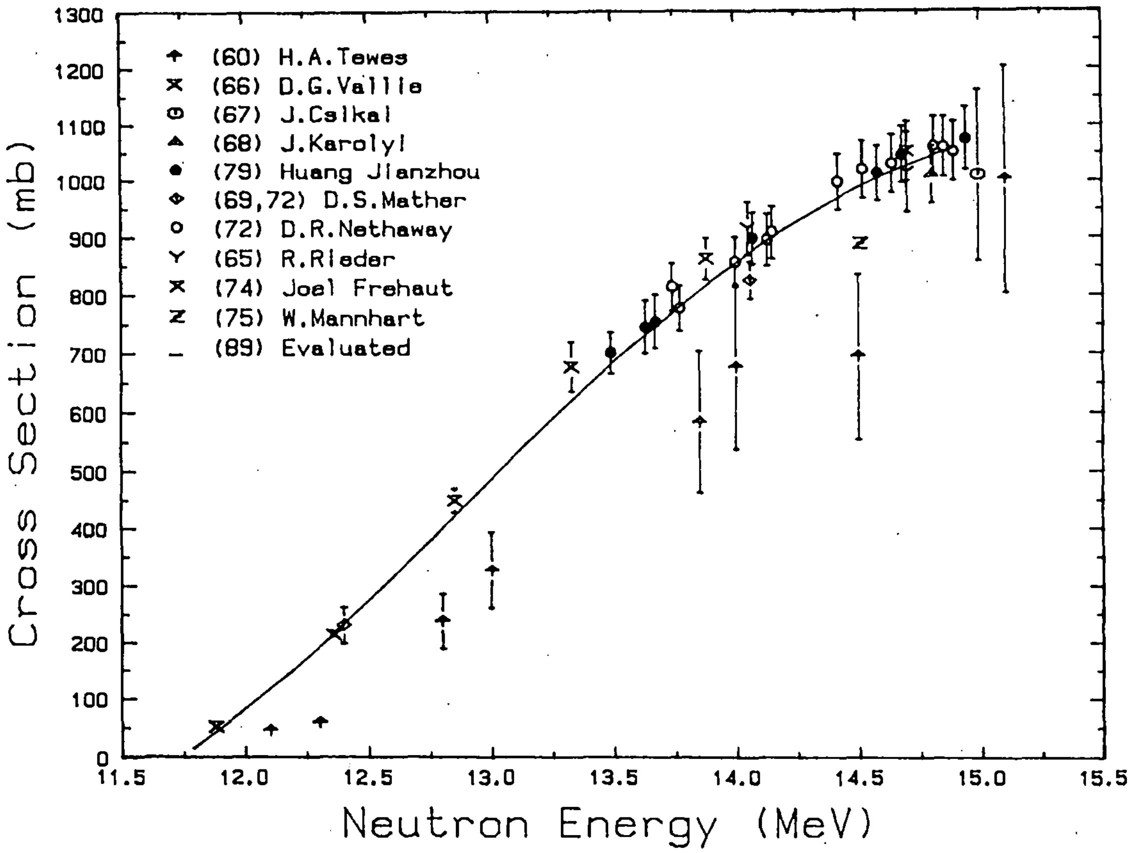

Fig.32(b) Y-89(n,2n)Y-88

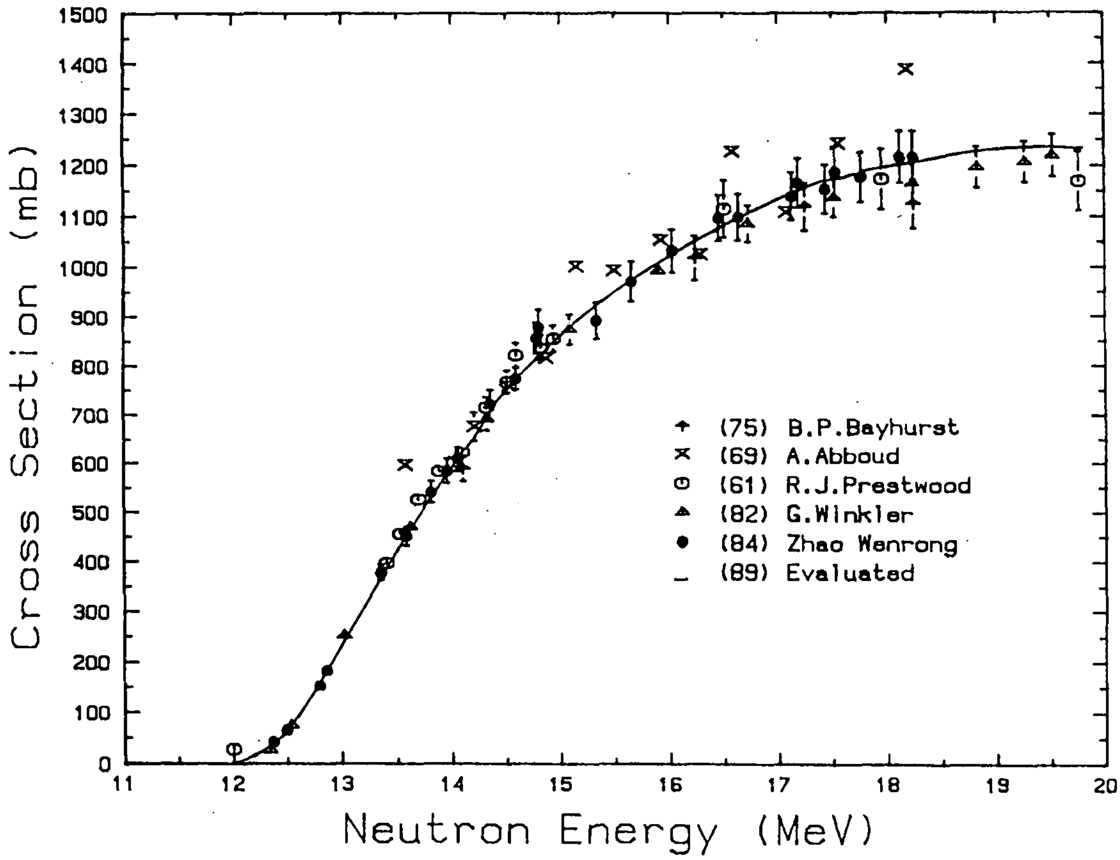

Fig.33(a) Zr-90(n,2n)Zr-89

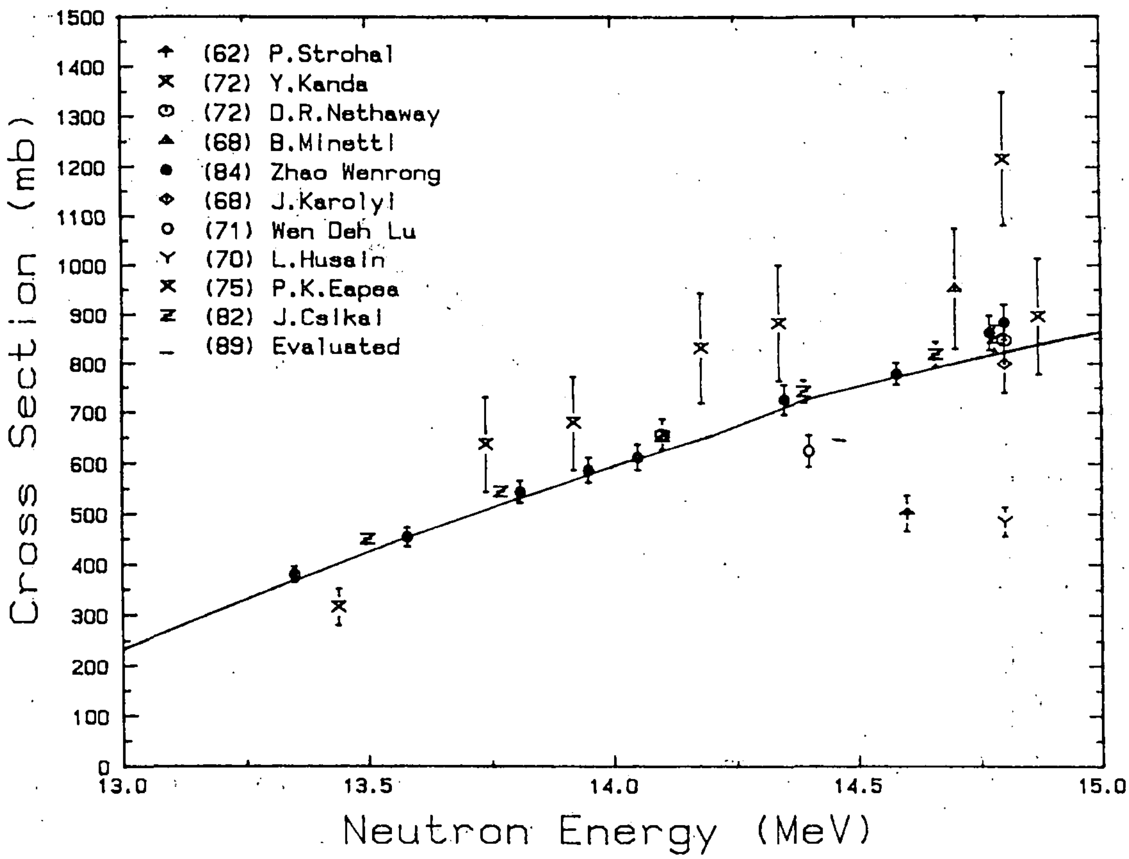

Fig.33(b) Zr-90(n,2n)Zr-89

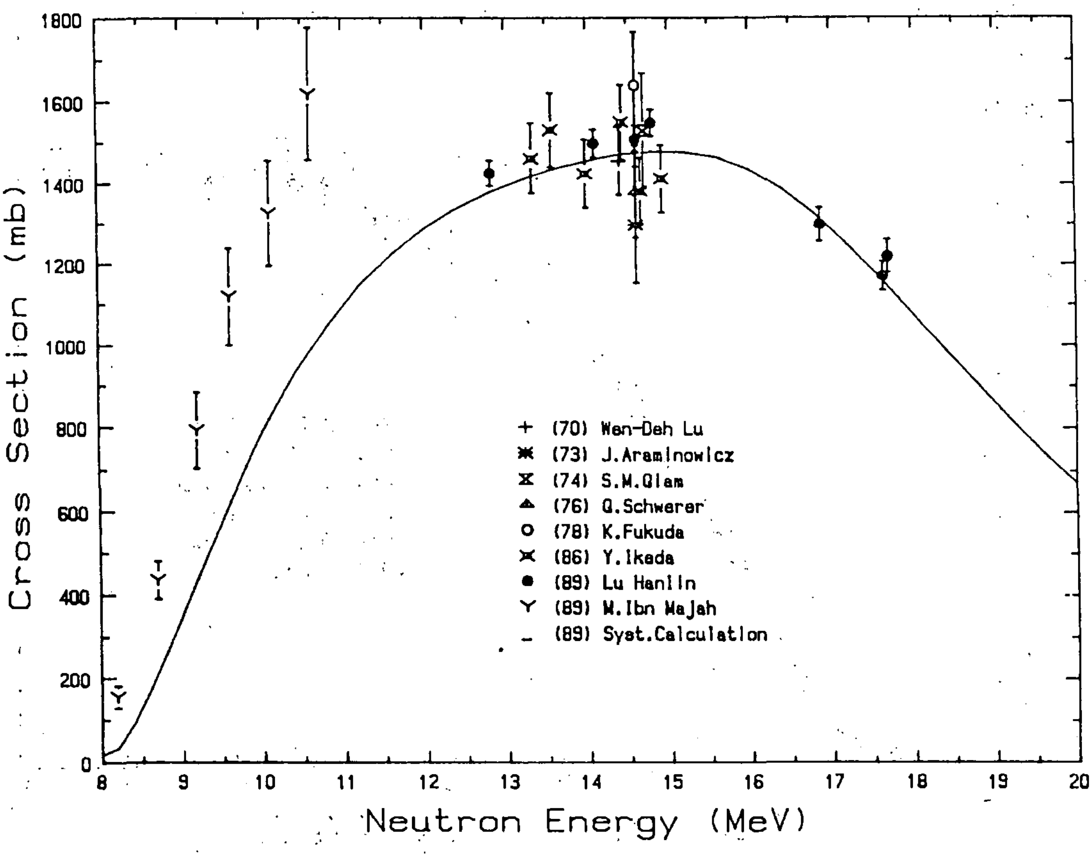

Fig.34 Zr-96(n,2n)Zr-95

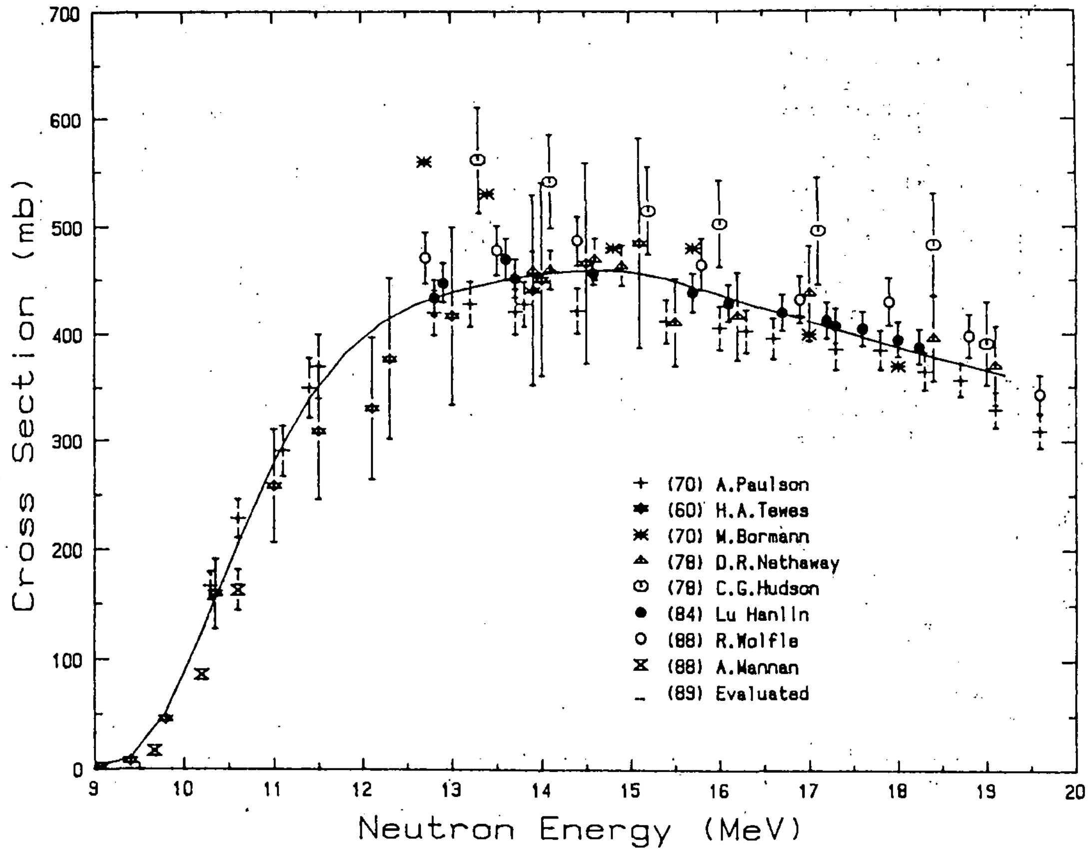

Fig.35(a) Nb-93(n,2n)Nb-92m

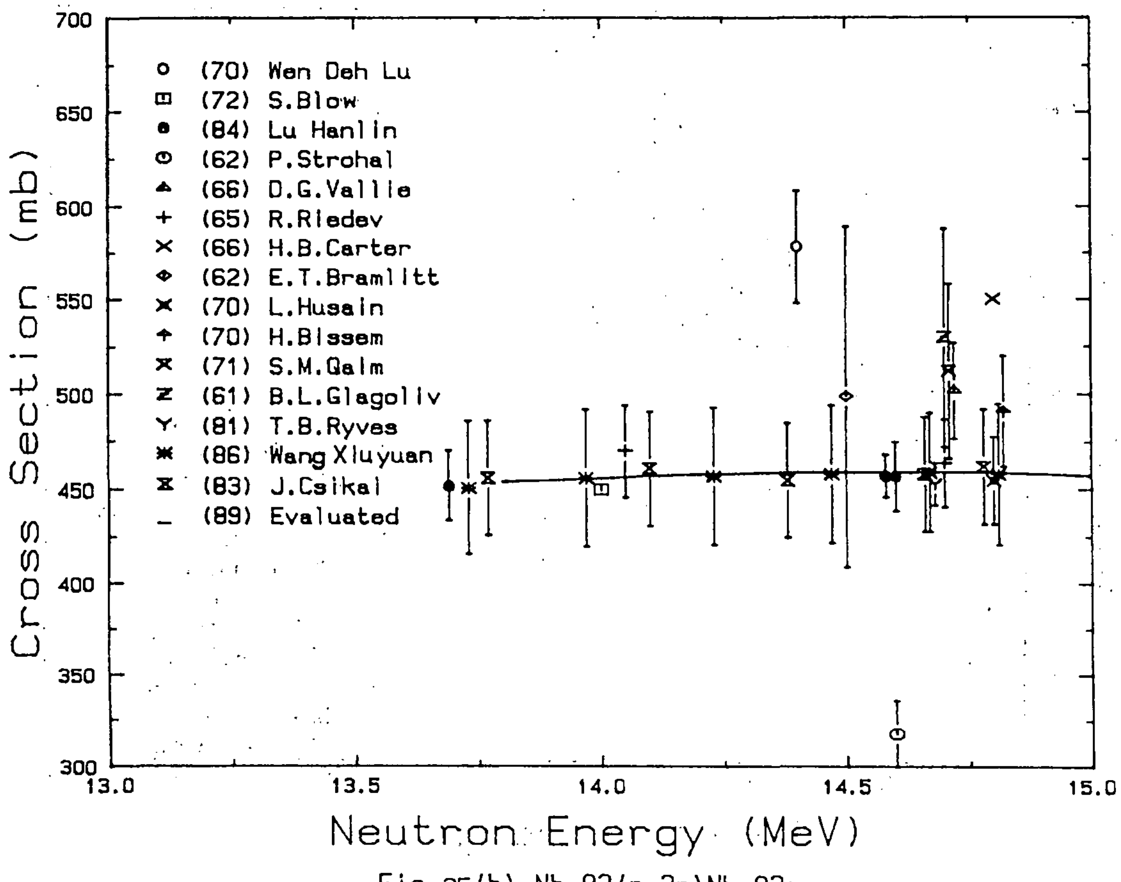

Fig.35(b) Nb-93(n,2n)Nb-92m

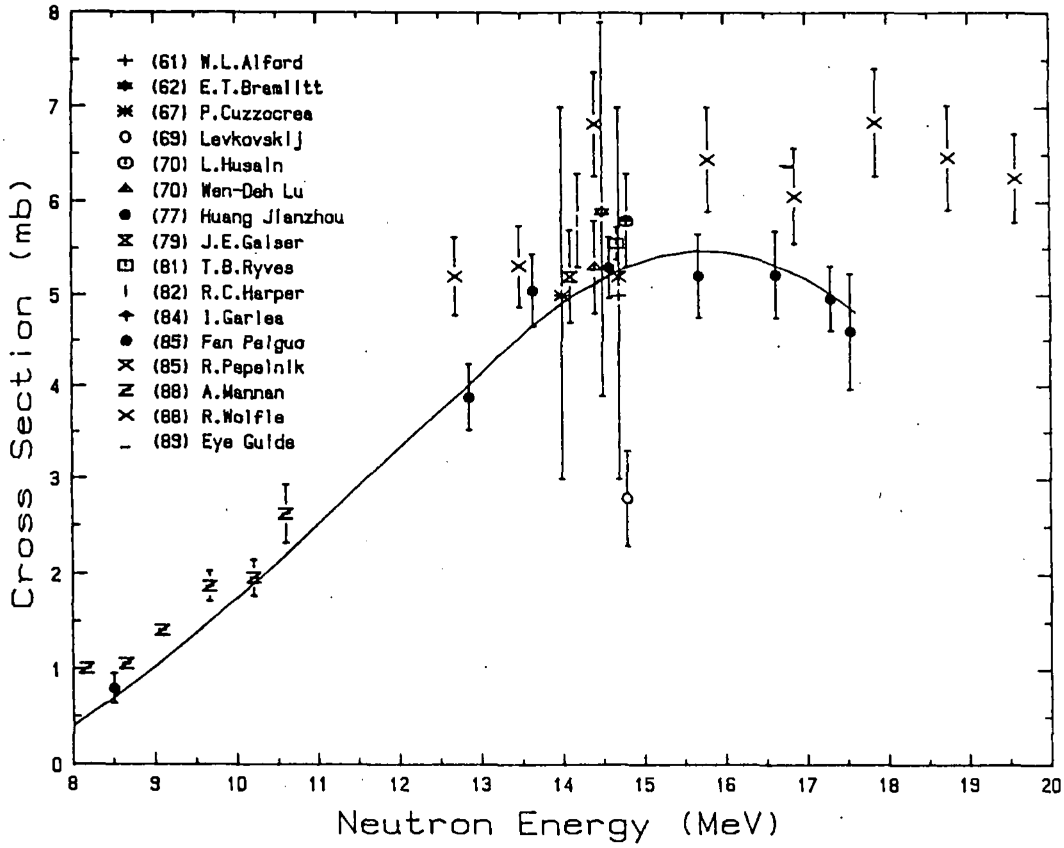

Fig.36 Nb-93(n,a)Y-90m

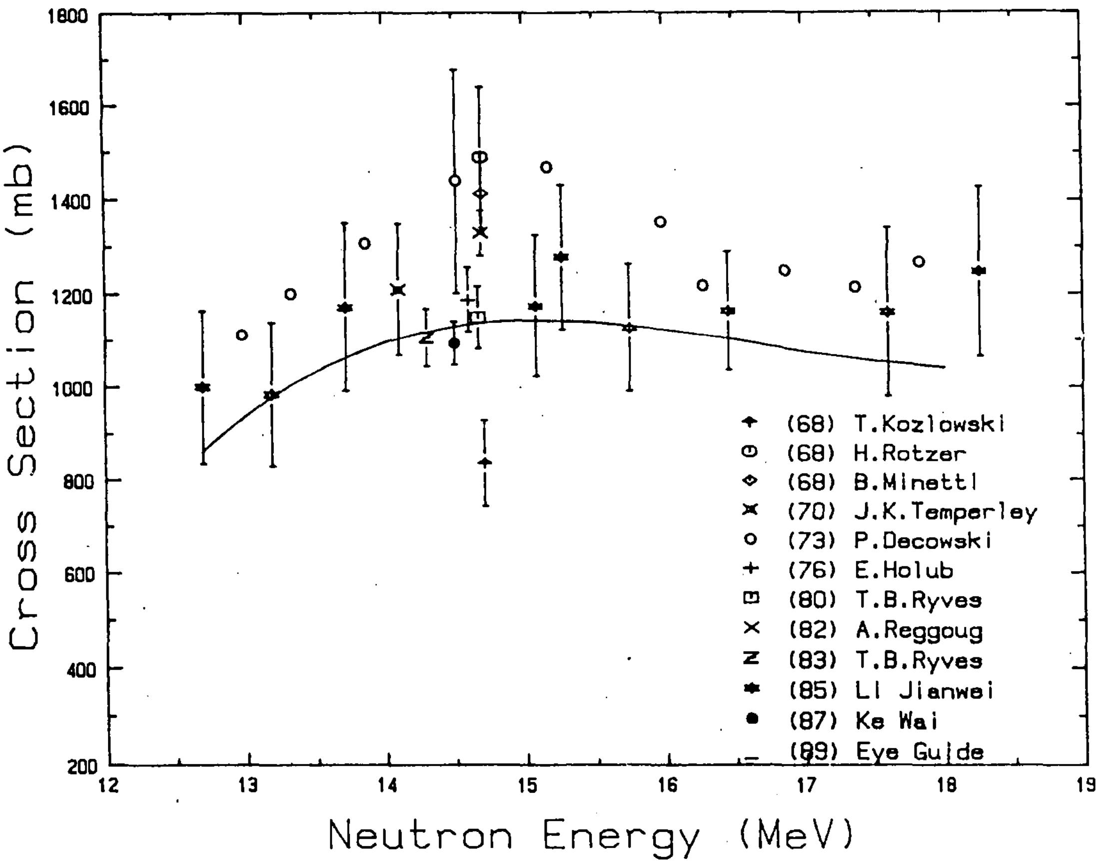

Fig.37 In-113(n,2n)In-112m

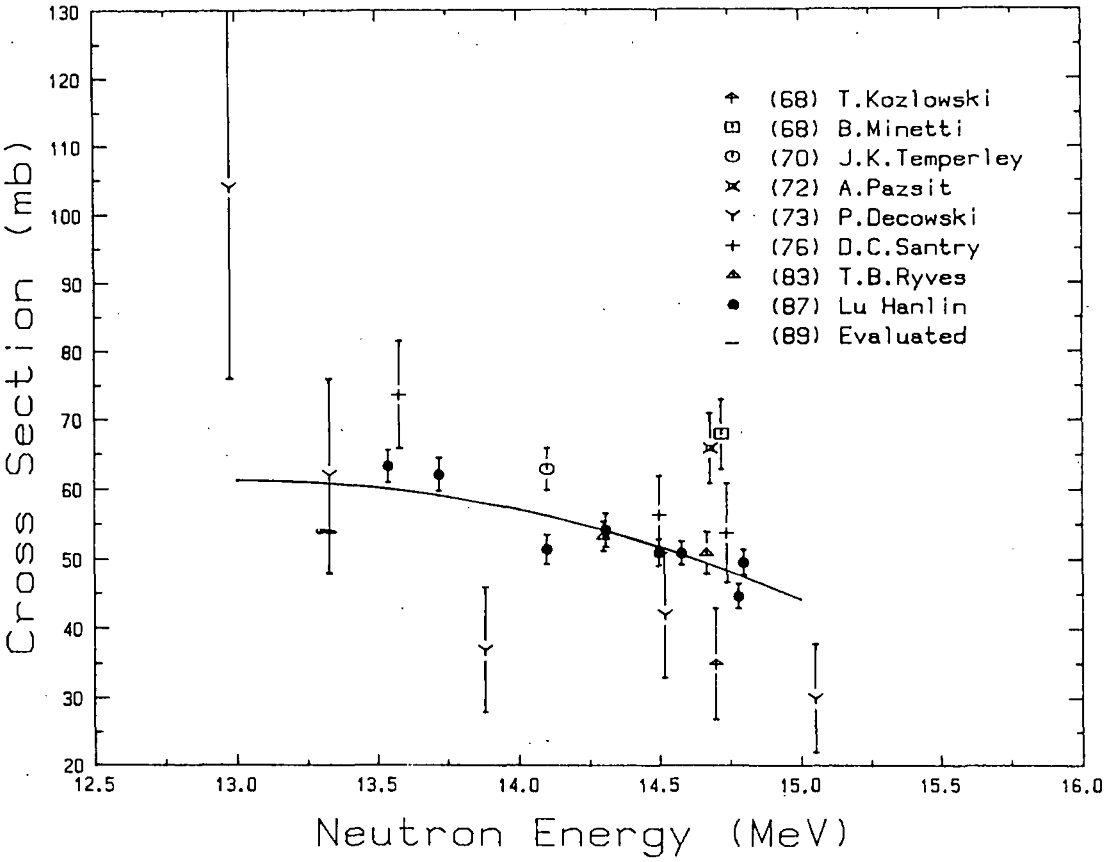

Fig.38 In-113(n,n')In-113m

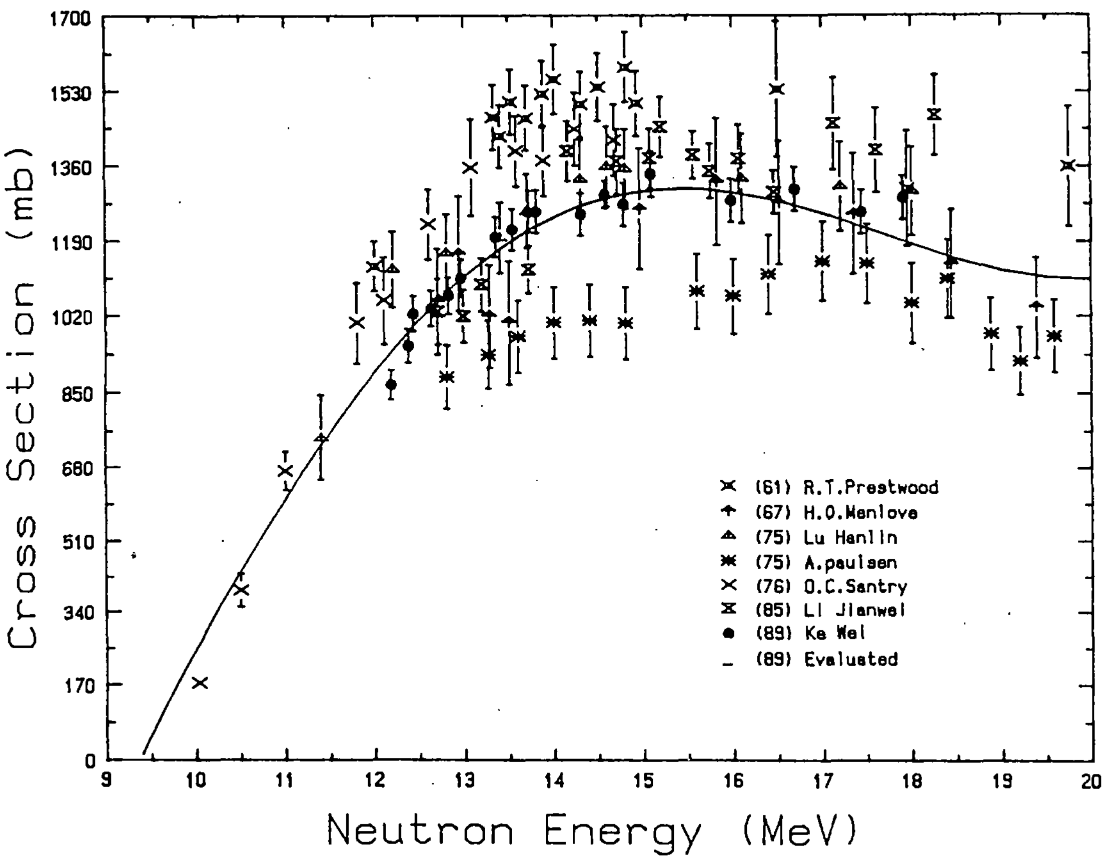

Fig.39(a) In-115(n,2n)In-114m

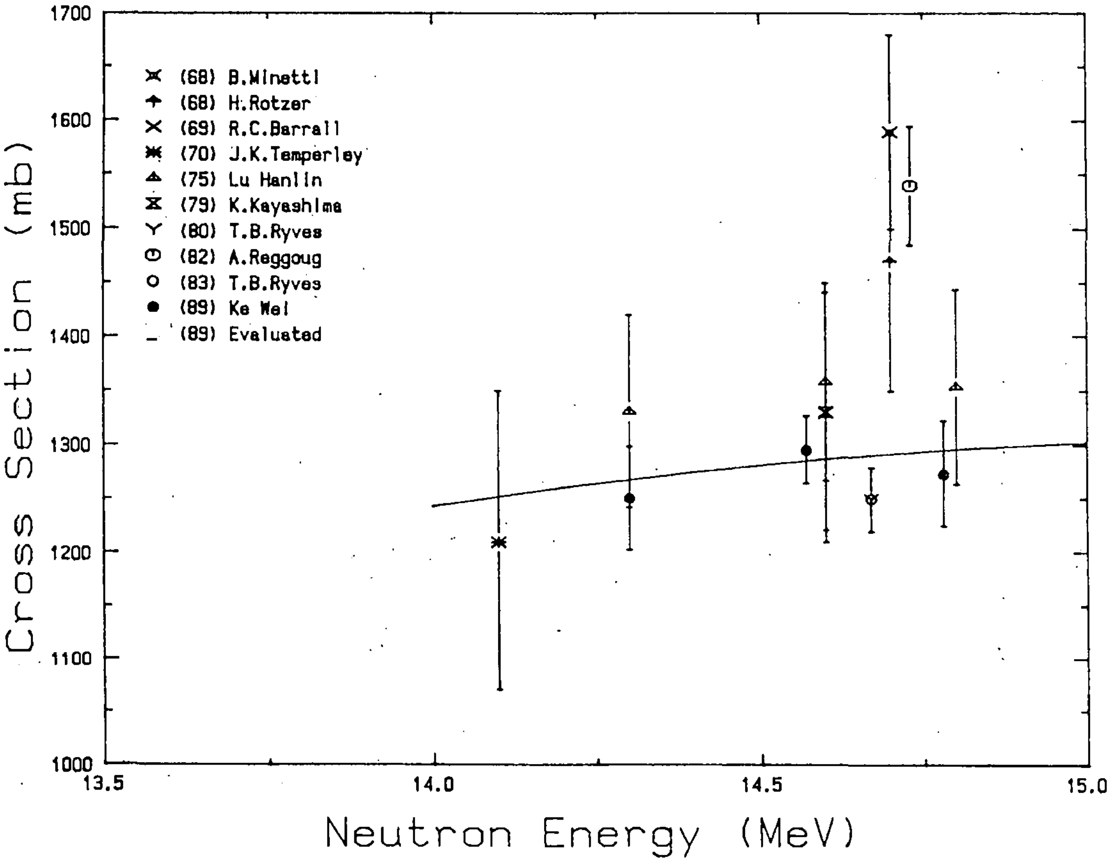

Fig.39(b) In-115(n,2n)In-114m

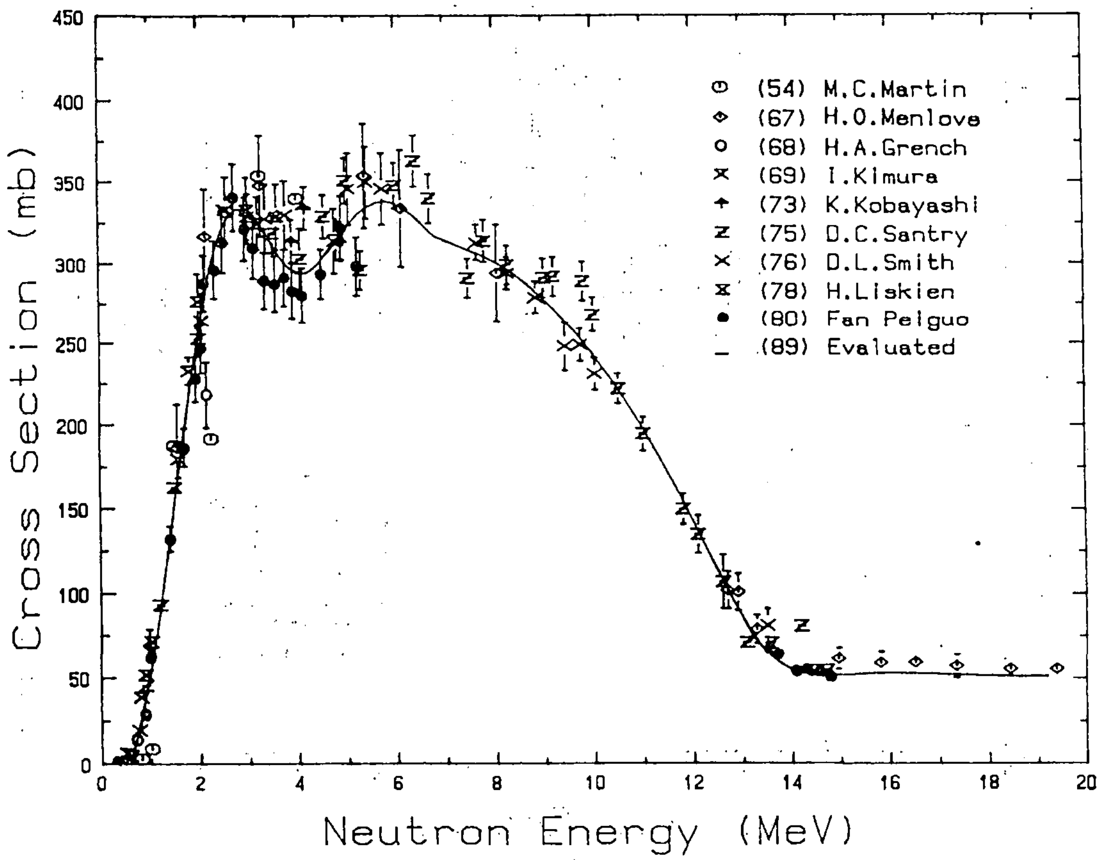

Fig.40(a) In-115(n,n')In-115m

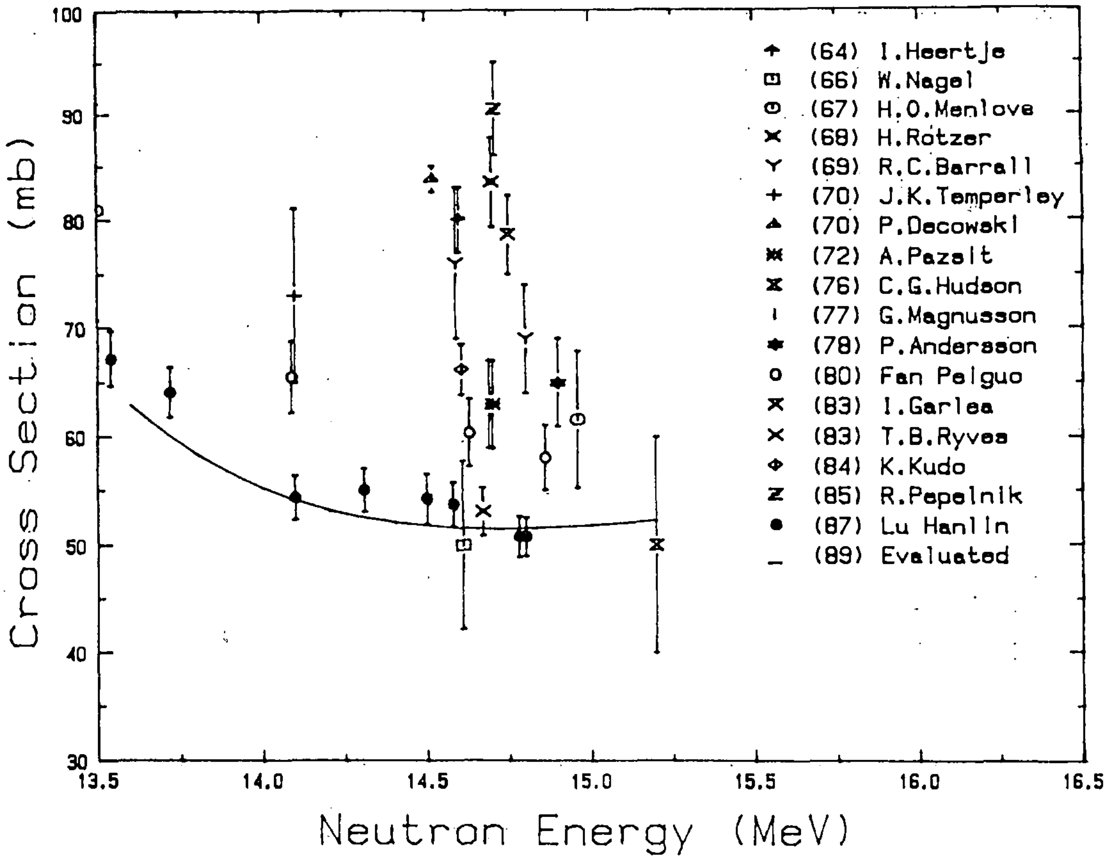

Fig.40(b) In-115(n,n')In-115m

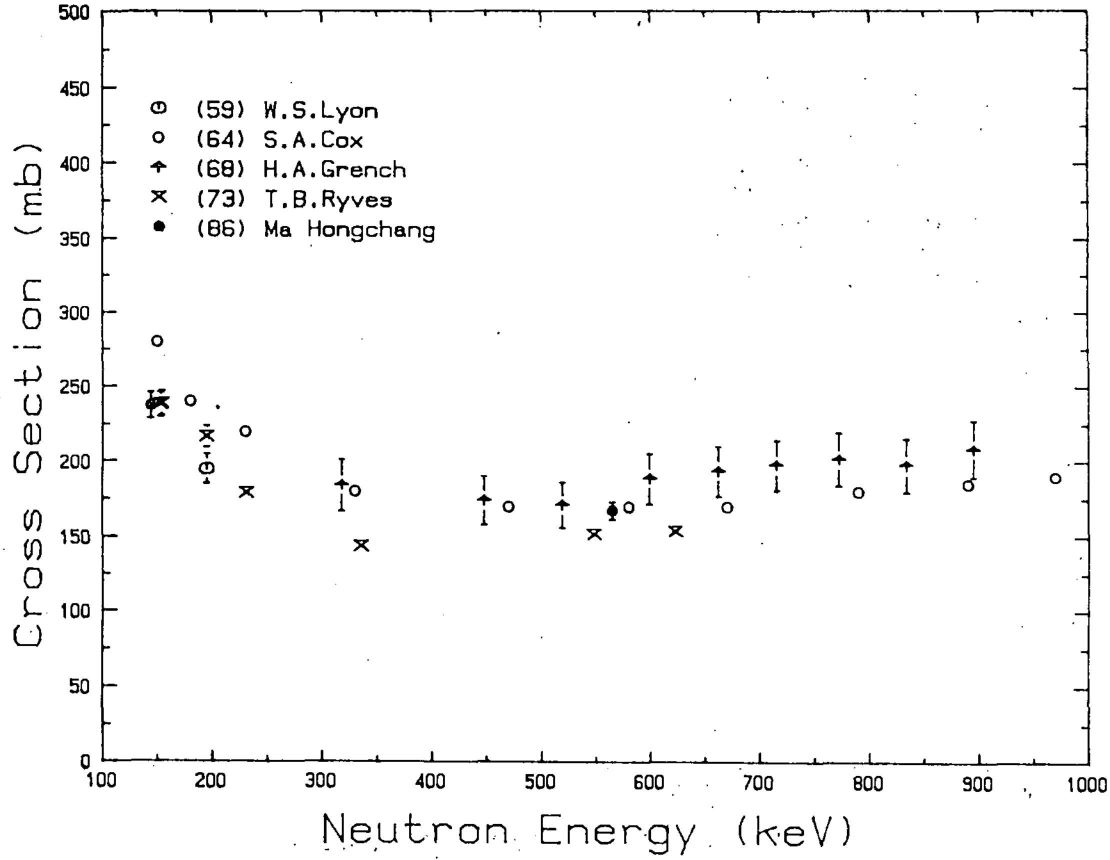

Fig.41 In-115(n,r)In-116m

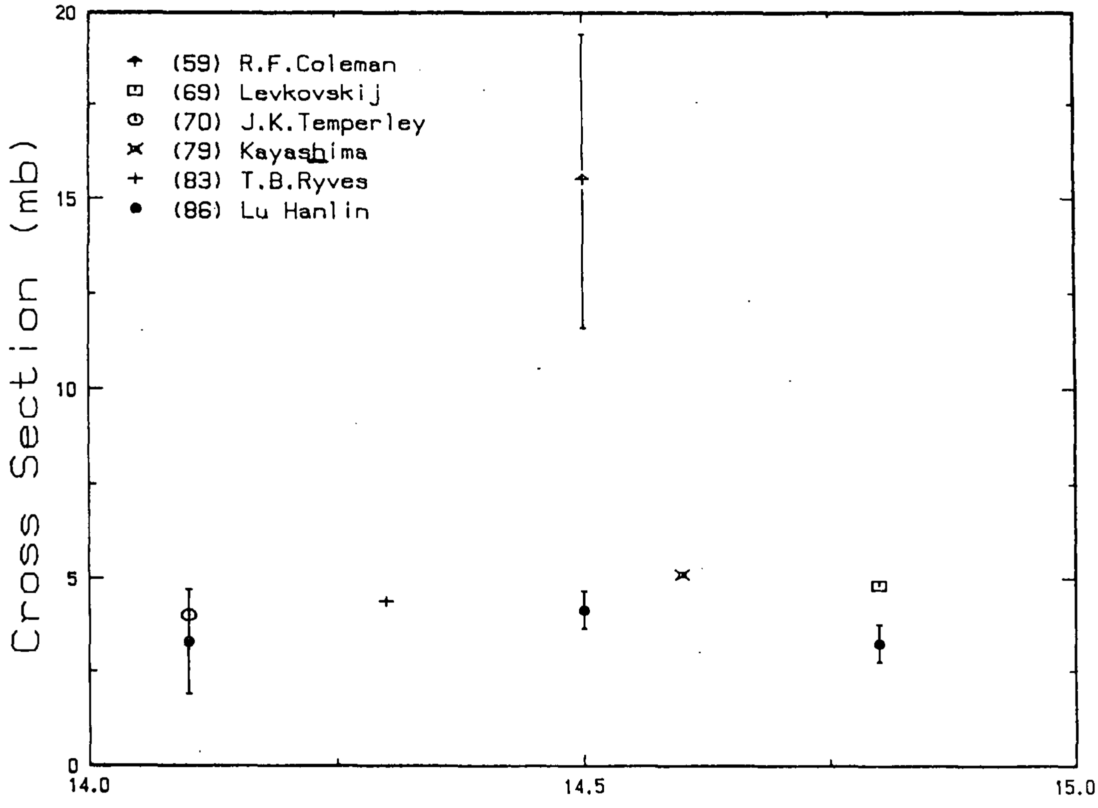

Fig.42 In-115(n,p)Cd-115

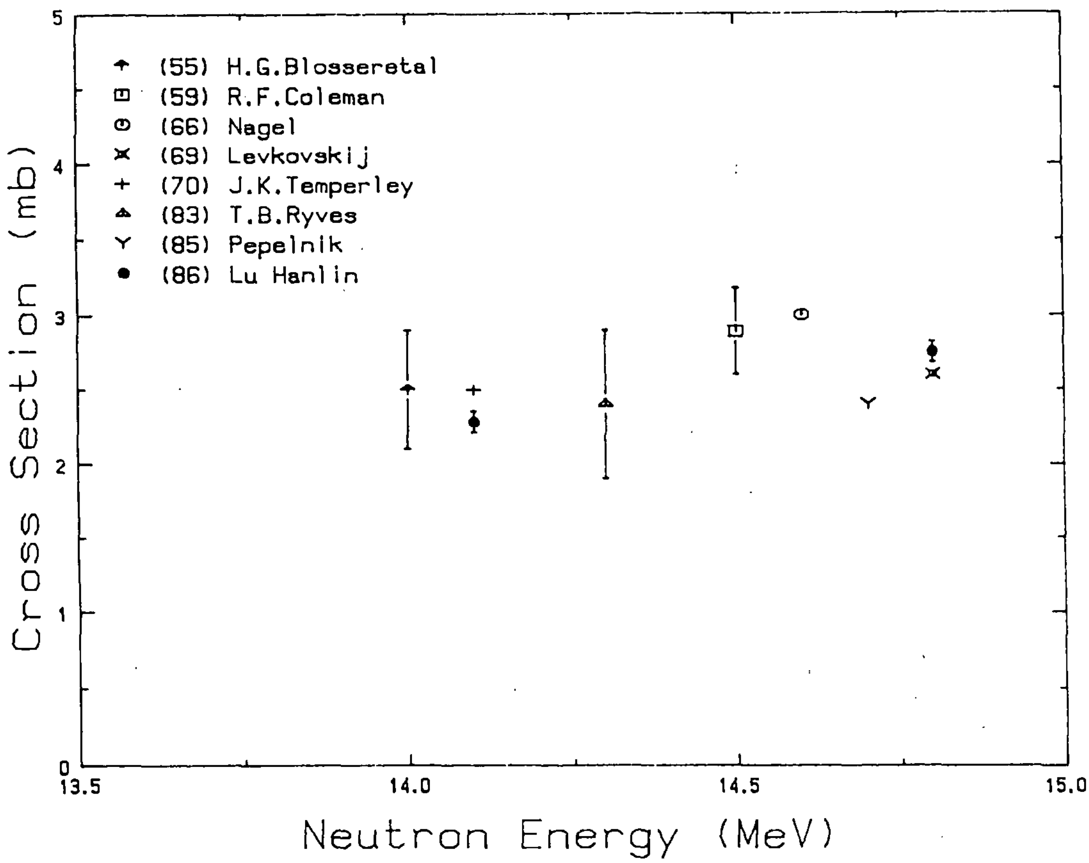

Fig.43 In-115(n,a)Ag-112

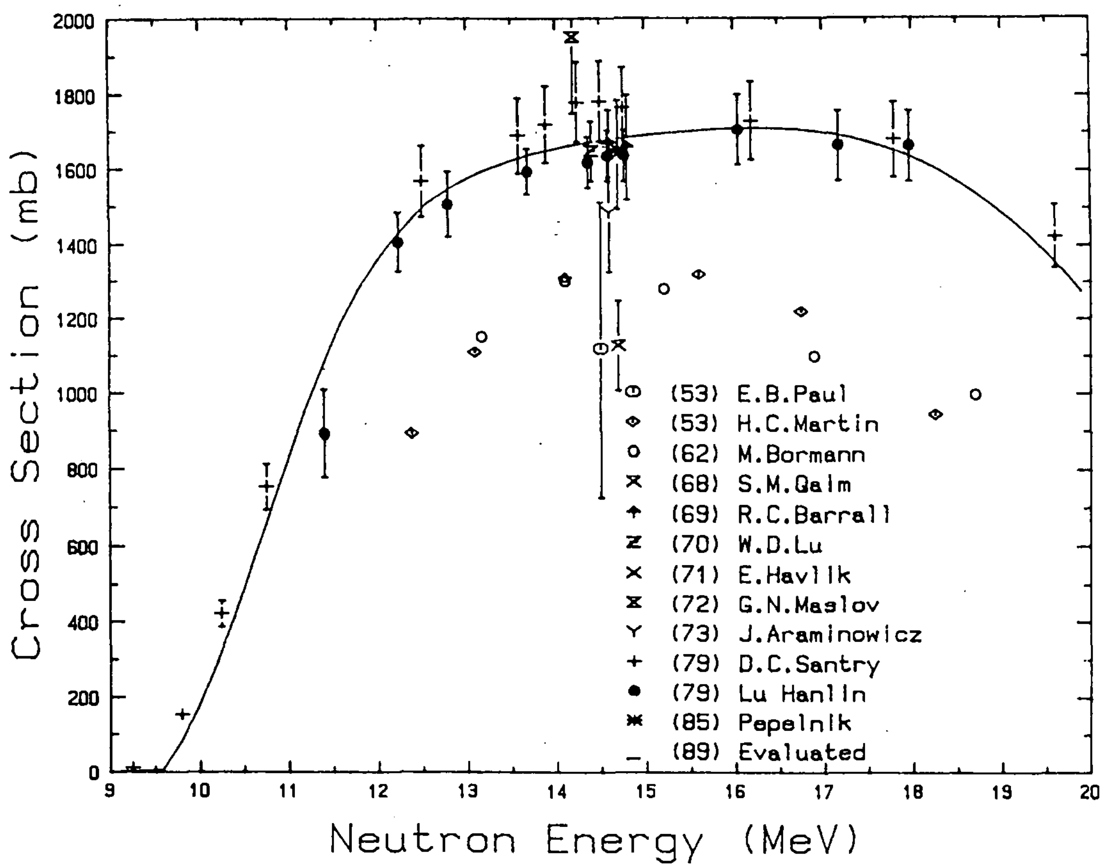

Fig.44 I-127(n,2n)I-126

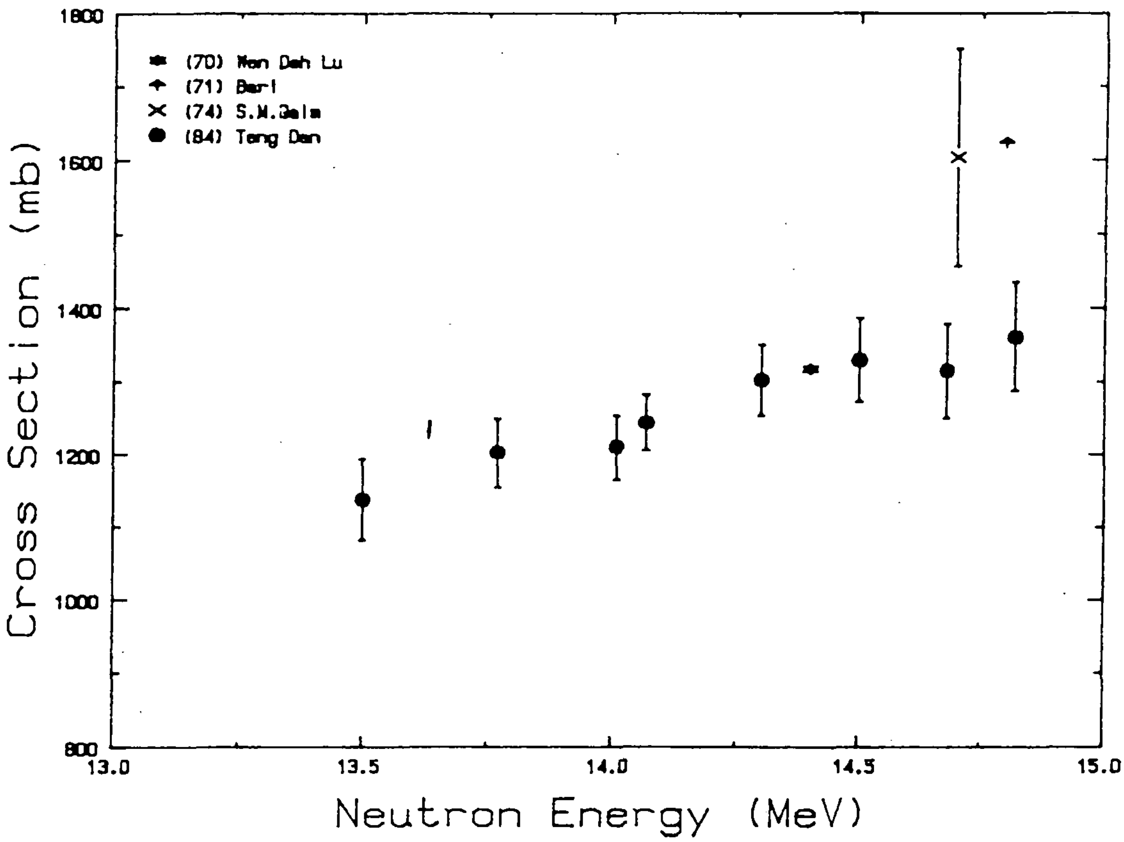

Fig.45 Ce-136(n,2n)Ce-135

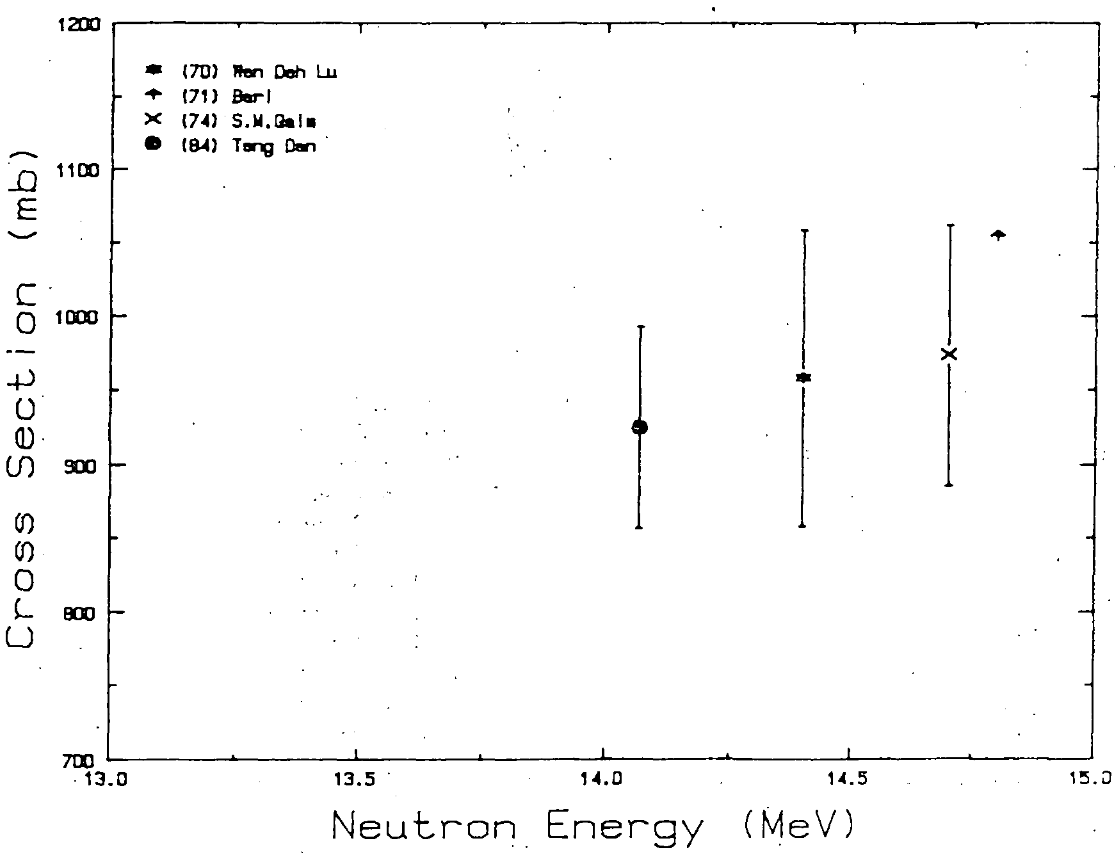

Fig.46 Ce-138(n,2n)Ce-137m

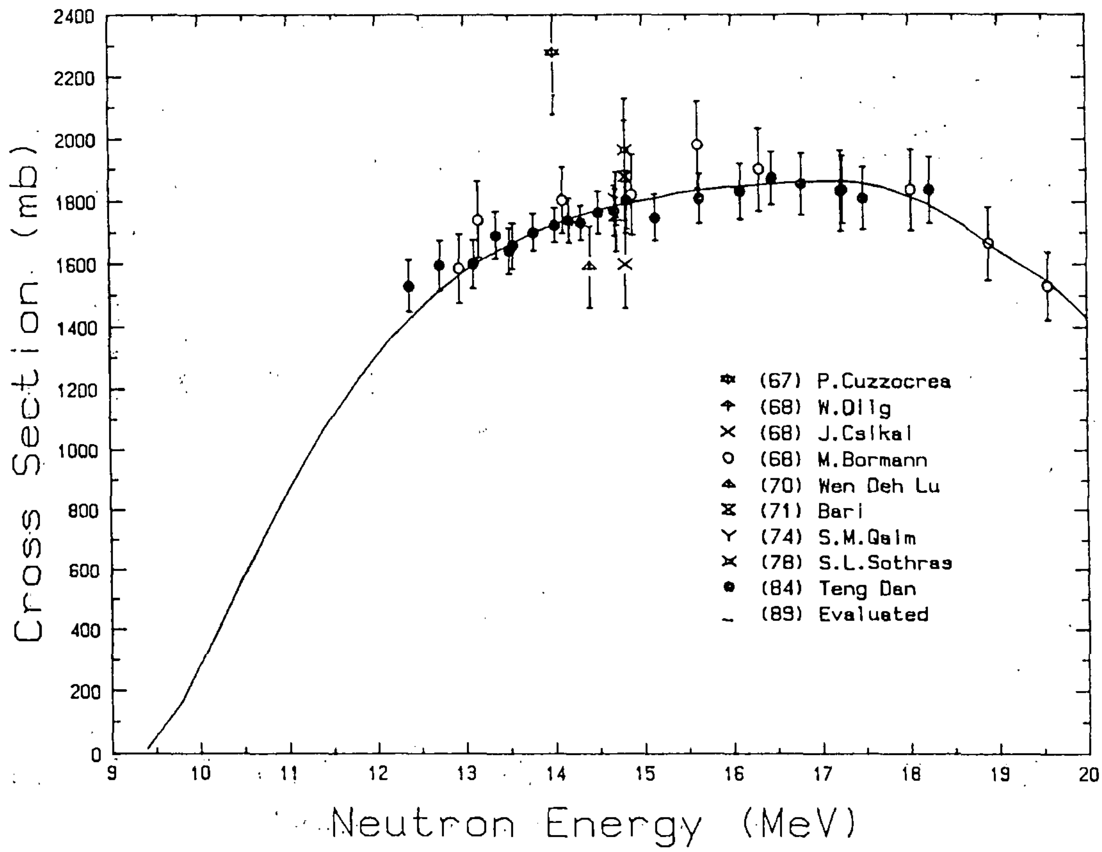

Fig. 47 Ce-140(n,2n)Ce-139

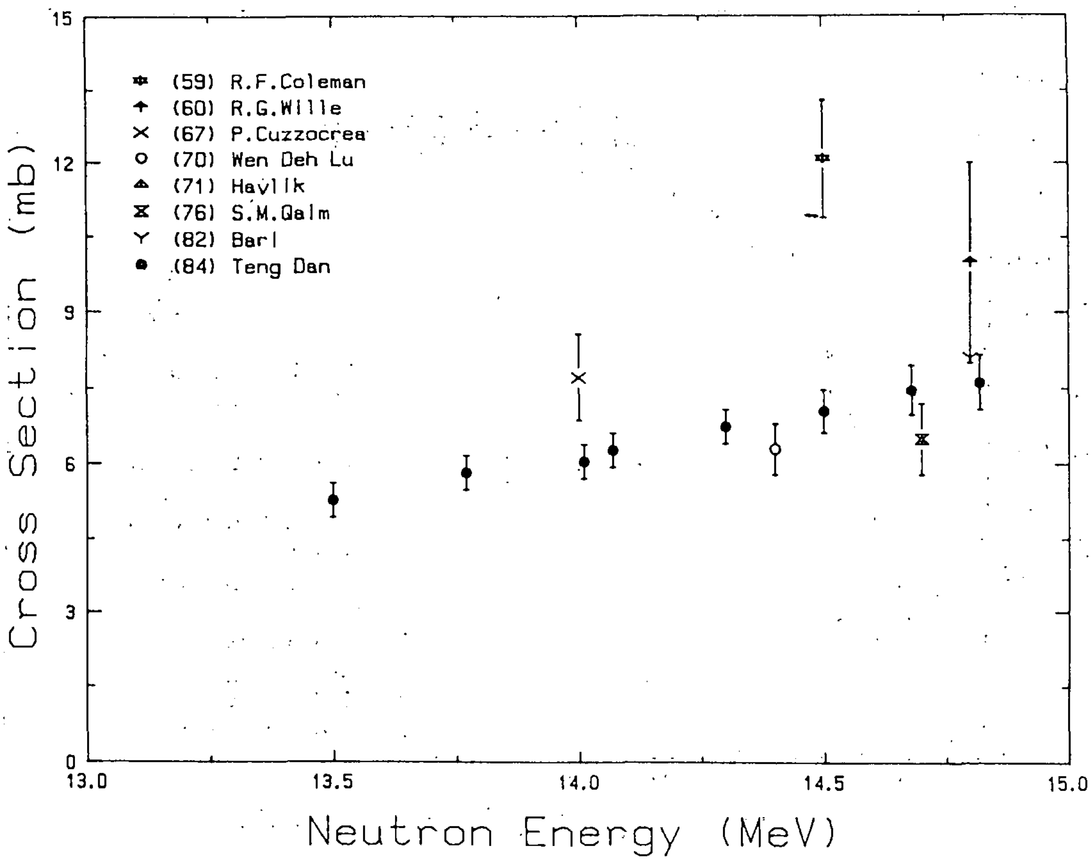

Fig. 48 Ce-140(n,p)La-140

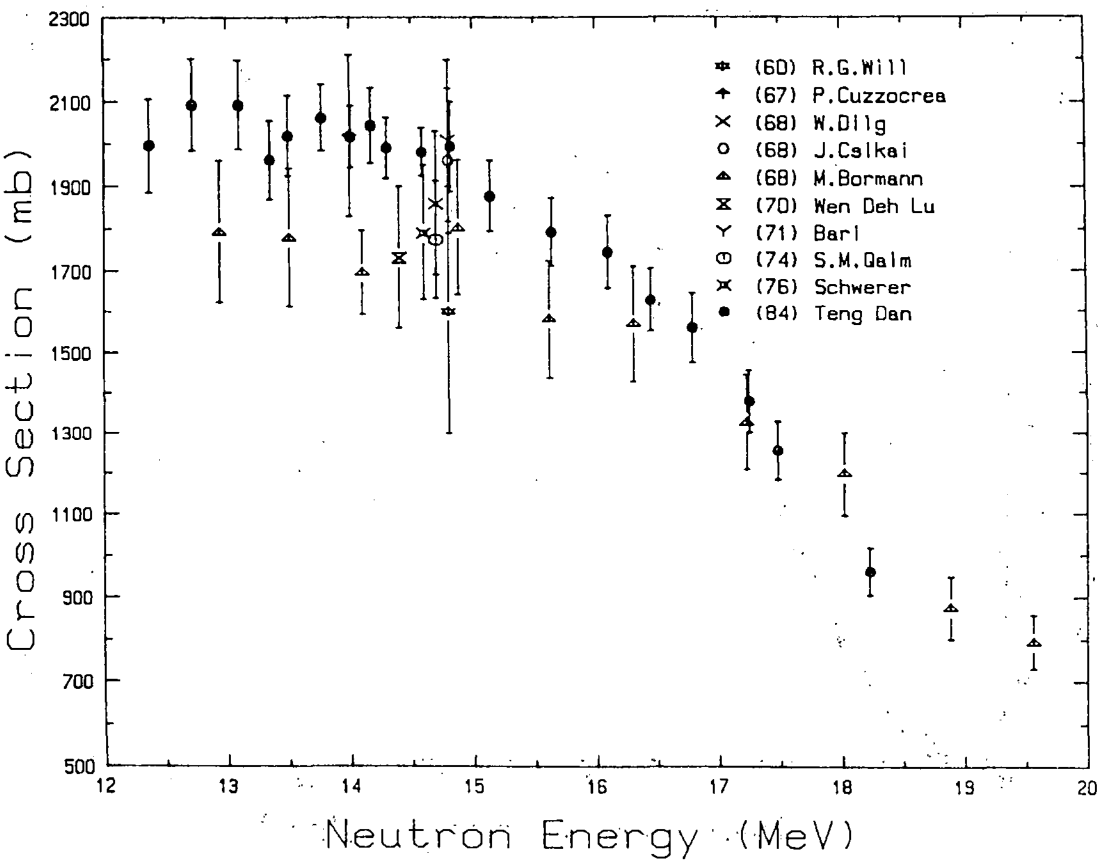

Fig. 49 Ce-142(n,2n)Ce-141

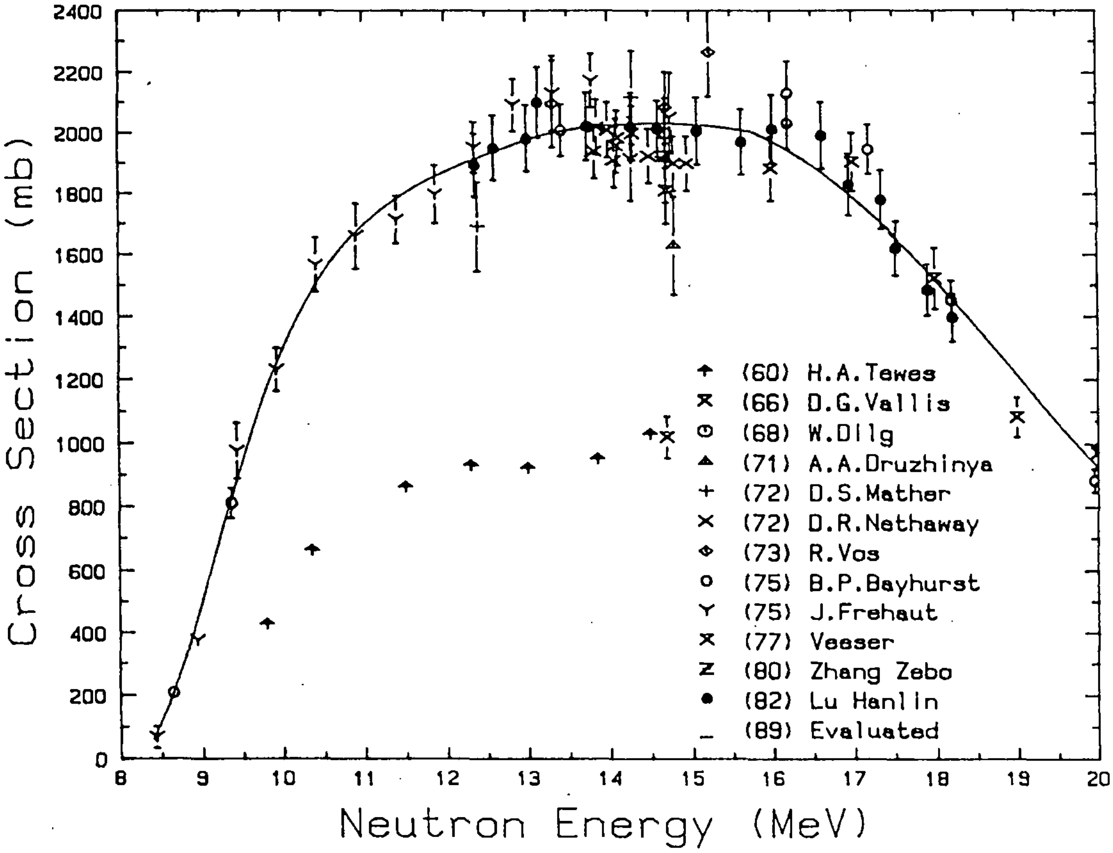

Fig.50 Tm-169(n,2n)Tm-168m

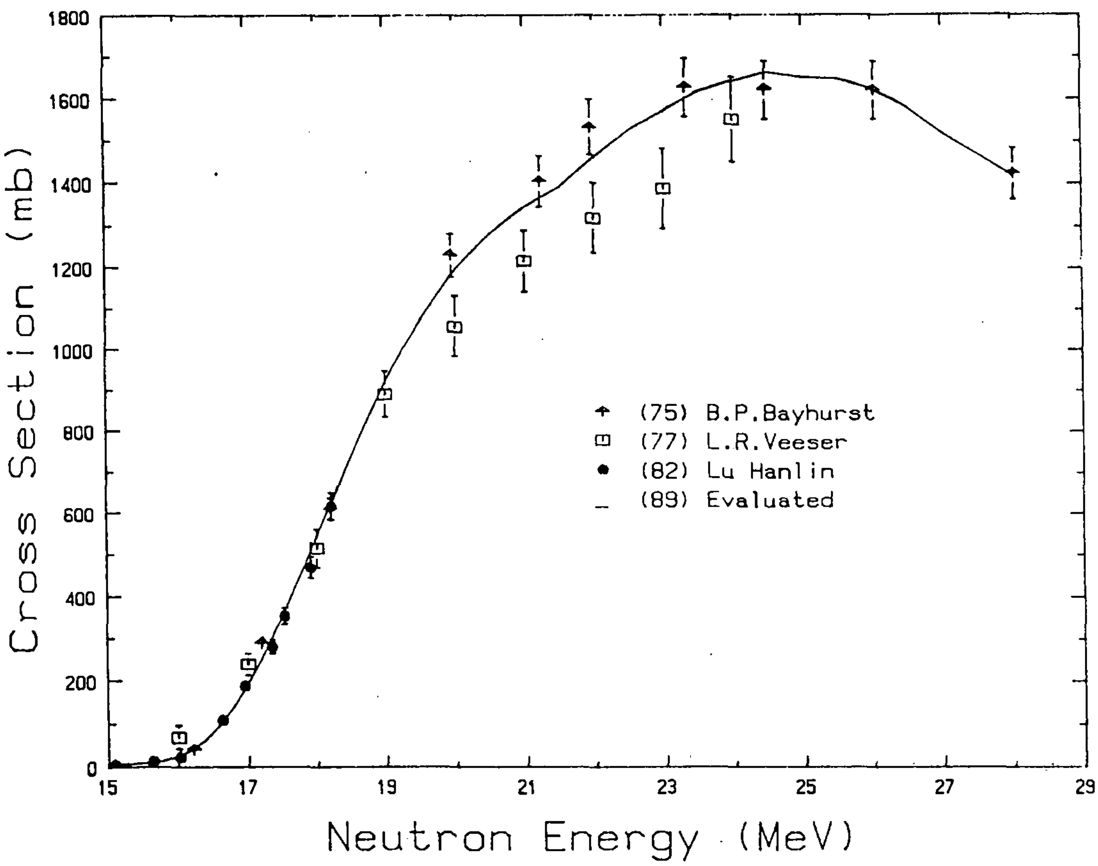

Fig.51 Tm-169(n,3n)Tm-167m

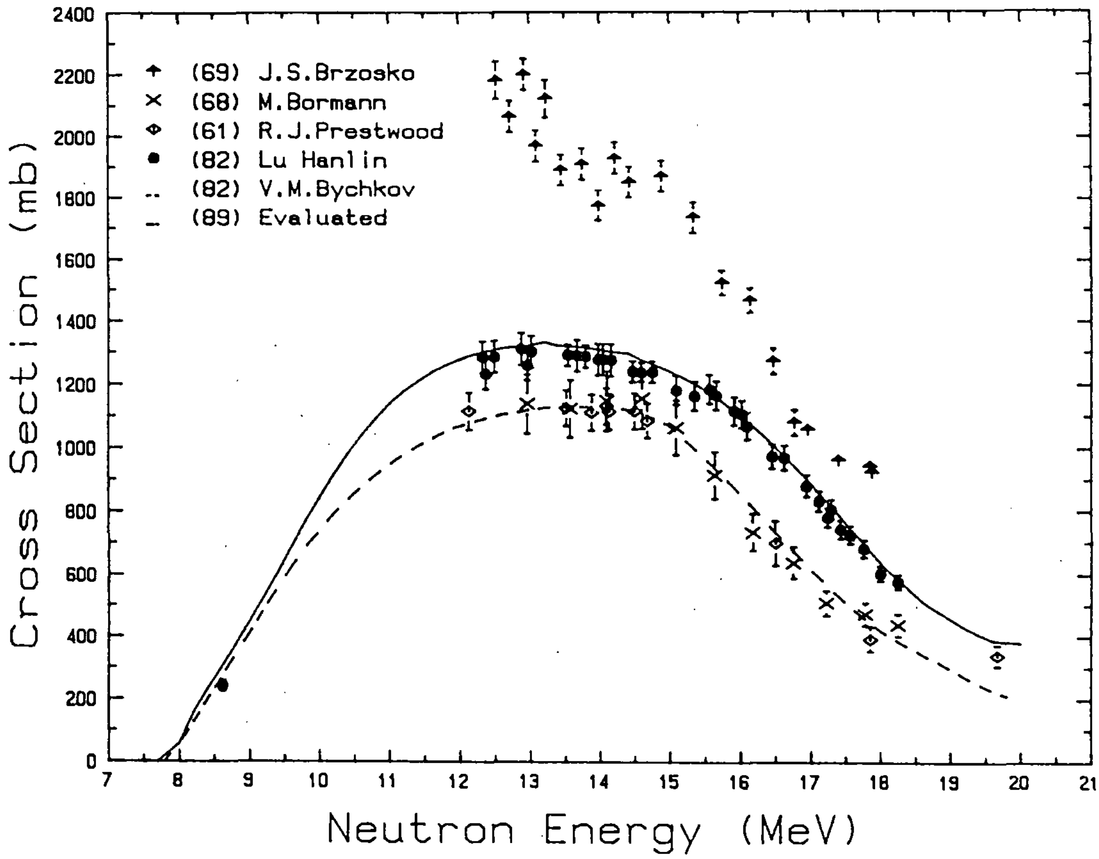

Fig. 52 (a) Ta-181 (n, 2n) Ta-180m

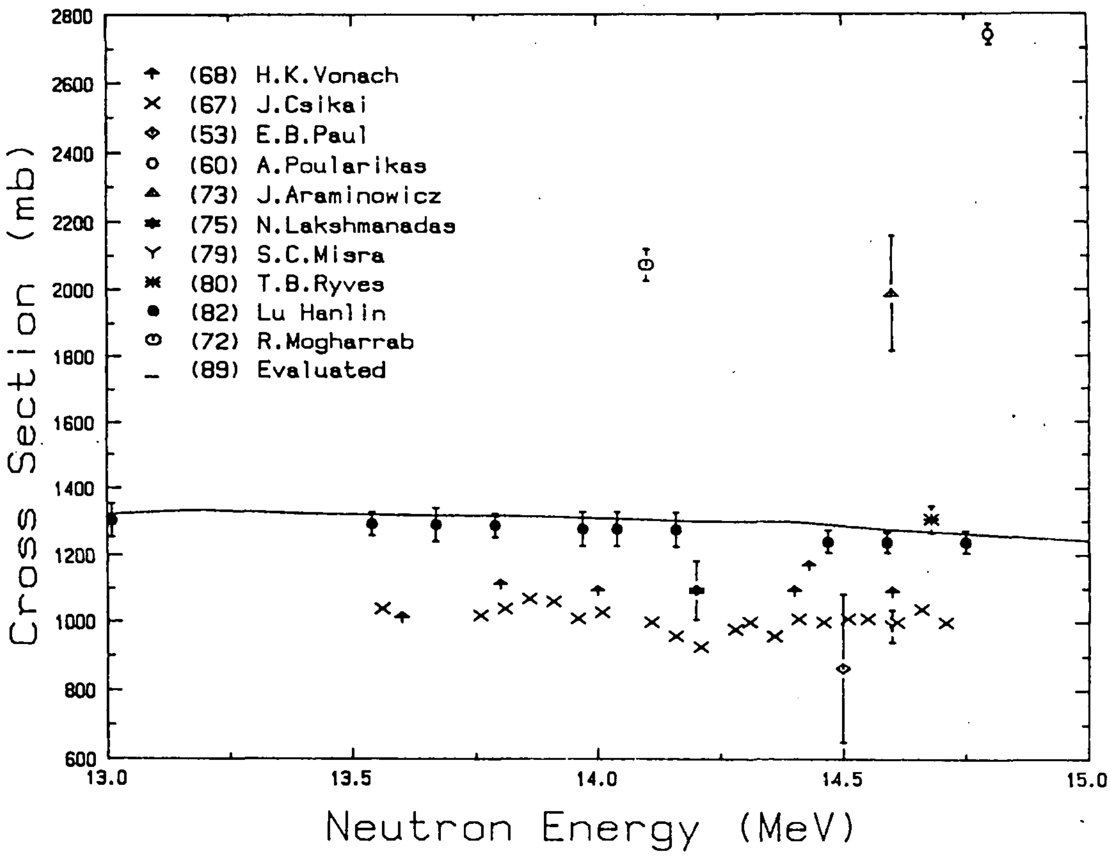

Fig. 52 (b) Ta-181 (n, 2n) Ta-180m

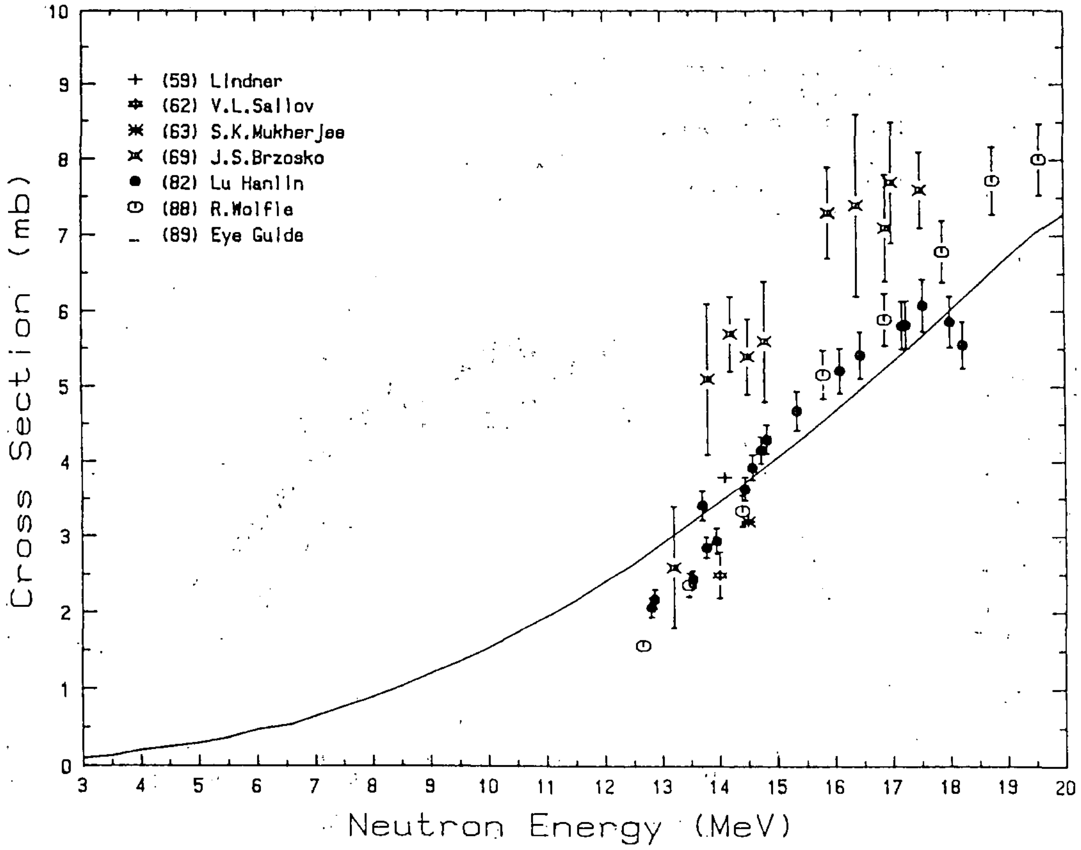

Fig.53 Ta-181(n,p)Hf-181

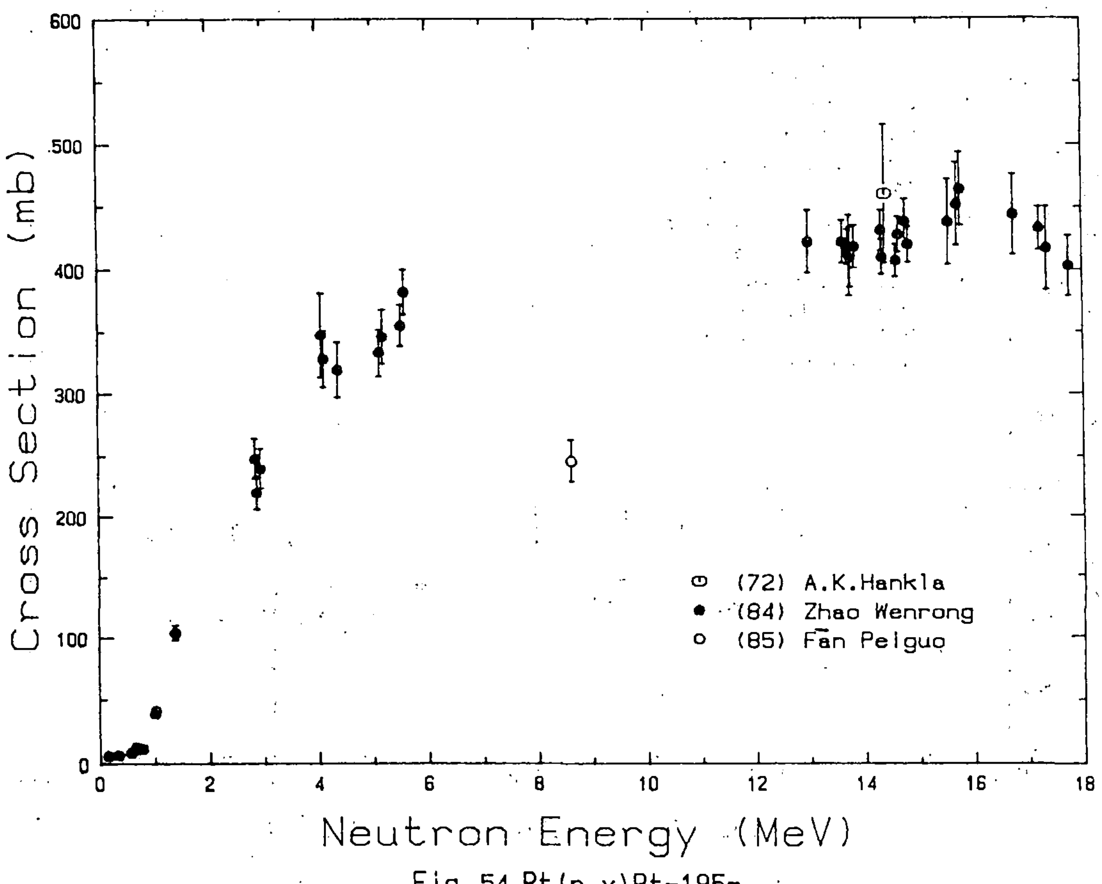

Fig.54 Pt(n,x)Pt-195m

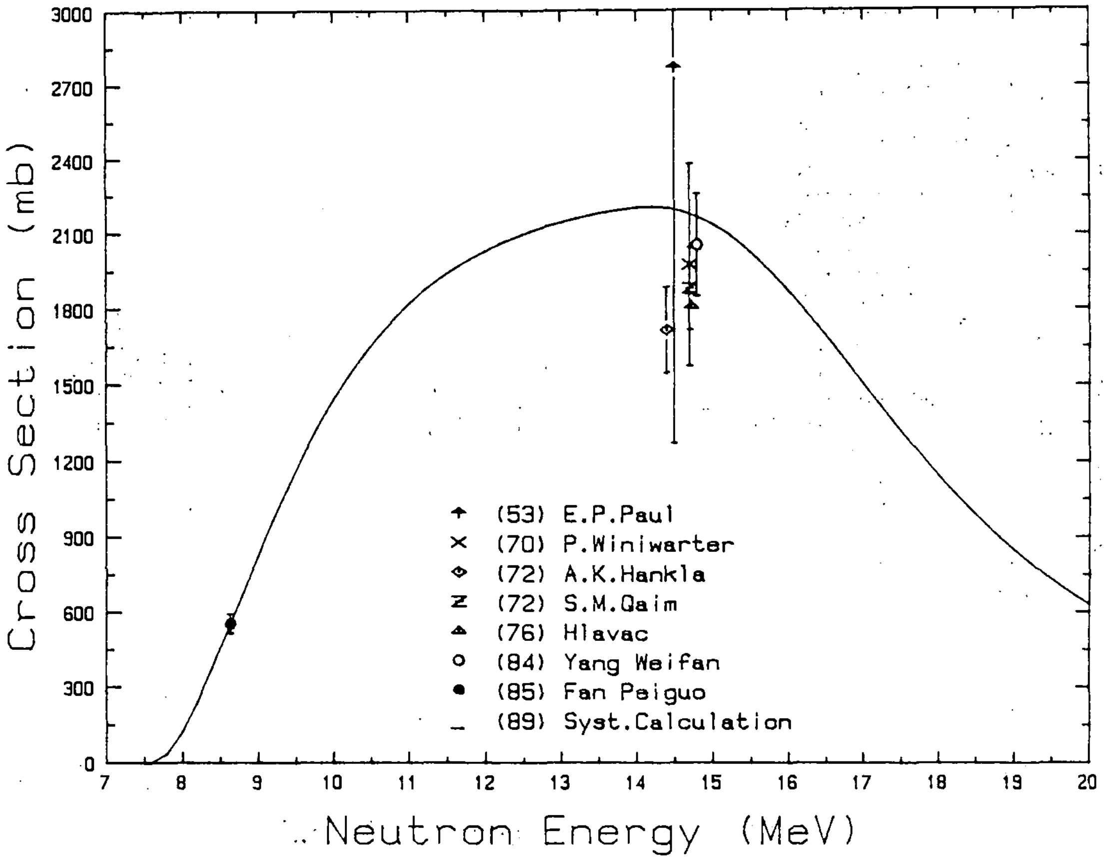

Fig. 55 Pt-198(n,2n)Pt-197

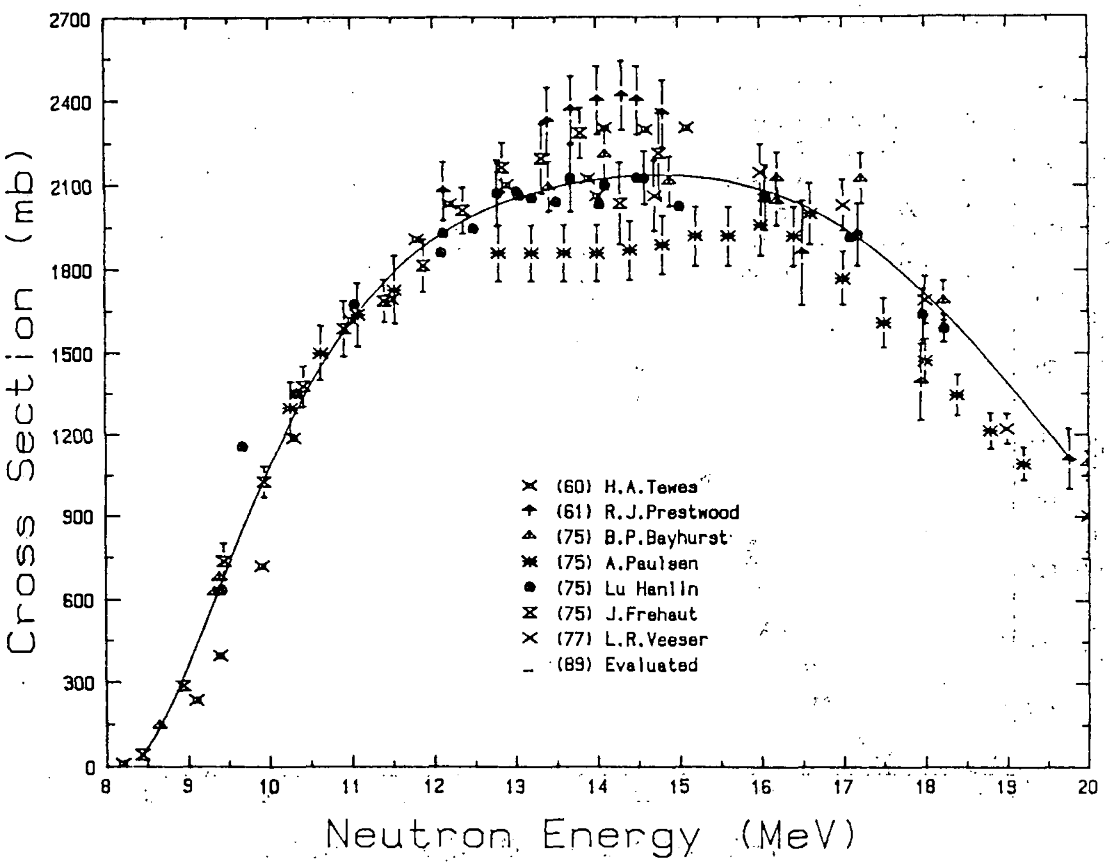

Fig. 56(a) Au-197(n,2n)Au-196

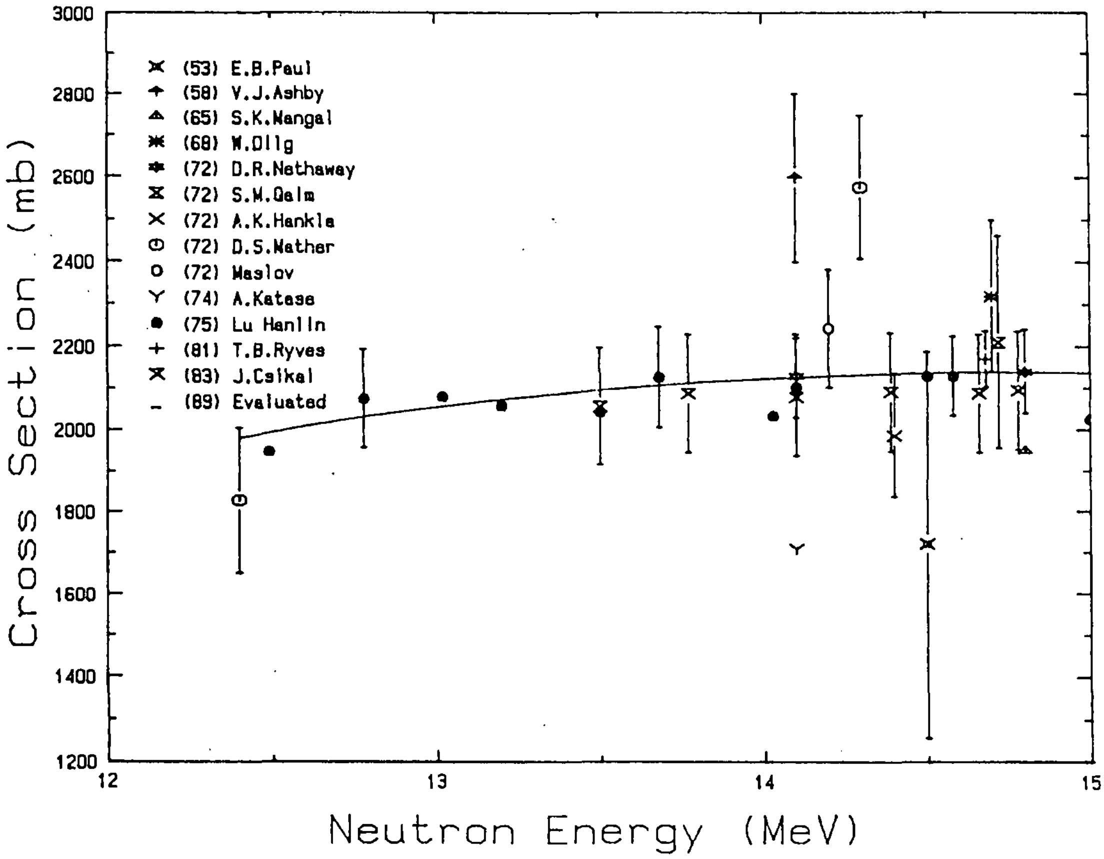

Fig. 56 (b) Au-197(n,2n)Au-196

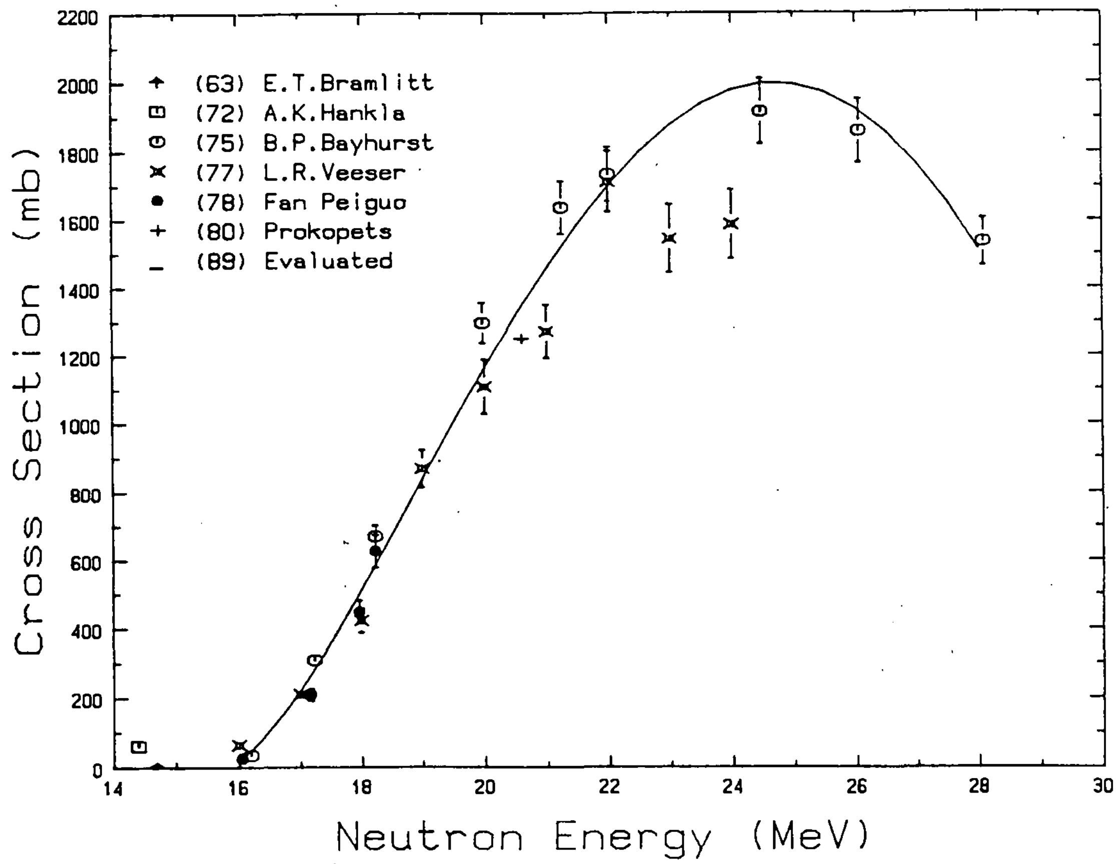

Fig. 57 Au-197(n,3n)Au-195

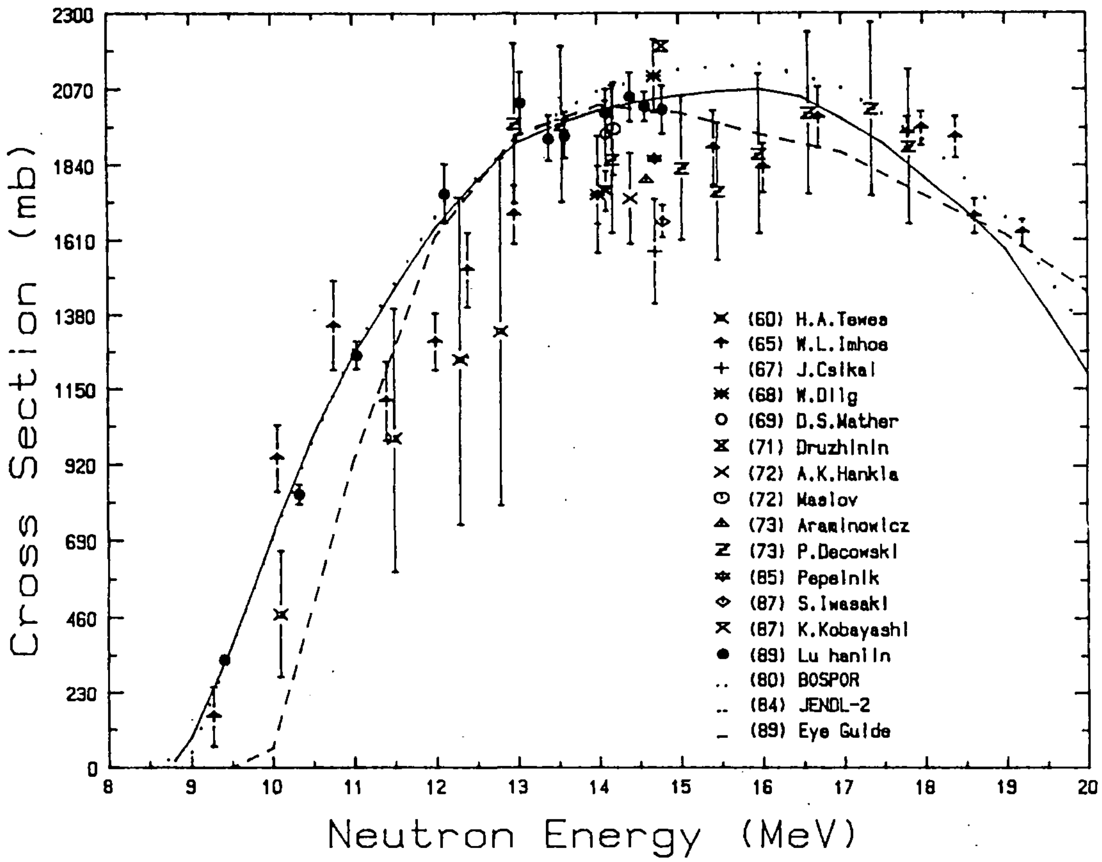

Fig.58 Pb-204(n,2n)Pb-203