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NEANDC(J)-67/U

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PROGRESS REPORT

(July 1979 to June 1980 inclusive)

September 1980

Editor

S. Kikuchi

Japanese Nuclear Data Committee

Japan Atomic Energy Research Institute

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Tokai-mura, Ibaraki-ken, Japan

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Editor's Note

This is a collection of reports which have been submitted to the Japanese Nuclear Data Committee at the Committee's request. The request was addressed to the individuals who might represent or be in touch with groups doing researches related to the nuclear data of interest to the development of the nuclear energy program.

Although the editor tried not to miss any appropriate addressees, there may have been some oversight. Meanwhile, contribution of a report rested with discretion of its author. The coverage of this document, therefore, may not be uniform over the related field of research.

In this progress report, each individual report is generally reproduced as it was received by the JNDC Secretariat, and editor also let pass some simple obvious errors in the manuscripts if any.

This edition covers a period of July 1, 1979 to June 30, 1980. The information herein contained is of a nature of "Private Communication". Data contained in this report should not be quoted without the author's permission.

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ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF	VOL	PAGE	DATE	COMMENTS
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BR	081	N, GAMMA		15+4	JAE	EXPT-PROG	NEANDC-J67U	1		SEP 80	OHKUBO+.CONTRIBUTED TO 79KNOXVILLE
BR	081	RESON PARAMS		15+4	JAE	EXPT-PROG	NEANDC-J67U	1		SEP 80	OHKUBO+.CONTRIBUTED TO 79KNOXVILLE
BR	081	STRNTH FNCTN		15+4	JAE	EXPT-PROG	NEANDC-J67U	1		SEP 80	OHKUBO+.CONTRIBUTED TO 79KNOXVILLE
RB		TOTAL	50+0	15+4	JAE	EXPT-PROG	NEANDC-J67U	2		SEP 80	OHKUBO+.LINAC,TOF.NDG
RB		RESON PARAMS	50+0	15+4	JAE	EXPT-PROG	NEANDC-J67U	2		SEP 80	OHKUBO+.LINAC,TOF.100 RES.NDG
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BA		NONELA GAMMA	48+6	64+6	TOH	EXPT-PROG	NEANDC-J67U	67		SEP 80	HINO+.DYNAMITRON,GE(LI).SIG IN FIG
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SM	147	N, GAMMA	33+3	30+5	JAE	EXPT-PROG	NEANDC-J67U	5		SEP 80	MIZUMOTO+.CONTRIBUTED TO 79KNOXVILLE
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ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF	VOL	PAGE	DATE	COMMENTS
SM	147	STRNTH FNCTN		20+3	JAE	EXPT-PROG	NEANDC-J670		5	SEP 80	MIZUMOTO+.CONTRIBUTED TO 79KNOXVILLE
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TH	232	FISSION	FISS		KTO	THEO-PROG	NEANDC-J670		46	SEP 80	KIMURA+.COMPARISON OF AV-SIG IN TBL
TH	232	SPECT FISS N	15+6		TOH	EXPT-PROG	NEANDC-J670		69	SEP 80	IWASAKI+.DYNAMITRON,LIQ SCIN.
U	233	EVALUATION	10+2	20+7	SAE	EVAL-PROG	NEANDC-J670		10	SEP 80	ASANO+.WORK AFTER NEANDC(J)610,47
U	233	FISS YIELD	PILE		KTO	EXPT-PROG	NEANDC-J670		36	SEP 80	NISHI+.ISOMER YIELDS OF I,XE,CS.TBL
U	235	FISS PROD GS	NDG		NAG	EXPT-PROG	NEANDC-J670		55	SEP 80	YAMAMOTO+.SUBMITTED TO JIN
U	235	FISS PROD GS	NDG		NAG	EXPT-PROG	NEANDC-J670		56	SEP 80	IKEDA+.PUBLISHED IN JPJ 47,1389
U	235	FISS PROD GS	NDG		NAG	EXPT-PROG	NEANDC-J670		57	SEP 80	IKEDA+.PUBLISHED IN JPJ 47,1039
U	235	FISS YIELD	PILE		KTO	EXPT-PROG	NEANDC-J670		36	SEP 80	NISHI+.ISOMER YIELDS OF I,XE,CS.TBL

ELEMENT S A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF	VOL	PAGE	DATE	COMMENTS
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PU 239	FISS YIELD	PILE		KTU	EXPT-PROG	NEANDC-J670	36		SEP 80	NISHI+.ISOMER YIELDS OF I,XE,CS.TBL
AM 242	EVALUATION	10-5	20+7	JAE	EVAL-PROG	NEANDC-J670	12		SEP 80	NAKAGAWA+.PUBLISHED IN JAERI-M 8903
MANY	DIFF INELAST	14+7		KYU	THEO-PROG	NEANDC-J670	53		SEP 80	KUMABE+.BY MULTISTEP DIRECT TH.NDG
MANY	DIFF INELAST	14+7		KYU	THEO-PROG	NEANDC-J670	54		SEP 80	KUMABE+.PUBLISHED IN PHYS LET 92B 15
MANY	N, 2N	FISS		KTU	THEO-PROG	NEANDC-J670	44		SEP 80	KOBAYASHI+.SYSTEMATICS OF SIG.
MANY	N, PROTON	14+7		KYU	THEO-PROG	NEANDC-J670	53		SEP 80	KUMABE+.BY MULTISTEP DIRECT TH.NDG
MANY	N, ALPHA	14+7		KYU	THEO-PROG	NEANDC-J670	54		SEP 80	KUMABE+.BY MULTISTEP DIRECT TH.NDG
MANY	FRAG NEUTS	NDG		KYU	THEO-PROG	NEANDC-J670	51		SEP 80	YAMAMOTO+.PUBLISHED IN NST 16,466
MANY	FRAG NEUTS	15+7		KYU	EXPT-PROG	NEANDC-J670	52		SEP 80	YAMAMOTO+.PUBLISHED IN NST 16,779
MANY	FISS YIELD	15+7		KYU	EXPT-PROG	NEANDC-J670	52		SEP 80	YAMAMOTO+.PUBLISHED IN NST 16,779

The content table in the CINDA format was compiled by the JNDC CINDA group;

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I. JAPAN ATOMIC ENERGY RESEARCH INSTITUTE

A. Linac Laboratory, Division of Physics

I-A-1 Resonance Parameters of ^{79,81}Br up to 15 keV

M. Ohkubo, Y. Kawarasaki and M. Mizumoto

An article titled above was reported in the Int. Conf. " Nuclear Cross Sections for Technology ", held at Knoxville in Oct. 1979, with the following abstract.

Resonance parameters of separated isotopes of bromine were measured using TOF spectrometer of Japan Atomic Energy Research Institute linear accelerator. Transmission and capture measurements were made with ^{6}Li-glass and Moxon-Rae detectors, on separated isotopes (~98 %) of ^{79}Br and ^{81}Br. Resonance analyses were made on transmission data with an area analysis code, and on capture data with a Monte-Carlo program CAFIT. For ^{79}Br $g\Gamma_n^0$ values for 156 levels below 10 keV are obtained, and for ^{81}Br 100 levels below 15 keV. Strength functions are obtained; for ^{79}Br $S_0 = (1.27 \pm 0.14)10^{-4}$ below 10 keV, and for ^{81}Br $S_0 = (0.86 \pm 0.14)10^{-4}$ below 15 keV. Intermediate structures are observed in the resonances of ^{81}Br showing clusters of levels at 1.2, (4), 10, 11.5 and 14 keV, where the sum of $g\Gamma_n^0$ vs. neutron energy shows steep rises.

I-A-2 Resonance Parameters of Rubidium up to 15 keV

M..Ohkubo and Y. Kawarasaki

Neutron transmission measurements on natural rubidium were carried out with 47-m station of the JAERI linac TOF spectrometer, to investigate resonance structures of near magic-N nuclei. About 100 resonances in the energy region from 5 to 15000 eV were observed, and their resonance parameters were analyzed. Strength function for ^{85}Rb are obtained to be $S_0 = (0.93 \pm 0.15)10^{-4}$ below 15 keV, using isotopic indentification of levels by Grebenyuk et al.[1)]

References:

1) Grebenyuk et al. JINR-p3-4357 (1969)

I-A-3 An effect of the 56 keV resonance of ^{28}Si on the detection efficiency of a ^{6}Li-glass detector.

M. Sugimoto*, M. Mizumoto and A. Asami

The efficiency of a 0.64 cm thick ^{6}Li-glass scintillation detector was calculated by a Monte Carlo method. The neutron multiple-scattering correction to the efficiency was made using evaluated cross sections and resonance parameters of the constituents of the detector. The effect of the neutrons scattered back form the photo-multiplier window was also taken into account. The measured neutron flux was derived using the calculated efficiency and compared with the assumed smooth flux shape ($\sim E_n^{const.}$) from a neutron target. The observed peak at 56 keV is attributed to the enhancement of the efficiency due to the sharp s-wave resonance of ^{28}Si contained both in the scintillator (25 % enhancement) and the photo-multiplier window (15 % enhancement).

* Department of Nuclear Engineering, Tohoku University.

I-A-4 Average Neutron Capture Cross Sections of Silver Isotopes in the keV region.

M. Sugimoto*, M. Mizumoto, Y. Nakajima, Y. Kawarasaki, Y. Furuta and A. Asami

The neutron capture cross sections of silver isotopes have been measured with the JAERI electron linac time-of-flight facility, using a 3500 l liquid scintillator tank at a 55 m station. Average cross sections were deduced from 3 to 700 keV with an accuracy of 5 to 15 %. An absolute normalization was made at a few saturated resonances in the eV region. The incident neutron flux was measured by a ^{6}Li-glass scintillator and a ^{10}B-NaI (Tl) detector.

The results for natural sample are in good agreement with the data of Kompe,[1] but lower than those of Diven et al.[2] above 200 keV energy range. Measurements for the separated isotopes of silver are in progress.

References

1) D. Kompe, Nucl. Phys. A133 (1969) 513.

2) B.C. Diven, J. Terrell and A. Hemmendinger, Phys. Rev. 120 (1960) 556.

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* Department of Nuclear Engineering, Tohoku University.

I-A-5 Neutron Radiative Capture and Transmission Measurements of ^{147}Sm and ^{149}Sm.

M. Mizumoto, M. Sugimoto*, Y. Nakajima, Y. Kawarasaki, Y. Furuta and A. Asami

A paper on this subject was presented at the International Conference on Nuclear Cross Sections for Technology, October 22-26, 1979, Knoxville with an abstract as follows:

The neutron capture and transmission of ^{147}Sm and ^{149}Sm were measured at the 55 m time-of-flight station of the Japan Atomic Energy Research Institute Electron Linear Accelerator. Measurements were carried out with a large liquid scintillation detector, a ^{6}Li-glass detector and ^{10}B-NaI detector using enriched samples of ^{147}Sm (98.34 %) and ^{149}Sm (97.72 %). The average capture cross sections were deduced from 3.3 to 300 keV with an estimated accuracy of 5 to 15 %. The transmission data were analyzed with a multi-level breit Wigner formula to obtain neutron widths of resonances up to 2 keV for ^{147}Sm (212 resonances) and 520 eV for ^{149}Sm (157 resonances). The s-wave strength functions and average level spacings were found to be $10^4 \cdot S_0 = 4.8 \pm 0.5$, $\bar{D} = 5.7 \pm 0.5$ eV for ^{147}Sm and $10^4 \cdot S_0 = 4.6 \pm 0.6$, $\bar{D} = 2.2 \pm 0.2$ eV for ^{149}Sm.

* Department of Nuclear Engineering, Tohoku University.

B. Nuclear Chemistry Laboratory

Division of Chemistry

I-B-1 Half-life of ^{242}Cm

S. Usuda and H. Umezawa

Pure ^{242}Cm was prepared by means of decay-product milking of 152-y ^{242m}Am which was extracted from an irradiated plutonium bearing fuel specimen and purified for curium and other actinides, after allowing it to stand for a several-month period to get the growth of ^{242}Cm. Five samples of ^{242}Cm were prepared for measurements which were carried out with two independent sets of proportional counters of window-less type. Alpha activity of each sample was 1.56×10^4 cpm at first, so that correction for counter dead-time was negligible. Those were measured every week in general over a period of 16 months. Stability of the counters used was checked by using a reference sample of ^{238}Pu, and the deviation of counting efficiency was corrected, though it was less than the order of 1%. Alpha activity due to ^{241}Am contamination was determined to be 0.01% at first stage of the measurements by gamma-ray spectrometry with a Ge(Li) detector(LEPS) and subtracted from the counting data. Contamination of the other americium isotopes did not affect the measurement results. Finally correction was made for the growth of the long-lived alpha-active daughter, ^{238}Pu.

Our results are compared with other data reported so far in Table 1. Our value is significantly short than the others. Taking threefold value of the statistical external error given, our best value of the half-life of ^{242}Cm is (161.2 ± 0.3) d.

Table 1. Measurements of the half-life of ^{242}Cm.

Reference	Half-life* (d)	Number of samples	Period of decay followed (d)	Number of measurement	Method
[1]	162.76 ± 0.04	5	262	3	Alpha counting
[2]	162.46 ± 0.14	?	210	14	Alpha counting
[3]	163.2 ± 0.3	2	287	34-35	Calorimetry
[4]	163.0 ± 1.8	1	365	?	Calorimetry
[5]	163.1# ± 0.4	?	1187	?	Alpha counting
[6]	162.5 ± 2	3	130-365	2-4	Alpha counting
This work	161.18 ± 0.10	5	540	61-190	Alpha counting

*: Errors were reduced to one standard deviation as taken in Ref. [1].

?: Not described.

#: Originally reported to be 164.4 d and recalculated by Diamond et al. in Ref.[1].

References: [1] H. Diamond et al., Phys. Rev. C, 15 (1977) 1034. [2] K. M. Glover et al., Nature, 173 (1954) 1238. [3] W. J. Kerrigan et al., J. Inorg. Nucl. Chem., 37 (1975) 641. [4] W. P. Hutchinson et al., Nature, 173 (1954) 1238. [5] K. F. Flynn et al., Nucl. Sci. Eng., 22 (1965) 416. [6] G. C. Hanna et al., Phys. Rev., 78 (1950) 617.

C. Nuclear Data Center, Division of Physics and Working Groups of Japanese Nuclear Data Committee

I-C-1 Evaluation of Neutron Cross Sections for Lead

T. Asami

Data evaluation was performed for the neutron cross sections of natural Pb and the Pb isotopes (^{204}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb) in the neutron energy range of 10^{-5} eV to 20 MeV.

In thermal and resonance regions, the neutron cross sections were generated with a multi-level Breit-Wigner formula by using the resonance parameters evaluated in this work. The upper limits of the resonance region were defined in examining level missing for observed resonances as follows; 50 keV for ^{204}Pb, 200 keV for ^{206}Pb, 400 keV for ^{207}Pb and 500 keV for ^{208}Pb. The resonance parameters were taken mainly from the recent high-resolution measurements at ORELA[1) - 6)], and for unknown radiative widths the averaged values were given for each isotope. The total cross section of natural Pb generated from the evaluated resonance parameters were compared with the experimental data to examine the evaluated parameters.

Fast neutron cross sections (total, capture, elastic and inelastic scattering) above the resonance region were derived from the optical- and statistical-model calculations[7)], in consideration of the threshold reaction cross sections as competing processes. Only the total cross section of natural Pb were estimated from the experimental data of Schwartz et al.[8)] by an eye-guide fitting using NDES(neutron data evaluation system)[9)]. The cross sections for threshold reactions ((n,2n), (n,3n), (n,p), (n,α), etc.) were calculated with the multi-step evaporation model code[10)]. A set of the optical-model parameters used in these calculations were determined to reproduce well the experimental total cross section of natural Pb in 0.5 to

20 MeV. The level density parameters for the back-shifted Fermi gas model were obtained from experimental resonance spacings and level scheme data, and from systematic survey.

These data are to be compiled in JENDL-2.

References:

1) B. J. Allen et al., Phys. Rev. C, 8 (1973) 1504

2) M. Mizumoto et al., Phys. Rev. C, 19 (1979) 335

3) D. J. Horen et al., Phys. Rev. C, 20 (1979) 478

4) S. Raman et al., Phys. Rev. Lett., 39 (1979) 598

5) D. J. Horen et al., Phys. Rev. C, 18 (1978) 722

6) R. L. Macklin et al., Astrophys. J., 217 (1977) 222

7) S. Igarasi, J. Nucl. Sci. Tech., 12 (1975) 67

8) R. B. Schwartz et al., NBS-MONO-138 (1974)

9) T. Nakagawa, to be published.

10) J. Gilat, BNL-50246 (1970)

I-C-2 Evaluation of the Neutron Nuclear Data for ^{233}U

N. Asano* and H. Matsunobu*

The study has recently been completed in the energy range of 100 eV to 20 MeV. The preliminary results which were published on the last progress report were somewhat modified as follows.

The total cross section in the energy range below 15 MeV was evaluated on the basis of adopted experimental data while the previous evaluation was based on the spherical optical model calculation. This is due to the fact that the calculation does not satisfactorily reproduce the energy dependence of experimental data although the discrepancy between them is small. However, the evaluation above 15 MeV relied on the calculation because the measurements have not been made yet. The normalization was made to the data of Foster and Glasgow[1].

In the fission cross section, the evaluation curve was appreciably modified because the fission cross section of ^{235}U used as a standard was partially revised taking account of the results of integral tests with the international benchmark cores for fast reactor.

The (n,2n) and (n,3n) reaction cross sections which were calculated by means of Pearlstein's method[2] were newly normalized

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* Sumitomo Atomic Energy Industries, Ltd.

to the fission-spectrum-averaged value by Kobayashi[3].

In keeping with the above modifications, the capture and inelastic scattering cross sections were also revised since the fission, (n,2n) and (n,3n) reactions were taken into consideration as competing processes in the optical and statistical model calculation. Therefore, the elastic scattering cross section was given as the difference between the total and reaction cross sections.

In addition, the averaged prompt and delayed neutron numbers per fission were revised in consequence of reexamination of the experimental data. For the prompt neutron number per fission, the thermal value revised is 2.486 and for the delayed one is 0.0067 which is to be evaluated by Lemmel[4].

The final results of present evaluation will soon be submitted to Journal of Nuclear Science and Technology, including the evaluation at thermal and resonance regions by Y. Kikuchi.

References:

1) D. G. Foster and D. W. Glasgow: Phys. Rev. Part C, 3, 576 (1971)

2) S. Pearlstein: Nucl. Sci. Eng. 23, 238 (1965)

3) K. Kobayashi, T. Hashimoto and I. Kimura: Nucl. Sci. Tech. 10, 668 (1973)

4) H. D. Lemmel: "The Third IAEA Evaluation of the 2200m/s and 20•C Maxwellian Neutron Data for U-233, U-235, Pu-239 and Pu-241", 4th Conf. on Nuclear Cross-Sections and Technology, p.286, Washington D. C. (1975)

I-C-3 Evaluation of Neutron Nuclear Data for ^{242m}Am and ^{242g}Am

T. Nakagawa and S. Igarasi

Evaluation of neutron nuclear data for ^{242m}Am and ^{242g}Am was performed in the energy range of 10^{-5} eV to 20 MeV. Cross sections of ^{242m}Am below 3.5 eV were represented by means of resonance parameters measured by Bowman et al.[1] From 3.5 eV to 1.5 keV, the fission cross section was evaluated by using spline function fitting to the experimental data by Bowman et al. and Seeger et al.[2] The capture and elastic scattering cross sections were estimated by assuming that their structure was similar to that of the fission cross section. The fission cross section was calculated up to 20 MeV by the semi-empirical formula;

$$\sigma_f(E_n) = \sigma_c(E_n)\{\sum_\lambda \frac{C_\lambda}{(E_n-E_\lambda^R)^2 + R_\lambda} + \sum_k \frac{B_k}{1 + \exp[\alpha_k(E_k^B-E_n)]}\},$$

where σ_c is the compound nucleus formation cross section obtained with the optical model. The potential parameters used here are as follows;

$$V(E_n) = 42.0 - 0.107\ E_n$$

$$W_s(E_n) = 9.0 - 0.339\ E_n + 0.0531\ E_n^2$$

(derivative Woods-Saxon)

$$V_{so} = 7.0$$

$$r_0 = r_{so} = 1.282, \qquad r_s = 1.290$$

$$a = a_{so} = 0.6\ , \qquad b = 0.5$$

(in MeV and fm)

Parameters E_λ^R, C_λ, R_λ, E_k^B, B_k and α_k in the above equation were determined so that the equation might represent well the average tendency of the data measured by Seeger et al.[2], Bowman et al.[1] and Browne et al.[3] In this evaluation, terms were considered up to $\lambda = 4$ and $k = 1$. The (n,2n) and (n,3n) reaction cross sections were obtained with Pearlstein's method[4]. Other cross sections and angular distributions of elastically scattered neutrons were calculated with

the optical and statistical models by taking account of the fission, (n,2n) and (n,3n) reactions as competing process. The ^{242}Am level scheme recommended by Ellis and Haese[5] was adopted. Fig. 1 shows the present results.

Neutron nuclear data of ^{242g}Am were estimated from those of ^{242m}Am because the experimental data were available only for thermal fission[6,7] and capture[6] cross sections. Fig. 2 shows the present results for ^{242g}Am cross sections.

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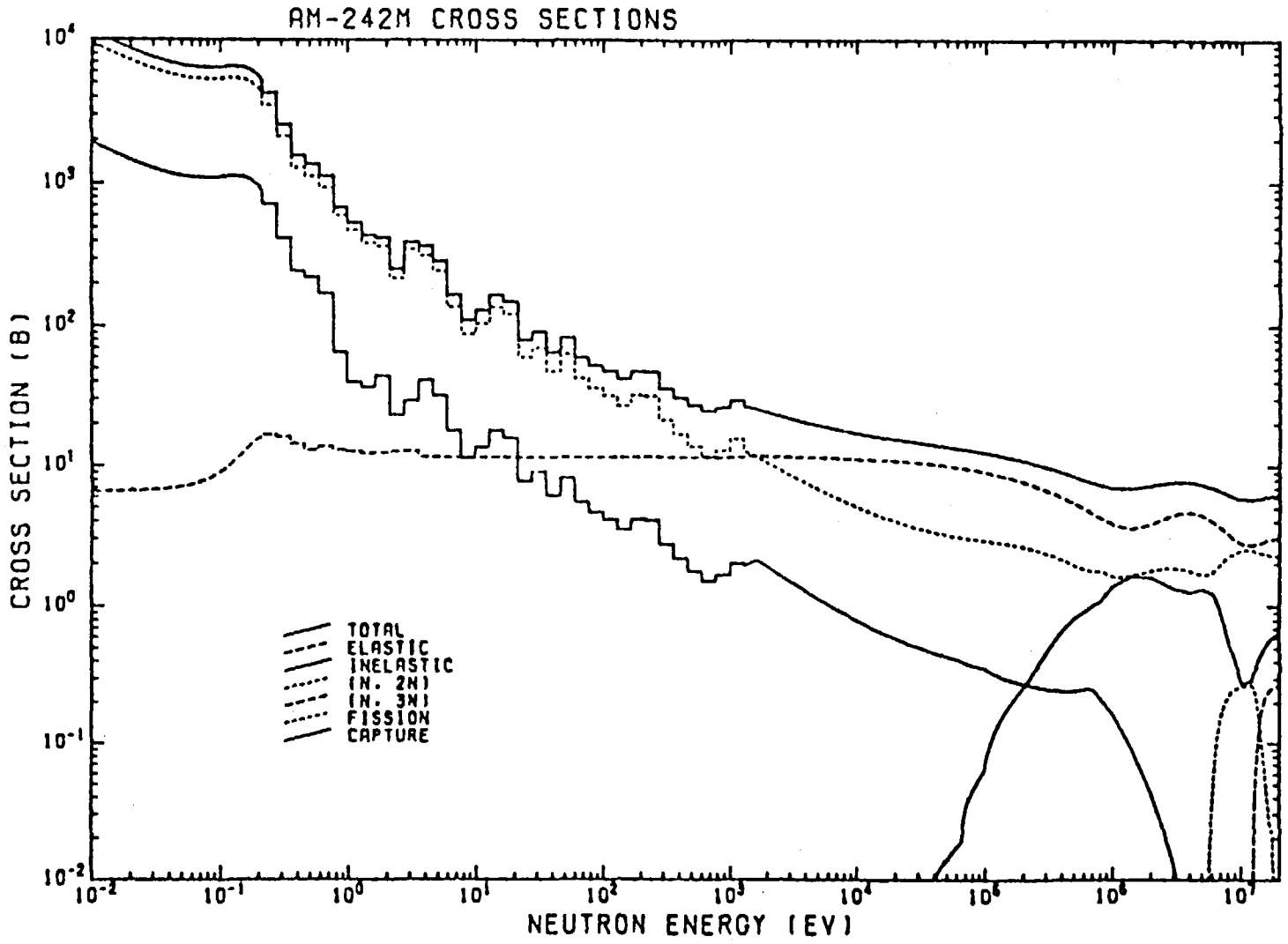

Fig. 1 ^{242m}Am cross sections.

All the cross sections evaluated in this work are shown from 0.01 eV to 20 MeV. In the energy range between 0.215 eV and 1.66 keV, shown are all the average cross sections in suitable energy intervals.

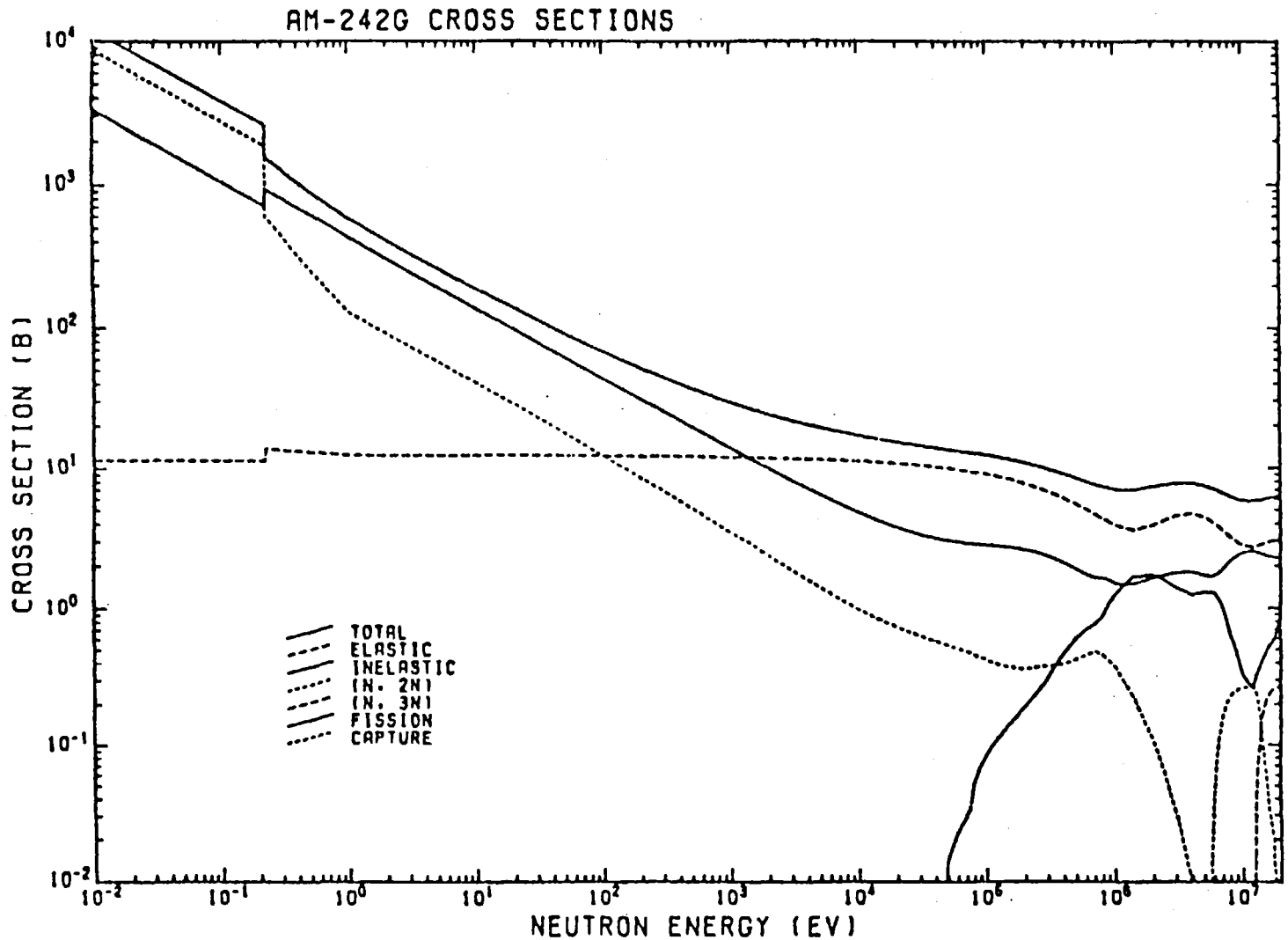

Fig. 2 ^{242g}Am cross sections.

All the cross sections evaluated in this work are shown from 0.01 eV to 20 MeV.

I-C-4 Preliminary Benchmark Tests on JENDL-2

Y. Kikuchi, H. Takano and T. Narita

Compilation of JENDL-2 is now under way. At its first step the highest priority was put to evaluation of most important nuclides for fast reactors: ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, Cr, Fe and Ni, responding to an urgent request to use JENDL-2 for analyses in the JUPITER project, joint USA-Japan mock-up experiments of large fast reactors in ZPPR facility. The evaluation of the 8 nuclides above mentioned was completed in November 1979. The benchmark tests were made on these evaluated data. The data of JENDL-1 were used for other nuclides. This combined library of JENDL-2 for the 8 nuclides and JENDL-1 for the others is called JENDL-2B library.

The benchmark problems are the same as those used in the benchmark tests of JENDL-1[1)], and are based on one dimensional diffusion and first order perturbation approximations. The calculated results are given in the form of C/E values, and are compared with those of JENDL-1[1)], JAERI-Fast-II[2)] and ENDF/B-IV[3)]. They are arranged statistically in the form of average and standard deviation. More detailed results are given in Ref. (4).

Effective Multiplication Factors : Table 1

JENDL-2B gives $\bar{k}_{eff}$ = 0.998 with standard deviation of 0.65 %. The discrepancy between the Pu cores and the U cores is 0.2 % and smaller than those with JENDL-1 and ENDF/B-IV.

Central Reaction Rate Ratios : Table 2

The ratio of ^{238}U fission to ^{235}U fission is overestimated by 6 % on an average. It should be noted however, that the C/E values of some

assemblies much deviate from unity with any library set. The ratio of ^{239}Pu fission to ^{235}U fission is underestimated by 1.2 % but is 1.5 % higher than JENDL-1. The C/E values are satisfactory for both the ratios of ^{238}U capture to ^{235}U fission and of ^{238}U capture to ^{239}Pu fission.

Central Reactivity Worths : Table 3

In order to avoid the scaling problem, both calculated and measured reactivity worths were normalized to those of ^{239}Pu, respectively. The C/E values of the normalized worth were compared in Table 3. The results of JENDL-2B are satisfactory for ^{235}U and ^{238}U, while the worths were a little overestimated with JENDL-1. The worth of ^{10}B obtained from JENDL-2B is underestimated by 9 % and becomes 3.5 % lower than that from JENDL-1. This difference is caused by the core neutron spectrum, because the cross sections of JENDL-1 were used for ^{10}B.

Doppler Coefficients : Table 4

Doppler coefficients are very satisfactorily predicted with JENDL-2B, while JENDL-1 overestimates them by 10 % and JAERI-Fast-II underestimates them by 10 %.

Discussion

JENDL-2B predicts various characteristics of fast reactors better than JENDL-1 as a whole. However, the following problems have been pointed out. The overestimate in the ratio of ^{238}U fission to ^{235}U fission suggests that the neutron flux is overestimated in MeV region with JENDL-2B. On the contrary, the slight underestimate in the fission rate ratio of ^{239}Pu to ^{235}U implies some underestimate of the flux in the energy region above 100 keV, because the microscopic fission cross

section ratio hardly seems to be underestimated. From the underestimate of ^{10}B worth, the underestimate of the flux in low energy region is suggested, though satisfactory results in Doppler coefficients implies the well-prediction of low energy spectrum. These problems should be further investigated.

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Table 1. Effective Multiplication Factors.

No. of Cores	*	JENDL-2B	JENDL-3	JAERI-Fast-II	ENDF/B-IV**
Pu cores	A	0.9971	0.9978	1.0019	0.9972
16 (11)	B	0.0049	0.0074	0.0044	0.0047
U cores	A	0.9992	1.0067	1.0033	1.0038
10 (6)	B	0.0082	0.0077	0.0100	0.0059
All cores	A	0.9979	1.0012	1.0024	0.9993
26 (17)	B	0.0065	0.0086	0.0072	0.0060

* A: Average of C/E, B: Standard Deviation.
** The values are taken from Ref. (3) for assemblies whose numbers are given in parentheses in the first column.

Table 2. Central Reaction Rate Ratios.

Quantities	No. of Cores	*	JENDL-2B	JENDL-1	JAERI -Fast-II	ENDF/B-IV**
U -238 Fission / U -235 Fission	Pu cores 15 (11)	A	1.086	1.008	1.021	1.019
		B	0.081	0.075	0.072	0.076
	U cores 10 (6)	A	1.024	0.960	1.011	1.046
		B	0.074	0.071	0.076	0.076
	All cores 25 (17)	A	1.061	0.988	1.017	1.029
		B	0.084	0.077	0.074	0.077
Pu-239 Fission / U -235 Fission	Pu cores 15 (11)	A	0.980	0.964	0.974	0.982
		B	0.032	0.031	0.031	0.036
	U cores 9 (5)	A	1.005	0.987	1.001	1.014
		B	0.055	0.058	0.058	0.026
	All cores 24 (16)	A	0.988	0.973	0.984	0.992
		B	0.044	0.045	0.045	0.036
Pu-240 Fission / U -235 Fission	All cores 13 (11)	A	1.064	1.009	1.059	1.074
		B	0.126	0.115	0.105	0.116
U -238 Capture / U -235 Fission	All cores 13 (10)	A	0.990	0.984	0.982	0.975
		B	0.032	0.030	0.031	0.040
U -238 Capture / Pu-239 Fission	All cores 12 (9)	A	1.003	1.012	0.999	0.976
		B	0.047	0.046	0.045	0.064

* A: Average of C/E, B: Standard Deviation of C/E.

** The values are taken from Ref. (3). The numbers of assemblies are given in parentheses in column 2.

Table 3. Sample Worths Normalized to Those of ^{239}Pu.

Sample	No. of Cores	*	JENDL-2B	JENDL-1	JAERI-Fast-II	ENDF/B-IV**
^{235}U	18	A B	1.007 0.058	1.037 0.072	1.005 0.058	1.014 0.060
^{238}U	17	A B	1.033 0.253	1.092 0.226	1.011 0.129	0.950 0.130
^{10}B	16	A B	0.909 0.143	0.944 0.122	0.928 0.120	0.836 0.115
Cr	10	A B	1.046 0.131	0.968 0.170	1.309 0.333	1.359 0.205
Fe	13	A B	0.979 0.156	0.905 0.150	1.018 0.130	1.109 0.275
Ni	11	A B	1.217 0.274	1.136 0.243	1.153 0.217	1.167 0.196

* A: Average of C/E, B: Standard Deviation of C/E.
** Taken from Ref. (3).

Table 4. Doppler Reactivity Coefficients (C/E).

		JENDL-2B	JENDL-1	JAERI-Fast-II
Small Sample Doppler Experiments	FCA V -1	0.96	1.09	0.78
	V -2	0.86	0.98	0.74
	VI-1	1.00	1.13	0.94
	VI-2	0.93	1.03	0.90
	ZPPR-2 (Normal)	1.13	1.25	1.08
	(Na voided)	0.85	0.96	0.81
	ZPR-3-47	0.97	1.04	0.95
Whole Core Doppler Experiment	SEFOR	1.05	1.12	1.05
Average of C/E		0.97	1.08	0.91
Standard Deviation of C/E		0.09	0.09	0.12

I-C-5 Effect of ^{56}Fe Angular Anisotropy on Neutron Penetration

N. Yamano*, K. Koyama and M. Kawai**

Effect of ^{56}Fe angular anisotropy on neutron penetration over the 27.67 keV resolved resonance minimum has been considered. Angular distributions of elastic scattering cross sections over the large s-wave resonances of ^{56}Fe were measured with high resolution and it was shown that the existence of angular anisotropy over the resonance[1]. To calculate the angular distributions, theoretical formula[2] is used as follows:

$$\sigma(E,\theta) = \frac{\sigma_0}{4\pi}\sum_{L=0}^{\infty} B_L(x)\,P_L(\cos\theta), \qquad (1)$$

where $x=(E-E_0)/(\Gamma/2)$ and $\sigma_0 = 4\pi/k_0^2$.

The components of Legendre coefficients are given as follows:

$$B_L = \frac{\Gamma_{n0}}{\Gamma}\frac{1}{1+x^2}\delta_{L,0} + H_L + \frac{\Gamma_{n0}}{\Gamma}\frac{2(2L+1)}{1+x^2}\sin\delta_L\left\{x\cos(2\delta_0-\delta_L)-\sin(2\delta_0-\delta_L)\right\}, \qquad (2)$$

$$H_L = \sum_{\ell=0}^{\infty}\sum_{\ell'=|\ell-L|}^{\ell+L}(2\ell+1)(2\ell'+1)(\ell\ell'00|L0)^2\sin\delta_\ell\sin\delta_{\ell'}\cos(\delta_\ell-\delta_{\ell'}), \qquad (3)$$

and the phase shift δ_ℓ for hard sphere scattering is given by

$$\tan\delta_\ell = -j_\ell(\rho)/n_\ell(\rho), \qquad (4)$$

where $\rho = k_0 R'$, R' being the scattering radius.

Numerical calculation was performed for ^{56}Fe up to eighth order of Legendre coefficients by assuming R'=5.4 fm[2] and $\Gamma_\gamma \ll \Gamma \ll E_0$. Adopted resonance parameters of Γ , Γ_γ and E_0 are 1300 eV, 1.4 eV and 27.67 keV, respectively. Total cross sections calculated by eq.(1) and experimental data[3] are shown in Fig. 1. A good agreement is obtained. Figure 2 shows the ratios of B_L to B_0 . It is clearly shown that the foward scattering components are extreamly large for the neutron energy just below the resonance minimum.

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** Nippon Atomic Industry Group Co. Ltd.

To assess the effect of angular anisotropy on the penetrating neutrons, temporary nuclear data were produced by edditing the angular information into evaluated nuclear data in JENDL-2 and one-dimensional transport calculations were performed in the case of ^{56}Fe bulk sphere of 50 cm radius. Group cross sections with ultra-fine group structure (a equi-lethargy width of 0.00625) were produced by FAIR-CROSS module of RADHEAT-V4 code system. The transport calculations were performed by DIAC[4)] code with S_{16} approximation. Neutron source with a flat energy distribution over 29.7 keV through 31.8 keV was given up to 2 cm from the center of sphere.

Penetrating neutron spectra and the ratio of the spectrum with considering angular anisotropy to the result with original data of ^{56}Fe in JENDL-2 are shown in Figs. 3 and 4, respectively. Spectral peak was shifted from 24.6 keV to 24.4 keV by considering the angular anisotropy. Neutron fluxes for the energy of the spectral peak and below the resonance minimum increased no more than 10 percent except for the energies of 21.6 and 22.9 keV at the distance of 50 cm from the center of sphere. Two peaks for the energies of 21.6 and 22.9 keV in Fig. 4 will be seem by the effect of the back scatterring contributions just above the resonance minimum but not of the p-wave resonance at the energy of 22.8 keV. The contributions of the angular anisotropy for dosimater and 1/v-absorber which located at the 18 cm from the center of sphere were about 2.0 and 2.2 percent, respectively. These results will be true of the other ^{56}Fe resonances, although a kind of detector and source condition were limited in this study. It will be seem that the effects of the angular anisotropy over the other ^{56}Fe resonances are not so remarkably because the resonance minima are not deep like the 27.67 keV resonance. Therefore, it has been concluded that the angular anisotropy over the resonance minima affects no much on neutron penetrations such as shielding problems.

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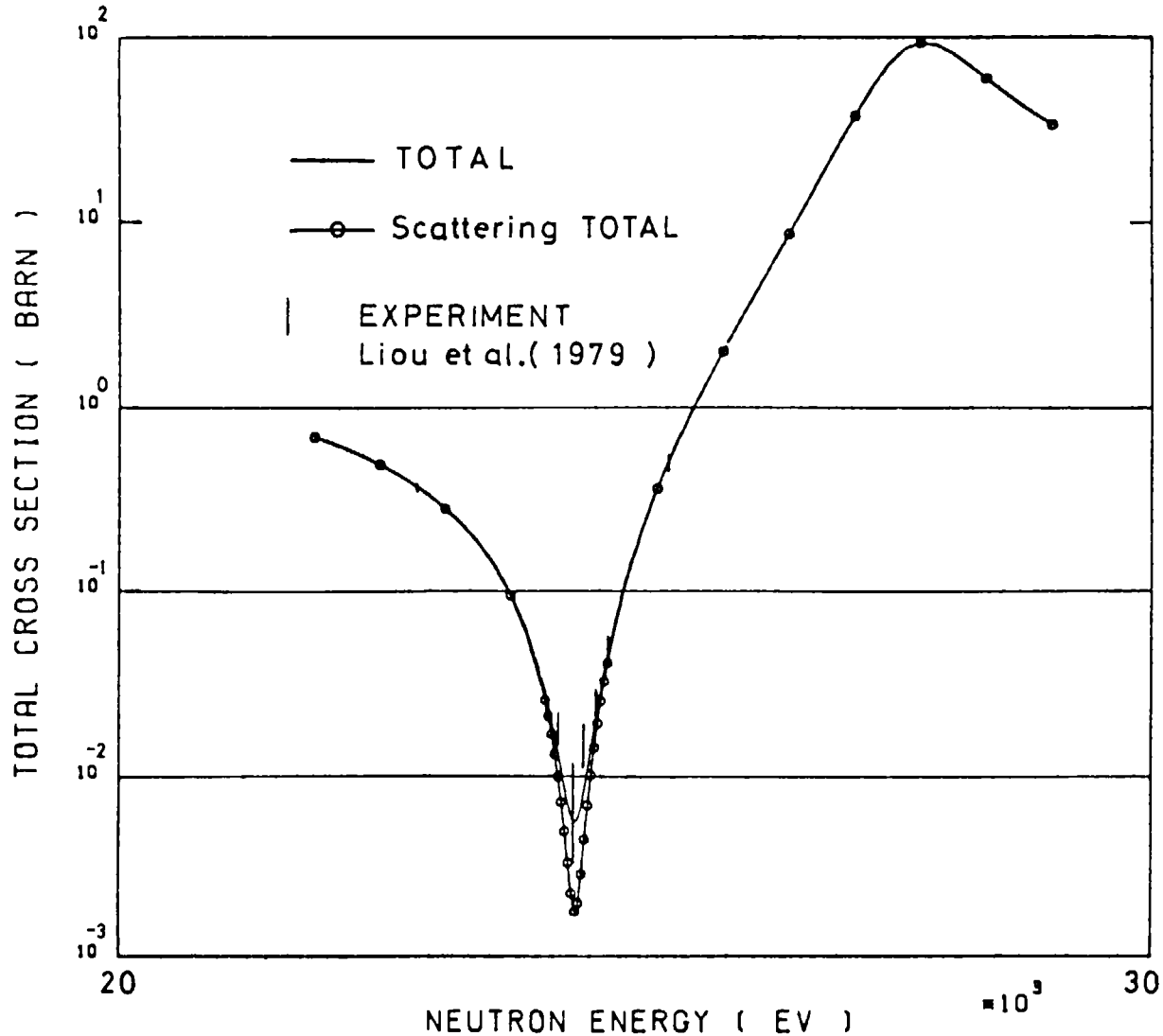

Fig. 1 Total cross section of ^{56}Fe calculated by the analytic formula

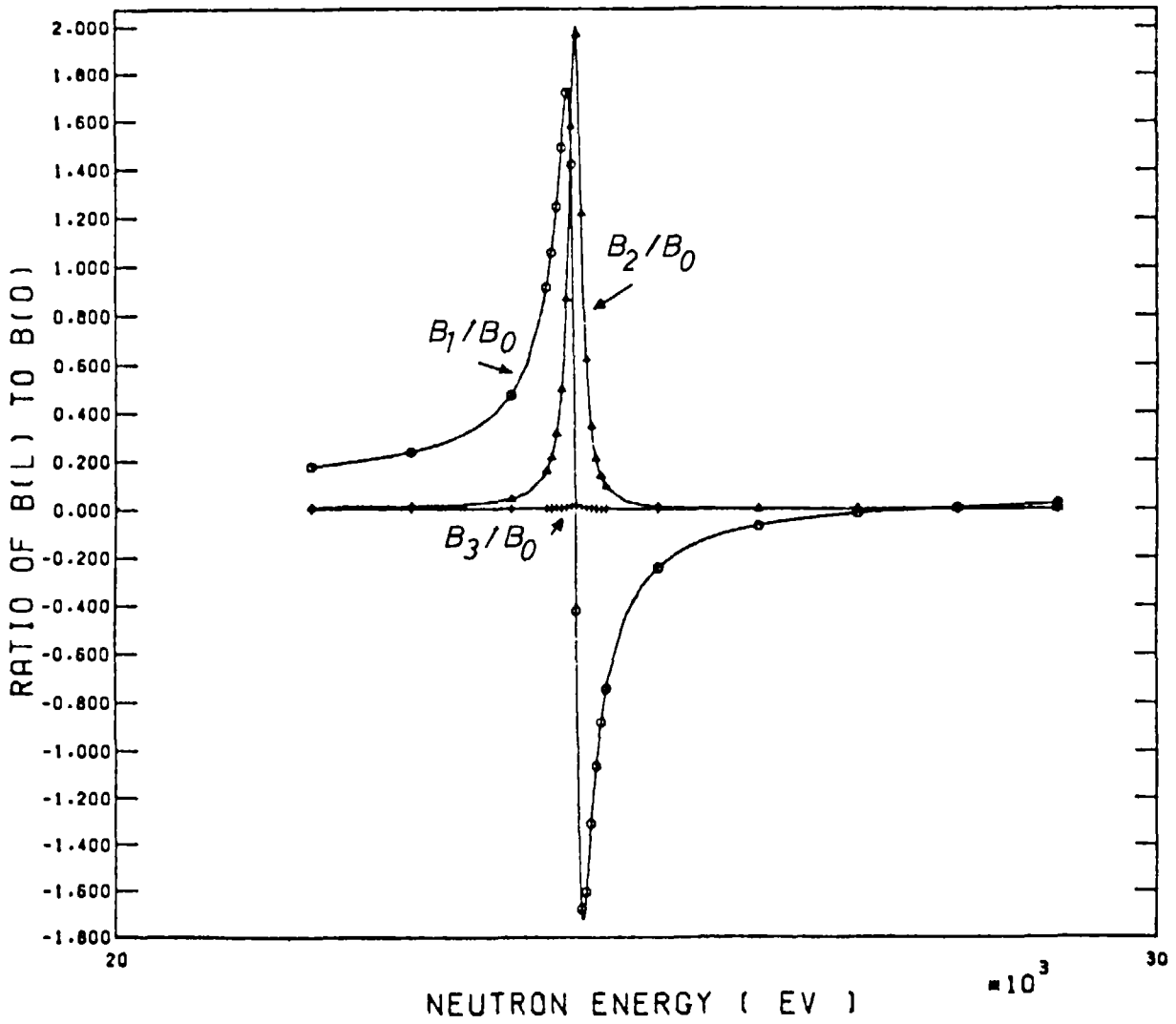

Fig. 2 Values of B_1 / B_0 calculated by the analytic formula

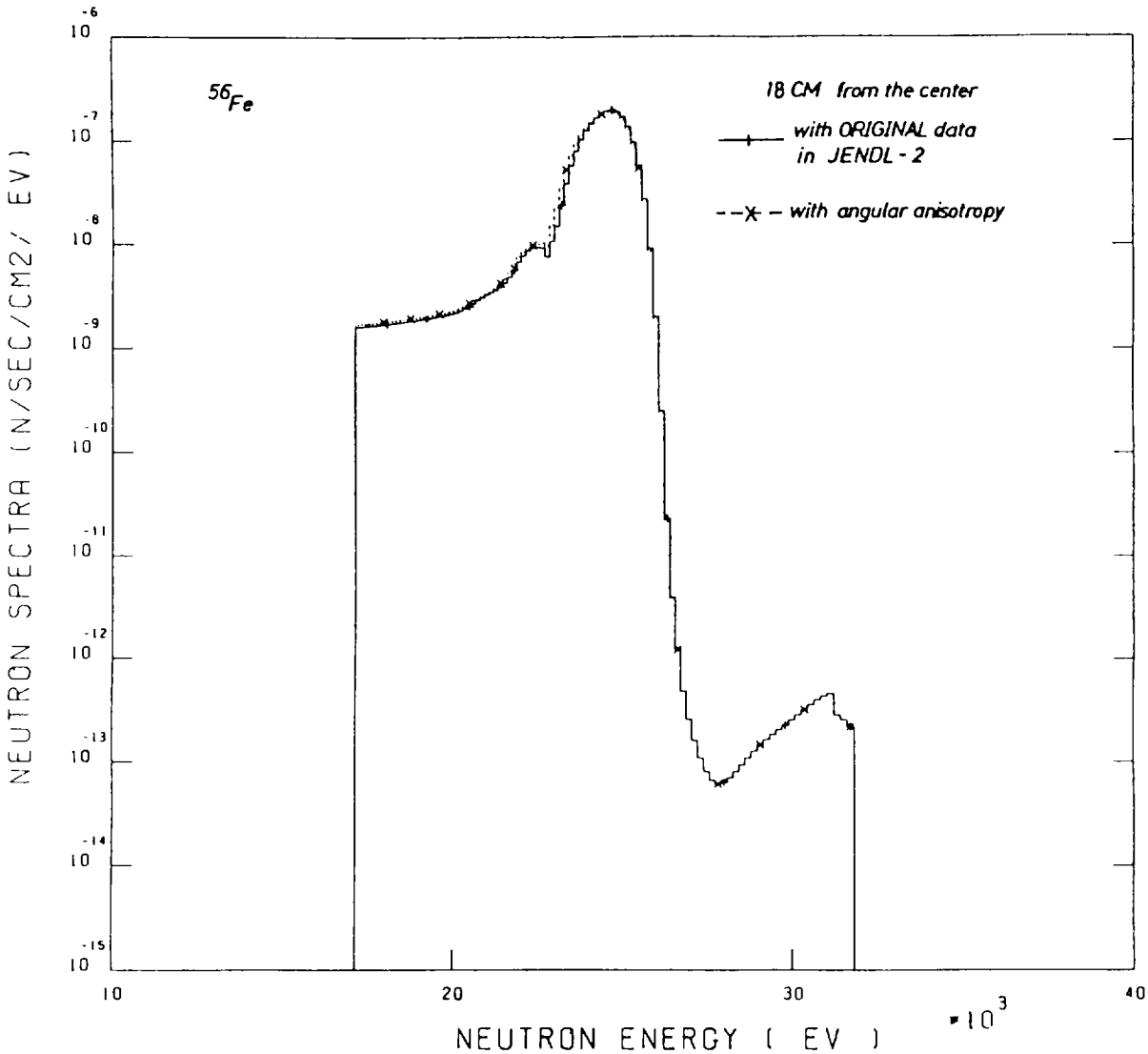

Fig. 3 Calculated neutron spectra

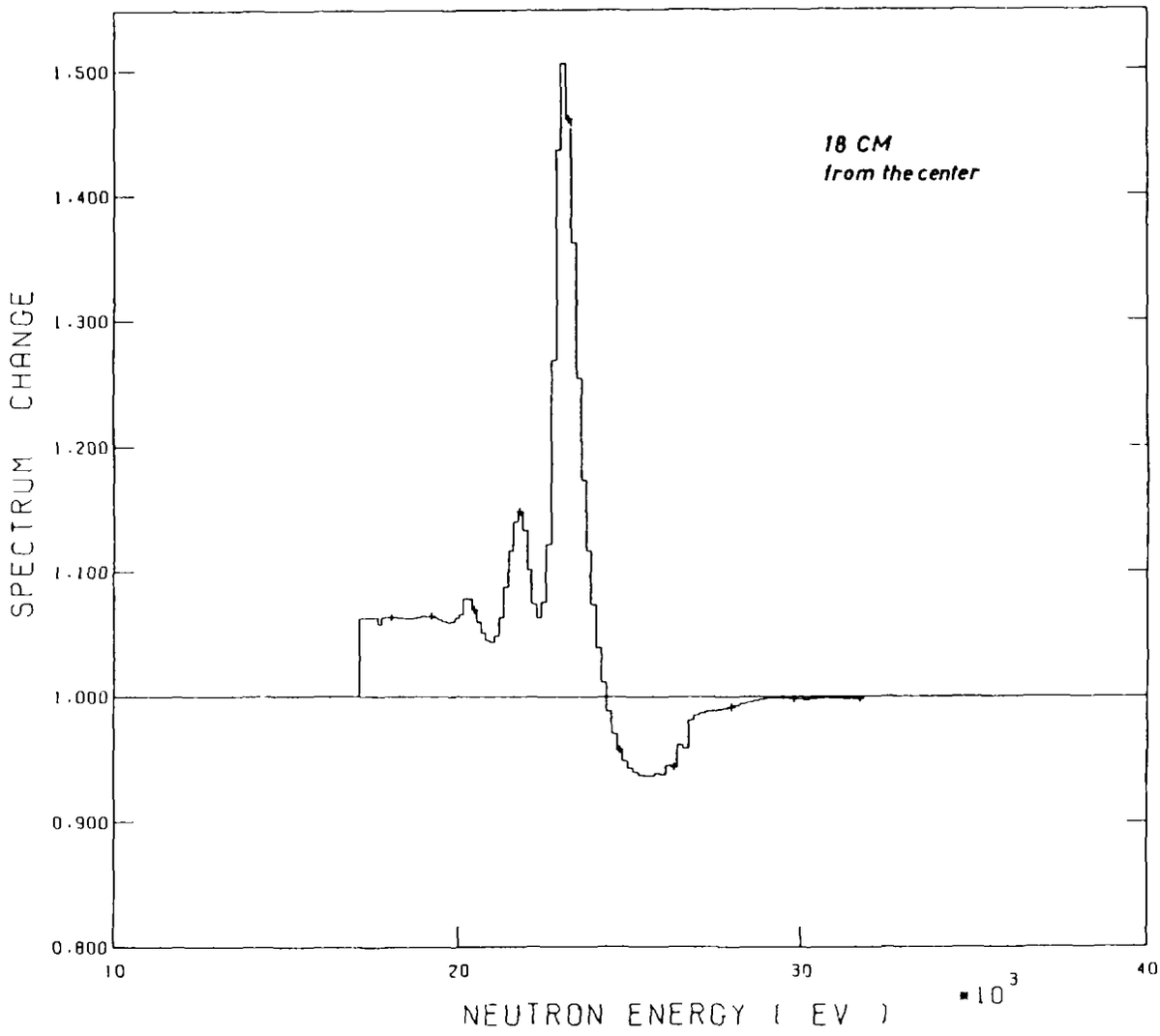

Fig. 4 Spectrum change by considering the angular anisotropy of ^{56}Fe

I-C-6 Effect of Iron Cross Section Valley at 24.4 keV on Neutron Penetration

N. Yamano* and K. Koyama

The self-shielding factor method[1] for preparing group cross sections has been widely used, particularly for fast reactor design and for the analysis of critical experiments. However, it was reported that calculations for shielding problems containing iron had often failed to achive the expected accuracy[2,3]. In this study, validity of self-shielded cross section for neutron penetrating problems of iron 27.67 keV resonance has been evaluated by comparing the results of transport calculations with ultra-fine group cross sections.

Ultra-fine group cross sections and self-shielded group cross sections used for the calculations were generated by FAIR-CROSS module of RADHEAT-V4[4] code system by processing the evaluated nuclear data in JENDL-2. Group structures of the cross sections are described in Table I. Calculated total cross sections and Bondarenko-type self-shielding factors of natural iron are shown in Fig. 1. It was shown that the effect of self-shielding on the total cross section can be ignored except for the 22.8 keV p-wave resonance in the ultra-fine group structure. On the contrary, the self-shielding contributions increased according as the energy width of each group cross section became large. Penetrating calculations with group structures shown in Table I were performed in the case of iron sphere by using one-dimensional S_N-transport code DIAC[5] with S_{16} approximation. Neutron source with a flat energy distribution of 29.7 keV through 31.8 keV was considered up to 2 cm from the center of sphere.

Calculated neutron spectra and inverse total cross sections in the

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sphere of natural iron and of pure ^{56}Fe are shown in Figs. 2 and 3, respectively. In these figures, the energies of the spectral dips for the ultra-fine group fluxes are agreed with the dips of the inverse total cross sections. However, the energies of the spectral peaks are not agreed.

In the Bondarenko method, the weighting flux is assumed to vary in proportion to $(\sigma_0 + \sigma_t)^{-1}$, where σ_t is the total microscopic cross section and the parameter σ_0 is used to allow for other materials and heterogeneity. In this study, the parameter σ_0 is zere because of a very large assembly of pure iron so that the self-shielding factor is produced by the weighting flux expressed as the inverse total cross section. However, calculated neutron fluxes are not shown by the narrow resonance approximation so that the self-shielding effect is not expressed accurately in the coarse-energy-grained group cross sections.

Maximum reaction rate changes comparering the results of the ultra-fine group calculations for 1/v-absorber, flat-energy absorber and dosimeter are shown in Tables II and III. The errors caused by the self-shielding factor have clearly shown in these tables. To eliminate the errors, it is necessary to estimate the weighting fluxes within the ultra-fine group structures or the correct value of σ_0 for each energy group and spatial resion in a problem. However it is not easy to assess the correct values in a general manner so that it must take special care to determine the energy structures in the calculations.

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Table I Group structures[+] used in the calculations

I.	100 groups with a equi-lethargy width of 0.00625
II.	50 groups with a equi-lethargy width of 0.0125
III.	25 groups with a equi-lethargy width of 0.025
IV.	10 groups with a equi-lethargy width of 0.0625

[+] Energy ranges of the group cross sections are same values of 17.036 keV through 31.828 keV.

Table II Maximum changes of reaction rates in natural iron

reaction type	changes of reaction rates	
	II / I (7 cm)*	IV / I (14 cm)
1/v-absorber	+ 0.60 %	+ 12.18 %
flat-absorber	+ 0.62	+ 12.89
dosimeter	+ 0.66	+ 14.06

* means the change of result at the distance of 7 cm from the center of sphere with group structure II compared with the result of group structure I, described in Table I.

Table III Maximum changes of reaction rates in pure ^{56}Fe

reaction type	changes of reaction rates	
	II / I (6 cm)*	IV / I (29 cm)
1/v-absorber	+ 0.39 %	+ 30.56 %
flat-absorber	+ 0.43	+ 31.70
dosimeter	+ 0.49	+ 33.52

* same meaning of Table II.

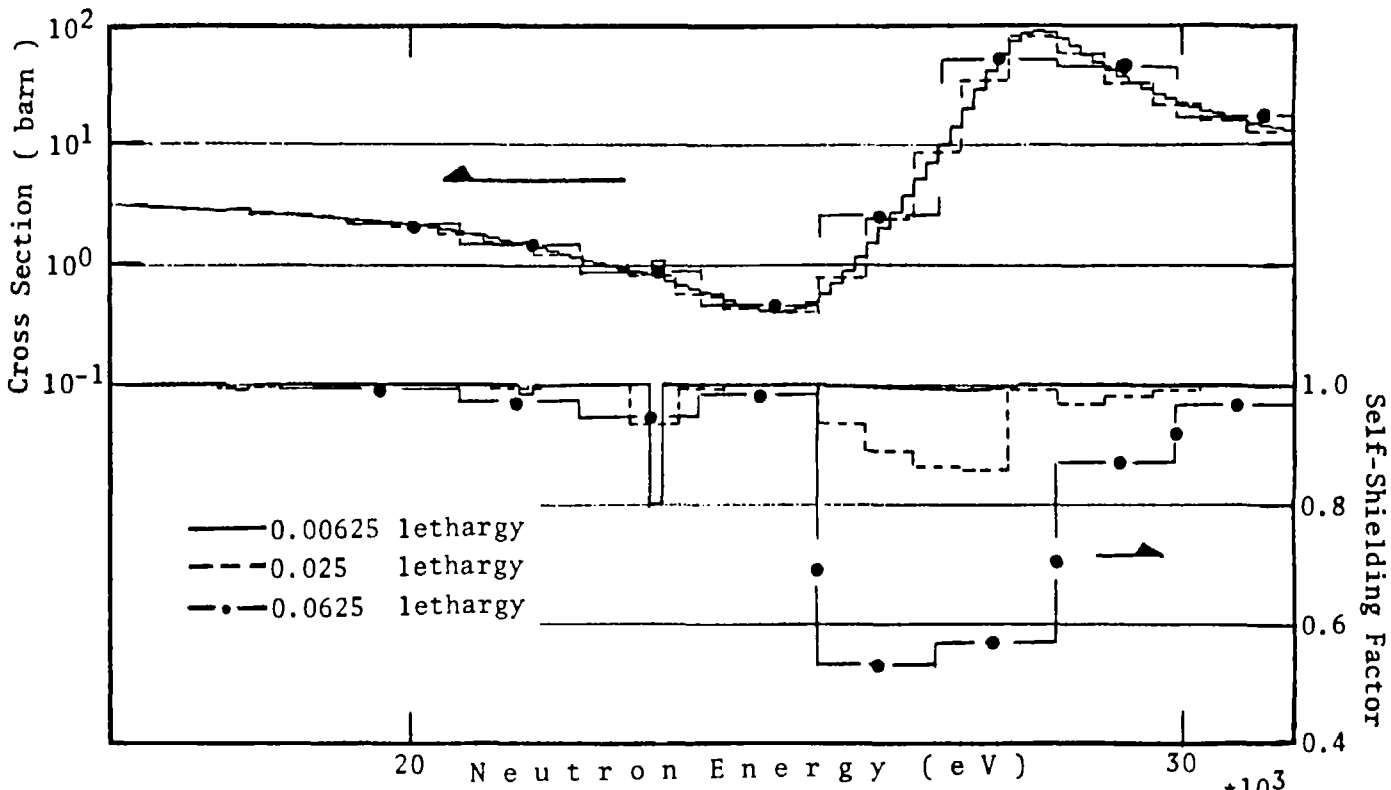

Fig.1 Cross Section and Self-Shielding factor of Natural Iron.

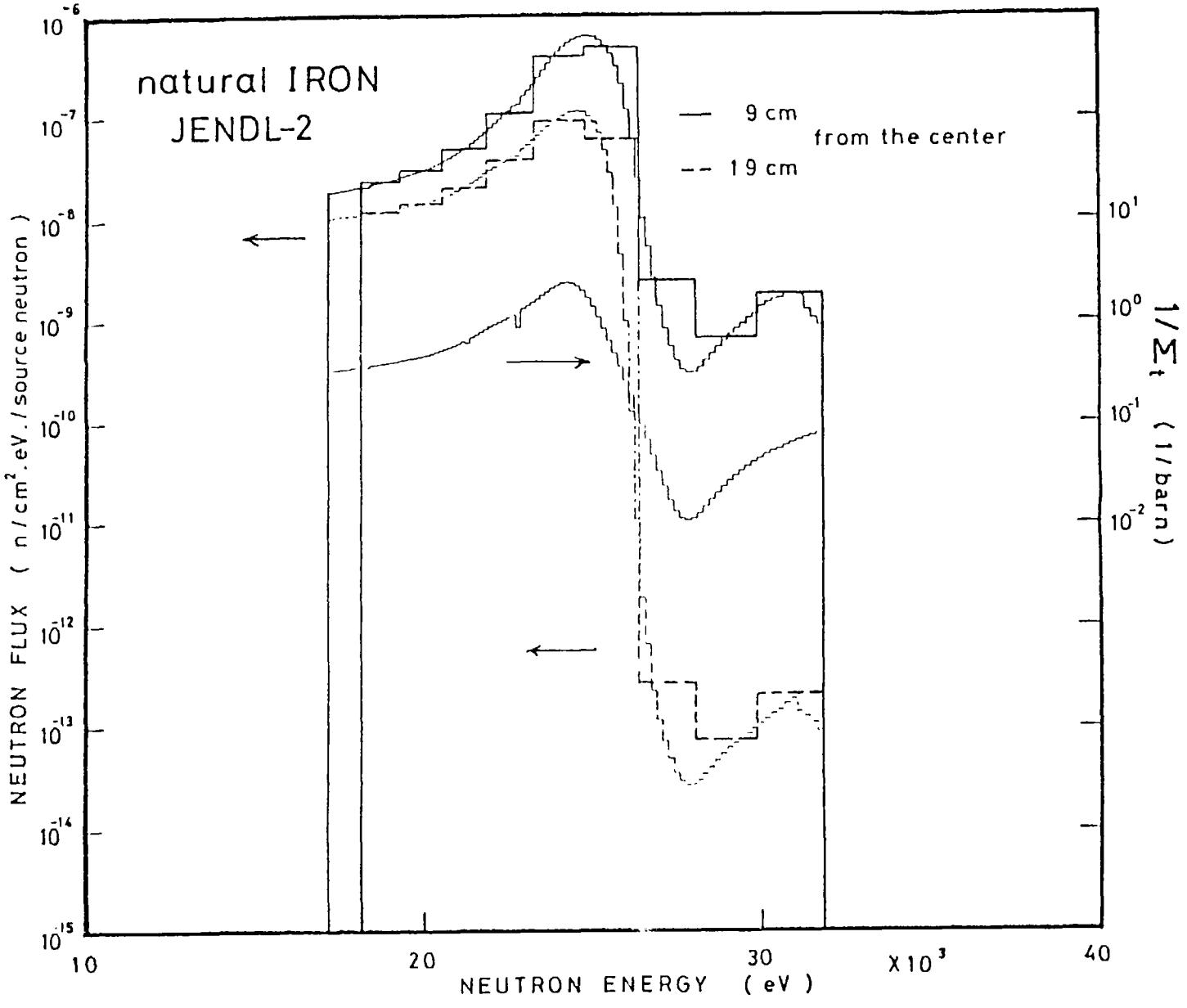

Fig. 2 Neutron spectra of natural iron calculated by DIAC

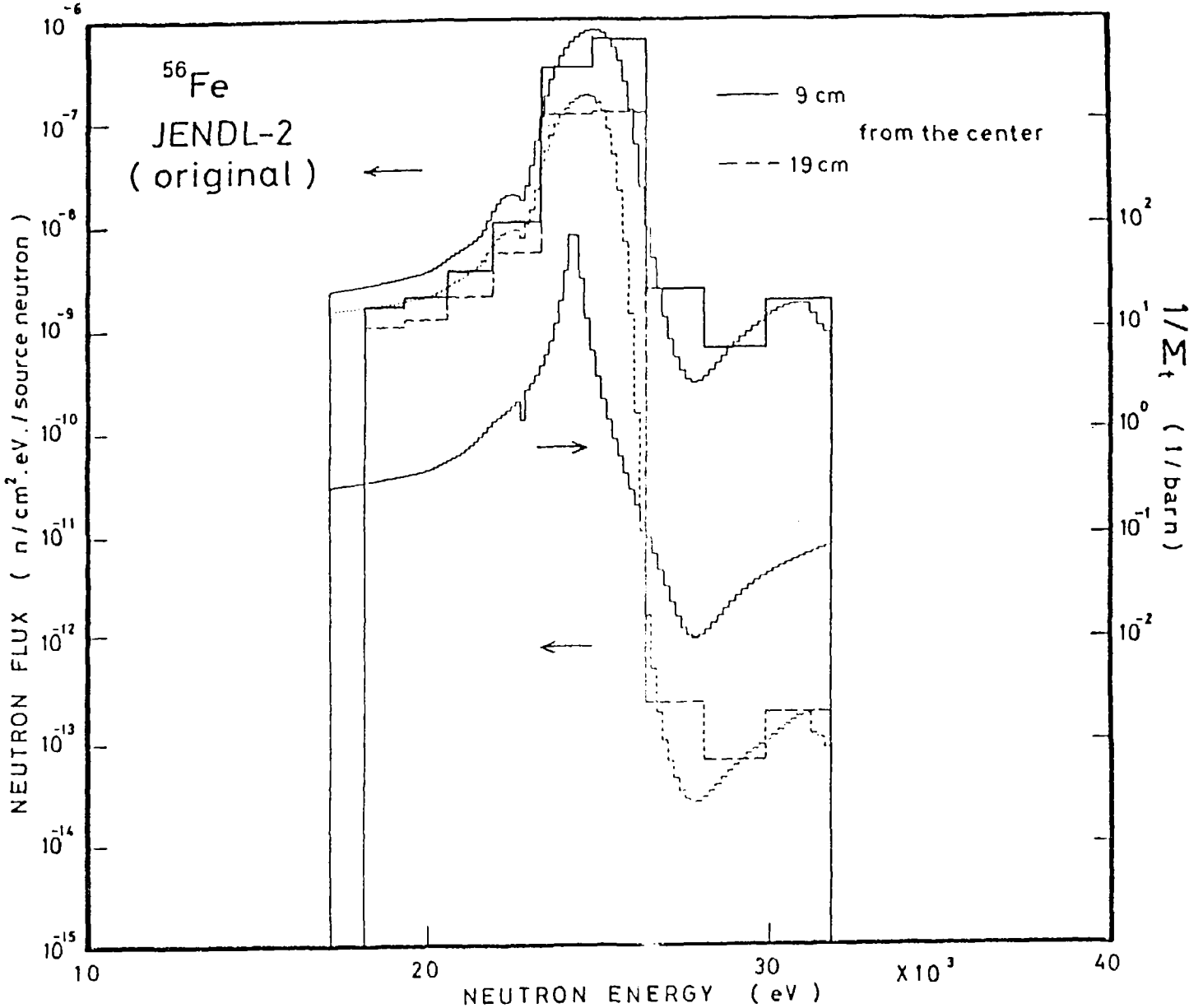

Fig. 3 Neutron spectra of ^{56}Fe calculated by DIAC

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A. Institute of Atomic Energy

II-A-1 Independent Isomer Yields of I, Xe and Cs Isotopes Produced in Thermal-Neutron Fission of ^{233}U, ^{235}U and ^{239}Pu.

T. Nishi, I. Fujiwara, N. Imanishi and H. Moriyama*

Targets containing 100 μg of ^{233}U, ^{235}U or ^{239}Pu were irradiated for 30 sec. by means of a pneumatic transport system of Kyoto University Reactor.

For the measurement of iodine isotopes, dilute nitrate solutions of fissile materials were used as targets. After irradiation, iodine was separated following the usual radiochemical method[1].

For the measurement of Xe and Cs isotopes, 100 mg of barium stearate powder containing fissile material was sealed in an evacuated polyethylene tube together with several chips of activated charcoal which were separated from the target by a plug of qualz wool and cooled to dry-ice temperature.

The xenon isotopes produced during irradiation were emanated from the stearate powder and absorbed on the charcoal chips. After irradiation, the center of the polyethylene capsule was melted and the capsule was divided into two pieces without exposing the charcoal to air. By compairing the fractional yields of xenon isotopes of the present experiment with those of the pub-

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lished, it was found that xenon isotopes were transfered to the charcoal from the target within about 0.5 sec.

The xenon activities collected on the charcoal were measured with a calibrated 38 cm^3 Ge(Li) detector connected to a 1024 channel pulse height analyser.

The barium stearate containing other fission products was dissolved in hot HCl containing Cs carrier. Cesium was absorbed on a small column of zirconium phosphate ion-exchanger after the contaminants such as I and Te were removed aby an anio-exchanger, and served for activity measurement.

In Tables I, II and III, the independent yields of ^{132}I, ^{134}I, ^{135}Xe and ^{138}Cs isomers and cumulative or independent yields of their precursors are shown for the thermal-neutron fission of ^{233}U, ^{235}U and ^{239}Pu. The values are corrected for the contribution due to the decay of the precursors during irradiation and the time of chemical separation, and are the means of more than three runs. The present isomer yields are refered to the fission yields of the respective monitor products, ^{135}I, ^{138}Xe and ^{139}Cs, which are also shown in the second column of the tables. The errors include uncertainties in the half lives, the absolute abundances of γ-rays, the counting efficiencies and the fission yields of the precursors and the fission monitors, in addition to the statistical errors in the activity measurements.

Amiel and Feldstein summarized the fission yields of ^{233}U and ^{235}U, which are also shown in the tables[2)]. Their yields agree with the present ones within the denoted errors, except those of ^{134}I and ^{135}Xe in the fission of ^{233}U. The present results for

^{135}Xe are in good agreement with those by Wolfsberg[6]. In the fission of ^{239}Pu, the agreements are also good between the present data and the previous ones[3,6-10].

References:

1) L. E. Glendenin and R. P. Metcalf, in Radiochemical Studies: The Fission Products, ed. C. D. Coryell and N. Sugarman, (McGraw-Hill, 1951) p. 1625
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10) S. J. Balestrini and L. Forman, Phys. Rev. C12 (1975) 413

Table I. Independent yields and isomer-yield ratios of ^{132}I and ^{134}I

Chain	Independent or cumulative yield (%)							$\sigma(8^-)/\sigma(4^+)$
	^{135}I	Sn[c]	Sb[c]	Te	$I(8^-)$	$I(4^+)$	I(total)	
^{233}U-132	4.95*[a]	0.11*	1.14	3.08[a]	0.082±0.01	0.11±0.01	0.19±0.02	0.75±0.12
							0.29±0.24[a]	
-134				3.80*[a]	0.77±0.04	1.02±0.06	1.79±0.07	0.75±0.06
							2.15±0.13[a]	
^{235}U-132	6.34*[a]	0.55*	2.0	1.55[a]	0.010±0.001	0.012±0.002	0.022±0.002	0.80±0.16
-134				6.66*[a]	0.36±0.02	0.42±0.02	0.78±0.06	0.86±0.07
							0.92±0.08[a]	
^{239}Pu-132	5.77*[b]	0.34*	1.75	2.75[d]	0.11±0.01	0.12±0.01	0.23±0.02	0.90±0.11
-134				5.58*[d]	1.10±0.06	1.24±0.06	2.34±0.08	0.89±0.06
							2.42±0.19[e]	

The cumulative yields of the fission monitor and the precursors are also listed, and indicated by asterisks.

a) Ref. 2) and references cited therein.

b) Ref. 3). c) Ref. 4).

d) Fission yields of ^{132}Te and ^{134}Te are measured by the same method given in Ref. 4).

e) Refs. 7 and 8)

Table II. Independent yields and isomer-yield ratios of ^{135}Xe

Chain	Independent or cumulative yield (%)					$\sigma(\frac{11}{2}^-)/\sigma(\frac{3}{2}^+)$
	^{138}Xe	I	$Xe(\frac{11}{2}^-)$	$Xe(\frac{3}{2}^+)$	Xe(total)	
^{233}U-135	4.91*[a]	4.95*[a]	1.01 ± 0.05	0.63 ± 0.06	1.64 ± 0.08	1.6 ± 0.1
			0.912 ± 0.05[d]	0.61 ± 0.07[d]	1.52 ± 0.09[d]	1.5 ± 0.2[d]
					1.31 ± 0.13[a]	
^{235}U-135	6.46*[a]	6.34*[a]	0.15 ± 0.02	0.083 ± 0.01	0.23 ± 0.02	1.8 ± 0.1
			0.19 ± 0.01[d]	0.094 ± 0.014[d]	0.28 ± 0.02[d]	2.1 ± 0.3[d]
					0.26 ± 0.07[a]	
^{239}Pu-135	4.82*[b]	5.77*[c]	0.85 ± 0.05	0.44 ± 0.05	1.29 ± 0.07	1.9 ± 0.24
			0.68 ± 0.03[d]	0.49 ± 0.06[d]	1.17 ± 0.07[d]	1.4 ± 0.2[d]
					1.07 ± 0.18[c]	
					1.29 ± 0.09[e]	

The cumulative yields of the fission monitor and the precursor are also listed, and indicated by asterisks.

a) Ref. 2). b) Ref. 5). c) Ref. 3).

d) Ref. 6)

e) Refs. 7 and 8).

Table III. Independent yields and isomer-yield ratios of ^{138}Cs

Chain	Independent or cumulative yield (%)				$\sigma(6^-)/\sigma(3^-)$
	^{139}Cs	$Cs(6^-)$	$Cs(3^-)$	Cs(total)	
^{233}U-138	2.79*[a]	0.83 ± 0.06	0.34 ± 0.03	1.17 ± 0.07	2.4 ± 0.3
				1.01 ± 0.07[a]	
^{239}Pu-138	2.34*[b]	0.58 ± 0.06	0.26 ± 0.03	0.84 ± 0.07	2.2 ± 0.3
				0.87 ± 0.22[b]	

The independent yields of the fission monitor are also listed.

a) Ref. 2 and references cited therein.

b) Ref. 10).

B. Research Reactor Institute

II-B-1

THE AVERAGE CROSS SECTIONS FOR THE (n,2n) REACTIONS OF ^{55}Mn, ^{58}Ni, ^{59}Co, AND ^{127}I TO THE FISSION NEUTRONS OF ^{235}U

Katsuhei Kobayashi and Itsuro Kimura

The fission spectrum averaged cross sections for the (n,2n) reactions of natural manganese, nickel, cobalt and iodine to the neutrons from the $^{235}U(n_{th},f)$ reaction have been measured. Metallic foils were used for the first three elements and iodine powder samples of NH_4I or PbI_2 were packed in polyethylene sheets. Irradiations were carried out with a fission plate and a core of a fast source reactor, YAYOI. The results are shown in Tables 1 ~ 4.

Table 1 Average cross sections for the $^{55}Mn(n,2n)^{54}Mn$ reaction (in mb)

Present result	0.202±0.010	Smith (ENDF/B-IV,	
Roy (60)	0.19	Maxwell, 1.97)	0.3516
Nasyrov (68)	0.202±0.018	Present(ENDF/B-V,	
Steinnes (70)	0.26±0.02	Maxwell, 1.97)	0.2970
Francois (73)	0.21	(Watt)	0.2291
Pearlstein (65)	0.13	(NBS)	0.2062
calamand (74)	0.258±0.013		
Fabry (78)	0.244±0.015		

Table 2 Average cross sections for the $^{58}Ni(n,2n)^{57}Ni$ reaction (in mb)

Present result	0.00360±0.00024	Present (ENDF/B-V,	
Roy (60)	0.006	Maxwell, 1.97)	0.004794
Braun (68)	0.004±0.0009	(Watt)	0.003218
Sekine (78)	0.0038±0.0005	(NBS)	0.00290
Pearlstein (65)	0.002	Present (ENDF/B-IV,	
Calamand (74)	0.0049±0.0014	Maxwell, 1.97)	0.004725
Zijp (78)	0.00577±0.00031		

Table 3 Average cross sections for the $^{59}Co(n,2n)^{58}Ni$ reaction (in mb)

Present result	0.227±0.011	Smith (ENDF/B-IV,	
Roy (60)	0.2	Maxwell, 1.97)	0.2514
Nasyrov (68)	0.340±0.0030	Present (ENDF/B-V,	
Sekine (78)	0.233±0.017	Maxwell, 1.97)	0.2702
Pearlstein (65)	0.11	(Watt)	0.2059
Calamand (74)	0.40±0.04	(NBS)	0.1857

Table 4 Average cross sections for the $^{127}I(n,2n)^{126}I$ reaction (in mb)

Present result	1.04±0.046	Smith (ENDF/B-IV,	
Roy (60)	1.7	Maxwell, 1.97)	1.578
Nasyrov (68)	1.62±0.24	Present(ENDF/B-V,	
Begge (68)	0.647±0.01	Maxwell, 1.97)	1.59
Steinnes (70)	1.02±0.01	(Watt)	1.29
Jenkins (71)	0.837	(NBS)	1.15
Pearlstein (65)	0.95		
Calamand (74)	1.09±0.1 *		
Fabry (78)	1.05±0.065		
Santry (79)	1.03		

* Misprint (0.9) ?

II-B-2

SYSTEMATICS OF SOME (n,2n) REACTIONS FOR ^{235}U FISSION NEUTRONS

Katsuhei Kobayashi and Itsuro Kimura

The fission spectrum averaged cross sections of some (n,2n) reactions have been measured with a fission plate and a core of a fast source reactor, YAYOI by the authors. Individual values were reported before, however the systematics of ten results has been examined by plotting $\bar{\sigma}_{n,2n}/\sigma_{n,M}$ versus threshold energy, E_{th} in referring Sekine and Baba's paper[1]. As shown in Fig.1, most of experimental values agree with the line given by Sekine and Baba:

$$\bar{\sigma}_{n,2n}/\sigma_{n,M} = 2.8 \times 10^3 \exp(-0.794\ E_{th})/\pi\ .$$

Reference :

1) T.Sekine and H.Baba: J. inorg. nucl. Chem., 40 (1978) 1977.

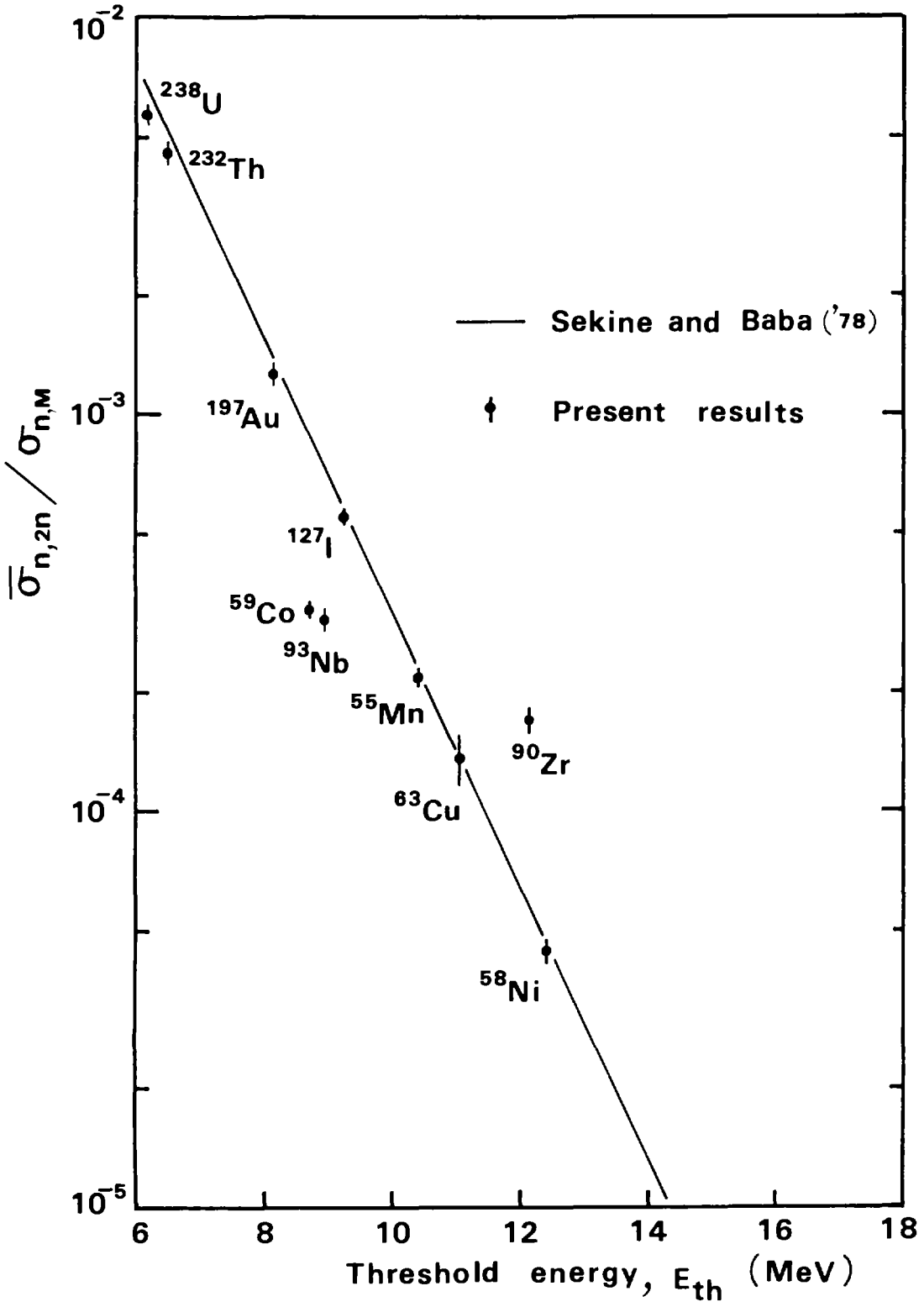

Fig.1 Ratio of $\bar{\sigma}_{n,2n}$ to $\sigma_{n,M}$ versus threshold energy, E_{th}

II-B-3

COMPARISON OF THE MEASURED AVERAGE CROSS SECTIONS FOR SOME THRESHOLD REACTIONS WITH THE CALCULATED BY MAKING USE OF ENDF/B-V

Itsuro Kimura and Katsuhei Kobayashi

The fission spectrum averaged cross sections of a large number of neutron threshold reactions have been measured with a fission plate, a core of a thermal reactor KUR and that of a fast reactor YAYOI for more than ten years. The results were published elsewhere[1)2)].

By making use of the seventeen reactions, the measured average cross sections were compared with those calculated. In the calculation, we took three types of the fission neutron spectra from ^{235}U and the cross sections from the dosimetry files of ENDF/B-IV and V. The results for the agreement between the measured and calculated average cross section are tabulated in Table 1. It can be seen that the NBS type fission spectrum provides better grade than others but there still exist quite a few unsatisfactory ones.

References :

1) K.Kobayashi, I.Kimura, M.Nakazawa and M.Akiyama: J. Nucl. Sci. Technol., 13 (1976) 531.

2) K.Kobayashi and I.Kimura: Proc. of the Third ASTM-EURATOM Symp. on Reactor Dosimetry, Ispra, Italy (1979) in print.

Table 1 Comparison of the ratio of the measured and calculated fission average cross sections, $\langle\sigma\rangle_c/\langle\sigma\rangle_m$

Reaction	This work with ENDF/B-V			ENDF/B-IV NBS type	Fabry IAEA-208 (1978)	Zijp ECN-70 (1979)
	Watt type	Maxwellian *	NBS type			
$^{27}Al(n,\alpha)^{24}Na$	- -	- -	-	-	+	+ +
$^{27}Al(n,p)^{27}Mg$	- -	- -	- -	- -	- -	-
$^{46}Ti(n,p)^{46}Sc$	-	+ +	+ +		- -	- -
$^{47}Ti(n,p)^{47}Sc$	- -	- -	- -		- -	- -
$^{48}Ti(n,p)^{48}Sc$	- -	- -	-		- -	- -
$^{54}Fe(n,p)^{54}Mn$	-	+ +	+ +	+ +	+	+
$^{55}Mn(n,2n)^{54}Mn$	- -	- -	+ +			+ +
$^{56}Mn(n,p)^{56}Mn$	- -	o	+ +		+ +	+ +
$^{58}Ni(n,p)^{58}Co$	-	+ +	+ +	+ +	+ +	-
$^{58}Ni(n,2n)^{57}Ni$	- -	- -	- -	- -		- -
$^{59}Co(n,\alpha)^{56}Mn$	o	o	o			+
$^{59}Co(n,2n)^{58}Co$	- -	- -	- -			
$^{63}Cu(n,\alpha)^{60}Co$	- -	- -	- -	- -		- -
$^{115}In(n,n')^{115m}In$	o	- -	- -	- -	+ +	+
$^{127}I(n,2n)^{126}I$	- -	- -	- -			- -
$^{232}Th(n,f)$	+	-	-	- -		- -
$^{238}U(n,f)$	o	+ +	+ +		+ +	+

$\varepsilon = \left| \frac{\langle\sigma\rangle_c}{\langle\sigma\rangle_m} - 1 \right|$, ++ : $\varepsilon \leq 2\%$, + : $2\% < \varepsilon \leq 4\%$, o : $4\% < \varepsilon \leq 6\%$, - : $6\% < \varepsilon \leq 8\%$, -- : $\varepsilon > 8\%$

II-B-4

MEASUREMENT AND ANALYSIS OF NEUTRON SPECTRUM IN A MOLYBDENUM PILE

T. Mori*, I. Kimura, Shu A. Hayashi, K. Kobayashi,
S. Yamamoto, H. Nishihara*, S. Kanazawa*, M. Nakagawa**

In order to assess the neutron cross section or group constants of molybdenum, angular neutron spectrum at r=15 cm and μ=0 in a molybdenum pile of 60 cm in diameter was measured by the linac-time-of-flight method with a ^{10}B-vaseline-plug NaI(Tl) detector and ^{6}Li glass scintillators[1]. The results have been compared with the theoretical ones predicted using two group constants produced from ENDF/B-IV (MAT=1287) and JENDL-1 (MAT=1420). The SUPERTOG code[2] was used for producing group constants and the one-dimensional Sn code ANISN[3] for neutron transport calculation. The sample powder of molybdenum was packed in a spherical vessel of soft steel 4.5 mm thick to form the test pile. The apparent density of molybdenum powder was approximately 2.15 g/cm^3.

General agreement between measurements and calculations can be seen for both cases, as shown in Fig. 1. However, the predicted spectrum with the ENDF/B-IV gives less flux about 30 % than the measured in the energy below 600 keV, while that with the JENDL-1 is in better agreement with the measured. This is probably due to the fact that discrete levels in ine-

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lastic scattering cross section are not given in the ENDF/B-IV.

In parallel with the spectrum measurements, neutron spatial distribution was measured by the activation method with nickel wires and the results showed spherical symmetry arround a photoneutron target at the center of the pile. This fact could verify validity of using one-dimensional transport code (ANISN) with spherical symmetry for analysis.

A part of this subject will be presented at the fall meeting of the Atomic Energy Society of Japan in September, 1980, and will be published in future.

Reference:

1) I. Kimura, et al., Nucl. Instr. Meth., 137 (1976) 85.

2) R. Q. Wright, et al., ORNL-TM-2679 (1969).

3) W. W. Engle, Jr., K-1693 (1967).

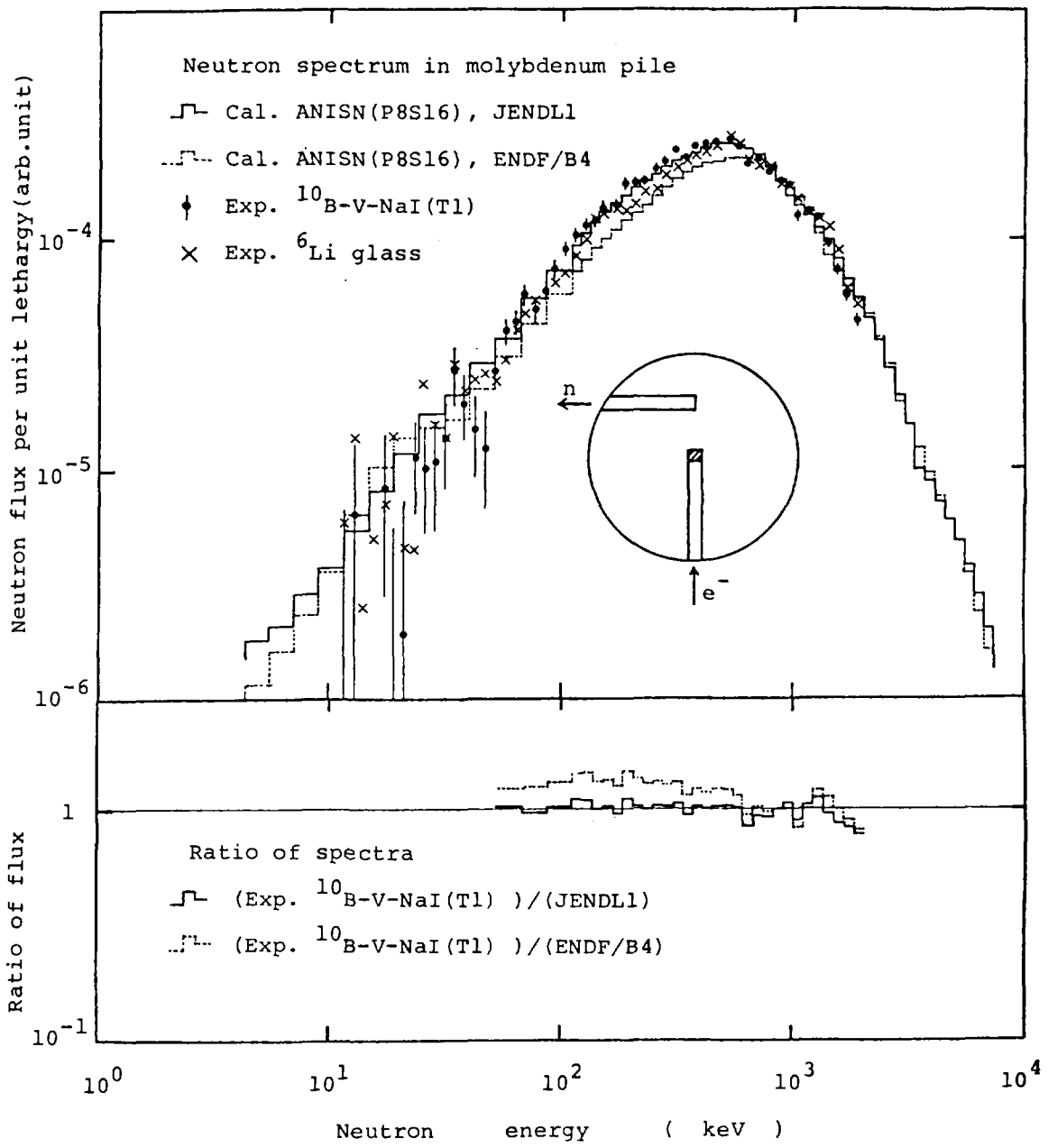

Fig. 1 Neutron spectrum in a molybdenum pile and ratio of spectra (measured/calculated).

III. KYUSYU UNIVERSITY

Department of Nuclear Engineering

Faculty of Engineering

III-1 Estimation of Neutron Yield from Individual Fragment in Medium-Excitation Fission+

H. Yamamoto, Y. Mori*, Y. Wakuta, A. Katase and M. Sonoda**

A method of calculation is described to estimate the average number of neutrons emitted per fragment in medium-excitation fission from published experimental data on neutron emission in thermal-neutron induced fission, average total kinetic energy as a function of fragment mass and mass yield in low- and medium-excitation fission reactions. Use is made of a relation of fragment excitation energy with internal excitation and deformation energies, and the difference in kinetic energy between the fission reactions at two-excitation energies. A tentative calculation is made for the fission of ^{238}U induced by 12 MeV protons. The results are in good agreement with experimental data.

The method developed in the present work may make it possible to predict the average number of neutrons emitted from individual fragment in medium-excitation fission which has not yet been measured experimentally.

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+ This paper was published in the Journal of Nuclear Science and Technology, 16[7], pp. 466~473 (July 1979).

III-2 Neutron Emission, Mass Distribution and Energetics in 14.5 MeV-Neutron Induced Fission of Uranium-238[+]

H. Yamamoto, Y. Mori*, Y. Wakuta, A. Katase and M. Sonoda**

A study is performed on 14.5 MeV-neutron induced fission of ^{238}U by means of three-parameter experiment in which the energies of both fragments and the time-of-flight of one fragment are measured. A mosaic-arrayed surface barrier detector of large sensitive area is used at the remote end of a flight tube. The pre- and post-neutron-emission fragment mass distributions are obtained, together with the average total kinetic energy of fragment as a function of its mass. The average number of neutrons emitted from an individual fragment and the average total number of emitted neutrons are also derived as a function of fragment mass. The results agree well with those calculated by the method developed in our laboratory for medium-excitation fission The average number of emitted neutrons and the mass distribution of fission fragment are derived for the respective reactions of first-, second- and third-chance fission.

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+ This paper was published in the Journal of Nuclear Science and Technology, 16[11], pp. 779~791 (November 1979).

III-3 Application of Multi-step Direct Reaction Theory to 14 MeV Neutron Reaction I (n,n')

I. Kumabe, M. Matoba and K. Fukuda

A paper on this subject will be published in Proceedings of 1980 RCNP International Symposium on Highly Excited States in Nuclear Reactions with an abstract as follows :

Multi-step direct-reaction theory proposed by Tamura et al. has been applied to continuous spectra of the 14 MeV (n,n') reaction with some modifications. Calculated results reproduce well the experimental 14 MeV (n,n') data for both the energy and angular distributions.

III-4 Application of Multi-step Direct Reaction Theory to 14 MeV Neutron Reaction II (n,p)

I. Kumabe, M. Matoba and K. Fukuda

A paper on this subject will be published in Proceedings of 1980 RCNP International Symposium on Highly Excited States on Nuclear Reactions with an abstract as follows :

Continuous spectra of the 14 MeV (n,p) reaction have been analyzed in term of multi-step direct-reaction theory proposed by Tamura et al. by using the effective Q value and the modified shell model. Calculated results reproduce well the energy and angular distributions of the ^{115}In (n,p) reaction. Calculated total (n,p) cross sections are in good agreement with the experimental ones in the region of mass number A = 110 ~ 150.

III-5 Application of Multi-step Direct Reaction Theory to 14 MeV Neutron Reaction III (n,α)

I. Kumabe, K. Kayashima and M. Matoba

A paper on this subject will be published in Proceedings of 1980 RCNP International Symposium on Highly Excited States on Nuclear Reactions with an abstract as follows :

Multi-step direct-reaction theory proposed by Tamura et al. has been applied to continuous spectra of the 14 MeV (n,α) reaction with some modifications. Calculated results reproduce well the experimental energy and angular distributions of the 14 MeV (n,α) reactions.

III-6 Multi-step Direct-reaction Analysis of Continuous Spectra of 14 MeV (n,n') Data

I. Kumabe, K. Fukuda and M. Matoba

A paper on this subject reported in NEANDC (J)-61/U p.86 has been published in Physics Letters 92B (1980) 15 with an abstract as follows :

The multi-step direct-reaction theory proposed by Tamura et al. was applied, with some modifications, to the continuous spectra of 14 MeV (n,n') reaction. The calculated results reproduced well the experimental 14 MeV (n,n') data for both the energy and angular distributions with a reasonable normalization procedure.

IV. NAGOYA UNIVERSITY

Department of Nuclear Engineering

IV-1 Decay Properties of ^{145}Ce and ^{146}Ce

H. Yamamoto, Y. Ikeda, K. Kawade, T. Katoh and T. Nagahara*

A paper on this subject was submitted to J. Inorg. Nuclear Chemistry.

Decay properties of ^{145}Ce and ^{146}Ce were studied. Sources were prepared by a rapid paper electrophoresis from fission products of ^{235}U. Thirty-two γ-rays from ^{145}Ce, including 14 new ones, and 26 γ-rays from ^{146}Ce, including 6 new ones, were observed, and 25 γ-rays and 21 ones were assigned to the decay schemes for ^{145}Ce including 3 new levels and for ^{146}Ce, respectively. The half-lives of ^{145}Ce and of ^{146}Ce are 3.01±0.06 and 13.52±0.13 min, and observed Q_β values for ^{145}Ce and for ^{146}Ce are 2.6±0.1 MeV and 952±50 keV, respectively.

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IV-2 Decay Study of ^{144}La

Y. Ikeda, H. Yamamoto, K. Kawade, T. Katoh and T. Nagahara*

A paper on this subject was published in J. Phys. Soc. Japan 47, p.1389(1979).

The decay of a short lived nucleus ^{144}La to levels of ^{144}Ce was investgated with Ge(Li), NaI(Tl) and plastic detectors in singles and coincidence modes. Radioactive sources were prepared by the chemical separation, a rapid paper electrophoresis, from the fission products of ^{235}U. The half-life of ^{144}La is 40.6±1.0 sec. Fifty-four γ-rays, including 17 new ones, were observed and 46 of them are incorporated in a decay scheme of ^{144}La including 11 new levels. The Q_β value was deduced to be 4.3±0.1 MeV on the basis of the results of the γ-β coincidence measurements.

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* Institute for Atomic Energy, Rikkyo University

IV-3 Decay of ^{148}Pr Isomers to Levels of ^{148}Nd

Y. Ikeda, H. Yamamoto, K. Kawade, T. Takeuchi, T. Katoh and T. Nagahara*

A paper of this subject was published in J. Phys. Soc. Japan 47, p.1039(1979).

The decay of ^{148}Pr to levels on ^{148}Nd has been investigated with Ge(Li) and plastic detectors in singles and coincidence modes. Sources were prepared by a chemical separation from the fission products of ^{235}U. Forty γ-rays associated with ^{148}Pr decay have been observed and thirty four of them are incorporated into a level scheme including six new levels at 723.7, 1275.0, 1512.4, 1687.5, 2543.0 and 3129.6 keV. In comparison with the decay study of ^{148}Pr produced by the ^{148}Nd(n,p) reaction, this work, for the first time, could make clear the existence of ^{148}Pr isomers by γ-ray intensity ratios and their half-lives which are 2.27±0.04 and 2.0±0.1 min. A low lying level at 723.7 keV is assigned as a 0^+ state from the γ-γ anisotropy measurements and low lying levels in the transitional nuclide ^{148}Nd are discussed in terms of the quasi-band description.

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V. OSAKA UNIVERSITY

Faculty of Engineering

V-1 Assessment of Differential Cross Section Data for Fusion Materials

J. Yamamoto, A. Takahashi and K. Sumita

A paper on this subject was published on the Journal of Nuclear Science and Technology[1]. Angular flux spectra from slab assemblies (lithium and graphite) were measured to test nuclear data and calculational methods for fusion reactor.

As for the numerical calculations, discrete ordinates transport codes (ANISN and NITRAN[2]) were used. The multi-group cross sections processed with SPTG4Z from ENDF/B-IV were used as nuclear data base. Comparison with the experimental spectra showed that the angular dependent cross sections for non-elastic scattering available in ENDF/B-IV were quite insufficient and that the anisotropy of the scattering could not be calculated with ANISN which utilized the scattering kernels generated by the incorrect treatment of scattering kinematics in the processing codes. Good agreement between measurements and calculations was attained by the use of NITRAN system with the appropriate processing codes of inelastic scattering anisotropies, when the additional data for differential inelastic scattering cross sections of several excitation levels were taken into the ENDF/B-IV data.

References :

1) J. Yamamoto, A. Takahashi, M. Ebisuya and K. Sumita, J. Nucl. Sci. Technol., Vol.17, No.4, pp.255 to 268 (1980)

2) A. Takahashi, D. Rusch, KfK-2832/I,II (1979)

VI. RIKKYO (ST. PAUL'S) UNIVERSITY

Department of Physics

VI-1 Alpha-Alpha Particle Correlation Experiment on the $^9Be(n,\alpha\alpha)nn$ Reaction at 14.1 MeV

K. Shibata, S. Higuchi, M. Saito and S. Shirato

In the $^9Be(n,\alpha\alpha)nn$ reaction, the α-α particle correlation spectrum measured at $\theta_1 = 40^o$ and $\theta_2 = -102^o$ using 14.1 MeV neutrons showed a dominant contribution from sequential decay via the excited states of ^6He and the n-n final-state interaction effect.[1,2] In order to confirm this result including the possible existence of excited states in ^6He, we continued the experiment at other angle pairs, where the two-body events from $^9Be(n,\alpha)^6He$ are kinematically excluded in the spectrum.

Fig. 1 shows measured α-α correlation spectra projected onto the E_2 axis in steps of the associated α-particle energy interval $\Delta E_1 = 1.6$ MeV. The arrows indicate the kinematic energy regions corresponding to the sequential decay processes (A) $^9Be + n \rightarrow \alpha_1 + {}^6He^* \rightarrow \alpha_1 + \alpha_2 + 2n$ and (B) $^9Be + n \rightarrow {}^6He^* + \alpha_2 \rightarrow \alpha_1 + 2n + \alpha_2$, where α_1 and α_2 represent the α-particles detected by the E_1 detector at θ_1 and the E_2 detector at θ_2, respectively. The subscripts 1, 2 and 3 in A and B stand for the first (1.797 MeV), second (3.4 MeV?) and third (6.0 MeV?) excited states in ^6He, respectively. The dashed curves represent the phase-space factor, which is proportional to $(E_1E_2E_{nn})^{\frac{1}{2}}$ where E_{nn} is the relative energy between two unobserved neutrons.

It is noted that the measured correlation spectra differ from the shape of the phase-space factor and reveal dominant yields of the reaction proceeded through sequential decay.

References:

1) S. Shirato, K. Shibata and M. Saito, Progress Report 1978, (JAERI), NEANDIC(J)-56/U, INDC(JAP)-42/U, p.54. Progress Report 1979, (JAERI), NEANDIC(J)-61/U, INDC(JAP)-47/U, p.108.

2) S. Shirato, K. Shibata and M. Saito, Rikkyo University Report RUP-78-16 (1978, unpublished).

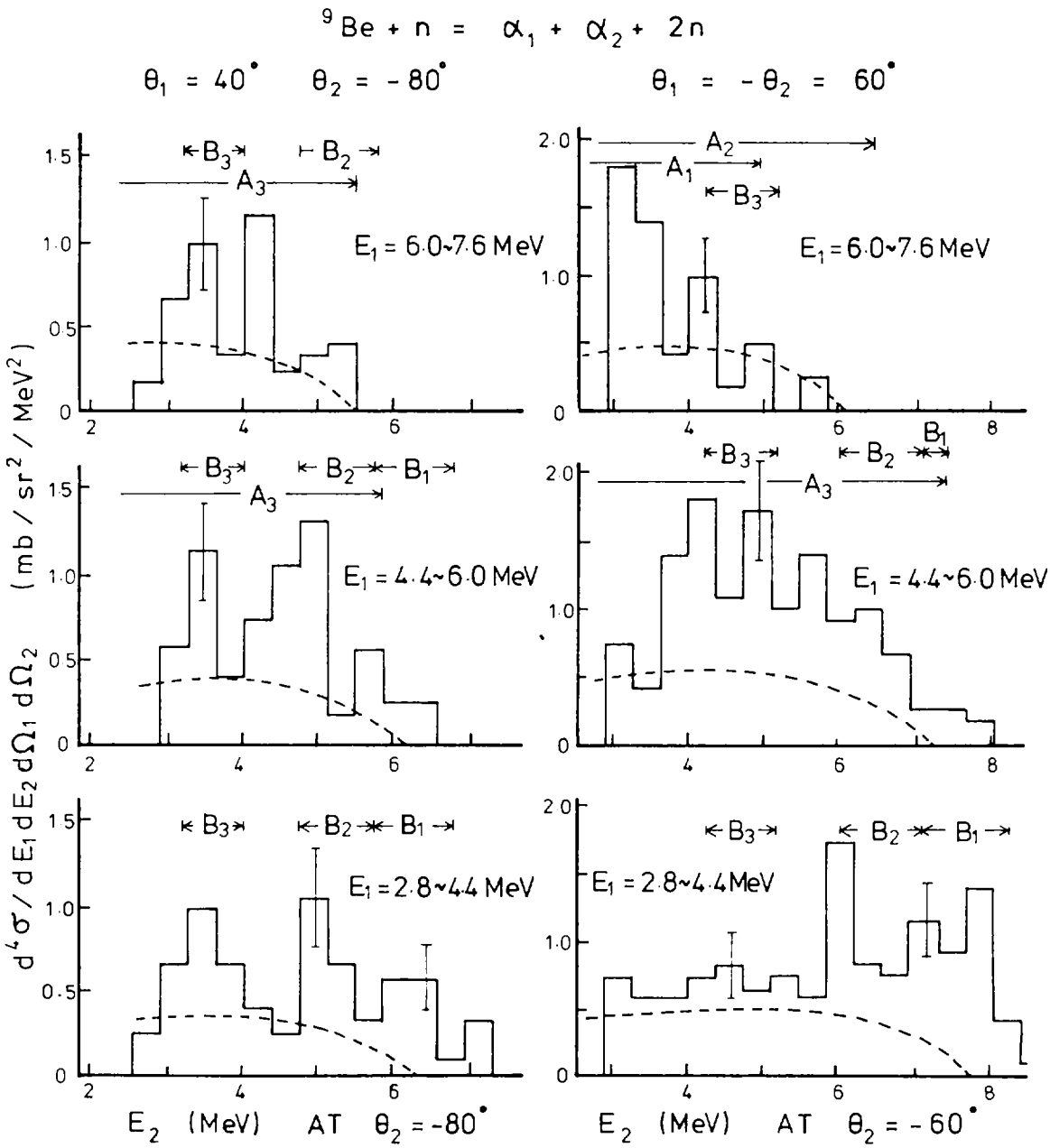

Fig. 1. α-α correlation spectra projected onto the E_2 axis.

VI-2 Deuteron Energy-Spectra from the $^6Li(n,d)^5He$ Reaction at 14.1 MeV

S. Higuchi, K. Shibata, M. Saito and S. Shirato

Energy spectra of deuterons emitted from ^6Li nuclei bombarded with 14.1 MeV neutrons were measured at forward counter-setting angles (θ_0) up to 60°. In this measurement, we used a ^6Li metal target of 3.74 mg/cm^2 thick and a counter telescope. (The details are in our following report V-3.)

In Fig. 1 is shown a typical deuteron energy-spectrum which was observed at $\theta_0 = 0^o$. The mean angle $\bar{\theta}$ in our finite geometry was calculated to be 6.3^o at $\theta_0 = 0^o$.

The measured spectrum was compared with a calculation based on the simple final-state interaction (FSI) theory[1,2]. In this theory the double differential cross section is approximately given by

$$\frac{d^2\sigma}{d\Omega dE_d} \sim (PSF)\frac{\sin^2 \delta_\ell^{2J}(k_{n\alpha})}{k_{n\alpha}{}^2 P_\ell(x)} .$$

Here, $\delta_\ell^{2J}(k_{n\alpha})$ is the phase-shift for the n-α FSI in ^5He, which is a function of the n-α relative momentum $k_{n\alpha}$. PSF $\propto (k_{n\alpha}{}^2 E_d)^{\frac{1}{2}}$ is the kinematic phase-space factor. $P_\ell(x)$ is the ℓ-wave penetrability factor[3], where $x = k_{n\alpha}R$ and R is the n-α interaction radius. The solid line indicated in Fig. 1 is the result of the calculation for the ground state of ^5He ($P_{3/2}$ resonance) using R = 2.6 fm and the values of the p-wave phase-shift δ_1^3 derived by Morgan and Walter[4]. This line normalized at the peak of the measured spectrum has been smeared with an overall experimental resolution of 630 keV and corrected for energy

losses of the deuterons in the target and the counter gas.

In accordance with the conclusion of Valković et al.[5] (who used a ^{6}LiF target and corrected for the contamination from F), the deuteron energy-spectra from the ^{6}Li(n,d)^{5}He reaction are well explained by the simple FSI theory without taking into account the spatial localization effect[2].

References:

1) K. M. Watson, Phys. Rev. 88 (1952) 1163.
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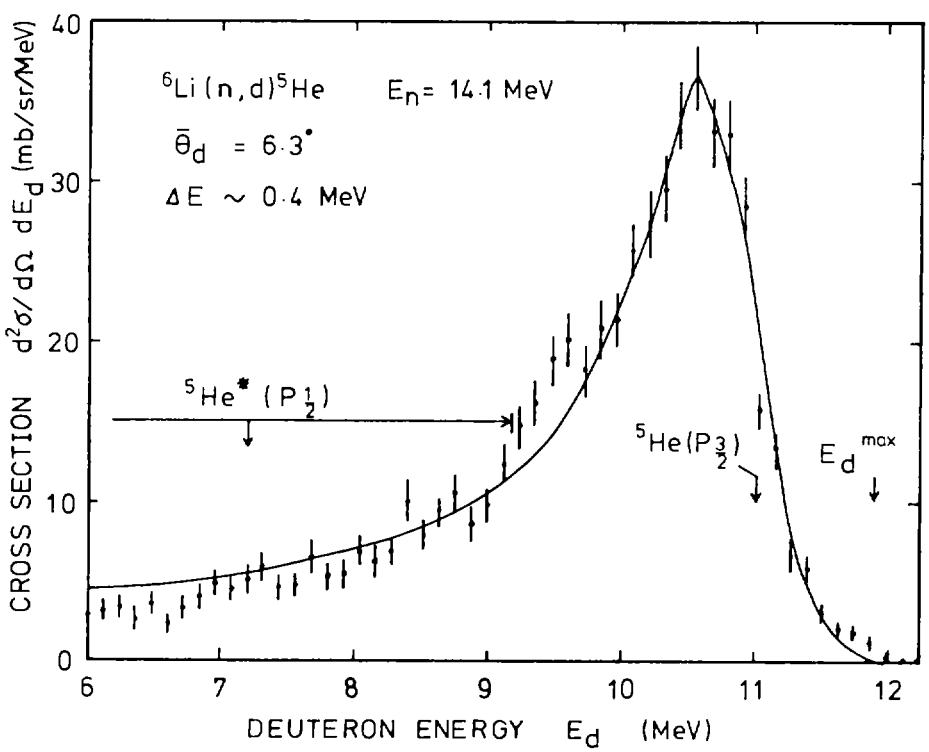

Fig. 1. Measured and calculated deuteron energy-spectra.

VI-3 Differential Cross Sections for the Reactions $^6Li(n,d)^5He$ and $^6Li(n,t)^4He$ at 14.1 MeV

S. Higuchi, K. Shibata, M. Saito and S. Shirato

Deuterons and tritons from ^6Li nuclei bombarded with 14.1 MeV neutrons were measured at forward angles (θ_0) of counter-setting up to 60°, using a counter telescope and a CAMAC data acquisition system. The counter telescope, which was set on an arm of a scattering chamber, consists of two gas proportional counters and 138 μm ΔE and 1500 μm E silicon detectors. The counter gas of 100 Torr Ar was filled in the scattering chamber. The particle identification for light charged particles (p, d, t and α) was completely done by using this relatively thick ΔE detector.

A ^6Li metal target of 3.74 mg/cm^2 thick was fabricated by flattening out an enriched (95.58%) ^6Li metal piece by a roller, and placed on the gold backing of a $(C^2H_2)_n$ target[1] which was set at the centre of the scattering chamber. The $(C^2H_2)_n$ target was used as a reference in the deuteron measurement by means of n-d elastic scattering. The FWHM of a recoil-deuteron energy-spectrum measured at $\theta_0 = 0^o$ was 632 keV, which is a measure of the energy resolution in the present experimental geometry. The measured differential cross section for n-d elastic scattering was in agreement with our previous result[2] of the n-d work done with a different counter telescope and the different experimental geometry.

The result on differential cross sections obtained from measured deuteron and triton energy-spectra are summarized in Table 1. The present values of the cross section for $^6Li(n,d)$

^{5}He have been corrected for a contribution from an unmeasured region below the ΔE cut-off energy. The errors indicated in Table 1 are only the statistical errors. The systematic error which includes uncertainties in target nuclei, incident neutrons and geometry is approximately 5%.

The present data are in fair agreement with the data of Valković et al.[3] for ^{6}Li(n,d)^{5}He and those of Valković et al.[4] and Rendić et al.[5] for ^{6}Li(n,t)^{4}He. It has been pointed out[6] that the DWBA calculation is in strongly disagreement with the (n,d) data on ^{6}Li by neglecting reaction mechanisms other than proton pick-up. Our preliminary analyses in DWBA and PWBA could not still completely remove the discrepancy. Further studies of the theoretical analysis are in progress.

References:

1) S. Shirato, K. Saitoh and N. Koori, Nucl. Phys. A215 (1973) 277.

2) S. Shirato and N. Koori, Few particle problems in the nuclear interaction, ed. I. Šlaus et al. (North-Holland, Amsterdam, 1972) p.472.

3) V. Valković, G. Paić, I. Šlaus, P. Tomaš, M. Cerineo and G. R. Satchler, Phys. Rev. 139 (1965) B331.

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5) D. Rendić et al., Rossendorf Reports 2 (1967) 143.

6) D. Miljanić and V. Valković, Nucl. Phys. A176 (1971) 110.

Table 1. Measured CM differential cross sections for the reactions $^{6}Li(n,d)^{5}He$ and $^{6}Li(n,t)^{4}He$ at 14.1 MeV.

Setting angle θ_0 (deg)	$^{6}Li(n,d)^{5}He$ CM mean angle $\overline{\Theta}$ (deg)	$^{6}Li(n,d)^{5}He$ $d\sigma(\overline{\Theta})/d\Omega$ (mb/sr)	$^{6}Li(n,t)^{4}He$ CM mean angle $\overline{\Theta}$ (deg)	$^{6}Li(n,t)^{4}He$ $d\sigma(\overline{\Theta})/d\Omega$ (mb/sr)
0	$8.0^{+5.4*)}_{-5.0}$	48.2 ± 0.7	$7.5^{+2.7*)}_{-5.0}$	7.4 ± 0.4
14	$17.7^{+7.8}_{-8.3}$	39.3 ± 0.6	$17.0^{+8.0}_{-8.9}$	5.5 ± 0.3
22	$26.5^{+8.0}_{-8.2}$	30.0 ± 0.5	$27.5^{+8.8}_{-8.8}$	2.7 ± 0.2
30	$34.7^{+6.8}_{-6.9}$	24.6 ± 0.4	$36.0^{+6.6}_{-6.5}$	2.1 ± 0.1
40	$50.4^{+6.3}_{-6.0}$	10.2 ± 0.2	$50.3^{+11.3}_{-3.6}$	2.0 ± 0.1
50	$62.3^{+6.0}_{-5.6}$	7.3 ± 0.2	$64.2^{+5.5}_{-5.2}$	1.5 ± 0.2
60	$74.3^{+4.7}_{-5.3}$	3.0 ± 0.3	$70.7^{+5.6}_{-3.0}$	(0.6 ± 0.2)

*) HWHM of the calculated frequency distribution.

VII. TOHOKU UNIVERSITY

Department of Nuclear Engineering

Faculty of Engineering

VII-1 Gamma-Ray Production Cross Sections for Fast Neutron Interactions with Tin and Barium

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A. Takahashi and K. Sugiyama

Previous studies[1] on fast neutron induced gamma-ray production cross sections were continued for natural samples of tin and barium at the neutron energies of 4.8, 5.3, 5.9 and 6.4 MeV. The pulsed monoenergetic neutrons were produced from the D(d,n) reactions using the 4.5 MV Dynamitron accelerator at Tohoku University. The gamma-rays from the sample were observed with a 70 cm^3 Ge(Li) detector at an angle of 125°. The details of the experimental procedures have been reported elsewhere[1]. Through the data analysis, cross sections for resolved gamma-lines were obtained, and those for unresolved gamma-rays were computed with a modified "FERDOR" unfolding code. The results have been fitted with the Howerton's semiempirical formula[2] in order to study the systematics of the fitting parameters. For the example, tentative results are shown in Figs. 1 and 2.

References:

1) Y. Hino, T. Yamamoto, T. Saito, Y. Arai, S. Itagaki and K. Sugiyama, J. Nucl. Sci. Tech., 15, 85 (1978), and Y. Hino T. Yamamoto, S. Itagaki and K. Sugiyama, International conf. on Nuclear Cross Sections for Technology, (1979, Knoxville).

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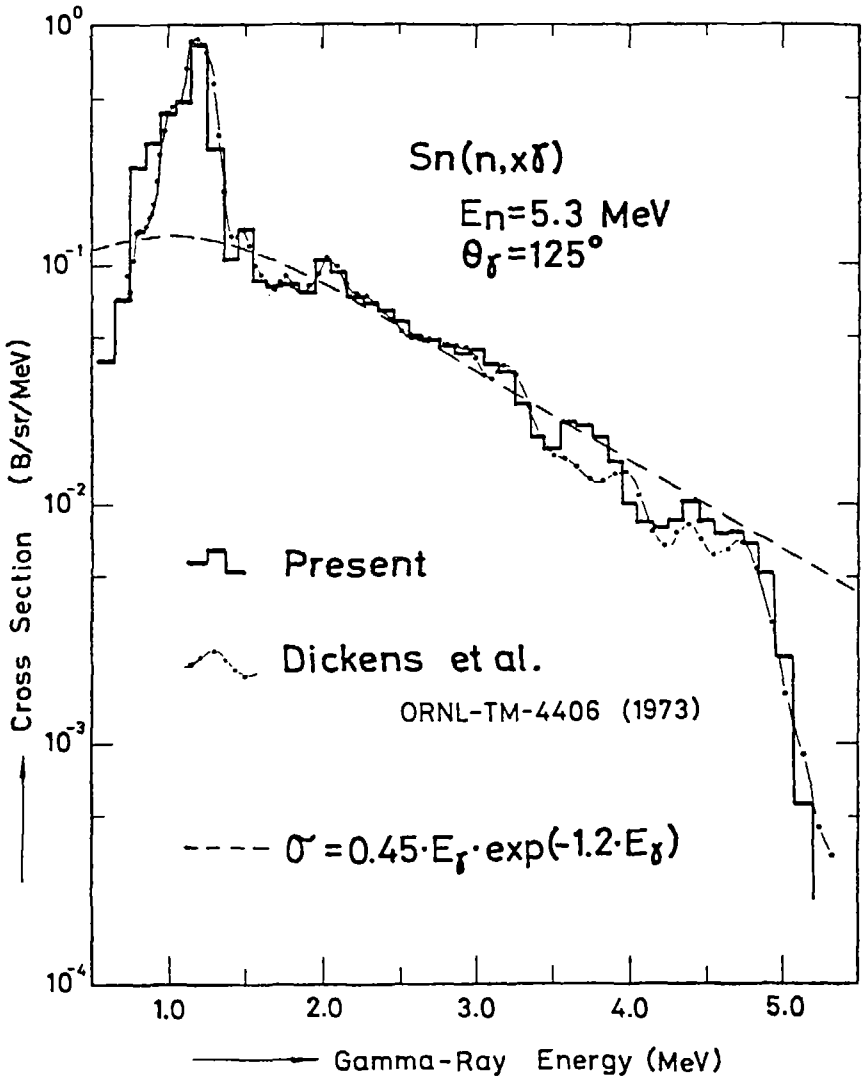

Fig. 1 Gamma-ray production cross sections for tin at 5.3 MeV.

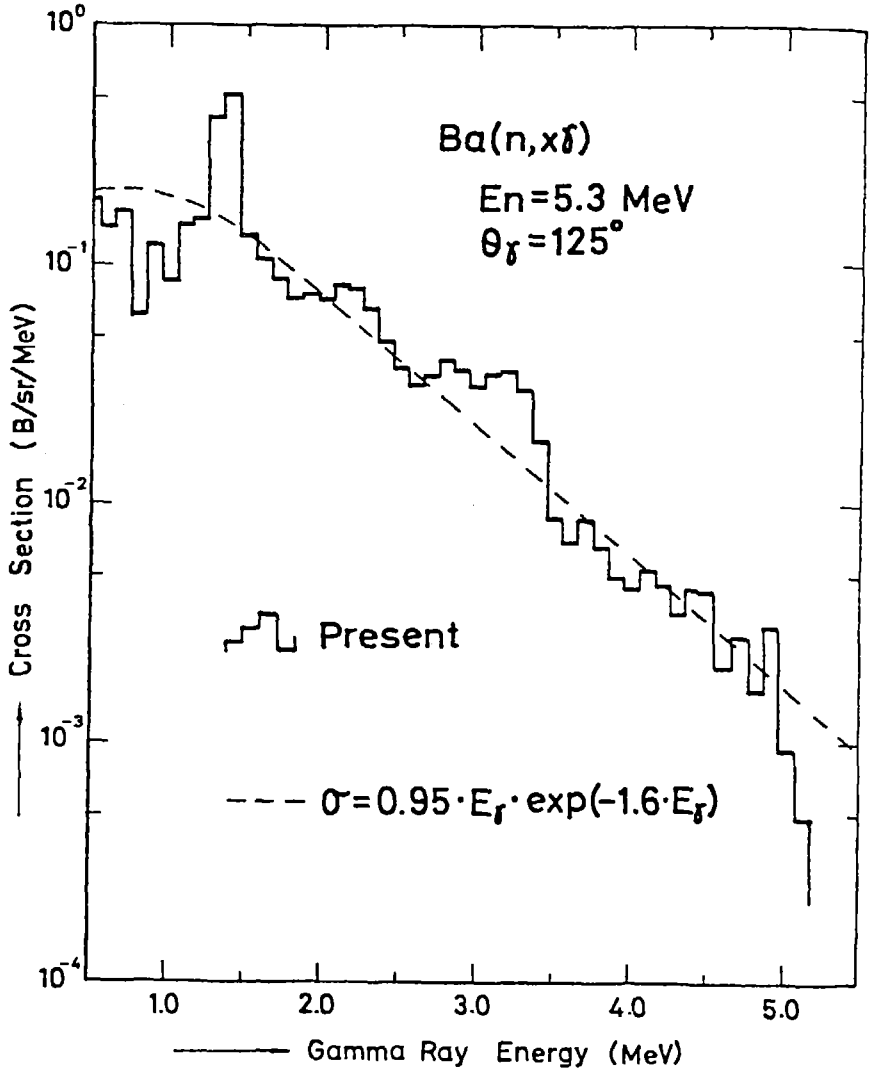

Fig. 2 Gamma-ray production cross sections for barium at 5.3 MeV.

VII-2 Measurement of Prompt Fission Neutron Spectrum of ^{232}Th at 1.5-MeV Incident Neutron Energy*

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H. Suwa, H. Takahashi and K. Sugiyama

The prompt fission neutron spectrum of ^{232}Th has been measured with a time of flight spectrometer using the Dynamitron accelerator of the Fast Neutron Laboratory at Tohoku University. Sixteen metal thorium plates** (5-cm square by 0.3-cm thick each) were arranged in the ring shape as the sample in order to get high yield of fission neutrons and good signal-background ratio. Source neutrons of 1.5 MeV were produced by bombarding a Li metal target with 3.4-MeV pulsed (2 nsec) proton beam. Secondary neutrons were measured by a 5" diam. and 2" thick NE213 liquid scintillator coupled to a RCA8854 photomultiplier tube. This detector was shielded from the primary neutrons with a 60-cm long paraffin shadow bar.

Tentative analysis of the energy spectrum above 2 MeV by a least square fitting of the Maxwellian distribution gave a temperature parameter of 1.37 ± 0.01 MeV. Detailed analysis is in progress. Further experiments will be made to confirm the obtained result.

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** The thorium plates were borrowed from Kyoto University Research Reactor Institute.

VIII. TOKYO INSTITUTE OF TECHNOLOGY

Research Laboratory for Nuclear Reactors

VIII-1 Measurement of Spectra of Gamma-rays from Capture of keV-Neutrons by ^{197}Au and ^{181}Ta

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Spectra of gamma-rays from capture of 1.5 to 75-keV neutrons by ^{197}Au and ^{181}Ta have been measured by means of time-of-flight method. Neutrons were generated by KURRI 46 MeV-linear accelerator and gamma-rays emitted from metallic sample, which was located at 12m from neutron source, were detected by a couple of C_6D_6 liquid scintillation counters.

To obtain the gamma-ray spectrum, the background subtracted measured spectrum has been unfolded using the response matrix for the scintillator, which was calculated by a Monte-Carlo code RESPO-M1. The results of spectra from $^{197}Au(n,\gamma)$ and $^{181}Ta(n,\gamma)$ reactions are shown in Figs.1 (a) and (b), respectively, together with other experimental data[1]. The agreements between them are fairly good.

It is shown that the present response function for the liquid scintillator appears slightly harder than the experimental in the range of higher energy gamma-rays, because the process of electron slowing down is briefly followed in the code RESPO-M1. The improvement for calculation of response is in progress. Capture gamma-ray spectra from $^{133}Cs(n,\gamma)$ and $^{165}Ho(n,\gamma)$ are also measured and the results are now analyzed.

Reference:

1) I. Bergqvist and N. Starfelt, Nuclear Physics 39 (1962) 353

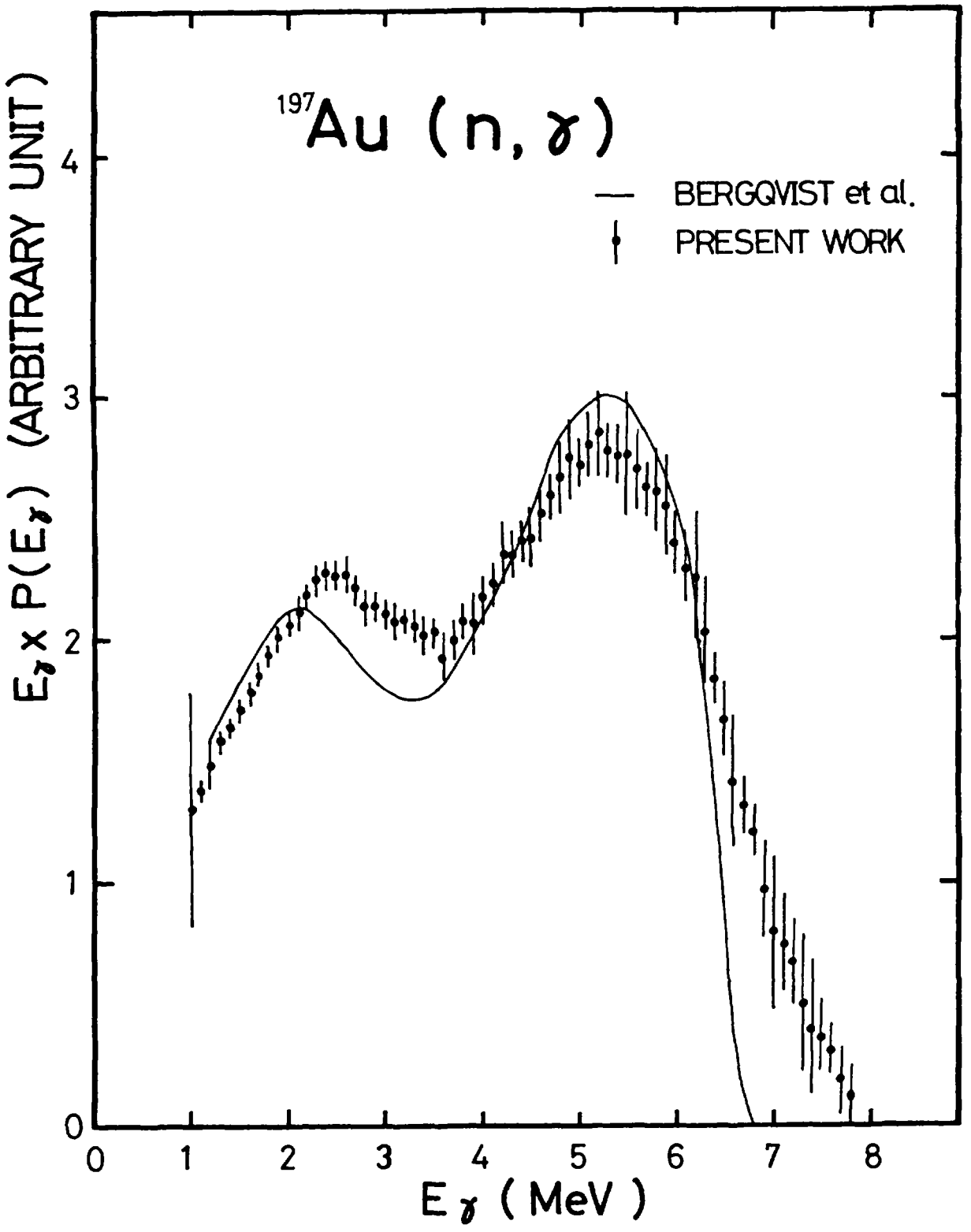

Fig.1 (a) Gamma-rays from (a) $^{197}Au(n,\gamma)$ and (b) $^{181}Ta(n,\gamma)$ reactions. The gamma-ray spectra multiplied by gamma-ray energy are normalized to equal area.

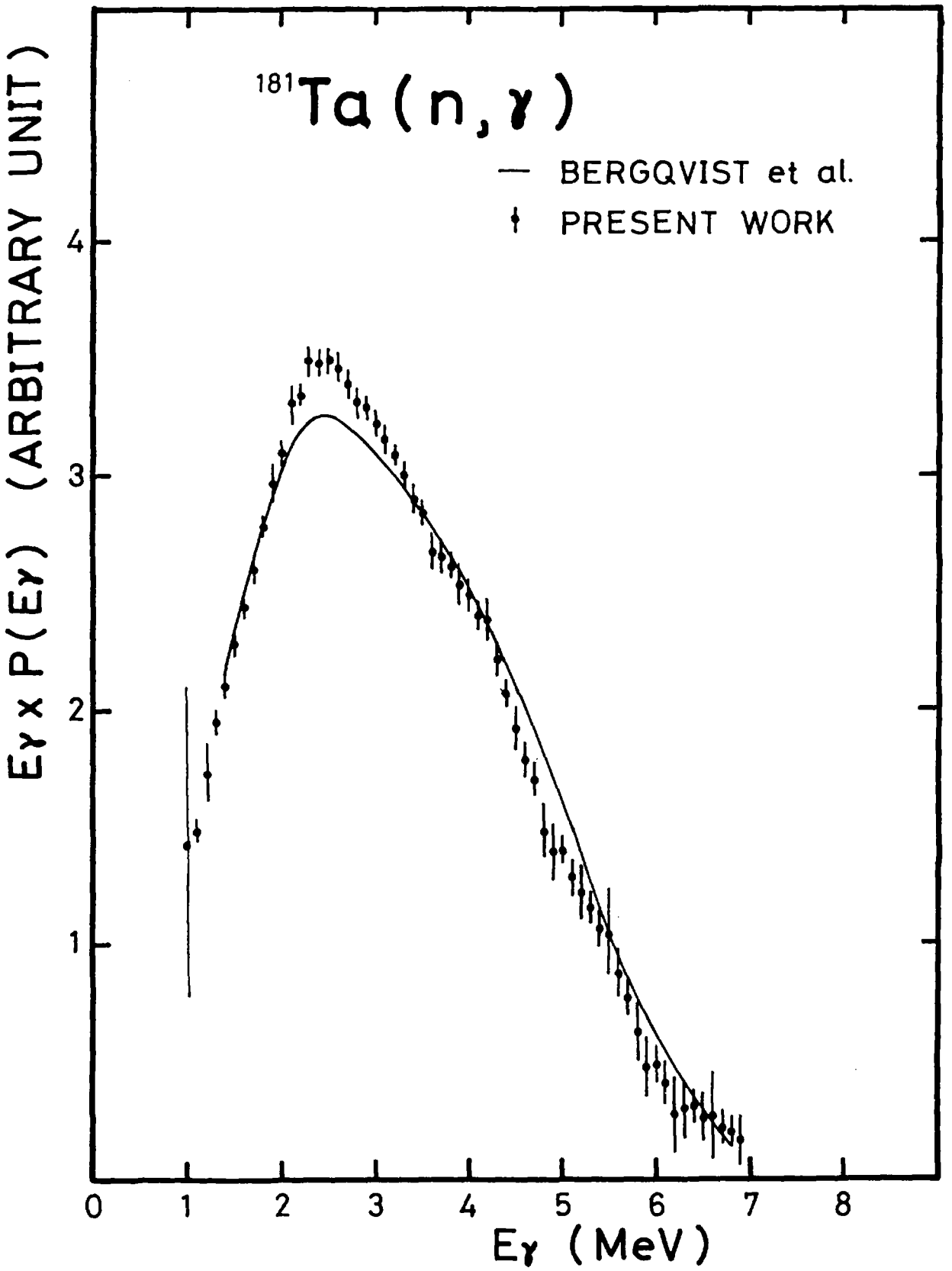
^{181}Ta (n, γ)
— BERGQVIST et al.
PRESENT WORK
Eγ x P(Eγ) (ARBITRARY UNIT)
Eγ (MeV)
0
1
2
3
4
5
6
7
8

Fig.1 (b)