NOT FOR PUBLICATION

INDC(JAP)-30"L"

NEANDC(J)-44"L"

PROGRESS REPORT

(July 1975 to June 1976 inclusive)

August 1976

Editors

T. Fuketa, T. Tamura and S. Kikuchi

Japanese Nuclear Data Committee

Japan Atomic Energy Research Institute

Tokai Research Establishment

Tokai-mura, Ibaraki-ken, Japan

NOT FOR PUBLICATION

INDC(JAP)-30"L"

NEANDC(J)-44"L"

PROGRESS REPORT

(July 1975 to June 1976 inclusive)

August 1976

Editors

T. Fuketa, T. Tamura and S. Kikuchi

Japanese Nuclear Data Committee

Japan Atomic Energy Research Institute

Tokai Research Establishment

Tokai-mura, Ibaraki-ken, Japan

Editors' 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 following 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 editors 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 the editors also let pass some simple obvious errors in the manuscripts if any.

This edition covers a period of July 1, 1975 to June 30, 1976. The information herein contained is of a nature of "Private Communication". No data contained in this report should be quoted without the author's permission.

Addressees of the request to submit report:

(in Alphabetical order)

1) Electrotechnical Laboratory
Tanashi Branch / 5-4-1, Mukaidai, Tanashi, Tokyo 188
(E. Teranishi)

2) Hiroshima University
Faculty of Science / 1-1-89 Higashi-senda, Hiroshima 730
(Y. Yoshizawa)

3) Hitach Ltd.
Atomic Energy Research Laboratory / Oozenji, Tama-ku, Kawasaki-shi, Kanagawa 215
(M. Yamamoto)

4) Hokkaido University
Faculty of Engineering / Kitajunijo, Kita-ku, Sapporo 060
(Y. Ozawa)

5) Hosei University
2-17-1 Fujimi, Chiyoda-ku, Tokyo 102
(R. Nakasima)

6) Japan Atomic Energy Research Institute
Tokai Research Establishment / Tokai-mura, Naka-gun, Ibaraki 319-11
(H. Amano, A. Asami, T. Fuketa, Y. Goto, K. Harada, M. Hirata, J. Hirota, H. Kuroi, S. Miyasaka, H. Natsume, S. Tsujimura, K. Tsukada, K. Ueno, et al.)

7) Konan University
Faculty of Science / Okamoto, Motoyama-cho, Higashinada-ku, Kobe 658
(K. Yuasa)

8) Kyoto University
a) Faculty of Engineering / Yoshida Hon-cho, Sakyo-ku, Kyoto 606
(H. Nishihara)

b) Faculty of Science / Kitashirakawa Oiwake-cho, Sakyo-ku, Kyoto 606
(J. Muto)

c) Institute of Atomic Energy / Gokanosho, Uji-shi, Kyoto 611
(T. Nishi)

d) Keage Laboratory of Nuclear Science, Institute for Chemical Research / 2 Torii-cho, Awataguchi, Sakyo-ku, Kyoto 606
(H. Takekoshi)

e) Research Reactor Institute / Kumatori, Sennan-gun, Osaka 590-04
(I. Kimura, K. Okano, S. Okamoto)

9) Kyushu University
a) Faculty of Engineering / Hakozaki-cho, Higashi-ku, Fukuoka 812
(A. Katase, M. Ohta)

b) Faculty of Science / Hakozaki-cho, Higashi-ku, Fukuoka 812
(A. Isoya, M. Kawai)

10) Mitsubishi Atomic Power Industries, Inc.
Engineering and Development Division / Kitafukuro, Omiya-shi, Saitama 330
(Y. Seki)

11) Nagoya University
Faculty of Engineering / Furo-cho, Chigusa-ku, Nagoya 464
(T. Katoh)

12) National Institute of Radiological Sciences
4-9-1 Anagawa, Chiba 280
(K. Kitao)

13) National Laboratory for High Energy Physics
Ooho-cho, Tsukuba-gun, Ibaraki 300-32
(K. Kato)

14) Nippon Atomic Industry Group Co., Ltd.
NAIG Nuclear Research Laboratory / 4-1, Ukishima-cho, Kawasaki-shi, Kanagawa 210
(S. Iijima)

15) Osaka University
a) Faculty of Engineering / Yamadaue, Suita-shi, Osaka 565
(T. Sekiya)

b) Faculty of Science / 1-1, Machikaneyama, Toyonaka-shi, Osaka 560
(M. Muraoka, K. Sugimoto)

c) Research Center for Nuclear Physics / Yamadaue, Suita-shi, Osaka 565
(S. Yamabe)

16) Radiation Center of Osaka Prefecture
704 Shinke-cho, Sakai, Osaka 593
(K. Fukuda)

17) Rikkyo (St. Paul's) University
a) Department of Physics / 3, Ikebukuro, Toshima-ku, Tokyo 171
(I. Ogawa)

b) Institute for Atomic Energy / 2-5-1, Nagasaka, Yokosuka-shi, Kanagawa 240-01
(M. Hattori)

18) Sumitomo Atomic Energy Industries, Ltd.
2-10 Kandakaji-cho, Chiyoda-ku, Tokyo 101
(H. Matsunobu)

19) The Institute of Physical and Chemical Research
2-1, Hirosawa, Wako-shi, Saitama 351
(A. Hashizume)

20) Tohoku University
a) Faculty of Engineering / Aza-Aoba, Aramaki, Sendai 980
(T. Momota)

b) Faculty of Science / Aza-Aoba, Aramaki, Sendai 980
(S. Morita)

c) Laboratory of Nuclear Science / 1 Kanayama, Tomisawa, Sendai 982
(Y. Torizuka)

21) Tokai University
Faculty of Engineering / 2-28-4 Tomigaya, Shibuya-ku, Tokyo 151
(Y. Kuroda)

22) Tokyo Institute of Technology
a) Faculty of Science / 2-12-1 Ohokayama, Meguro-ku, Tokyo 152
(K. Hisatake, Y. Oda, H. Taketani)

b) Research Laboratory of Nuclear Reactor / 2-12-1 Ohokayama, Meguro-ku, Tokyo 152
(N. Yamamuro)

23) University of Tokyo
a) Faculty of Engineering / 7-3-1 Hongo, Bunkyo-ku, Tokyo 113
(S. An, A. Sekiguchi)

b) Faculty of Science / 7-3-1 Hongo, Bunkyo-ku, Tokyo 113
(Y. Nogami)

c) Institute for Nuclear Study / 3-2-1 Midori-cho, Tanashi, Tokyo 188
(Y. Ishizaki, H. Kamitsubo, M. Sakai)

d) The Institute for Solid State Physics / 7-22-1 Roppongi, Minato-ku, Tokyo 106
(K. Ohno)

24) University of Tsukuba
Institute of Physics / Ooaza-Saiki, Sakura-mura, Niihari-gun, Ibaraki-ken 300-31
(J. Sanada)

25) Waseda University
School of Science and Engineering / 4-170 Nishi-Ohkubo, Shinjuku-ku, Tokyo 160
(M. Yamada)

CONTENTS

Contents of the Japanese Progress Report INDC(JAP)30L (NEANDC(J)44L) August 1976

ELEMENT S A	QUANTITY	ENERGY(EV) MIN	MAX	LAB	TYPE	DOCUMENTATION REF VOL PAGE	DATE	COMMENTS
LI 006	Evaluation	1.0-5	2.0+7	JAE	Eval Prog	NEANDC(J)44L16	8/76	NAKAGAWA.DATA IN JENDL-1 LIBRARY
LI 007	Diff Elastic	4.5+6	7.0+6	TOH	Expt Prog	NEANDC(J)44L61	8/76	BABA+.TOF, FROM 30 TO 135 DEG.NDG
LI 007	Diff Inelast	4.5+6	7.0+6	TOH	Expt Prog	NEANDC(J)44L61	8/76	BABA+.TOF, FROM 30 TO 135 DEG.NDG
LI 007	(n,nt)	4.5+6	7.0+6	TOH	Expt Prog	NEANDC(J)44L61	8/76	BABA+.TOF, FROM 30 TO 135 DEG.NDG
C 012	Nonelastic γ	5.3+6	1.4+7	TOH	Expt Prog	NEANDC(J)44L62	8/76	HINO+.DIFF.SIG (N,XG) GIVEN IN TBL
O 016	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND. TO JENDL-1, NDG
F 019	(n,α)	TR	2.0+7	JAE	Eval Prog	NEANDC(J)44L19	8/76	SUGI+.STATISTICAL CAL ABOVE 9 MEV, NDG
F 019	(n,d)	TR	2.0+7	JAE	Eval Prog	NEANDC(J)44L19	8/76	SUGI+.STATISTICAL CALCULATION, NDG
F 019	(n,p)	TR	2.0+7	JAE	Eval Prog	NEANDC(J)44L19	8/76	SUGI+.STATISTICAL CAL ABOVE 9 MEV, NDG
F 019	(n,t)	TR	2.0+7	JAE	Eval Prog	NEANDC(J)44L19	8/76	SUGI+.STATISTICAL CALCULATION, NDG
F 019	Tot Inelastic	5.0+5	5.0+6	JAE	Eval Prog	NEANDC(J)44L18	8/76	SUGI+.OPTICAL MODEL CALCULATION, NDG
F 019	Total	5.0+6	2.0+7	JAE	Eval Prog	NEANDC(J)44L18	8/76	SUGI+.OPTICAL MODEL CALCULATION, NDG
NA 023	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND.TO JENDL-1, NDG
AL 027	(n,α)	TR	2.0+7	JAE	Eval Prog	NEANDC(J)44L20	8/76	ASAMI.NORM TO NEW STD AND 14 MEV DATA
AL 027	Nonelastic γ	5.3+6	1.4+7	TOH	Expt Prog	NEANDC(J)44L62	8/76	HINO+.DIFF.SIG (N,XG) GIVEN IN TBL
AL 027	(n,p)	TR	2.0+7	JAE	Eval Prog	NEANDC(J)44L20	8/76	ASAMI.NORM TO NEW STD AND 14 MEV DATA
S 032	Diff Elastic	2.2+7		JAE	Expt Prog	NEANDC(J)44L12	8/76	YAMANOUTI+.REPORTED AT ICINN 76LOWEL
S 032	Diff Inelast	2.2+7		JAE	Expt Prog	NEANDC(J)44L12	8/76	YAMANOUTI+.REPORTED AT ICINN 76LOWEL
V 051	Diff Inelast	1.4+7		KYU	Expt Prog	NEANDC(J)44L53	8/76	IRIE+.PUBLISHED IN NST 13 (76) 334
CR	Evaluation		1.5+7	JAE	Eval Prog	NEANDC(J)44L21	8/76	IGARASI+.DATA IN JENDL-1 LIBRARY
CR 050	Evaluation		1.5+7	JAE	Eval Prog	NEANDC(J)44L21	8/76	IGARASI+.DATA IN JENDL-1 LIBRARY
CR 052	Evaluation		1.5+7	JAE	Eval Prog	NEANDC(J)44L21	8/76	IGARASI+.DATA IN JENDL-1 LIBRARY
CR 053	Evaluation		1.5+7	JAE	Eval Prog	NEANDC(J)44L21	8/76	IGARASI+.DATA IN JENDL-1 LIBRARY
CR 054	Evaluation		1.5+7	JAE	Eval Prog	NEANDC(J)44L21	8/76	IGARASI+.DATA IN JENDL-1 LIBRARY
FE	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND.TO JENDL-1, NDG
FE	Nonelastic γ	5.3+6	1.4+7	TOH	Expt Prog	NEANDC(J)44L62	8/76	HINO+.DIFF.SIG (N,XG) GIVEN IN TBL
FE 056	(n,p)	1.5+7		JAP	Expt Prog	NEANDC(J)44L 5	8/76	KUDO.SIG=107.1+-3.1 MB
CO 059	Spect (n,γ)		5.0+3	JAE	Expt Prog	NEANDC(J)44L 9	8/76	MIZUMOTO.LINAC.20M TOF,GH(LI) DET NDG
NI	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND.TO JENDL-1, NDG
NI 058	(n,p)	TR	2.0+7	JAE	Eval Prog	NEANDC(J)44L20	8/76	ASAMI.NORM TO NEW STD AND 14 MEV DATA
CU	Evaluation	1.0-5	1.5+7	JAE	Eval Prog	NEANDC(J)44L22	8/76	SASAKI.DATA IN JENDL-1 LIBRARY
CU	Nonelastic γ	5.3+6	1.4+7	TOH	Expt Prog	NEANDC(J)44L62	8/76	HINO+.DIFF.SIG (N,XG) GIVEN IN TBL
CU 063	Evaluation	1.0-5	1.5+7	JAE	Eval Prog	NEANDC(J)44L22	8/76	SASAKI.DATA IN JENDL-1 LIBRARY
CU 065	Evaluation	1.0-5	1.5+7	JAE	Eval Prog	NEANDC(J)44L22	8/76	SASAKI.DATA IN JENDL-1 LIBRARY
ZR 090	Tot Inelastic	1.5+7		NAG	Expt Prog	NEANDC(J)44L57	8/76	BHORASKAR+.SIG TO META=700+-94 MB
NB 093	Diff Inelast	1.4+7		KYU	Theo Prog	NEANDC(J)44L55	8/76	IRIE+.PUBLISHED IN JPJ 39(76) 537
NB 094	(n,γ)	PILE		JAE	Expt Prog	NEANDC(J)44L42	8/76	SEKINE+.ACT. SIG (G+META)=15.4+-0.6 B
MO 092	Evaluation	1.0-5	1.5+7	JAE	Eval Prog	NEANDC(J)44L23	8/76	HOJUYAMA.DATA IN JENDL-1 LIBRARY

ELEMENT S A	QUANTITY	ENERGY(EV) MIN	MAX	LAB	TYPE	DOCUMENTATION REF VOL PAGE	DATE	COMMENTS
MO 094	Diff Elastic	5.1+6	8.0+6	JAE	Expt Prog	NEANDC(J)44L13	8/76	TANAKA+.REPORTED AT ICINN 76LOWELL
MO 094	Diff Inelast	5.1+6	8.0+6	JAE	Expt Prog	NEANDC(J)44L13	8/76	TANAKA+.REPORTED AT ICINN 76LOWELL
MO 094	Inelastic γ	1.5+6	4.0+6	JAE	Expt Prog	NEANDC(J)44L14	8/76	SUGIYAMA+.PUBLISHED IN NP/A264, 179
MO 094	Evaluation	1.0-5	1.5+7	JAE	Eval Prog	NEANDC(J)44L23	8/76	HOJUYAMA.DATA IN JENDL-1 LIBRARY
MO 096	Diff Elastic	5.1+6	8.0+6	JAE	Expt Prog	NEANDC(J)44L13	8/76	TANAKA+.REPORTED AT ICINN 76LOWELL
IN	(n,γ)	2.4+4		TIT	Expt Prog	NEANDC(J)44L65	8/76	YAMAMURO+.LINAC, FE-FILTER.SIG=750MB
CS 133	(n,γ)	2.4+4		TIT	Expt Prog	NEANDC(J)44L65	8/76	YAMAMURO+.LINAC, FE-FILTER.SIG=580MB
DY 165	(n,γ)	PILE		JAE	Expt Prog	NEANDC(J)44L43	8/76	SEKINE+.ACT.SIG (DY165G)=4400+-300B
DY 165	(n,γ)	PILE		JAE	Expt Prog	NEANDC(J)44L43	8/76	SEKINE+.ACT.SIG (DY165M)=2100+-300B
TA 181	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND.TO JENDL-1, NDG
TA 181	(n,γ)	2.4+4		TIT	Expt Prog	NEANDC(J)44L65	8/76	YAMAMURO+.LINAC, FE-FILTER.SIG=850 MB
AU 197	Diff Inelast	1.4+7		KYU	Expt Prog	NEANDC(J)44L53	8/76	IRIE+.PUBLISHED IN NST 13 (76) 334
PB 207	Tot Inelastic	4.1+6	5.2+6	NAG	Expt Prog	NEANDC(J)44L57	8/76	BHORASKAR+.SIG(META)=316 TO 788 MB
PB 208	(n,γ)	5.0+6	2.0+7	TIT	Theo Prog	NEANDC(J)44L66	8/76	KITAZAWA+.PUBLISHED IN JPJ 41 (76)
TH 232	(n,γ)	2.4+4		TIT	Expt Prog	NEANDC(J)44L65	8/76	YAMAMURO+.LINAC,FE-FILIER. SIG=490 MB
U 233	Fiss Yield	THR		KTO	Expt Prog	NEANDC(J)44L44	8/76	IMANISHI+.PUBLISHED IN NP/A 263,141
U 235	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND.TO JENDL-1, NDG
U 235	Fission	6.0+6	1.5+7	JAE	Eval Prog	NEANDC(J)44L24	8/76	NAKAGAWA.DATA IN JENDL-1 LIBRARY
U 235	Fiss Yield	THR		KTO	Expt Prog	NEANDC(J)44L44	8/76	IMANISHI+.PUBLISHED IN NP/A 263, 141
U 238	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND. TO JENDL-1, NDG
U 238	Evaluation	1.0-5	2.0+7	JAE	Eval Prog	NEANDC(J)44L25	8/76	NAKAGAWA.DATA IN JENDL-1 LIBRARY
U 238	Reson Params	2.0+1	5.0+3	JAE	Expt Prog	NEANDC(J)44L 8	8/76	NAKAJIMA+.D=21.9EV. SO=1.15×10-4
U 238	Spect (n,γ)	2.5-2	1.0+6	KYU	Theo Prog	NEANDC(J)44L55	8/76	OHSAWA+.STATISTICAL MODEL CALC. NDG
PU 239	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND.TO JENDL-1, NDG
PU 239	Evaluation	1.0+2	1.5+7	JAE	Expt Prog	NEANDC(J)44L28	8/76	KAWAI.TOT, SEL, NF, NG, ETC.FIGS GIVEN
PU 239	Fiss Yield	THR		KTO	Expt Prog	NEANDC(J)44L44	8/76	IMANISHI+.PUBLISHED IN NP/A 263, 141
PU 240	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND.TO JENDL-1, NDG
PU 241	Evaluation			JAE	Eval Prog	NEANDC(J)44L37	8/76	MATSUNOBU+.RECOMMEND.TO JENDL-1, NDG
PU 241	Evaluation	THR	1.5+7	JAE	Eval Prog	NEANDC(J)44L32	8/76	KIKUCHI.DATA IN JENDL-1 LIBRARY
AM 241	Evaluation	THR	1.5+7	JAE	Eval Prog	NEANDC(J)44L35	8/76	NAKAGAWA+.FIG OF (N,F) GIVEN
MANY	Diff Inelast	1.4+7		KYU	Theo Prog	NEANDC(J)44L54	8/76	IRIE+.PUBLISHED IN PL/B 62(76) 9
MANY	(γ,n)			JAP	Eval Prog	NEANDC(J)44L 1	8/76	TOMIMASU. SYSTEMATICS. A=63 TO 209

I. ELECTROTECHNICAL LABORATORY

Quantum Technical Division

I-1 Systematic Discrepancy in Photoneutron Cross Sections

T. Tomimasu

A part of this paper is published in Proceedings of Kawatabi Conference on New Giant Resonances[1]. The shape and magnitude of the photoneutron cross sections for medium and heavy nuclei of mass number ranging from 63 to 209 are compared to find out a systematic discrepancy between the cross sections obtained using the NBS P2 chamber as a bremsstrahlung beam monitor and those obtained by other experimental techniques such as the positron annihilation-in-flight. The Shape of the both cross sections is in good agreement at least in the low energy side of the giant resonance but the former cross sections in general are observed to be systematically larger than the latter. The discrepancy of about 10 % is demonstrated in the peak cross section values for medium nuclei as shown in Fig.1. This may be explained in the good direction by a systematic discrepancy of 6 % in the calibration constants of the NBS P2 chamber shown in Fig.2, because the highest values in thse calibration constants can almost eliminate the 10 % discrepancy. The definite discrepancy can not be demonstrated for heavy nuclei because of the large discrepancy of about 30 % found in the cross sections obtained with γ-rays from positron annihilation-inflight as shown in Figs.3 and 4.

1) T. Tomimasu, Supplement to Research Peport of Laboratory of Nuclear Science, Tohoku University, Vol.8, p.23 (Dec. 1976)

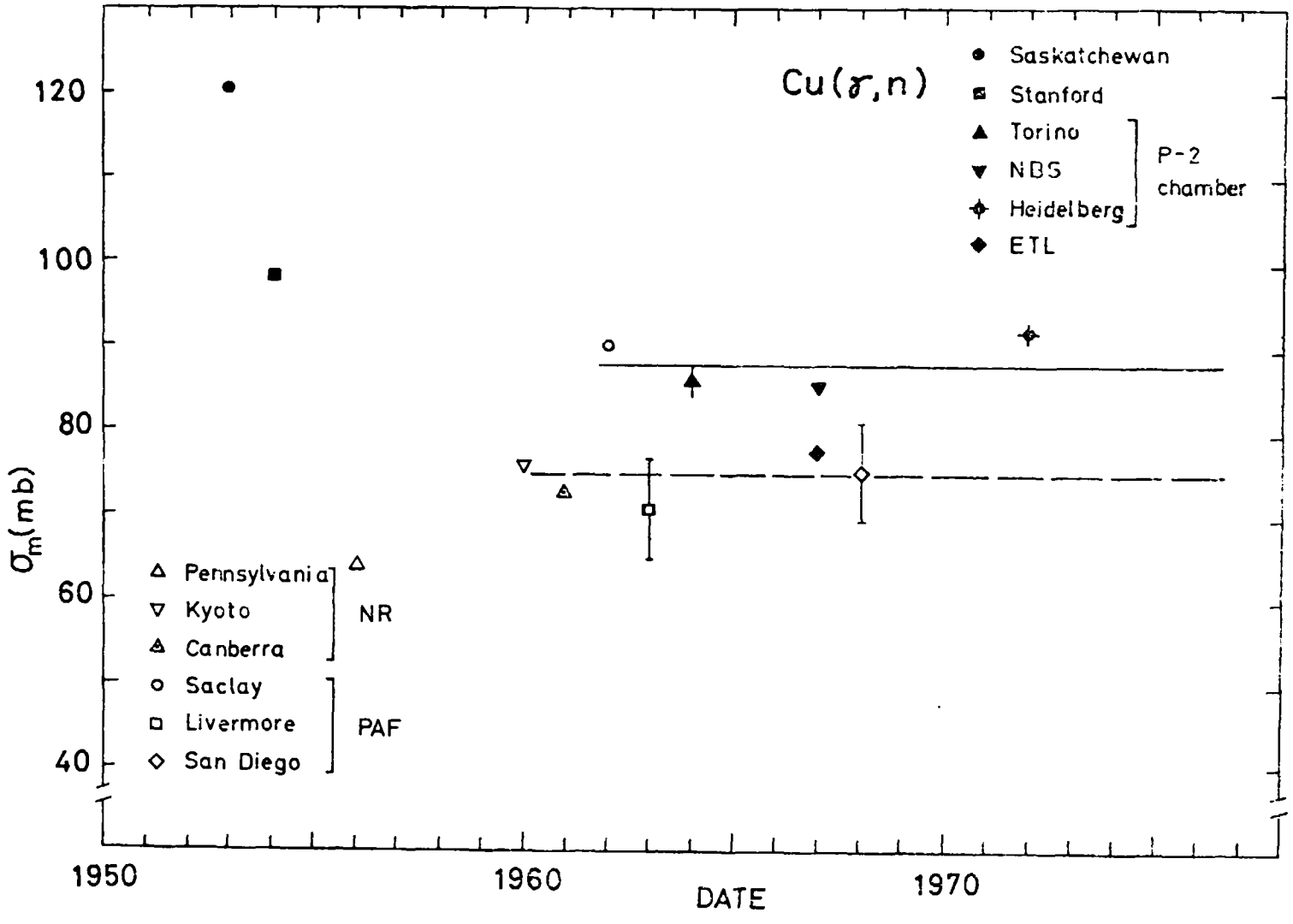


Fig.1 Annalistic change in absolute peak cross section values for copper. The solid line shows the average value of the BS peak values obtained using the NBS P2 chamber. The dotted line shows the average value of the PAF and NR values.

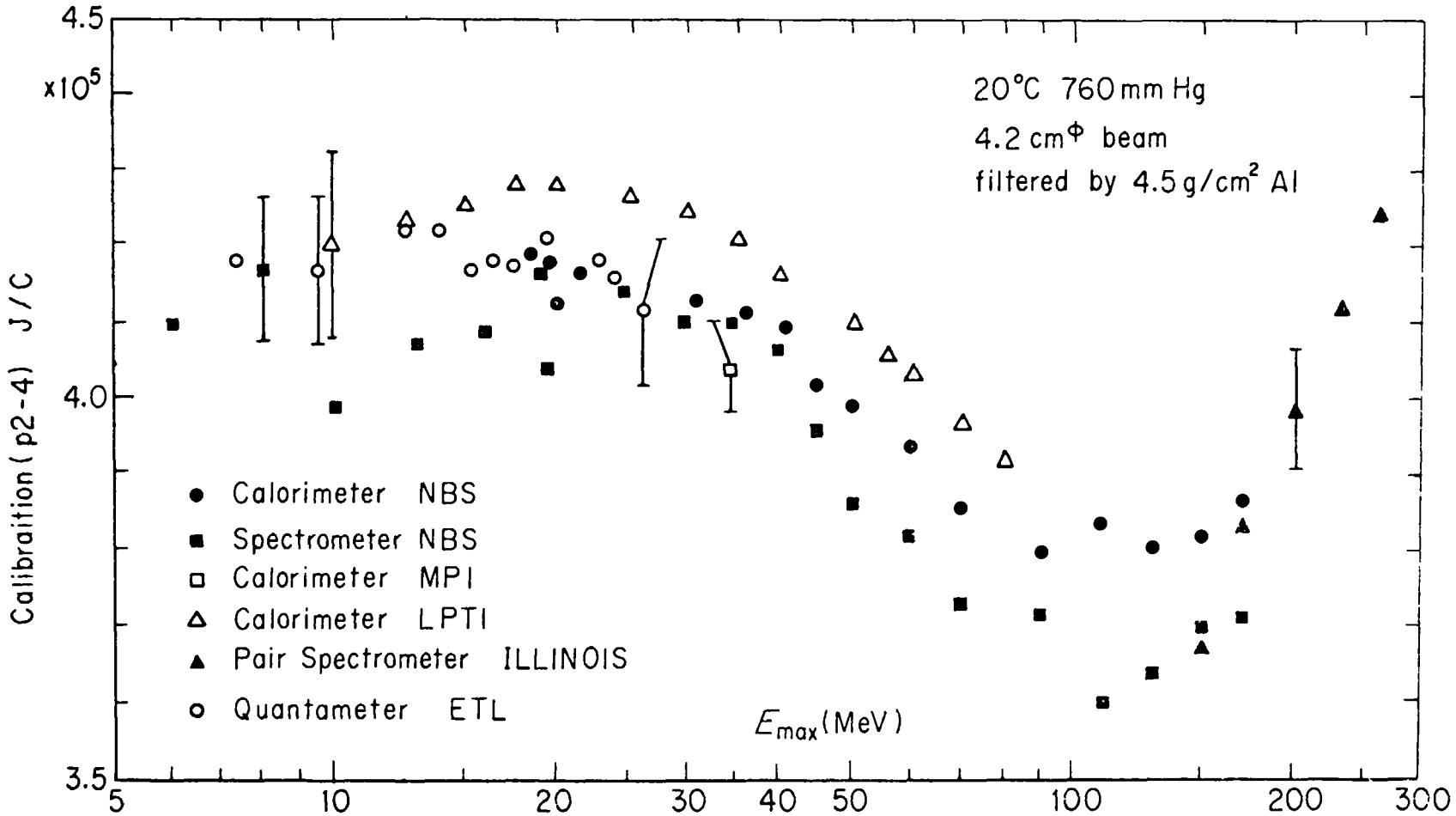


Fig.2 Calibration constants of the NBS P2 chamber at 20°C and 760 mmHg.

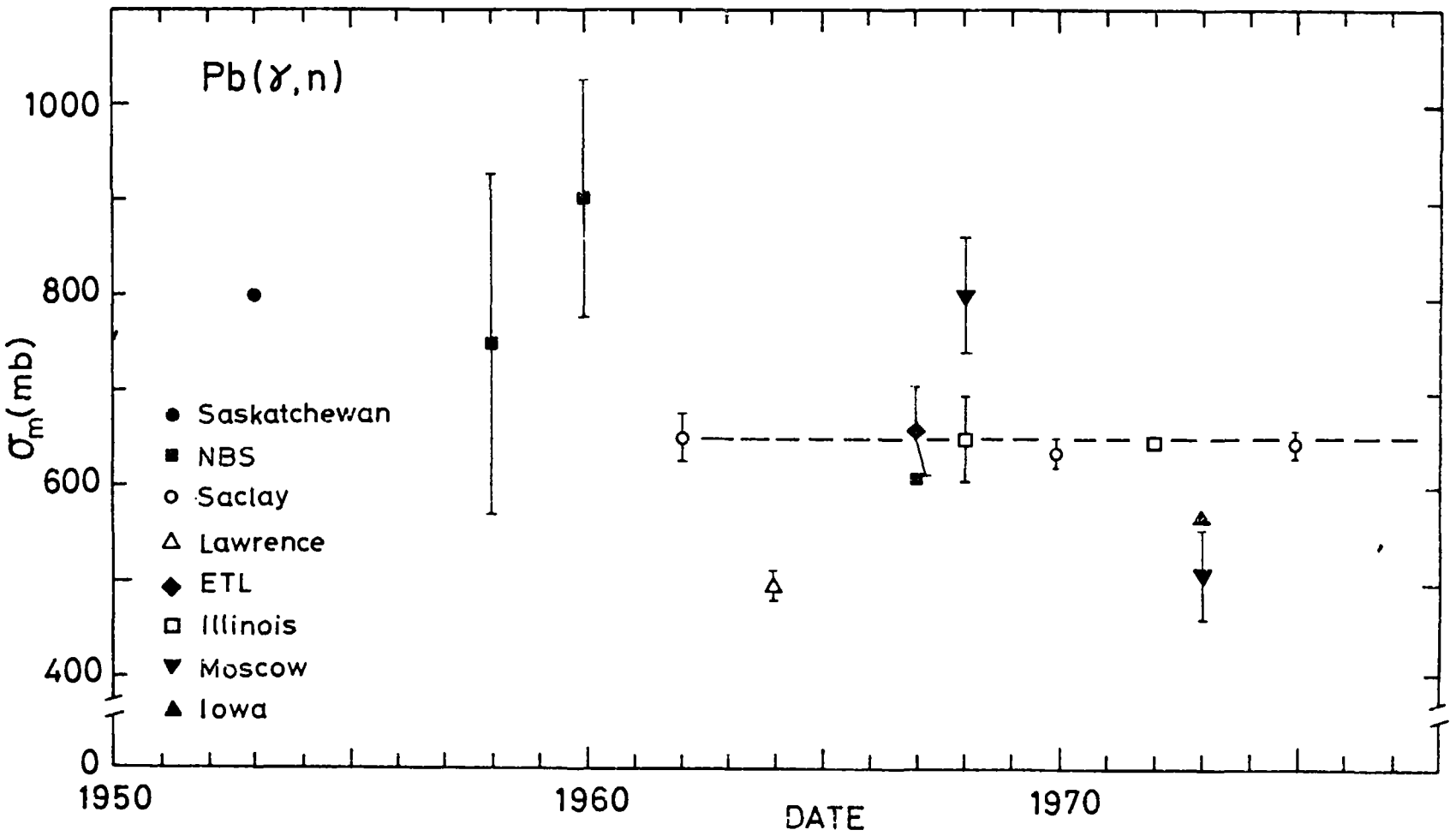


Fig.3 Annalistic change in absolute peak values for lead. The dotted line shows the average value of the peak values obtained at Saclay, NBS, ETL, and Illinois.

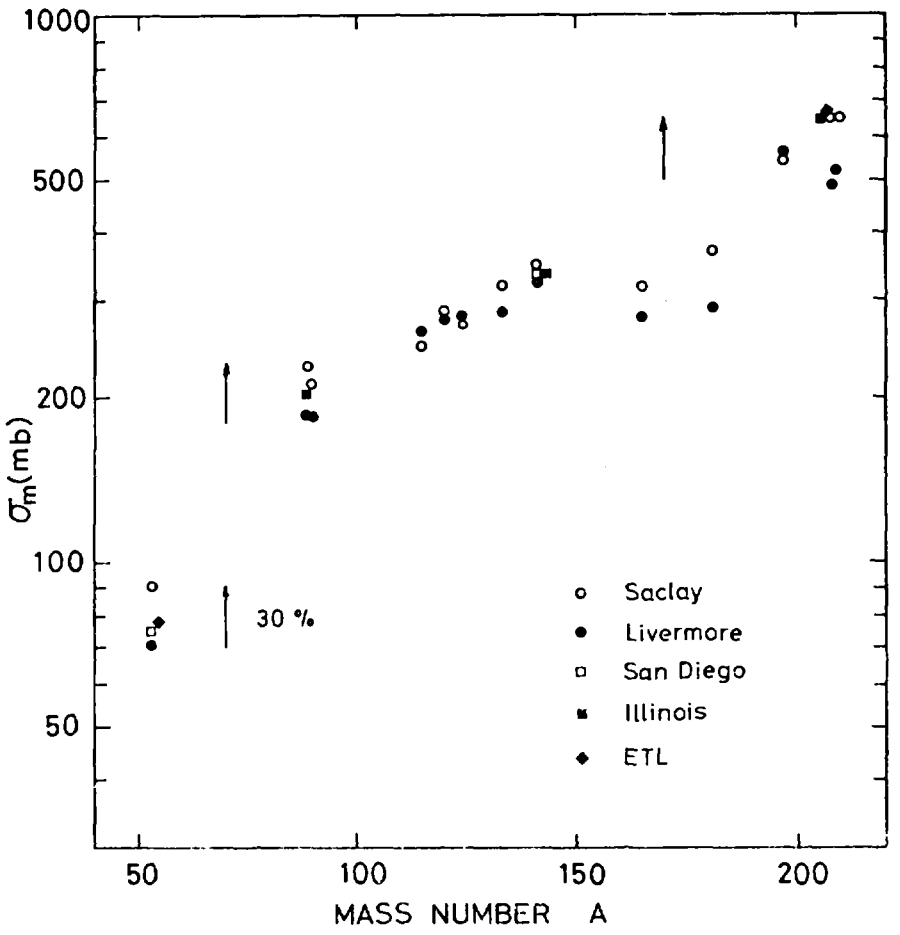


Fig. 4 Large discrepancies found in the PAF and PT cross sections. Our BS values are shown as references.

I-2 Absolute Measurement of $^{56}Fe(n,p)^{56}Mn$ Cross Section at 14.8MeV

K.Kudo

The value of $^{56}Fe(n,p)^{56}Mn$ cross section obtained was 107.1 ± 3.1 mb at 14.8MeV neutron energy, and the square root of quadratic sum of errors in this measurements was ± 2.9 %.

II. HIROSHIMA UNIVERSITY

Department of Physics, Faculty of Science

II-1 Evaluation of Gamma-Ray Intensities

Y. Yoshizawa, H. Inoue, M. Hoshi and K. Shizuma

Relative intensities and intensities per decays of gamma rays for ten nuclides were evaluated. For some of them intensities per decays are nearly 100% and the source strengths can be accurately determined by the beta-gamma or X-gamma coincidence method. These gamma-ray intensities are almost independent of the gamma-ray intensity measurement. Therefore, these gamma rays are the best basic standards and are listed in the following table of the primary standards. Intensities of other gamma rays which were in requests of the atomic fuel problem are evaluated by using observed intensities.

Table I Gamma-ray intensities of primary standards

Nuclide	Energy (keV)	Relative intensity (%)	Intensity per decay (%)
^{22}Na	1275		99.94 ±0.02
^{46}Sc	889	99.9953±0.0020	99.9829±0.0017
	1120	100.0000	99.9875±0.0011
^{48}Sc	983	99.9968±0.0015	99.9876±0.0012
	1037	97.53 ±0.16	97.52 ±0.16
	1312	100.0000	99.9908±0.0009
^{48}V	983	100.00	99.9826±0.0013
	1312	97.22 ±0.33	97.20 ±0.33
^{54}Mn	834		99.976 ±0.003
^{60}Co	1173	99.91 ±0.02	99.89 ±0.02
	1332	100.00	99.9813±0.0015
^{95}Nb	766		99.80 ±0.02
^{134}Cs	605	100.00	97.50 ±0.07
	796	87.26 ±0.43	85.08 ±0.42
^{203}Hg	279		81.48 ±0.08

Table II Other gamma-ray intensities

Nuclide	Energy (keV)	Relative intensity (%)	Intensity per decay (%)
^{22}Na	511	178.6 ±0.1	178.5 ±0.1
	1275	100.0 ±0.02	99.94 ±0.02
^{95}Zr	724	80.6 ±0.8	44.04 ±0.24
	757	100.00	54.62 ±0.24
^{106}Ru	512	100	20.5 ±0.6
	616	3.64 ±0.23	0.75 ±0.05
	622	48.1 ±1.1	9.85 ±0.31
	874	2.10 ±0.06	0.431±0.017
	1050	7.36 ±0.21	1.51 ±0.06
	1128	1.94 ±0.05	0.398±0.015
	1562	0.772±0.023	0.158±0.007
^{134}Cs	242	0.020±0.010	0.020±0.010
	326	0.020±0.010	0.020±0.010
	475	1.56 ±0.06	1.52 ±0.08
	563	8.88 ±0.29	8.48 ±0.33
	569	15.7 ±0.5	15.3 ±0.7
	605	100.0 ±3.2	97.50 ±0.07
	796	89.1 ±2.7	85.08 ±0.42
	802	9.03 ±0.33	8.81 ±0.43
	1038	1.04 ±0.04	1.01 ±0.05
	1168	1.97 ±0.04	1.92 ±0.07
	1365	3.36 ±0.10	3.28 ±0.14
^{137}Cs	662		85.2 ±0.4

III. JAPAN ATOMIC ENERGY RESEARCH INSTITUTE

A. Linac Laboratory

III-A-1 Neutron Resonance Parameters of ^{238}U

Y. Nakajima, A. Asami, M. Mizumoto,
T. Fuketa and H. Takekoshi*

Preliminary results of the transmission measurements on ^{238}U were presented at the Conference on Nuclear Cross Sections and Technolgy held at Washington, USA in March, 1975.

Excluding p-wave resonances assigned by F. Corvi et al.[1], a mean level spacing $\bar{D}$ = 21.9 ± 1.5 eV was determined up to 1300 eV neutron energy.

Assuming that all observed resonances in the energy range up to 4000 eV are due to s-wave neutrons, the strength function $s_o=(1.15\pm0.18)\times10^{-4}$ was obtained.

Final results will be published in near future.

References:

1) F. Corvi et al., Proc. Conf. on Nuclear Cross Sections and Technology, Washington, 1975, Vol.2, p. 733

---

* Present address: Keage Laboratory of Nuclear Science, Kyoto University.

III-A-2 A Facility for Neutron Capture Gamma Ray Experiments

Motoharu Mizumoto

The study of neutron capture gamma-rays was started on the 20m flight path of the neutron TOF spectrometer at the JAERI linac.

Capture gamma rays are detected with a 55 cc Ge(Li) detector and recorded on a magnetic tape using a gain stabilizer and an event recording system.

In order to check the performance of this facility a preliminary experiment was carried out to measure the gamma ray spectra of the $^{59}Co\ (n,\gamma)\ ^{60}Co$ reaction as a function of neutron energy in the region below 5 keV.

III-A-3

Decay of ^{109}Rh

M.Kanazawa*, Z.Matumoto, T.Tamura and S.Ohya**

The γ-and β-radiations of ^{109}Rh have been studied by using Ge(Li) and anthracene detectors. The activities were produced by the ^{110}Pd(γ,p) reaction. From the decay curve analyses of β-and γ-ray spectra, the half-life of ^{109}Rh was determined to be 80±2sec. No other activities reported earlier in the literatures[1,2] were observed. From $\gamma\gamma$-coincidence experiments, 16 γ-rays observed were incorporated in the level scheme of ^{109}Pd. The half-life of the first excited state at 113keV was determined to be 0.38 ± 0.05 μsec. This value is quite close to the single-particle E2 transition rate for the $s_{1/2} \rightarrow d_{5/2}$ configuration (enhance factor≈1.3).

References:

1) Nuclear Data Sheets 6 1 (1971)

2) Fettweis et al., Z.phys.A275 359 (1975)

---

* Research student from Niigata University

** Niigata University

III-A-4 Decay of ^{113m}Ag (1.2min)

Z.Matumoto and T.Tamura

The decay properties of ^{113m}Ag (1.2 min) was reported previously.[1] We recently reinvestigated the ^{113m}Ag by high resolution semi-conductor detectors.

A 43.2 keV γ-ray, KX-rays and L-conversion lines were observed and an E3 character of this isomer was verified experimentally. From the deduced IT and β-transition rates, the log ft values for the β-transitions to the ^{113}Cd levels were determined. The low log ft value of 4.6 to the 708.5 keV level indicates allowed favoured character in the following scheme:

$$[(g_{9/2})^3_{p\ 7/2^+} + (g_{7/2})^2_{n\ 0^+})^{7/2} \rightarrow [(g_{9/2})^2_{p\ 2^+} + (g_{7/2})_{n\ 7/2^+}]^{5/2}$$

$$\therefore\ (g_{7/2}) \xrightarrow{\beta^-} (g_{9/2})_p\ .$$

Reference:

1) Z.Matumoto and T.Tamura, J. phys. Soc. Japan 29 116 (1970)

B. Nuclear Physics Laboratory

III-B-1 SCATTERING OF 21.5 MeV NEUTRONS FROM ^{32}S

Y. YAMANOUTI and S. TANAKA

The results of the coupled-channel analysis of the elastic and inelastic scattering of 21.5 MeV neutrons from ^{32}S(a continuation of NEANDC(J)-42"L" p.6) were reported at the International Conference on the Interactions of Neutrons with Nuclei held at Lowell, Massachusetts, U.S.A. in July 6-9, 1976. The abstract is as follows:

In order to study the reaction mechanism of the (n,n') reaction in the unexplored energy region and the collective properties on ^{32}S, differential cross sections for elastic scattering and inelastic scattering leading to the 2.230(2^+), 3.778(0^+), 4.281(2^+), 4.458(4^+) and 5.007 MeV (3^-) states and to the excited states around 6 MeV were measured at an incident energy of 21.5 MeV. The 21.5 MeV neutrons were generated by the $^3H(d,n)^4He$ reaction using pulsed deuteron beams from the JAERI 5.5 MV Van de Graaff accelerator. The conventional time-of-flight technique was employed to detect neutrons. These differential cross sections were corrected for finite angular resolution, flux attenuation and multiple scattering in the sample by the Monte Carlo method.

The data were analyzed by the optical model and the coupled-channel theory. Better fit to the experimental cross sections was obtained in the coupled-channel calculations based on the vibrational model by introducing the admixture of the one-phonon component into the two-phonon state. This admixture between the 2^+states removed discrepancies between the vibrational model B(E2) values and the observed B(E2) values, and also explained the non-vanishing electric quadrupole moment of ^{32}S.

III-B-2 Neutron Scattering from ^{94}Mo and ^{96}Mo

S. Tanaka and Y. Yamanouti

The paper on this subject was presented at the International Conference on the Interactions of Neutrons with Nuclei held at Lowell, Massachusetts, USA in July 6 - 9, 1976 with an abstract as follows:

We have recently shown that in the energy region of several hundred keV to 15 MeV coupled-channel calculations with one set of the optical parameters well reproduce the total scattering cross sections of neutrons over a wide mass region[1]. As a continuing study of this, neutron scattering cross sections of ^{94}Mo and ^{96}Mo were measured in the energy range of 5.1 to 8.0 MeV by using the TOF method, and the results were compared with the coupled-channel and spherical optical model calculations.

The measurement was done by using a multi-angle TOF spectrometer with four detectors of 12.5 cm in diameter and with flight paths of 8 m. The absolute differential cross section scale was fixed with reference to $^{1}H(n,n)^{1}H$ cross sections by observing the neutron group scattered from a polyethylene sample. The ^{94}Mo sample* was a metal right cylinder, 2 cm in diameter and 2.2 cm high, and the ^{96}Mo sample* was metal powder packedin a cylinder of a thin aluminium pouch, 3.5 cm in diameter and 6.5 cm high. For ^{96}Mo, only the elastic scattering cross sections were obtained for the reason that the observed spectra showed the presence of an appreciable impurity of about mass 16. The cross sections were corrected for source-to-sample geometrical effect and for flux attenuation and multiple scattering in the samples by Monte-Carlo technique.

In the theoretical analysis, the same values of the optical parameters as those in ref. 1) were used, and the coupled-channel calculations showed better fit to the observed elastic cross sections for ^{94}Mo and ^{96}Mo and to inelastic cross sections for the first excited state in ^{94}Mo than the spherical optical-model and Hauser-Feshbach calculations. In the former calculations the values of the coupling parameters taken from ref. 2) were used. Thus, the present study confirms further the validity of our optical parameter values.

---

* Borrowed from the ORNL pool by the courtesy of NEANDC andusaec.

1) S. Tanaka, JAERI-M 5984, p. 212 (1975).

2) H.F. Lutz, D.W. Heikkinen and W. Bartolini, Phys. Rev. C4 (1971) 934.

III-B-3 Study of ^{94}Mo through the (n,n'γ) Reaction

Y. Sugiyama and S. Kikuchi

The paper on this subject is published in "Nuclear Physics A264(1976) 179". The abstract of this study is as follows:

The ^{94}Mo(n,n'γ) reaction has been studied in the neutron energy range 1.5-4.0 MeV. Neutron inelastic scattering cross sections for levels up to an excitation energy of 2.6 MeV have been measured from 1.5 to 3.0 MeV. The results have been analyzed with the optical-statistical and coupled-channels theories. The 1.74 MeV level has been observed and has been assigned to be 0+. The branching ratios for the γ-rays deexciting the levels below the 3.5 MeV excitation have also been obtained.

The authors are greatly indebted to EANDC and US AEC for the use of ^{94}Mo sample in the ORNL pool.

C. Nuclear Data Center and Japanese Nuclear Data Committee

III-C-1 On Compilation of Japances Evaluated Nuclear Data Library, Version-1 (JENDL-1)

JENDL-1 Compilation Group

Compilation work on first version of Japanese Evaluated Nuclear Data Library (JENDL-1) was started at the beginning of 1974 fiscal year. Since then, members of this compilation group were engaged in the works on collection of all available evaluations and on selection of the most reliable data among them or on modification of some parts in the selected data, if necessary. When there are no relevant data, they performed reevaluation. In particular, they made every effort to provide self-consistent data of the heavy elements in the unresolved resonance region, and to give reliable data of the inelastic scattering and capture cross sections. Followings are nuclides whose evaluated data are stored in the JENDL-1;

H	^{6}Li	^{7}Li	^{10}B	^{11}B	^{12}C	^{16}O
^{23}Na	^{27}Al	Si	Cr	^{50}Cr	^{52}Cr	^{53}Cr
^{54}Cr	^{55}Mn	Fe	^{54}Fe	^{56}Fe	^{57}Fe	^{58}Fe
Ni	^{58}Ni	^{60}Ni	^{61}Ni	^{62}Ni	^{64}Ni	Cu
^{63}Cu	^{65}Cu	^{90}Sr	^{93}Zr	Mo	^{92}Mo	^{94}Mo
^{95}Mo	^{96}Mo	^{97}Mo	^{98}Mo	^{100}Mo	^{99}Tc	^{101}Ru
^{102}Ru	^{104}Ru	^{106}Ru	^{103}Rh	^{105}Pd	^{107}Pd	^{109}Ag
^{129}I	^{131}Xe	^{133}Cs	^{135}Cs	^{137}Cs	^{144}Ce	^{143}Nd
^{144}Nd	^{145}Nd	^{147}Pm	^{147}Sm	^{149}Sm	^{151}Sm	^{153}Eu
^{155}Eu	^{181}Ta	^{232}Th	^{233}Pa	^{234}U	^{235}U	^{238}U
^{239}Np	^{239}Pu	^{240}Pu	^{241}Pu	^{241}Am		

This compilation work has finished at the end of 1975 fiscal year.

III-C-2 Evaluation of Neutron Cross Sections of ^{6}Li

T. Nakagawa

As one of the contributions to JENDL-1, the neutron cross sections of ^{6}Li below 400 keV were evaluated. Above 400 keV, the evaluated data in ENDF/B-4 were adopted, because there are no needs to modify them at all at the present status of the data.

The (n,α) cross section below about 10 keV has a 1/v form which makes a large value at the thermal neutron energy. The existent evaluated data agree well with each other on the whole as well as the experimental data in this range. However, there are large discrepancies among the experimental data around the p-wave resonance at 250 keV. In this work, a least squares fit was carried out by using the recent experimental data by Poenitz[1] and Coates et al.[2] in the range up to 400 keV. In this fitting, the coefficient of the 1/v term was fixed to 0.1495[3] by the reason mentioned above. The (n,α) cross section obtained is expressed by following formula,

$$\sigma_{n,\alpha} = \frac{0.1495}{\sqrt{E}} + \frac{0.0133289\sqrt{E}}{(0.23937-E)^2+(0.099902)^2/4} - 0.032317, \quad \text{(barns)}$$

where E is the neutron energy in MeV. This result agrees well with the other experimental data measured after 1970.

The elastic scattering cross sections adopted in the region from 10^{-5} eV to 10 keV are the recommended value in BNL 325 (3rd edition)[4]; 0.72 ± 0.02 barns. From 10 keV to 400 keV, the elastic scattering cross sections were obtained by the following relation,

$$\sigma_{el} = \sigma_{tot} - \sigma_{n,\alpha} - \sigma_{n,\gamma}$$

where σ_{tot} and $\sigma_{n,\gamma}$ were adopted from ENDF/B-4. A good agreement was obtained with the experimental data by Asami et al.[5]

References

1) Poenitz, W.P. ; Z.Physik 268 (1974) 359.

2) Coates, M.S., et al. ; Proc. of Second IAEA Panel on Neutron Standard Reference Data, Vienna (1972) 105.

3) Uttley, C.A., et al ; Symposium on Neutron Standards and Flux Normalization, Argonne (1970) 80.

4) Mughabghab, S.F. et al ; BNL 325 Third Edition, Volume 1 (1973).

5) Asami, A. et al. ; Proc. of Conference on Nuclear Data for Reactor, Helsinki (1970) 153.

III-C-3 Evaluation of the Neutron Inelastic Scattering and Total Cross Sections for ^{19}F

T. Sugi* and K. Nishimura*

A set of optical-model parameters, with which averaged experimental data of neutron total cross sections for ^{19}F were fitted in the energy region from 0.65 to 20 MeV, was obtained by using TOTALCS code[1]. With the use of this optical-model parameters, excitation functions of inelastic neutron cross sections were calculated for the levels of ^{19}F from the 1st to the 7th excited state by using ELIESE-3 code[2]. The calculated excitation functions reproduced reasonably the experimental data of the (n,n'γ) reactions in the energy region from 0.5 to 5 MeV.

The neutron total cross sections calculated from the above optical-model parameters, however, did not reproduced the experimental data so well below about 3 MeV; since there are resonances. Then, another set of optical-model parameters was searched for in the energy region from 3 to 20 MeV by using TOTALCS code again. By adopting this set of optical-model parameters, an evaluated neutron cross sections was obtained in the energy region from 5 to 20 MeV.

Evaluation for inelastic scattering cross sections below 0.5 MeV and above 5 MeV, and evaluation for total cross sections below 5 MeV are now in progress.

References:

1) S. Igarasi et al., private communication.

2) S. Igarasi, JAERI 1224 (1972)

---

* Radioisotope and Nuclear Engineering School, JAERI.

III-C-4 Evaluation of Charged Particle Emission Cross Sections for ^{19}F induced by Fast Neutrons

T. Sugi* and K. Nishimura*

There are four data sets of $\sigma(n,\alpha)$ and two data sets of $\sigma(n,p)$ for ^{19}F in the energy regions from thresholds to 9 MeV. Discrepancy in the cross-section values is about $\pm$ 30% at the maximum, and several resonances exist in both reactions. These experimental data were examined critically, and evaluated cross-section curves for the reactions of $^{19}F(n,\alpha)^{16}N$ and $^{19}F(n,p)^{19}O$ were obtained in the energy regions from the thresholds to 9 MeV.

From 9 to 20 MeV, the experimental data for $\sigma(n,\alpha)$ and $\sigma(n,p)$ are sparsely distributed. In present work, it was assumed that $\sigma(n,\alpha)$ and $\sigma(n,p)$ vary smoothly in this energy region, and evaluated cross-section curves for these reactions were calculated by using empirical formula of Pearlstein's model[1].

The values for $\sigma(n,d)$ and $\sigma(n,t)$ were estimated from the measurement of angular distributions at about 14 MeV. Evaluated cross-section curves for the reactions of $^{19}F(n,d)^{18}O$ and $^{19}F(n,t)^{17}O$ were drawn through these values by using Pearlstein's model.

Reference:

1) S. Pearlstein, J. Nucl. Energ. 27, 81 (1973)

* Radioisotope and Nuclear Engineering School, JAERI.

III-C-5 Evaluations of $^{27}Al(n,\alpha)^{24}Na$, $^{27}Al(n,p)^{27}Mg$ and $^{58}Ni(n,p)^{58}Co$ Cross Sections

T. Asami

The cross sections of $^{27}Al(n,\alpha)^{24}Na$, $^{27}Al(n,p)^{27}Mg$ and $^{58}Ni(n,p)^{58}Co$ reactions were evaluated in the neutron energies up to 20 MeV. The evaluations were performed entirely based on the experimental data which had been compiled until June 1976, as follows:

1) The measured data relative to standard were corrected using the recent evaluated value of the standard cross section.

2) The most probable value of the absolute cross section around 14 MeV was determined making use of the data from one-point measurements around 14 MeV.

3) The measured data on excitation function were renormalized to the value obtained from 2).

The evaluated values for these reactions are somewhat different from the recent other evaluated data, for example the data in ENDF/B-IV, in particular around the maximum of the excitation curve. The detailed comparison of the present evaluations with the other evaluations is now in progress.

III-C-6 Neutron Cross Section Evaluation on Cr

S. Igarasi and T. Asami

Neutron cross sections of Cr (natural and A=50, 52, 53 and 54) were evaluated below 15 MeV, as one of the contributions to JENDL-1 compilation work. Available experimental data were used to look for the parameters of the optical potential, to estimate the cross sections of threshold reactions such as (n,2n), (n,p), (n,α) and (n,np) reactions and to adjust the capture cross section in the low energy region just above the resonance.

The optical and statistical model calculations were applied to estimate the capture and inelastic scattering cross sections of the natural chromium. Level schemes for each isotope were adopted from the compilations in Nuclear Data Sheets[1] and Table of Isotopes[2]. The γ-ray transmission coefficients $2\pi\Gamma\gamma/D$ for each isotope were adjusted so as to reproduce the experimental data.

Resonance parameters for each isotope were adopted after investigation of the parameters given in KFK-2063[3] and BNL-325 (3rd ed).[4] The data given in KFK-2063 were mainly adopted, except for ^{54}Cr. When the values of $\Gamma\gamma$ are not given in both KFK-2063 and BNL-325, the values obtained from the above mentioned $2\pi\Gamma\gamma/D$ were adopted tentatively.

References:

1) Nuclear Data Sheets, Vol. 3, No. 5,6, (1970).

2) C.M. Lederer, J.M. Hollander and I. Perlman : Table of Isotope, 6-th Edition (1968).

3) H. Beer and R.R. Spencer : KFK-2063 (1974).

4) S.F. Mughabghab and D.I. Garber : Neutron Cross Sections Vol. 1, Resonance Parameters, BNL-325, 3rd Edition (1973).

III-C-7 Evaluation of the Neutron Cross Sections of Cu^{63}, Cu^{65} and Cu^{Nat}

Makoto Sasaki *

An evaluation of Cu^{63}, Cu^{65} and Cu^{Nat} neutron cross sections has been made for total, capture, elastic scattering, inelastic scattering and (n, 2n) cross sections in the energy range between 10^{-5} eV to 15 MeV. In the resonance region, the resolved resonance parameters are based on BNL-325 3rd edition (1973). In the fast region, cross sections are calculated with a computer code, CASTHY, developed by S. Igarashi (JAERI). The (n, 2n) cross sections are taken from Kanda's evaluated values[1]. The cross sections of Cu^{Nat} are obtained from Cu^{63} and Cu^{65} cross sections.

The results of the present evaluation will be published as a JAERI report.

Reference:

1) Y. Kanda and R. Nakashima, "Evaluation of Some Fast Neutron Cross Section Data", JAERI-1207 (Feb. 1972)

* Mitsubishi Atomic Power Industries, Inc.

III-C-8 Evaluation of the Neutron Cross Sections for Mo^{92} and Mo^{94}

Takeshi Hojuyama *

An evaluation of nuclear data for Mo^{92} and Mo^{94} has been performed on total, elastic scattering, capture and inelastic scattering cross sections in the energy range from 10^{-5} eV to 15 MeV. In the resonance region, the resolved resonance paramters are based on BNL-325 3rd edition (1973). In the fast neutron energy region, the neutron cross sections were theoretically obtained using CASTHY code developed by S. Igarashi (JAERI). The evaluated capture cross sections obtained in this work are considered to be midway in other data.

The results of the present evaluation will be published as a JAERI report.

* Mitsubishi Atomic Power Industries, Inc.

III-C-9 The Fission Cross Section of ^{235}U in JENDL-1

T. Nakagawa

In the compilation work of JENDL-1, most parts of the evaluated data on ^{235}U above resonance region were adopted from the Matsunobu's evaluation[1] except for the fission cross section. His evaluated values of the fission cross section from 9 to 12 MeV were apparently smaller than the other evaluations as well as the data recently measured by Czirr et al.[2),3)] Czirr et al. had normalized their data to those by Poenitz[4)] in the range from 3 MeV to 4 MeV.

In the present work, the shape of the data by Czirr et al. was adopted from 6 MeV up to 15 MeV and it was re-normalized to the values of the Matsunobu's evaluation from 3 MeV to 5.4 MeV where his data agree well with most of the experimental data.

Recerences

1) Matsunobu, H. ; private comunication (1975).

2) Czirr, J.B., and Sidhu, G.S. ; Nucl. Sci. Eng. 57 (1975) 18.

3) Czirr, J.B., and Sidhu, G.S. ; Nucl. Sci. Eng. 58 (1975) 371.

4) Poenitz, W.P. ; Nucl. Sci. Eng. 53 (1974) 370.

III-C-10 Evaluation of Neutron Cross Sections of ^{238}U

T. Nakagawa

The evaluation of neutron cross sections of ^{238}U had been performed by Kanda[1] from 1 keV to 20 MeV on the basis of the experimental data reported before 1972. In order to contribute to JENDL-1, the reevaluation was done by using recent experimental data in the range fron 10^{-5} eV to 20 MeV.

Most of the experiments on the fission cross section of ^{238}U are the relative measurements to the fission cross section of ^{235}U. Therefore, the reliable fission cross section data of ^{235}U should be selected in order to obtain the absolute values of the fission cross section of ^{238}U. In this work, we adopted the fission cross sections of ^{235}U given in ref. 2 and two sets of the ratio data which were recently measured by Coates et al.[3] and by Meadows.[5),6] Coates et al. measured the ratio in the wide energy range from 600 keV to 20 MeV, and normalized the data at 14 MeV to the evaluated data by Sowerby et al.[4] Meadows made his experiments in the range from 1 to 10 MeV, in particular, the absolute measurement of the ratio from 2 to 3 MeV. Since the data by Coates et al. were slightly higher than those by Meadows, we adopted the shape of the former data in all range and renormalized them to the latter in the range from 2 to 3 MeV. The absolute values of the fission cross section of ^{238}U were obtained by using the ratio values thus determined and the fission cross section of ^{235}U mentioned above. The values of the subthreshold fission cross section were adopted from the data measured by Silbert et al.[7] and Block et al.[8] in the energy range lower than 200 keV.

Since Kanda had given only the total inelastic scattering cross section. partial inelastic scattering cross sections for each level were calculated below 3 MeV with the statistical model. The optical potential parameters and level scheme used were those by Igarasi et al.[9] Above 3 MeV, Kanda's

evaluated data were adopted.

The total, (n,2n), (n,3n) and capture cross sections above 46.5 keV were adopted from the evaluation by Kanda. The elastic scattering cross sections were obtained by subtraction of the non-elastic cross sections from the total cross sections.

The unresolved resonance parameters evaluated by Kikuchi[10] were adopted in the region from 4 keV to 46.5 keV. Below 4 keV, the evaluated data in ENDF/B-4 were adopted for the cross sections in the thermal energy region and for the resolved resonance parameters. The background data were added in the resolved reconance region in order to remove the appearance of negative values of the elastic cross section calculated by the use of a single-level Breit-Wigner formula.

Angular distributions of elastically scattered neutron were calculated by using the optical potential parameters by Igarasi et al.[9] For the neutrons emitted after excitation of the 1-st and 2 nd level, the evaluated data by Guenther et al.[11] were adopted. For the other neutrons, the isotropic angular distributions were assumed in the center of mass system.

For the $\bar{\nu}$, the fission yield data and the fission spectrum, the data in ENDF/B-4 were adopted.

References

1) Kanda, Y. ; JAERI-1228 (1973) P. 13 and private comunication.

2) Nakagawa, T. ; "The Fission Cross Section of ^{235}U in JENDL-1" in this Progress report.

3) Coates, M.S., Grayther, D.B., and Pattenden, N.J., ; Proc. of Washington Conference (1975) p. 568.

4) Sowerby, M.G., Patrick, B.H., and Mather, D.S., ; Annals of Nuc. Sci. & Eng. I (1974) 409.

5) Meadows, J.W., ; Nucl. Sci. Eng. 49 (1972) 310.

6) Meadows, J.W. ; Nucl. Sci. Eng. 58 (1975) 255.

7) Silbert, M.G. and Bergen, D.W. ; Phys. Rev. C4 (1971) 220.

8) Block, R.C., Hockenbury, R.W., Slovacek, R.E., Bean, E.B., and Cramer, D.S. ; Phys. Rev. Letters 31 (1973) 247.

9) Igarasi, S., Nakamura, H., Murata, T., and Nishimura, K. ; Proc. of Helsinki Conference (1970) 869.

10) Kikuchi, Y. ; to be published.

11) Guenther, P., Havel, D., and Smith, A.; ANL/NDM-16 (1975).

III-C-11 Evaluation of Fast Neutron Cross Section for Pu-239

Masayoshi Kawai*

An evaluation of fast neutron cross sections for Pu-239 was completed from 100 eV to 15 MeV as one of the activities in JNDC. Evaluated quantities are σ_{tot}, σ_f, $\sigma_{n,\gamma}$, σ_{el}, σ_{in}, $\sigma_{n,2n}$, $\sigma_{n,3n}$, $d\sigma_{el}/d\Omega$ and ν_p.

The evaluation of σ_{tot}, σ_f, $\alpha(=\sigma_{n,\gamma}/\sigma_f)$ and ν_p was based on the experimental data since 1956, most of which were collected from NEUDADA Library of CCDN. The data were renormalized by the use of the following standard cross sections: (n,α) cross section of B-10 evaluated by Sowerby et al[1], fission cross sections of U-235 and U-238 by Matsunobu[2] and Kanda[3], respectively, and ν_p of Cf-252 spontaneous fission and Pu-239 thermal fission by Hanna et al.[4] The least squares fit with suitable polynomials was applied to the renormalized data in each small energy interval. The recent experimental data were given higher weights in this least squares fit.

Fig.1 shows the present results for σ_f comparing with the recent evaluated and experimental data in the energy range from 1 keV to 10 MeV. There is the discrepancy of 15 % at maximum among four evaluated curves below 10 keV. Above 10 keV, they agree each other within the error of 5 %, but do not agree on details of the structure, for instance, from 50 keV to 100 keV and near 2 MeV.

Evaluated curve of ν_p is described as follows;

---

*) Nippon Atomic Industry Group Co., Ltd.

$$\nu_p = \begin{cases} 2.8738+0.083192E+0.071643E^2-0.016536E^3 & ; \quad E<1.5 \text{ MeV} \\ 2.8621+0.16275E-9.984\times10^{-4}E^2-3.178\times10^{-6}E^3 & ; \quad E\geq1.5 \text{ MeV} \end{cases}$$

The evaluation of σ_{el}, σ_{in}, $\sigma_{n,2n}$, $\sigma_{n,3n}$, $d\sigma_{el}/d\Omega$ and $\sigma_{n,\gamma}$ (higher energy), of which experimental data were scant, was based on the statistical model calculation coupled with the optical model by using CASTHY code developed by Igarasi[5]. In this calculation, the competing process of fission was taken into account. The potential parameters had been determined so as to reproduce the evaluated total cross section. Calculated values agree well with the experimental data for each quantity and the present evaluated data for σ_{tot}, σ_f and $\sigma_{n,\gamma}$.

The numerical data of present results were converted into ENDF/B Format after the slight modification of σ_{el} (5% at most) so as to conserve the consistency for total cross section. Fig. 2 compares present evaluation with ENDF/B-4. Large discrepancy is found in the data of σ_{in}, $\sigma_{n,2n}$ and $\sigma_{n,3n}$.

New measurements[6] are performed for U-235, U-238 and Pu-239 fission cross sections. They may force to revise present evaluation.

References:

1) M. G. Sowerby et al., J. Nucl. Energy 24 323 (1970)

2) H. Matsunobu, private communication.

3) Y. Kanda, Proc. of AESJ 1973 Topical Meeting on Fast Reactor Physics, Tokai, p. 10 (1973)

4) G. C. Hanna et al., At. Energy Rev., 7 No.4, 3 (1969)

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

6) Specialist Meeting on Fast Neutron Fission Cross Sections of ^{233}U, ^{235}U, ^{238}U and ^{239}Pu, June 28-30, 1976, at ANL.

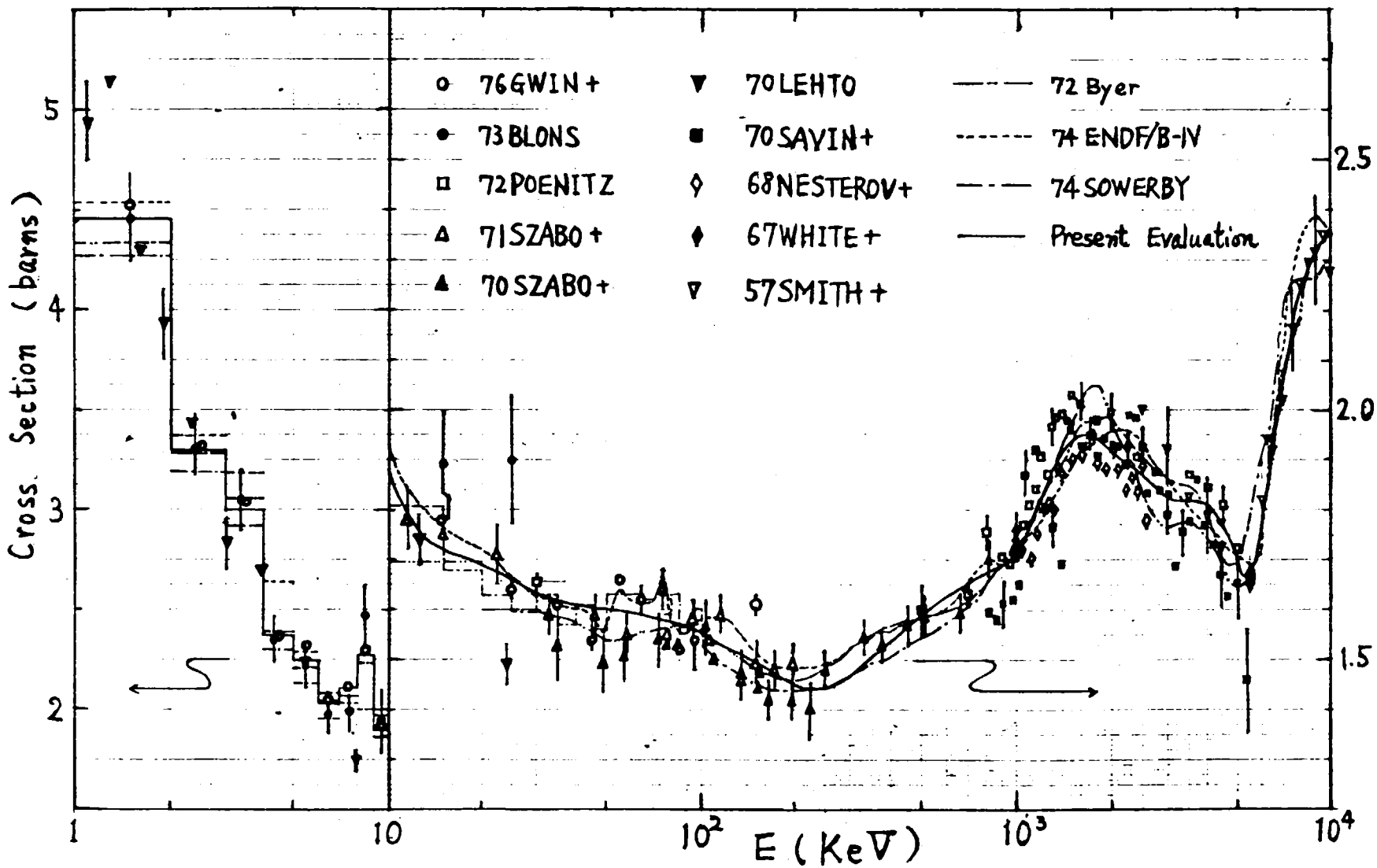


Fig. 1 Pu-239 Fission Cross Sections

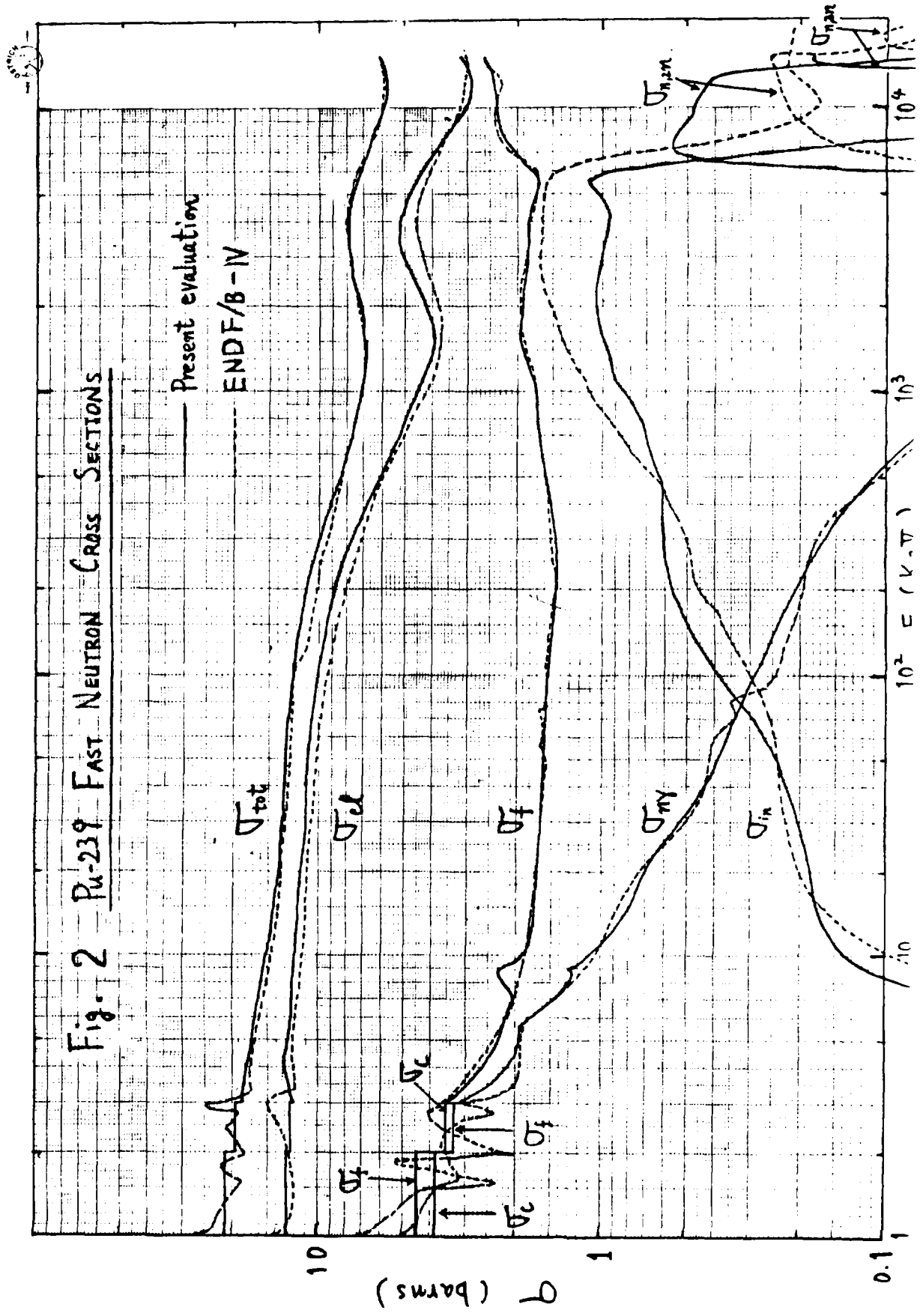


Fig. 2 Pu-239 Fast Neutron Cross Sections
Present evaluation
ENDF/B-IV
σtot
σel
σf
σnγ
σin
σc
σf
σc
σf
σn,2n
σn,2n
σ (barns)
10
1
0.1
10
10²
10³
10⁴
E (keV)

III-C-12 Evaluation of Neutron Cross Sections of ^{241}Pu

Y. Kikuchi

Neutron cross sections have been evaluated for ^{241}Pu as an activity of Japanese Nuclear Data Committee (JNDC). The evaluated data are stored in the Japanese Evaluated Nuclear Data Library Version - 1 (JENDL-1). The evaluated quantities are the total, elastic and inelastic scattering, fission, capture, (n,2n) and (n,3n) cross sections from the thermal neutron energy up to 15 MeV.

As to the 2200 m/s neutron cross sections, the evaluation by Lemmel[1)] was adopted. The cross sections below 1 eV were evaluated by means of available experimental data and resonance calculations.

The cross sections are represented with the resonance parameters between 1 eV and 21.5 keV. The resolved resonance parameters were given up to 100 eV, and were mainly taken from BNL-325, 3rd edition. The cross sections calculated with these parameters agree satisfactorily with the experimental data. The unresolved resonance parameters were given above 100 eV. The parameters were determined so as to represent the available experimental data of the fission and capture cross sections.

Above the resonance region, there are considerable number of experimental data for the fission cross section but exists only one measurement of α, i.e., the capture to fission ratio. No experimental data are available for inelastic scattering, (n,2n), (n,3n) and total cross sections.

Evaluation of the fission cross sections was based on the experimental data by Szabo[2)] Kaeppeler[3)] and Behrens[4)]. The data by Kaeppeler and Behrens were given as the ratios to the fission cross section of ^{235}U, and were renormalized with the evaluated fission cross section of ^{235}U by Matsunobu[5)]. The fission cross section of ^{241}Pu thus renormalized agrees well with the values of absolute measurement by Szabo. The present

evaluation is shown in Fig. 1 with the experimental data as well as the evaluated curve of the ENDF/B-4. The ENDF/B-4 seems to adopt Smith'S data above 1 MeV and gives higher values.

The capture cross section was obtained up to 250 keV by means of the measured α- data by Weston[6]. Above 250 keV, the calculation was carried out with the optical and statistical models. First the (n,2n) and (n,3n) cross sections were calculated approximately with Pearlstein's method. Considering the fission, (n,2n) and (n,3n) reactions as the competing processes, we calculated the capture, elastic and inelastic scattering cross sections with the statistical model, in which the competition with each other is treated adequately[7]. The gamma-ray strength function $\Gamma\gamma/D$ was adjusted so that the calculated capture cross sections connects smoothly at 250 keV with the value obtained from the experimental α data.

References

1) Lemmel, H.D. : Nuclear Cross Section and Technology, Proc. Conf. Washington, D.C., March 3-7, 1975, p. 286.

2) Szabo, et al. : Proc. Conf. on Neutron Physics, Kiev, 28 May - 1 June, 1973, Vol. 3, p. 27.

3) Kaeppeler, F.& Pfletschinger, E. : Nucl. Scie. Eng. 51, 124 (1973).

4) Behrens, J. W.& Carlson, C.W. : UCRL-51925 (1975).

5) Matsunobu, H. : Private communication (1975).

6) Weston, L. W.& Todd, J. H. : Trans. Am Nucl. Soc. 15, 480 (1972).

7) Igarasi, S. : J. Nucl. Scie. Technol. 12, 67 (1975).

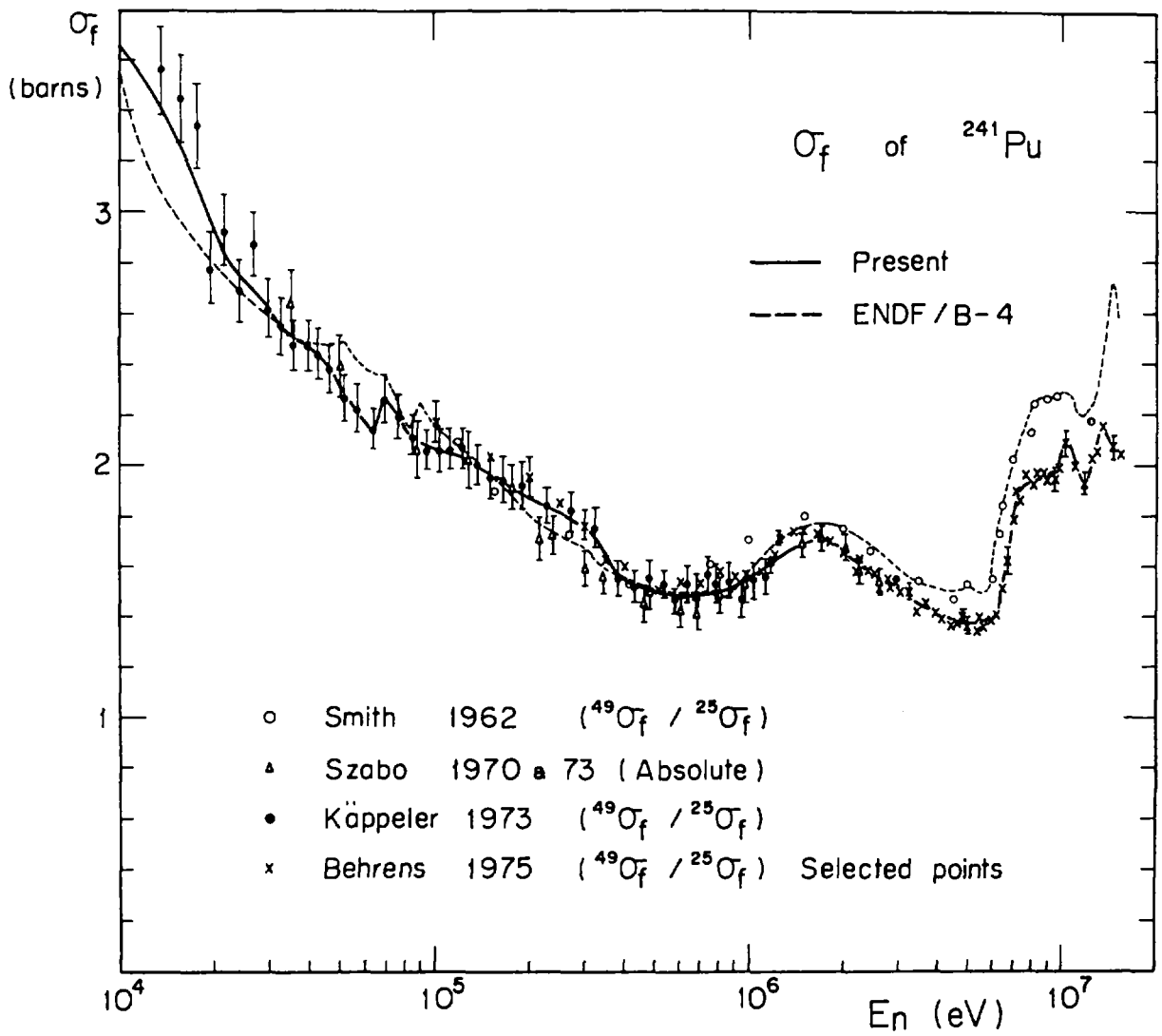

σf
(barns)
3
2
1
σf of 241Pu
Present
ENDF/B-4
Smith 1962 (49σf / 25σf)
Szabo 1970 a 73 (Absolute)
Käppeler 1973 (49σf / 25σf)
Behrens 1975 (49σf / 25σf) Selected points
10^4
10^5
10^6
10^7
En (eV)

Fig. 1

III-C-13 Evaluation of the Neutron Data of ^{241}Am

T. Nakagawa, T. Fuketa and S. Igarasi

Neutron data of ^{241}Am were evaluated in the energy region from thermal to 15 MeV. The best values were adopted for the capture and fission cross sections at 0.0253 eV and the resonance parameters. The adopted data in this work were mainly those given by Derrien and Lucas.[1] When there are no available parameters at each resonance level, averaged Γ_γ and/or Γ_f were adopted. Thus, the resonance parameters were obtained in the energy region from 0.3 eV to 150 eV.

Above 150 eV, the fission cross section was reinvestigated in this work because the previous result[2] seemed to be rather larger than that expected from the averaged cross section in the resonance region. Since the larger cross section values were dependent upon the experimental data by Seeger et al.[3], their values were artificially reduced in our evaluation by multiplying an energy dependent factor below 100 keV. The least squares method was then applied to reproduce the smooth trend of the experimental data including the above modified values. The fission cross section thus obtained is shown in Fig. 1 from 10 eV to 15 MeV.

After making these investigations, the most probable values were obtained for the whole energy region from thermal to 15 MeV taking the previous evaluation[2] for the region above 1 keV into account.

References.

1) H. Derrien and B. Lucas : Proc. of Conf. on Nuclear Cross Sections and Technology, Washington (1975) 637.

2) S. Igarasi : JAERI-M 6221 (1975),& J. Nucl. Sci and Tech. to be published.

3) P.A. Seeger, A. Hemmendinger and B.C. Diven : Nucl. Phys. A96 (1967) 605.

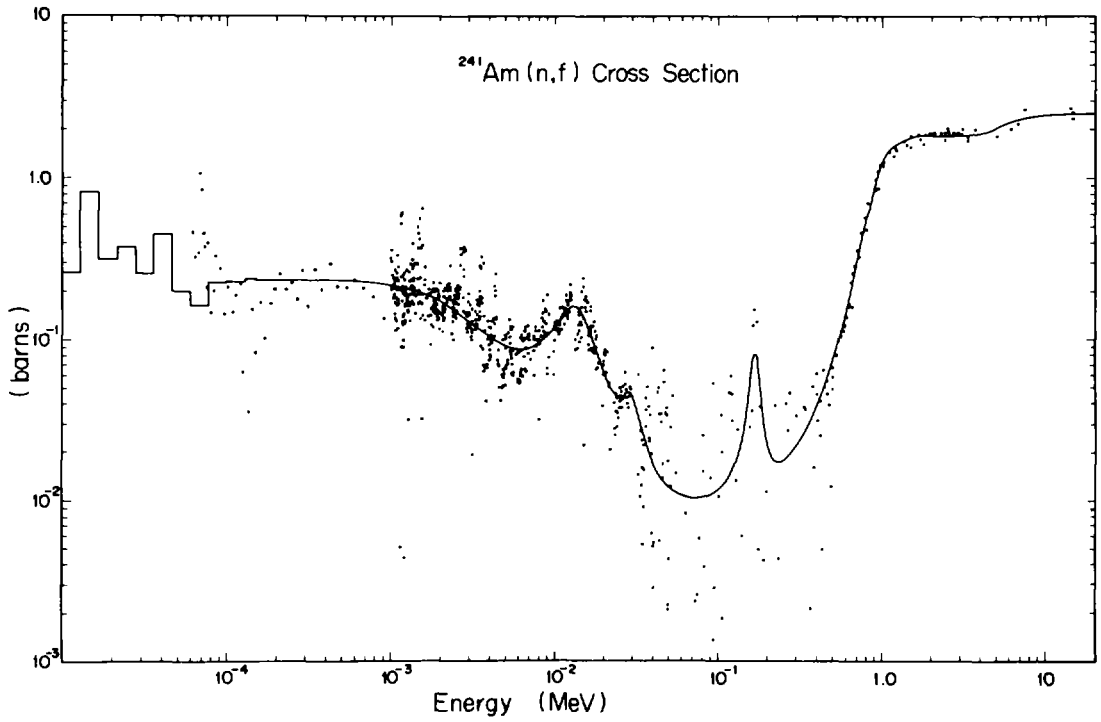


Fig. 1 Fission cross section of ^{241}Am from 10 eV to 15 MeV.

III-C-14

Activity of the Nuclear Data Evaluation Working Group

H. Matsunobu* and other members

The object of this group is to prepare for the evaluated nuclear data which are required for fast reactor design, and to provide the original data of JENDL-1 (Japanese Evaluated Nuclear Data Library, Version-1).

The group is composed of three sub-working groups which take charge of the following tasks respectively.

1) Evaluation of the nuclear data for heavy nuclides

In this sub-working group, the nuclear data for ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, and ^{241}Pu in the energy range 1 keV to 15 MeV were evaluated by five evaluaters on the basis of the compiled experimental data. Theoretical calculation by computer codes was also performed for quantities of which experimental data were very poor or did not exist. The evaluation works for each nuclide were reported in previous documentations[1-3] and in this report. The results of evalustion were submitted to the Compilation Group of JNDC, and adopted in JENDL-1 after some modifications.

In this work, consistency of the evaluated data among five nuclides is not examined rigorously, because the evaluation for each nuclide was independently performed except some quantities. Therefore,

---

* Sumitomo Atomic Energy Industries, Ltd.

a work for consistency check will be commenced in the near future.

2) Compilation of the resonance parameters of heavy nuclides

Compilation of the resonance parameters of ^{235}U, ^{238}U, and ^{240}Pu has been recently completed. The reviews of these compiled data will be published in JAERI-M report. The review for ^{239}Pu was alreac published by Yoshida[4]. In preparation of JENDL-1, recommendations on the data to be adopted were submitted by each compiler on the basi of the compiled data. A simple method for evaluation of the resonance parameters is surveyed at present.

3) Compilation and evaluation of the nuclear data for light and medium-heavy nuclides

In this sub-working group, compilation of the nuclear data for O, Na, Fe, Ni, and Ta which are indispensable for fast reactor design was performed. Evaluation of the compiled experimental data was performed for Fe, Ta, and threshold reaction cross sections of Ni isotopes by cooperation of the compilers and the Compilation Group of JNDC. For O and Na, recommendations were submitted for the data to be adopted in JENDL-1.

References

1) Progress Report : INDC(JAP) 17L, EANDC(J) 30L (1973)

2) Progress Report : INDC(JAP) 23L, EANDC(J) 36L (1974)

3) Progress Report : INDC(JAP) 28L, EANDC(J) 42L (1975)

4) T. Yoshida : JAERI-M 5979 (1975)

III-C-15 JNDC FP Fast Reactor Constants System

Y. Kikuchi, A. Hasegawa, H. Nishimura and K. Tasaka

Japanese Nuclear Data Committee (JNDC) revised the evaluated data of 28 important fission products[1] with applying more sophisticated models and taking account of the resonance structure. According to this revision work, the group constants of these nuclides were also revised. Considering the situation that the number of FP nuclides evaluated by JNDC will become 100 in a year, we have developed a system in which the lumped group constants can be produced rather automatically from the nuclear data file contained in the Japanese Evaluated Nuclear Data Library (JENDL) with the ENDF/B-4 format. This system is called "JNDC FP Fast Reactor Constants System". The detail of the system is described in Ref. 2.

The reliability of the group constants based on the revised JNDC data was tested with the integral data measured at RCN, Petten, the Netherlands[3]. The reactivity worths of separated FP isotopes were calculated for 5 STEK cores with four FP constants sets, i.e., the present set (JNDC set), the preliminary JNDC set[4] (JNDC-P set), the constants based on Cook's evaluation (Cook set) and those on the ENDF/B-4 (ENDF/B-4 set). The calculated worths were compared with each other and with the experimental values. The results are shown in Fig. 1. as the C/E ratios. The detailed discussion are given in Ref. 2. Followings can be pointed out from the comparison:

1) The JNDC set gives satisfactory results for ^{93}Zr, ^{95}Mo, ^{97}Mo, ^{101}Ru, ^{103}Rh, ^{109}Ag, ^{129}I, ^{133}Cs, ^{143}Nd and ^{147}Sm.

   (Category 1)

2) The results with the JNDC set deviate from the experiments, but give the best or one of the best agreement with the experiments for

^{102}Ru, ^{104}Ru, ^{144}Nd, ^{145}Nd, ^{149}Sm, ^{151}Sm and ^{153}Eu. (Category 2)

3) The JNDC-P set might give the best agreement with the experimental data for
^{99}Tc, ^{105}Pd, ^{107}Pd and ^{147}Pm. (Category 3)

4) The Cook set often shows the extreme values, for example, for ^{101}Ru, ^{102}Ru, ^{105}Pd, ^{144}Nd, ^{153}Eu and ^{151}Sm.

5) The ENDF/B-4 set gives slightly better results than the JNDC set for ^{103}Rh, ^{105}Pd and ^{147}Pm but gives much worse results for ^{101}Ru and ^{149}Sm.

As a conclusion, it can be said that the JNDC set is the most reliable set among the four sets compared here. Further investigation should be required for the nuclides of categories 2 and 3. Especially we are checking the cases of ^{105}Pd, ^{107}Pd and ^{147}Pm for which the JNDC-P set gives better results and no differential experimental data exist above 1 keV.

References

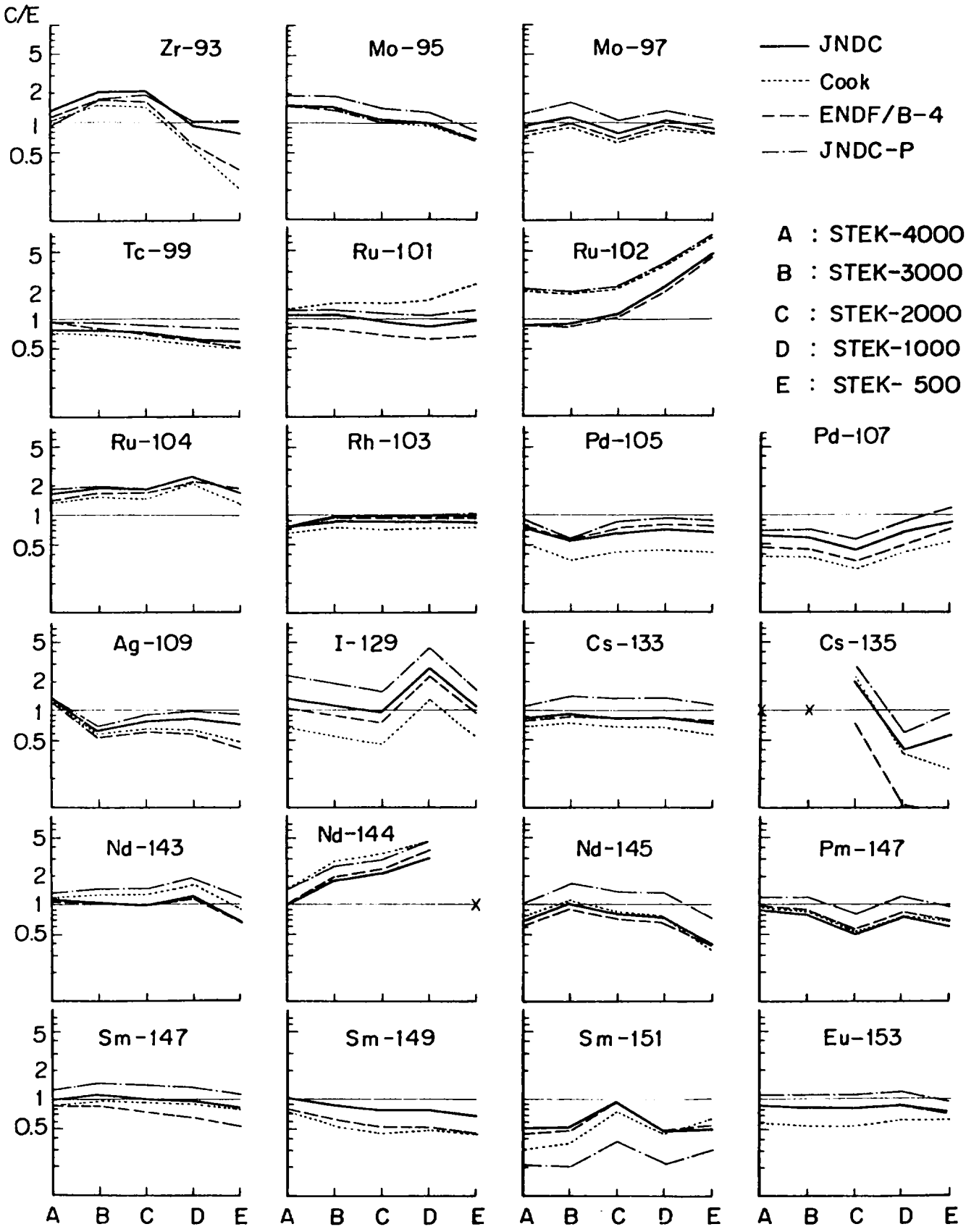
1) Iijima, S., et al.: to be published in J. Nucl. Scie. Technol.

2) Kikuchi, Y., et al.: JAERI-1248 (1976)

3) Bustraan, M., et al.: Proc. International Symp. on Physics of Fast Reactors, Tokyo, Oct. 1973, Paper B-26.

4) Kikuchi, Y., et al.: "JNDC Fission Product Group Constants (Preliminary Version)", JAERI-M 6001 (1975)

5) Kikuchi, Y., et al.: "Production of FP Group Constants for Fast Reactors with Cook's Evaluated Data", JAERI-M 5492 (1973).


C/E
Zr-93
Mo-95
Mo-97
JNDC
Cook
ENDF/B-4
JNDC-P
Tc-99
Ru-101
Ru-102
A : STEK-4000
B : STEK-3000
C : STEK-2000
D : STEK-1000
E : STEK- 500
Ru-104
Rh-103
Pd-105
Pd-107
Ag-109
I-129
Cs-133
Cs-135
Nd-143
Nd-144
Nd-145
Pm-147
Sm-147
Sm-149
Sm-151
Eu-153
5
2
1
0.5
A B C D E

D. Production Development Section

Division of Radioisotope Production

III-D-1 Reactor-Neutron Capture Cross Section of ^{94}Nb

T. Sekine and H. Baba

Neutron capture cross section of ^{94}Nb has been obtained by the activation method with reactor-neutrons.

Niobium targets were purified with the hexone extraction to remove tantalum impurity before or after irradiation. The targets were irradiated in the JRR-3 reactor for about 200 hours. Yields of ^{95m}Nb and ^{95g}Nb formed via double neutron capture of ^{93}Nb were determined by γ-ray measurement with Ge(Li) detector.

Cross sections were found to be 0.59 ± 0.03 b for $^{94}Nb(n,\gamma)$-^{95m}Nb reaction and 14.8 ± 0.5 b for $^{94}Nb(n,\gamma)^{95g}Nb$ reaction. The total cross section, 15.4 ± 0.6 b, is in agreement with the reported value, 13.6 ± 1.5 b, within the error[1].

Reference:

1) S. F. Mughabghab and D. I. Garber, BNL-325 3rd ed. Vol. 1 (1973)

III-D-2 Reactor-Neutron Capture Cross Sections of ^{165m}Dy and ^{165g}Dy

T. Sekine and H. Baba

Neutron capture cross sections of ^{165m}Dy and ^{165g}Dy have been obtained by the activation method with reactor-neutrons.

Small amounts of dysprosium chloride were irradiated for 3 to 60 minutes with the pneumatic rabit of the JRR-3 reactor. Yields of ^{166}Dy formed via double neutron capture were determined by γ-ray measurement with Ge(Li) detector.

Cross sections for $^{165m}Dy(n,\gamma)^{166}Dy$ and $^{165g}(n,\gamma)^{166}Dy$ reactions were determined as 2100±300 b and 4400±300 b, respectively, by the analysis of the yield dependence on irradiation time. The latter cross section is in good agreement with the reported value, 3900±300 b[1].

Reference:

1) S. F. Mughabghab and D. I. Garber, BNL-325 3rd ed. Vol. 1 (1973)

IV. KYOTO UNIVERSITY

A. Institute of Atomic Energy

IV-A-1 Independent Isomer-Yields of Sb and Te Isotopes in Thermal-Neutron Fission of ^{233}U, ^{235}U and ^{239}Pu

N. Imanishi, I. Fujiwara and T. Nishi

A paper on this subject was published in Nuclear Physics A263 (1976) 141 with an abstract as follows:

Independent isomer-yields of $^{130}Sb(5^+,8^-)$, $^{132}Sb(4^+,8^-)$, $^{131}Te(\frac{3}{2}^+,\frac{11}{2}^-)$ and $^{133}Te(\frac{3}{2}^+,\frac{11}{2}^-)$ in the thermal neutron fission of $^{233}U(\frac{5}{2}^+)$, $^{235}U(\frac{7}{2}^-)$ and $^{239}Pu(\frac{1}{2}^+)$, and those of $^{128}Sb(5^+,8^-)$ for ^{233}U and ^{239}Pu were measured by the conventional radiochemical method. The mean angular momentum $\bar{J}\hbar$ of the primary fragments has been deduced from the isomer-yield ratios. The result may indicate that the value of $\bar{J}$ tends to decrease overally as the number of neutrons in Sb and Te isotopes approaches to the neutron magic number, and is independent of the angular momentum of the fissioning nucleus as far as the thermal-neutron fission is concerned.

B. Research Reactor Institute

IV-B-1 Measurement and Analysis of Energy Spectra of Fast Neutrons in Aluminium

Shu A. Hayashi, Itsuro Kimura, Katsuhei Kobayashi, Shuji Yamamoto, Hiroshi Nishihara*, Satoshi Kanazawa*, Tetsuo Matsumura* and Masayuki Nakagawa**

In order to assess the nuclear data or group constants of aluminium, neutron spectra in an aluminium pile 70 cm cube were measured by the time-of-flight method using an electron linear accelerator as a pulsed neutron source.

The obtained neutron spectra have been compared with the predicted ones by theoretical calculations with several group constants, namely, Abagyan et al!s (ABBN), JAERI-FAST, DLC-2D (ENDF/B-III) and DLC-2D (ENDF/B-III) with resonance self-shielding.

The results are shown in Fig. 1. It can be seen that the measured spectrum in the aluminium pile (r=15 cm, μ=0.0) agrees with those predicted by theoretical calculations, especially by ANISN with DLC-2D constants using resonance self-shielding.

---

* Department of Nuclear Engineering, Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto

** Japan Atomic Energy Research Institute, Tokai-mura, Ibaraki

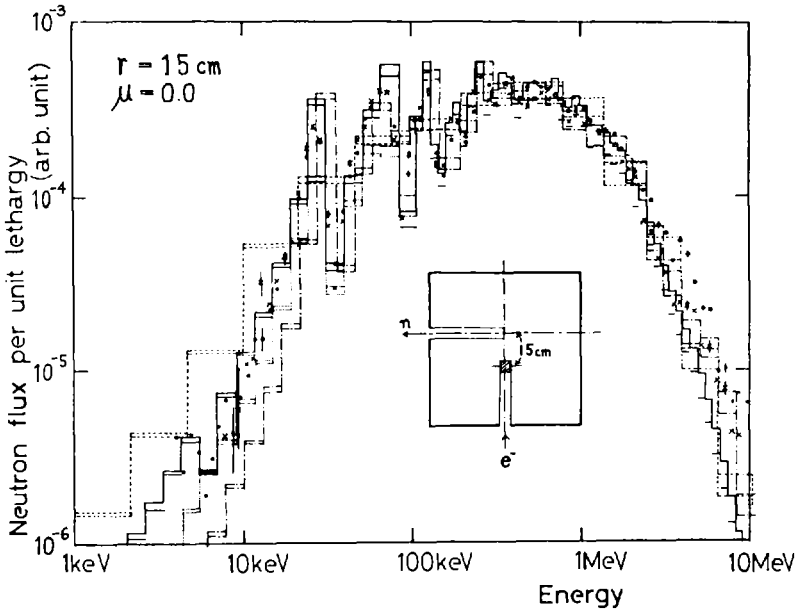


Fig.1 Fast neutron spectra in the aluminium pile

measured ··|···|···· ^{6}Li glass scintillation counter

xx|xxx|x ^{10}B-vaseline-NaI(Tl) counter

calculated —·—|—·— DTF-IV (JAERI-FAST)

----|---- DTF-IV (ABBN)

——|—— ANISN (DLC-2D)

·····|····· ANISN (DLC-2D self-shielded)

IV-B-2 Measurement and Analysis of Neutron spectrum in a Small Iron Pile Surrounded by a Lead Reflector

Itsuro Kimura, Tetsuo Matsumura*, Hiroshi Nishihara*
Shu A. Hayashi, Katsuhei Kobayashi and Masayuki Nakagawa**

A part of this work will be submitted to the Journal of Nuclear Science and Technology.

A possibility to assess group constants of a reactor material through measurement and analysis of neutron spectra in a small sample pile (iron) surrounded by a heavy moderator reflector (lead) was investigated. Theoretical calculation revealed that both the neutron flux spectrum and the sensitivity coefficient of the smaller iron sphere 35 cm in diameter surrounded by the lead reflector 25 cm thick were close to those of the larger bare iron sphere 108 cm in diameter. Although the time dispersion of the former was considerably prolonged by the lead reflector and thus the energy resolution in neutron spectroscopy by the time-of-flight method became rather worse, this may not interfere the assessment of group constants.

The neutron spectra in the small iron pile surrounded by the lead reflector (Fig.1) were measured by the time-of-flight method with an electron linear accelerator and the result was compared with the predicted values with the DLC-2D constants, the Abagyan et al's constants (ABBN) and the JAERI-FAST set (Fig.2). Good agreement was seen in general for the case of the DLC-2D constants, however it was rather poorer for the rest. These results are similar to those observed for the large bare iron pile by the present authors.

* Department of Nuclear Engineering, Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto

** Japan Atomic Energy Research Institute, Tokai-mura, Ibaraki

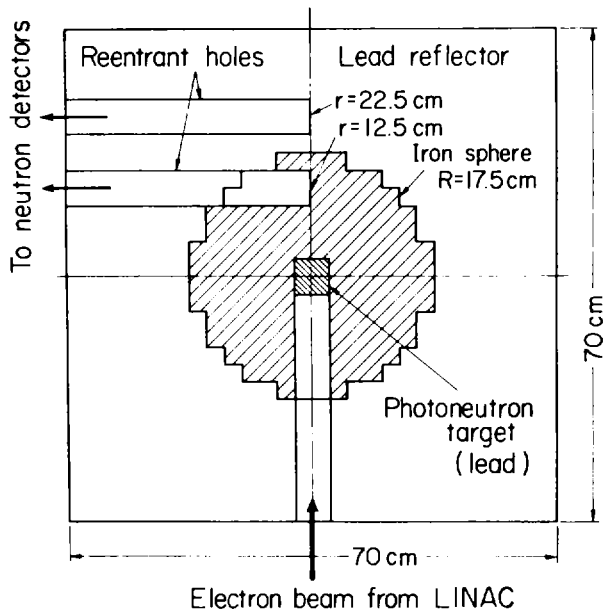


Fig. 1
Experimental arrangement

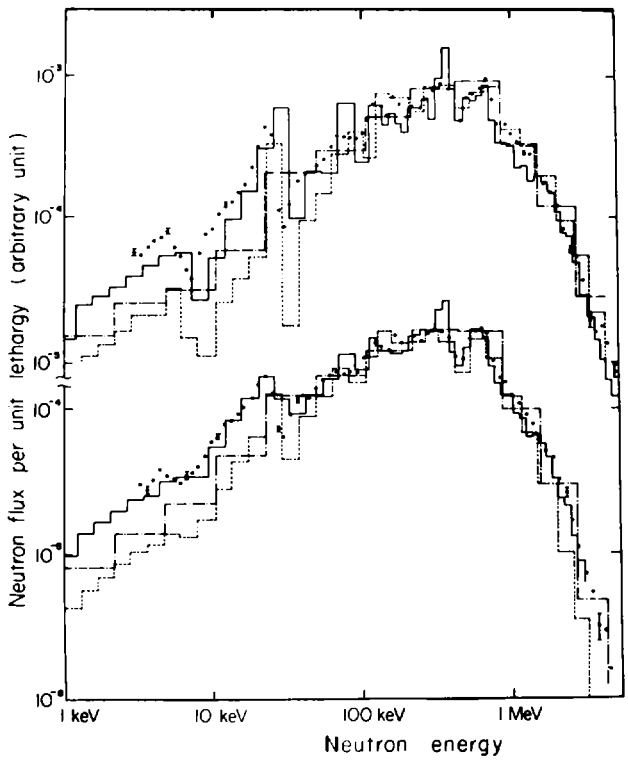


Fig. 2
Neutron spectra in a small iron pile surrounded by a lead reflector

Experimental
Calculated, ANISN/DLC-2D
" , DTF-IV /JAERI-FAST
" , DTF-IV /ABBN

IV-B-3 Gamma-ray Transitions in ^{106}Pd following the Decay of ^{106}Ru-^{106}Rh

K. Okano, Y. Kawase and S. Yamada

Gamma-ray transitions in ^{106}Pd have been studied using a ^{106}Ru-^{106}Rh source to investigate the structure of higher excited states in ^{106}Pd and also to supply γ-ray data for application fields as ^{106}Ru is a long-lived fission product nuclei. Preliminary reports on this work have previously been published[1-2].

Recently, singles and coincidence spectra have been measured precisely with a 58 cc and a 65 cc coaxial Ge(Li) detectors. The relative efficiency curve was determined using radioisotopes ^{22}Na, ^{24}Na, ^{192}Ir and ^{56}Co and is believed to be known to within the error of 5 %. The relative intensities obtained for the 621.8, 1050.4, 1128.1 and 1562.2 keV lines (taking the strongest 511.9 keV line as standard) are in good agreement with the recently reported values of Marsol et al.[3]. For the 873.5 keV line, however, our value is near to those obtained by the older measurements[4-6]. Several weak lines reported by Marsol et al.[3] or Strutz et al.[4] were found to be considerably weaker than reported, if present. On the other hand, several new lines not reported by them were confirmed.

From the NaI-Ge(Li) coincidence measurements, excited states at 1909.5(2+), 2472.3((2+)) and 2484.8(1-) keV and a few levels above 3 MeV were newly found to be fed by the decay of ^{106}Ru-^{106}Rh. Spins of several levels were also newly determined.

References:

1) K. Okano and Y. Kawase, Annu. Rep. Res. Reactor Inst. Kyoto Univ. 7 (1974) 62

2) K. Okano, Y. Kawase and S. Yamada, Annu. Rep. Res. Reactor Inst. Kyoto Univ. 8 (1975) 86

3) C. Marsol, O. Rahmouni and G. Ardisson, C. R. Acad. Sci. B 275 (1972) 805

4) K. D. Strutz, H. J. Strutz and A. Flammersfeld, Z. Physik 221 (1969) 231

V. KYUSHU UNIVERSITY

Department of Nuclear Engineering, Faculty of Engineering

V-1 Position Sensitive Counter Telescope for Neutron Induced Reactions

N.Koori, T.Goto and I.Kumabe

Position sensitive proportional counters were introduced to improve the efficiency of counter telescope. Two single-wire position sensitive proportional counters (pspc) were combined to the ΔE-E counter telescope and used to determine trajectories of the charged particles emitted from target. Hence, the solid angle of the telescope was enlarged without sacrifice of the angular resolution.

Position information was obtained by the charge division method. As the anode wire of pspc, a high resistance carbon film (8kΩ/mm) coated on a quartz fibre (25μmϕ) was used. Position resolution of the pspc was found to be better than 0.5 mm fwhm when the ^{210}Po 5.3 MeV α-ray beam of 0.2 mm fwhm was collimated on the anode wire.

ΔE counter is of an ordinary proportional type and it is divided into two parts which can be operated individually for background reduction. By ΔE-E correlation method, good discrimination between protons and deuterons both emitted from

target was possible. Two solid state detectors (30 mm ϕ) were used as E counter to cover large solid angle. A larger rectangular Si(Li) detector (15 $\times$ 60 mm^2) adaptable to this position sensitive counter telescope is under development.

Six parameters (4 parameters for 2 pspc's, 2 for ΔE and E) from the telescope were measured by a TOSHIBA USC-3 on-line computer in the raw data mode and were stored on magnetic tapes. Experimental position spectra for pspc's were compared with spectra simulated with the Monte Carlo calculations for the n-p scattering at 14 MeV. Good agreement was obtained:the angular distribution of n-p scattering was reproduced well over the angular range up to 50° in the laboratory proton angle.

Position sensitive counter telescope developed has large solid angle of 58 msr, wide angular range up to 34° and good angular resolution of 4° in fwhm. The efficiency of counter telescope was improved about 5 times.

V-2 Neutron from Interaction of 14.1 MeV Neutrons with Vanadium and Gold

Y. Irie, M. Tsuji, M. Hyakutake, N. Koori, M. Matoba and I. Kumabe

A paper on this subject was published in the Journal of Nuclear Science and Technology, 13 (1976) 334.

The energy spectra of neutrons inelastically scattered from V and Au were measured in 30° steps from 20° to 150° in laboratory angle at an incident energy of 14.1 MeV. The experimental energy spectra for V and Au integrated over solid angle were analyzed by means of both the pre-equilibrium model and the statistical evaporation model. The energy spectra for Nb and Ta obtained by Hermsdorf et al.[1] were also analyzed. From this analysis the α -value, which is only one unknown parameter for determining the absolute cross section on the basis of the pre-equilibrium model, was empirically determined.

References :

1) D. Hermsdorf et al : J. Nucl. Energy 27 (1973) 747, Kernenergie 16 (1973) 252.

V-3 On the Counting Efficiency of Neutron Detector in the Energy Range of 2 ~ 10 MeV

Y. Irie, M. Matoba, M. Hyakutake and M. Sonoda

The paper on this subject is published in Oyo Butsuri 45 (1976) 424 (in Japanese) with an abstract as follows :

A simple method is described for calibrating the counting efficiency of a neutron detector. First, the absolute efficiency is measured by the usual method of neutrons scattered at different angles from hydrogen, the incident energy being fixed. At the same time, the energy spectrum (reference spectrum) is measured of neutrons scattered at a given angle from a certain scatterer (for example, Fe scatterer). Then, any variation of counting efficiency because of different experimental conditions may be found by comparing the energy spectrum of neutrons measured in the same way by using the Fe scatterer with the reference spectrum. An example is given for the case of 14.1 MeV neutrons. This method makes it possible to save considerably the time and labor to calibrate the counting efficiency.

V-4 Angular Distribution of Neutrons from Precompound Decay in Inelastic Scattering

Y. Irie, M. Hyakutake, M. Matoba and M. Sonoda

The paper on this subject is published in Physics Letters 62B (1976) 9 with an abstract as follows :

Precompound angular distribution in inelastic scattering of 14 MeV neutrons are analysed in terms of surface interaction with the higher exciton states taken into account. This model is applied to some (p,α) reactions also.

V-5 Angular Distributions of Neutrons from Pre-Compound Decay

Y. Irie, M. Hyakutake, M. Matoba and M. Sonoda

A paper on this subject reported in NEANDC (J) 42L, p. 40 has been published in J. Phys. Soc. Japan 39 (1975) 537.

V-6 Statistical-Model Calculation of Neutron Capture Gamma-Ray Spectra for ^{238}U

Takaaki Ohsawa, Masao Ohta, Sin-iti Igarasi*
and Noriaki Sakamoto**

A paper on this subject is to be published in Memoirs of the Faculty of Engineering, Kyushu University, vol.36, No.2, with an abstract as follows :

The gamma-ray spectra following neutron capture by ^{238}U are calculated on the basis of the statistical model, with the aim of providing information of the spectra for fast neutrons, of which no experimental data are available. The calculations are carried out using the low-lying discrete levels with known values of energy, spin and parity, and statistical assumptions for the distribution of levels in the continuum region. All radiative transitions are assumed to be of the electric dipole type. The gamma-ray cascade process are exactly treated by taking into account the possibility of neutron emission at excitation energies above the neutron binding energy.

---

* Japan Atomic Energy Research Institute

** Present address : Japan IBM Co. Ltd.

Comparisons are given between experimental capture spectra and corresponding spectra calculated with varying assumptions with respect to pertinent nuclear parameters. Capture spectra are calculated for incident neutron energies, 0.025 eV, 10.1 keV, 101 keV and 1.0 MeV. The effect of gamma cascade neutrons on the spectral form is found to be appreciable for higher incident energies.

VI. NAGOYA UNIVERSITY

Department of Nuclear Engineering, Faculty of Engineering

VI-1 Formation Cross-sections of ^{90m}Zr and ^{207m}Pb with Fast Neutrons

V. Bhoraskar, S. Amemiya, K. Katoh, T. Matsui and T. Katoh

A paper on this subject was submitted for the publication in J. Nucl. Sci. Technol.

The cross-sections for the formation of the metastable states of ^{90}Zr, (σ_{Zr}), for neutron energy of 14.8 MeV, and that of ^{207}Pb, (σ_{Pb}), for neutron energies from 4.1 to 5.2 MeV have been measured and the results are reported. The experimentally determined value of the cross-section for the former is 700 $\pm$ 94 mb, while for the latter, the cross-section increases from 316 $\pm$ 44 mb to 788 $\pm$ 110 mb. The cross-section ratio, σ_{Pb}/σ_{Zr}, is also studied, which is found to vary from 1.87 to 2.18 for neutron energies from 14.8 to 18.2 MeV respectively. The equality in the half-lives of the metastable states of ^{90}Zr and ^{207}Pb is exploited in the present measurements, which enabled comparative evaluation of the cross-sections. Natural samples of zirconium and lead were irradiated simultaneously and the gamma-rays were measured off-line by a 55 cm^3 Ge(Li) detector. Cyclic activation process was adopted to improve the counting statistics. The overall accuracy achieved in the measurements is about 10 %.

VII. NIPPON ATOMIC INDUSTRY GROUP CO., LTD.

Nuclear Research Laboratory

VII-1 Estimation of Decay Heat Nuclear Data for Short-lived Fission Products [1)]

T. Yoshida

The gross theory of beta-decay[2)] has been applied to estimation of decay heat nuclear data for short-lived fission products. As for the half-lives, about one-hundred fission products with sub-minute half-lives have been tested. Roughly speaking, the half-lives are predicted within a factor of 5 for 70% of them, and within a factor of 10 for 90%.[3)]

The theory is also capable of predicting the average energies of emitted β- and γ-rays. Calculation has been performed with the most probable value of a parameter Q_{oo}, which represents the energy of the lowest level actually fed by beta transition. Results have been summarized in the form of simple fitting formulas. When half-life has been determined experimentally for a nuclide in question, uncertainty of the calculation can be improved through a search for the best Q_{oo} with the aid of the half-life data. Fig. 1 displays the energy fractions of β- and γ-rays thus obtained along with the experimental values compiled by Tobias.[4)] By use of this method, average β- and γ-ray energies were calculated for nearly one-hundred fission products with meager or no experimental information on the released energies. Evaluation of confidence bands has been also performed.

References

1) T. Yoshida, submitted to Nucl. Sci. Eng.

2) For example, K. Takahashi, M. Yamada, T. Kondoh, Atom. and Nucl. Data Tables, 12, 101 (1973)

3) T. Yoshida, JAERI-M 6313 (1975), (in Japanese)

4) A. Tobias, RD/B/M2669, Central Electricity Generating Board, (1973)

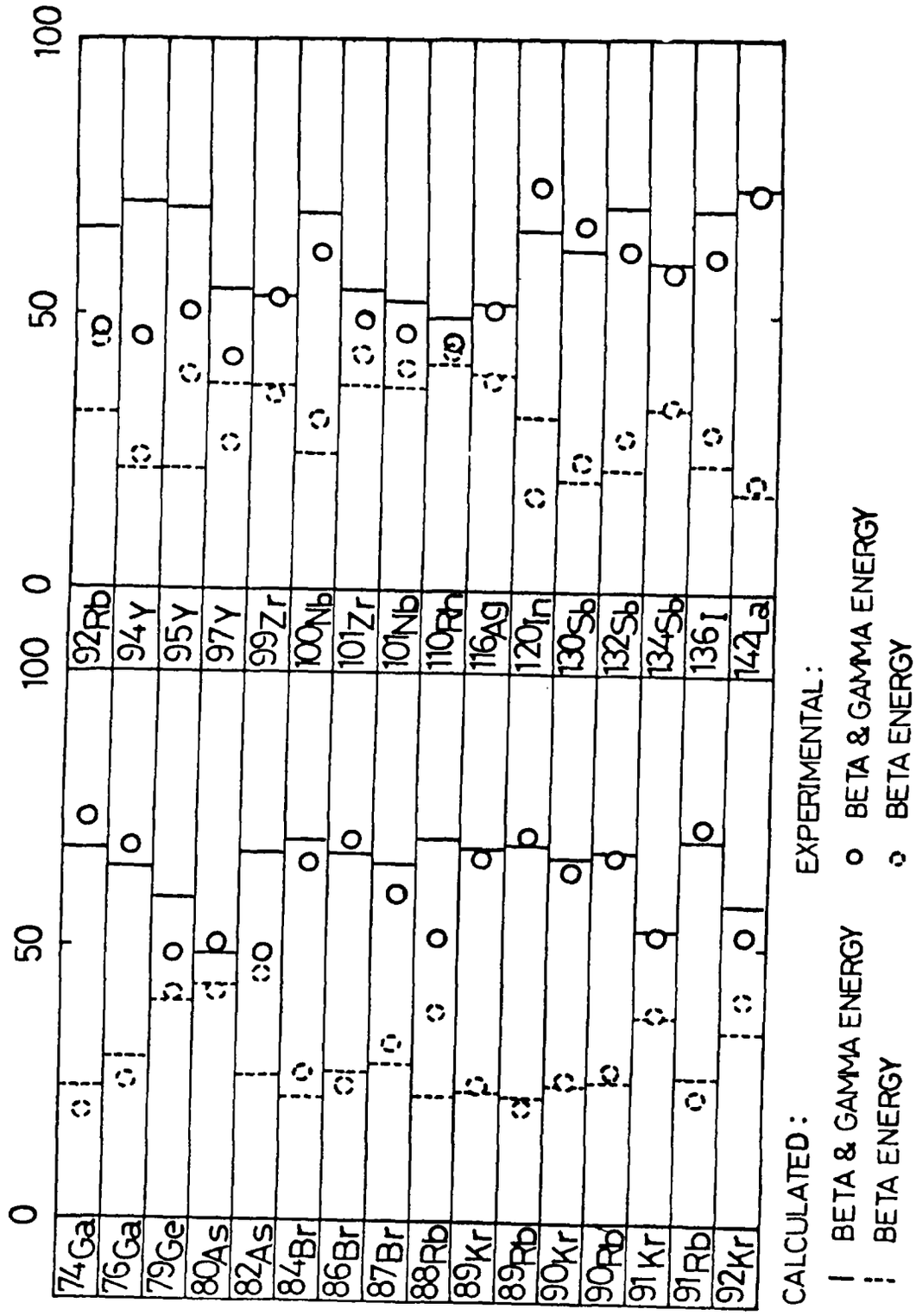


Fig. 1 Average Energy Fractions of Beta and Gamma-Rays from Short-lived Fission Products (Total Decay Energy = 100)

VIII. TOHOKU UNIVERSITY

Department of Nuclear Engineering, Faculty of Engineering

VIII-1 Yields and Spectra of Neutrons from the Li+d reaction

K. Miyagi, M. Baba, E. Fujii, T. Sakase,
M. Ichikawa, and T. Momota

Yields and spectra of neutrons from a thick target of lithium bombarded with deutrons have been measured. Neutrons were generated by the pulsed deutron beam of the Tohoku University Dynamitron and measurement was made by the use of a conventional time-of-flight spectrometer with a 2"dia×2" NE-213 liquid scintillater.

The spectra of neutrons were measured at 0° and 90° direction for a deutron energy range of 0.8-4.0 MeV and 1.5-3.5 MeV respectively, and the yields were calculated with the data.

The results will soon be publicized.

VIII-2 Scattering and Secondary Emission of Neutrons from ^{7}Li Bombarded with Neutrons of Energies 4.5-7.0 MeV.

M. Baba, E. Fujii, K. Miyagi, M. Ichikawa,
T. Sakase, and T. Momota

As a part of studies on $^{7}Li(n,n')\alpha t$ reaction , reaction nutrons have been investigated for an incident energy range of 4.5-7.0 MeV and for an angular range of 30°-135°. Measurements were made with a pulsed source of thick-target Li+D neutrons and a conventional time-of-flight spectrometer.

Angular distributions of elastically scattered neutrons, inelastically scattered neutrons (Q=-4.6 MeV) and secondary neutrons due to $^{7}Li(n,n')\alpha t$ reaction were measured. Spectrum of the secondary neutrons which was deduced from the measured data, resembled those of neutrons from $^{7}Li(pn)^{3}He$[1]. and $^{6}Li(d,n)^{3}He$[2]. and could fairly well be reproduced by the empirical formula of Elwyn and smith[2].

Further refinement of the measurement is in progress.

References:

1) J. W. Meadows and D. L. Smith, ANL-7938
2) A. J. Elwyn, R. E. Holland, F. J. Monahan, and F. P. Mooring, Conference Proceedings, Nuclear Cross Sections and Technology Vol. II, 692,(1975).

VIII-3 Gamma-Ray Production Cross Sections for Fast Neutron Interactions with Several Elements

Y. Hino, T. Yamamoto, T. Saito, Y. Arai,
S. Itagaki and K. Sugiyama

The differential cross sections for the productions of gamma-rays from the (n,xγ) reactions have been measured at incident neutron energies of 5.3 MeV for aluminum and copper, and 14.2 MeV for carbon, aluminum, iron and copper. The former measurements were performed using pulsed neutrons from the d-D reaction produced by deuteron beam of 2 nsec width and 1 MHz repetition rate with the 4.5 MV Dynamitron accelerator. The neutron flux at the target were determined by means of a NE-213 liquid scintillation counter with time-of-flight and n-γ discrimination system. On the latter measurements, continuously produced neutrons by the d-T reaction were used with the Cockcroft-Walton accelerator. The incident neutrons to the sample were determined by counting the associated-particles on the d-T reaction. The gamma-ray spectra were measured with a 70 cm^3 Ge(Li) spectrometer emplying a time-of-flight technique to eliminate the neutron background. The corrections were made for multiple scattering and attenuation of the incident neutron in the sample and for the absorption of gamma-ray in the sample.

The obtained results are presented in Tables I and II. Indicated errors were estimated from counting statistics in gamma-ray peak area, the full-energy peak efficiency of the Ge(Li) detector, neutron monitor efficiency and errors on the corrections. A full report will be published soon.

Table I. Differential cross sections for γ-ray productions from 5.3 MeV neutron interactions with aluminum and copper, at $\theta_\gamma = 55^\circ$.

Al (n , x γ)			Cu (n , x γ)		
E_γ (keV)	dσ/dω (mb/sr)	error (mb/sr)	E_γ (keV)	dσ/dω (mb/sr)	error (mb/sr)
792	2.2	0.4	667	9.6	1.8
843	10.9	1.7	735	1.3	0.6
984	2.1	0.4	750	1.4	0.5
1013	18.7	2.8	766	4.4	0.9
1692	} 11.0	1.9	876	2.3	0.7
1719			899	6.3	1.3
2210	23.4	3.5	956	} 27.3	5.0
2300	3.6	0.7	973		
2732	3.4	0.6	1082	1.6	0.7
2980	} 16.9	2.7	1113	22.6	4.2
3001			1161	} 3.9	1.0
3212	0.8	0.3	1173		
3396	2.1	0.4	1240	} 2.7	0.9
3956	2.5	0.5	1250		
4409	2.8	0.5	1325	20.9	3.8
4580	3.6	0.6	1346	2.5	0.6
4811	0.7	0.2	1380	1.9	0.6
			1410	8.6	1.7
			1440	3.6	0.8
			1480	12.6	2.4
			1548	7.6	1.5
			1581	2.7	0.7
			1619	4.6	1.0
			1641	1.7	0.6
			1703	} 4.1	1.0
			1722		
			1848	} 7.6	1.5
			1860		
			2003	2.0	0.7
			2073	} 5.1	0.7
			2090		
			2330	4.0	1.1

Table II. Differential cross sections for -ray productions from 14.2 MeV neutron interactions with carbon, aluminum, iron and copper, at $\theta_\gamma = 55^\circ$.

C (n , x γ)			Fe (n , x γ)			Cu (n , x γ)		
E_γ (keV)	dσ/dω (mb/sr)	error (mb/sr)	E_γ (keV)	dσ/dω (mb/sr)	error (mb/sr)	E_γ (keV)	dσ/dω (mb/sr)	error (mb/sr)
4430	12.4	2.2	413	5.3	0.8	212	7.6	1.2
			847	64.0	9.9	280	6.8	1.0
			930	0.8	0.3	348	10.6	1.6
			1038	4.0	0.7	386	5.3	0.8
			1235	22.0	3.4	669	7.4	1.2
			1303	6.4	1.0	962	18.1	2.8
			1408	3.0	5.2	1132	9.9	1.6
			1412			1172	12.7	2.0
			2113	2.2	0.4	1327	12.5	2.0
			2523	0.5	0.3	1481	6.6	1.0
			2603	4.0	0.9	1547	2.9	0.5
						1862	4.3	0.7

Al (n , x γ)		
E_γ (keV)	dσ/dω (mb/sr)	error (mb/sr)
984	5.0	1.0
1013	15.7	2.9
1810	10.0	1.6
2210	16.2	2.6
3001	13.8	2.2

IX. Tokyo Institute of Technology

Research Laboratory for Nuclear Reactors

IX-1 Measurement of Neutron Capture Cross Sections of In, Cs, Ta and Th at 24 kev

N. Yamamuro, T. Miyakawa, Y. Fujita* and K. Kobayashi*

Neutron capture cross sections of In, ^{133}Cs, ^{181}Ta and ^{232}Th have been measured at 24 kev using the Fe-filtered beam produced by the KUR 46 Mev electron linac. The experimental arrangement was same as described in elsewhere[1]. Capture gamma-rays were detected by two C_6F_6 scintillation detectors and the pulse height weighting technique was used to determine the absolute capture probability[2]. Metallic foils of In, Ta and Th and powder of Cs_2O canned into an alumiuum capsule were used as samples, respectively. Neutron self-shielding and multiple scattering corrections in samples were applied, resulting in 24 kev capture cross sections shown in Table. Errors include an estimated systematic error of 4%.

Table: 24 kev Neutron Capture Cross Sections

Nuclei	Sample Thickness (10^{-3}a/b)	Scattering Correction (%)	σ_γ (mb)
In	3.64	4.7	750 ± 45
^{133}Cs	8.21	9.5	580 ± 35
^{181}Ta	4.52	7.6	850 ± 50
^{232}Th	1.33	4.0	490 ± 40

*Kyoto University Research Reactor Institute

References :

1) N. Yamamuro et al. : Proc. of Conf. on Nuclear cross Sections and Technology, NBS special publication 425, P.802 (1975)

2) N. Yamamuro et al. : Nucl. Instrum. Methods., 133, 531 (1976)

IX-2 Giant Quadrupole Capture of Energetic Nucleons by Nuclei

Hideo KITAZAWA and Nobuhiro YAMAMURO

This work is concerned with nucleon radiative capture reactions via giant electric quadrupole (T=0) states in nuclei. The coupling potential between an incident particle and the quadrupole vibrational mode of a target nucleus is described in terms of the hydrodynamic model. A cross section formula for quadrupole capture is derived on the analogy of the collective capture model which has been proposed by Clement et al.[1]. Moreover, calculations of the cross section for the $^{208}Pb(n,\gamma)$ ^{209}Pb reaction with 5- to 20-MeV neutrons are presented for both dipole capture process and quadrupole one. The results show that excitation of the giant quadrupole state by nucleon radiative capture is considerably weak, and so masked by giant dipole resonance (T=1). This work is published in J. Phys. Soc. Japan Vol.41 No.4 (1976).

References :

1) C. F. Clement et al. : Nuclear Phys. 66 (1965) 273.

X. UNIVERSITY OF TOKYO

Department of Physics, Faculty of Science

X-1 ^{4}He(d,pα)n Reaction at a Low Incident Energy

K. SAGARA, M. HARA, N. TAKAHASHI, T. MOTOBAYASHI
F. TAKEUTCHI*, F. SOGA** and Y. NOGAMI

The paper on this subject was reported in an internal report UTPN-70, Department of Physics, Faculty of Science, University of Tokyo (1976) with an abstract as follows:

Absolute cross sections of the ^{4}He(d,pα)n reaction have been measured at E=8.9 MeV in order to study the reaction mechanism at low energy. A gas target in a cell with very thin wall (0.25 mg/cm^2) is used to detect low energy α-particles. In the coincidence spectra, prominent peaks are observed corresponding to the strong n-α final state interaction. Shapes of the spectra are well reproduced by the simple impulse approximation and the single-level R-matrix theory, but the absolute values as well as the angular dependence of the experimental peak cross section cannot be fitted by these calculations. Independence of the peak cross section from kinematical variables such as the spectator energy and the nucleon-α scattering angle indicates that effects of multiple processes in the reaction are dominant at this low energy. A simple physical picture of the processes is presented.

---

*) Present address; Institut für Experimentelle Kernphysik der Universität und des Kernforshungszentrums, Karlsruhe, Germany. Visitor at CERN, NP division, Geneva, Switzerland.

**) Present address; Institute for Nuclear Study, University of Tokyo