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PROGRESS REPORT

(July 1983 to June 1984 inclusive)

September 1984

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 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 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 or 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, 1983 to June 30, 1984. 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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CR	52	N, PROTON	FISS		KTO	EXPT-PROG	NEANDC-J106	41		SEP 84	KOBAYASHI+.CF252.SIG=1.470+-0.098MB.
FE	56	SPECT N,GAMM	28+4		TIT	EXPT-PROG	NEANDC-J106	66		SEP 84	KOMANO+,PUBLISHED IN PR C29 345.
FE	56	SPECT N,GAMM	20+4	10+5	TIT	EXTH-PROG	NEANDC-J106	69		SEP 84	KITAZAWA+.AT 84KNOXVILLE SYMPOSIUM.
RB	85	RESON PARAMS	NDG		JAE	EXPT-PROG	NEANDC-J106	14		SEP 84	OHKUBO+.PUBLISHED IN NST 21 254.
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RB	87	STRNTH FNCTN	NDG		JAE	EXPT-PROG	NEANDC-J106	14		SEP 84	OHKUBO+.PUBLISHED IN NST 21 254.
NB	93	DIFF INELAST	14+7		KYU	THEO-PROG	NEANDC-J106	50		SEP 84	WATANABE+.PREEQ MDL.DDX GIVEN IN FIG
NB	93	N, PROTON	14+7		KYU	EXPT-PROG	NEANDC-J106	45		SEP 84	KOORI+.PUBLISHED IN NSE 87 34.
MO	92	N, PROTON	14+7		NAG	EXPT-PROG	NEANDC-J106	55		SEP 84	ATSUMI+.ACT-METH.SIG=68MB TO ISOMER.
MO	92	N, ALPHA	14+7		NAG	EXPT-PROG	NEANDC-J106	55		SEP 84	ATSUMI+.ACT-METH.SIG=27MB.

ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF	VOL	PAGE	DATE	COMMENTS
MO	95	N, PROTON	14+7		NAG	EXPT-PROG	NEANDC-J106	55		SEP 84	ATSUMI+.ACT.5.8MB TO ISOM,32MB TO GS
MO	96	N, PROTON	14+7		NAG	EXPT-PROG	NEANDC-J106	55		SEP 84	ATSUMI+.ACT-METH.SIG=24MB .
MO	96	N,N PROTON	14+7		NAG	EXPT-PROG	NEANDC-J106	55		SEP 84	ATSUMI+.ACT.1.7MB TO ISOM,4.6MB GS.
MO	97	N,N PROTON	14+7		NAG	EXPT-PROG	NEANDC-J106	55		SEP 84	ATSUMI+.ACT-METH.SIG=4.2MB.
MO	98	N, ALPHA	14+7		NAG	EXPT-PROG	NEANDC-J106	55		SEP 84	ATSUMI+.ACT-METH.SIG=5.8MB.
MO	100	N, 2N	14+7		NAG	EXPT-PROG	NEANDC-J106	55		SEP 84	ATSUMI+.ACT-METH.SIG=1500MB.
MO	100	N, ALPHA	14+7		NAG	EXPT-PROG	NEANDC-J106	55		SEP 84	ATSUMI+.ACT-METH.SIG=2.7MB.
AG		DIFF INELAST	14+7		KYU	THEO-PROG	NEANDC-J106	50		SEP 84	WATANABE+.PREEQ MDL.DDX GIVEN IN FIG
AG	107	RESON PARAMS	40+2	70+3	JAE	EXPT-PROG	NEANDC-J106	15		SEP 84	MIZUMOTO+.PUBLISHED IN NST 20 883.
AG	107	STRNTH FNCTN	40+2	70+3	JAE	EXPT-PROG	NEANDC-J106	15		SEP 84	MIZUMOTO+.PUBLISHED IN NST 20 883.
AG	109	RESON PARAMS	40+2	70+3	JAE	EXPT-PROG	NEANDC-J106	15		SEP 84	MIZUMOTO+.PUBLISHED IN NST 20 883.
AG	109	STRNTH FNCTN	40+2	70+3	JAE	EXPT-PROG	NEANDC-J106	15		SEP 84	MIZUMOTO+.PUBLISHED IN NST 20 883.
IN	115	TOT INELAST	25+6	15+7	JPN	EXPT-PROG	NEANDC-J106	1		SEP 84	KUDO+.ACT METH,TO IN-115M,SIG GIVEN.
SN	122	RESON PARAMS		30+4	JAE	EXPT-PROG	NEANDC-J106	16		SEP 84	MAKAJIMA+.LINAC,TOF,TRAN.D=1.17KEV
SN	122	STRNTH FNCTN		30+4	JAE	EXPT-PROG	NEANDC-J106	16		SEP 84	MAKAJIMA+.LINAC,TOF,TRAN.SO=0.30
SB	123	N, PROTON	14+7		KYU	EXPT-PROG	NEANDC-J106	46		SEP 84	INENAGA+.ACT RATIO TO SB124(N2N) GVN
TE	126	N, ALPHA	14+7		KYU	EXPT-PROG	NEANDC-J106	46		SEP 84	INENAGA+.ACT RATIO TO SB124(N2N) GVN
BA	135	RESON PARAMS	NDG		JAE	EXPT-PROG	NEANDC-J106	17		SEP 84	MIZUMOTO+.LINAC,TOF.NDG.
BA	137	RESON PARAMS	NDG		JAE	EXPT-PROG	NEANDC-J106	17		SEP 84	MIZUMOTO+.LINAC,TOF.NDG.
BA	138	RESON PARAMS	NDG		JAE	EXPT-PROG	NEANDC-J106	17		SEP 84	MIZUMOTO+.LINAC,TOF.NDG.

ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF	VOL	PAGE	DATE	COMMENTS
CE	142	RESON PARAMS	10+2	10+5	JAE	EXPT-PROG	NEANDC-J106	17		SEP 84	OHKUBO+.LINAC,TOF.NDG.
PR		SPECT N,GAMM	10+4	80+5	TIT	EXPT-PROG	NEANDC-J106	67		SEP 84	IGASHIRA+.AT 84KNOXVILLE SYMPOSIUM.
GD	155	N, GAMMA	11+3	22+5	JAE	EXPT-PROG	NEANDC-J106	12		SEP 84	NAKAJIMA+.LINAC,TOF,LIQUID SCINT.
GD	155	RESON PARAMS	11+3	22+5	JAE	EXPT-PROG	NEANDC-J106	12		SEP 84	NAKAJIMA+.LINAC,TOF,AV-WG FOR S+P.
GD	155	STRNTH FNCTN	11+3	22+5	JAE	EXPT-PROG	NEANDC-J106	12		SEP 84	NAKAJIMA+.LINAC,TOF,S0=3.00,S1=3.66
GD	157	N, GAMMA	11+3	22+5	JAE	EXPT-PROG	NEANDC-J106	12		SEP 84	NAKAJIMA+.LINAC,TOF,LIQUID SCINT.
GD	157	RESON PARAMS	11+3	22+5	JAE	EXPT-PROG	NEANDC-J106	12		SEP 84	NAKAJIMA+.LINAC,TOF,AV-WG FOR S+P.
GD	157	STRNTH FNCTN	11+3	22+5	JAE	EXPT-PROG	NEANDC-J106	12		SEP 84	NAKAJIMA+.LINAC,TOF,S0=2.23,S1=2.18
TB		SPECT N,GAMM	10+4	80+5	TIT	EXPT-PROG	NEANDC-J106	67		SEP 84	IGASHIRA+.AT 84KNOXVILLE SYMPOSIUM.
HO		SPECT N,GAMM	10+4	80+5	TIT	EXPT-PROG	NEANDC-J106	67		SEP 84	IGASHIRA+.AT 84KNOXVILLE SYMPOSIUM.
TA		SPECT N,GAMM	10+4	80+5	TIT	EXPT-PROG	NEANDC-J106	67		SEP 84	IGASHIRA+.AT 84KNOXVILLE SYMPOSIUM.
TA	181	TOTAL	24+4	10+6	JAE	EXPT-PROG	NEANDC-J106	13		SEP 84	TSUBONE+.TO BE PUBLISHED IN NSE.
TA	181	RESON PARAMS	24+4	10+6	JAE	EXPT-PROG	NEANDC-J106	13		SEP 84	TSUBONE+.TO BE PUBLISHED IN NSE.
TA	181	STRNTH FNCTN	24+4	10+6	JAE	EXPT-PROG	NEANDC-J106	13		SEP 84	TSUBONE+.TO BE PUBLISHED IN NSE.
AU		SPECT N,GAMM	10+4	80+5	TIT	EXPT-PROG	NEANDC-J106	67		SEP 84	IGASHIRA+.AT 84KNOXVILLE SYMPOSIUM.
PB	204	DIFF INELAST	FISS		KTO	EXPT-PROG	NEANDC-J106	41		SEP 84	KOBAYASHI+.CF252.SIG=20.84+-0.92MB
TH	232	TOTAL	25-2	30+2	KTO	EXPT-PROG	NEANDC-J106	40		SEP 84	KOBAYASHI+.TBP ANE.
TH	232	DIFF INELAST	16+6	60+6	TOH	EXPT-PROG	NEANDC-J106	64		SEP 84	NAKASHIMA+.DYNAMITRON,TOF.DDX,NDG.
TH	232	SPECT FISS N	20+6		TOH	EXPT-PROG	NEANDC-J106	63		SEP 84	NAKASHIMA+.TOF.CFD JENDL-2.T=1.24MEV
U	235	FISSION	NDG		KYU	THEO-PROG	NEANDC-J106	53		SEP 84	UENOHARA+.PUBLISHED IN NST 20 967.

ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF	VOL	PAGE	DATE	COMMENTS
U	238	TOTAL	24+4	10+6	JAE	EXPT-PROG	NEANDC-J106	13		SEP 84	TSUBONE+.TO BE PUBLISHED IN NSE.
U	238	FISSION	NDG		KYU	THEO-PROG	NEANDC-J106	53		SEP 84	UENOHARA+.PUBLISHED IN NST 20 967.
U	238	RESON PARAMS	24+4	10+6	JAE	EXPT-PROG	NEANDC-J106	13		SEP 84	TSUBONE+.TO BE PUBLISHED IN NSE.
U	238	STRNTH FNCTN	24+4	10+6	JAE	EXPT-PROG	NEANDC-J106	13		SEP 84	TSUBONE+.TO BE PUBLISHED IN NSE.
PU	241	EVALUATION	10-5	20+7	JAE	EVAL-PROG	NEANDC-J106	25		SEP 84	KIKUCHI+.JENDL-2.PUB JAERI-M84-111.
CM	248	EVALUATION	10-5	20+7	JAE	EVAL-PROG	NEANDC-J106	26		SEP 84	KIKUCHI+.JENDL-3.PUB JAERI-M84-116.
CM	249	EVALUATION	10-5	20+7	JAE	EVAL-PROG	NEANDC-J106	26		SEP 84	KIKUCHI+.JENDL-3.PUB JAERI-M84-116.
MANY		STRNTH FNCTN	NDG		HOS	THEO-PROG	NEANDE-J106	11		SEP 84	FURUOYA+.PUBLISHED IN NST 21 247.
MANY		LVL DENSITY	NDG		KYU	THEO-PROG	NEANDC-J106	52		SEP 84	UENOHARA+.LEAST SQUARES FIT.NDG.

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

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I. ELECTROTECHNICAL LABORATORY

Quantum Technology Division

I-1 Cross Section Measurements of $^{115}In(n,n')^{115m}In$ Reaction at 2.49 and 14.6MeV

K. Kudo, T. Michikawa, T. Kinoshita and Y. Kawada

The reaction $^{115}In(n,n')^{115m}In$ is widely used to measure fast neutron fluxes for reactor dosimetry, because of its convinient half life(4.486h) and appropriate γ-ray energy(336keV) for γ spectroscopy with a Ge detector.

This reaction was adopted as a transfer instrument in the international intercomparison of monoenergetic neutron fluence rate at 2.5, 5 and 14.8MeV organized under the auspices of Comité Consultatif pour les Etalons de Mesure des Rayonnements Ionisants/Comité International des Poids et Mesures(CCEMRI/CIPM) in 1981 and seven national standardizing institutes participated in it.

The calibration for the $^{115}In(n,n')^{115m}In$ transfer instrument was performed at Electrotechnical Laboratory(ETL) in the last quarter of 1981. Monoenergetic neutrons of 2.49 and 14.6MeV were produced through

the d+D and d+T reaction by bombarding a deuterated titanium and a tritiated titanium target with analyzed deuterons of 260keV respectively. The activation samples were 20mm diameter and 4.94mm thickness foils of natural indium. The foils were placed at a distance of 153mm from the target at 45° to the direction of the incident deuteron beam and normal to it at 14.6MeV and 124.3mm on the 90° direction at 2.49MeV.

Associated alpha particle and proton recoil techniques were used at 14.6MeV for the neutron fluence determination, and two methods of a Si-semiconductor detector with a thick polyethylene radiator and a proton recoil telescope were adopted for 2.49MeV neutron measurements. The uncertainty of each technique described above is corresponding to ±1.0,1.9, 2.2 and 2.4% in turn[1],[2]. The correction for secondary neutrons from the target backing, the target mount and the room were evaluated by coupling the results of a two dimentional discrete ordinates transport code Pallas[3] and a simple one collision model. The corrections for secondary neutrons to the $^{115}In(n,n')^{115m}In$ activities were estimated to be 9% for 14.6MeV and 0.9% for 2.5MeV experiments.

Eleven irradiations were performed at 2.5MeV and 14.6MeV respectively and after 5 hours irradiation, the γ counting of the 336 keV γ-rays from ^{115m}In were performed with a well-calibrated Ge(Hp) detector(64.9cc) shielded by a lead box. The source-detector distances were 35 and 50mm for 2.49 and 14.6MeV neutron calibration respectively. To decrease the uncertainty originated from each condition of γ spectrometry in the participants,the method of the intercomparison was based on the determination of γ count rate ratio between ^{115m}In and calibrated ^{51}Cr source delivered from the Central Bureau for Nuclear

Measurements(CBNM) in Belgium, and finally the ratio of it to the neutron fluence was reported to the co-ordinator of BCMN. the result of 2.5MeV intercomparison was published[4] and ETL's result show very good agreement with those of other laboratories.

$^{115}In(n,n')^{115m}In$ cross sections were derived by using the result of the intercomparison together with the photo-efficiency of 336keV γ-rays. The Ge detector was calibrated by the use of standard samples of ^{203}Hg(279.2keV), ^{51}Cr(320.0keV), ^{85}Sr(514.0keV) and ^{134}Cs(604.7keV) which were prepared by the method of a simple deposition from radioactive solution and standardized by the $4\pi\ \beta-\gamma$ coincidence counting method.[5]

So far the cross sections of $^{115}In(n,n')^{115m}In$ reaction have been measured as (386 ± 8)mb at 2.49MeV and(66.2 ± 2.3)mb at 14.6MeV. The results show differeces of up to 15% at 2.49MeV and 6% at 14.6MeV compared with those of ENDF/B-V[6].

References:

(1) K. Kudo et al., Bull. of Electrotechnical Laboratory 923,47(1983).

(2) N. Kobayashi et al., ibid. 935,47(1983).

(3) K. Takeuchi et al., JAERI-M9695(1981).

(4) H. Liskien, Metrologia 55,20(1984).

(5) Y. Kawada, Researches of Electrotechnical Laboratory No730(1972).

(6) F. Schmittroth et al., ENDF/B-V dosimetry file MAT6437, MF=3,MT=51 (1979).

I-2 International Intercomparison of 14.6MeV Neutron Fluence by Using Zr/Nb Activation Method

K. Kudo, T. Michikawa and T. Kinoshita

Methods of fluence determination for 14.8MeV neutrons as performed in national standards laboratories have been compared by using niobium and zirconium activation technique.

Ingot of natural 99.9% purity niobium and zirconium were delivered from National Physical Laboratory(NPL) in England to 10 participants in 1981. After the standard irradiation in each laboratory, the induced activites of ^{93}Zr($T_{1/2}$=78.43h, E_{γ}=909keV) and ^{92}Nb(243.6h, 935keV) were measured in a well-type Ge(Li) detector of NPL. Finally, the niobium specific activities were compared with the fluences as determined by the participants and the ratio of zirconium to niobium specific activities were also compared with the mean neutron energies obtained by the participants.

The standard irradiation of 14.6MeV neutrons at Electrorechnical Laboratory(ETL) was performed in October of 1981. The ingots were 5mm diameter and 25mm length and held in a small Teflon holder. They were irradiated at 153mm from the Ti-T target and at 45° to the direction of 260keV deuteron beam. Neutron fluence was determined by associated alpha particle technique and proton recoil telescope method with the uncertainties of ±1.0 and ±1.9% respectively. The mean energy of neutrons in the irradiation field, which plays a very important role to determine the mean solid angle conversion factor from the LAB to the CM system in the associated alpha particle technique[1], was

evaluated by two methods of Si(n, α) energy calibration in a Si surface barrier detector and associated alpha fluence ratio technique between 89° and 131° direction to the deuteron beam.

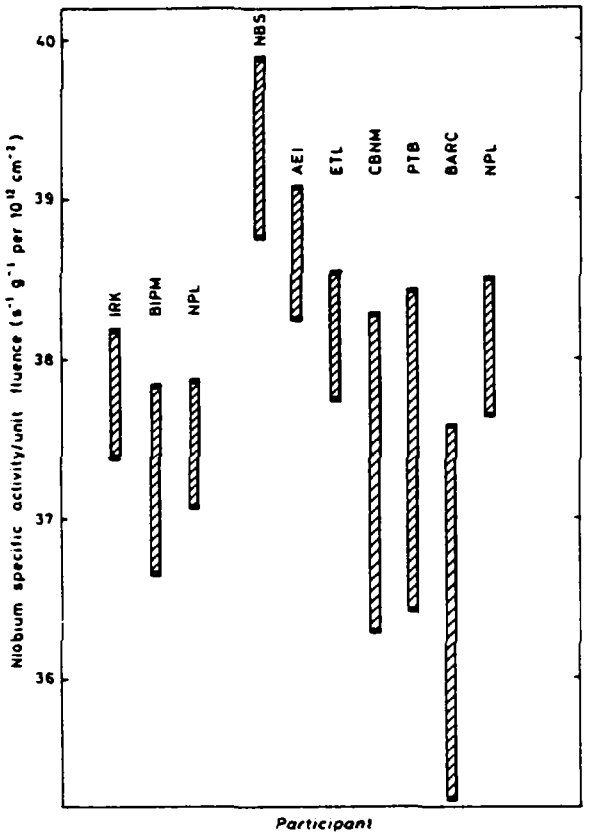
The results of the international comparison were published from the co-ordinator of NPL[2]. Figure 1[2] shows the results for d+T neutron fluence by the activation of niobium. All of the results agreed with the maximum deviation ±4% from the mean value of the participants and the result of ETL show the only 0.97% deviation to the mean value. Figure 2 [2] shows the results of d+T neutron energy by the NPL's evaluation of the Zr/Nb activation method and by each laboratory's evaluation. There is good agreement between NPL evaluation and ETL's energy measurement with the difference of 30keV to 14.6MeV neutron energy.

Further additional intercomparison is being planned to improve the uncertainty of the d+T neutron fluence measurement.

References:

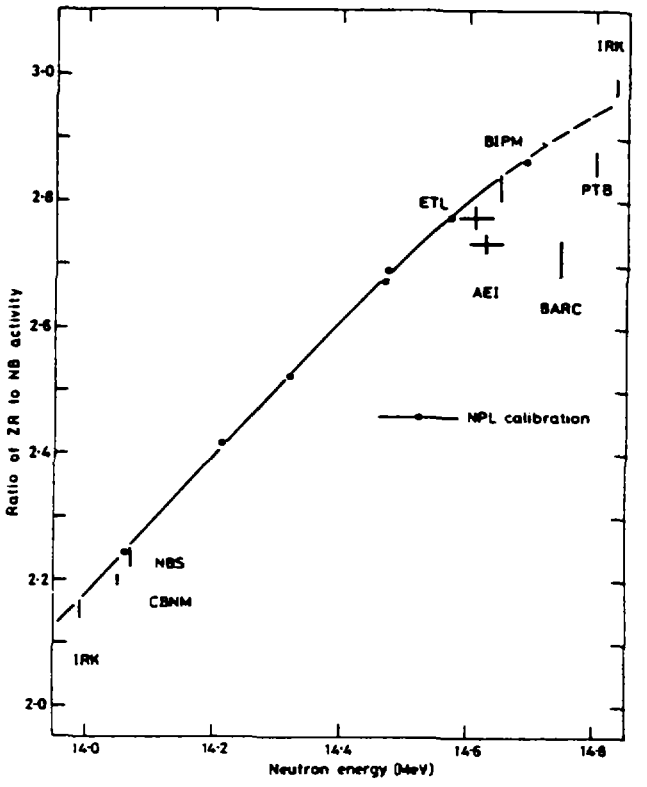
(1) K.Kudo et al., Bull. of Electrotechnical Laboratory 923,47(1983).

(2) V.E.Lewis, Metrologia 49,20(1984).



NIOBIUM ACTIVATION INTERCOMPARISON 1981

Fig. 1. Summary of results for intercomparison of d + T neutron fluence by the activation of niobium



NIOBIUM/ZIRCONIUM ACTIVATION INTERCOMPARISON 1981

Fig. 2. Summary of results for intercomparison of d + T neutron energy by the simultaneous activation of zirconium and niobium. The vertical error bars indicate the uncertainty due to counting statistics and the horizontal ones are those of the actual energy measurements

Participating laboratories

IRK: Institute für Radiumforschung und Kernphysik, Austria

BIPM: Bureau International des Poids et Mesures, France

NPL: National Physical Laboratory, U.K.

NBS: National Bureau of Standards, U.S.A.

AEI: Institute of Atomic Energy, Peoples Republic of China

ETL: Electrotechnical Laboratory, Japan

CBNM: Central Bureau of Nuclear Measurements, Belgium

PTB: Physikalisch-Technische Bundesanstalt,Federal Republic of Germany

BARC: Bhabha Atomic Research Centre, India

I-3

Decay Data of ^{111}In

Y.Kawada and Y.Hino

In spite of the relatively short half life, ^{111}In seems to provide advantageous features for the γ-ray intensity standard in low energy region, since the decay scheme is simple as shown in Fig.1 and the γ-ray intensities per decay are determined a priori from the total internal conversion coefficients (ICCs). Several data have been reported so far for the total ICCs and the γ-ray intensities per decay. However there are still considerable discrepancies among the data.

In most of experiments reported in the past, α_k, α_L and α_M were determined first from the electron spectrometries and γ-ray measurements, and the total ICCs were finally deduced. In the course to get the final data on the total ICCs, considerable error should be originated. In order to overcome such a difficulty, we determined absolutely the total ICCs and the γ-ray intensities per decay of ^{111}In with much improved accuracy by applying a 4πβ-γ coincidence spectrometry with a combination of a 4πβ counter and a Ge detector.

The counting arrangement is shown in Fig.2, in which spectrometric means were employed instead of simple countings in the γ- and coincidence channels of the 4πβ-γ coincidence experiment. Here the γ-spectrum coincident with the β-pulses were recorded in the latter half of the 4k memory of a MCA by the aid of a "Digiplex", and another γ-spectrum not coincident with the β-pulses were recorded in the first half. The total γ-spectrum can be easily obtained

by adding these two spectra after data aquisition. In this experiment, only photopeak areas in the total and coincidence spectra are undertaken to derive the γ- and coincidence counting rates, $n_{\gamma k}$ and n_{ck}, for the kth γ-transition. From a simple analysis, one can realize that the ratio, $n_{ck}/n_{\gamma k}$, of the counting rates in the coincidence and γ-channels corresponds to the counting efficiency, ε_k, of the β-channel to all events including electron capture and γ-transitions except for the kth γ-transition. If a number of such $4\pi\beta$-γ coincidence countings are made with different source conditions and/or with altering the kind of the flowing gas, plotting of $n_\beta\ n_{\gamma k}/(n_{ck}\ m)$ versus $(1 - \varepsilon_k)/\varepsilon_k$ will result a straight line, and the slope to intercept ratio, R_k, gives $\left[(\alpha_T\ \varepsilon_{ce} + \varepsilon_{\beta\gamma})/(1 + \alpha_T)\right]_k$, from which the total ICC, α_{Tk}, of the kth γ-transition can be deduced as $\alpha_{Tk} = \left[(R - \varepsilon_{\beta\gamma})/(\varepsilon_{ce} - R)\right]_k$. It should be noted here that ε_{ce} remains unchanged from very near unity[1], and $\varepsilon_{\beta\gamma}$ is usually very small[2].

Fig.3 represents plotting of $n_\beta\ n_{\gamma k}/(n_{ck}\ m)$ versus $(1 - \varepsilon_k)/\varepsilon_k$ for the 171 keV and 245 keV transitions. From the slope to intercept ratios, the total ICCs and the γ-intensities per decay were determined for both transitions. The final results are given in Fig.4 and Table 1 together with other reported data. In the above determination, accidental coincidences, dead time effects, problem of radioactive impurities, possible deviation of ε_{ce} from unity and the value of $\varepsilon_{\beta\gamma}$ were fully discussed.

Our results are in excellent agreements with the data by Sparrmann et al.[3], while considerable discrepancies are found from the values of Shevelev et al.[4]. The difference from the data of Shevelev amounts to 20 % for α_T of 171 keV. Compared with the NDS evaluation, our results show appreciable difference of ~5 % for α_T of 171 keV and 3.2 % for α_T of 245 keV. One of reasons of the

discrepancies is likely due to the fact that the NDS evaluation was made taking account of the values of Shevelev et al. as one of data sources.

References:

1) Y.Kawada: Nucl. Instrum. Methods 98, 21 (1972)

2) Y.Kawada: Int. J. appl. Rad. Isotopes 20, 413 (1969)

3) P.Sparrman et al.: Z. Phys. 192, 439 (1966)

4) G.A.Shevelev et al.: Izv. Akad. Nauk. SSSR, Ser. Fiz.39 2038 (1975)

5) B.Harmatz: Nuclear Data Sheets 27, 453 (1979)

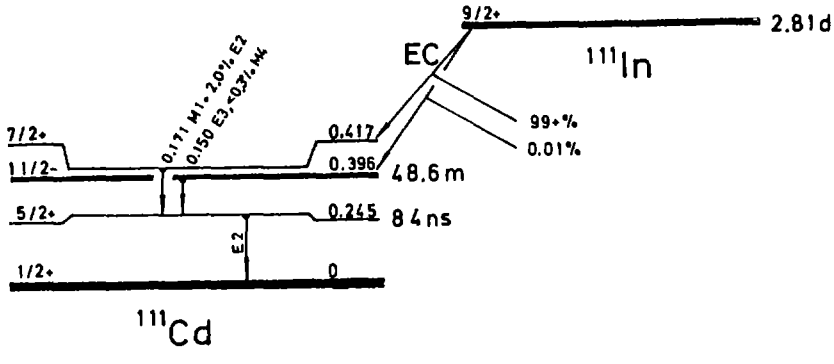


Fig.1 Decay Scheme of ^{111}In as quoted from Table of Isotopes

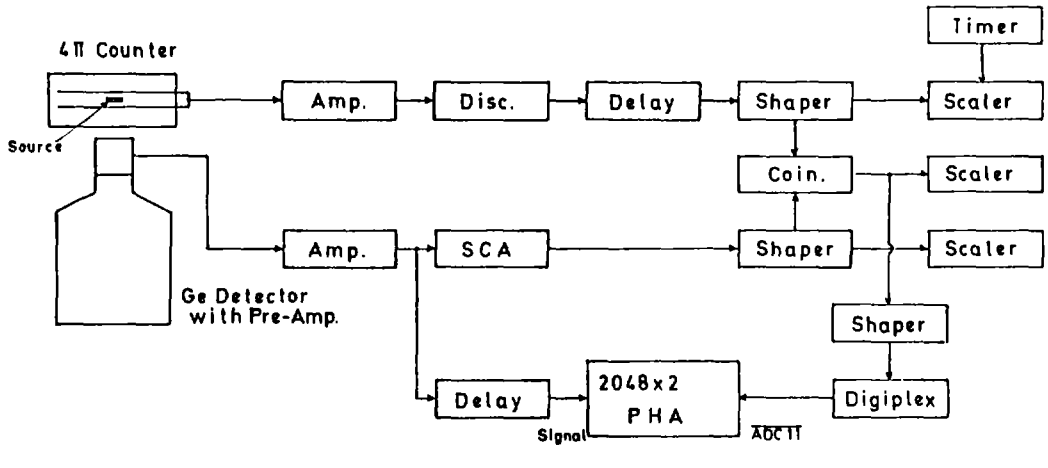
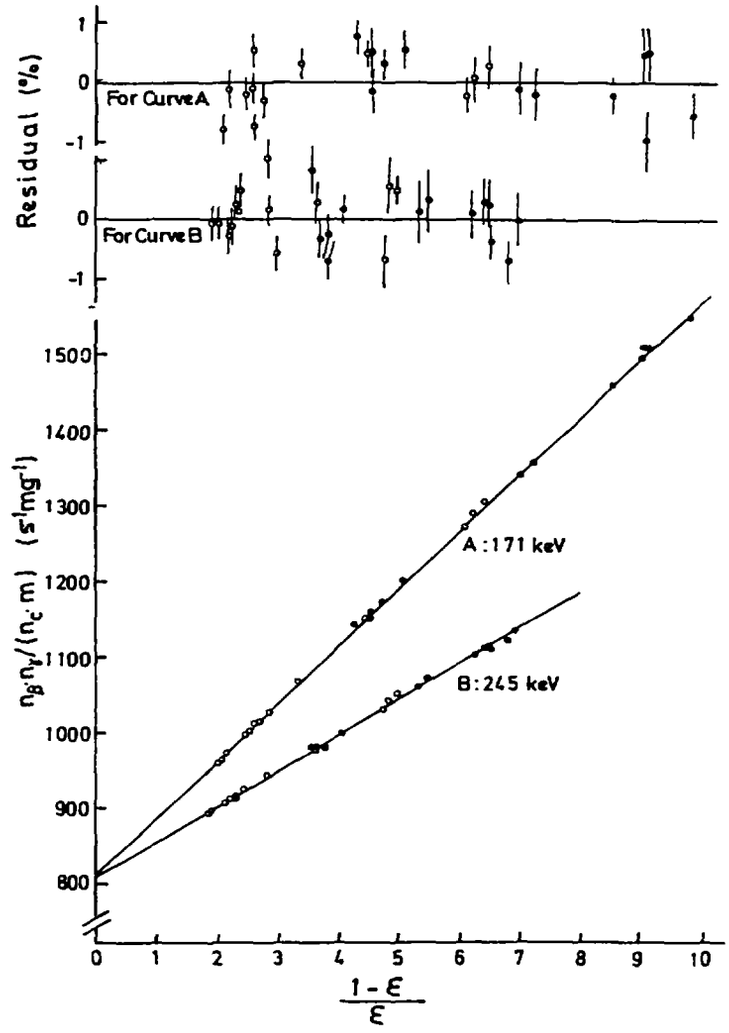


Fig.2 Experimental Arrangement

Fig.3 Plotting of $n_\beta n_{\gamma k}/(n_{ck} m)$ versus $(1 - \varepsilon)/\varepsilon$ in the $4\pi\beta$-γ Coincidence Spectrometry.



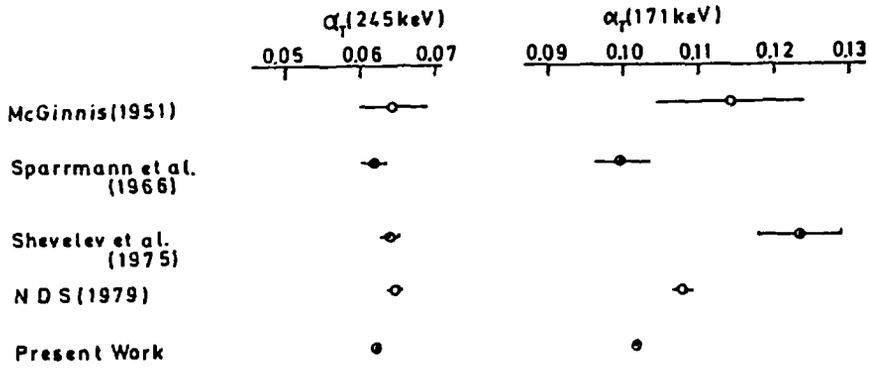


Fig.4 Graphical Representation of Results on ICCs.

Table 1 Summary of Results on ICCs and γ-Intensities per Decay.

	171 keV		245 keV	
	α_T	I_γ	α_T	I_γ
Sparrmann et al. (1966)	0.09983 ± 0.0029	0.9090 ± 0.0026	0.06188 ± 0.0016	0.9417 ± 0.0015
Shevelev et al. (1975)	0.12398 ±0.0059	0.8897 ±0.0053	0.06340	0.9404
N D S (1979)	0.1074 ±0.0001	0.9024	0.064	0.94
Present Work	0.10180 ±0.0009	0.9076 ±0.0008	0.06203 ±0.0007	0.9416 ±0.0007

II. HOSEI UNIVERSITY

Department of Physics

II-1 **P-Wave Neutron Strength Functions in Nuclear Vibrational Region**

Izumi FURUOYA and Ryuzo NAKASIMA

A paper on this subject was published in
Journal of Nuclear Science and Technology, 21[4], pp.247∿253 (1984).

The effect of doorway states on the p-wave neutron strength functions is investigated for even-even target nuclei in the vibrational region. A semi-empirical formula including contributions from both doorway state and coupled channel is derived for the p-wave strength function. The calculated results are compared with experimental data. Overall agreement in the mass region of 40∿180 is fairly well except for a few nuclides. In addition, isotopic trends of the p-wave neutron strength functions are studied for Cr, Fe, Ni, Zn, Se, Zr, Mo, Ru, Pd, Cd and Nd.

III. JAPAN ATOMIC ENERGY RESEARCH INSTITUTE

A. Linac Laboratory, Department of Physics

III-A-1

Neutron Capture Cross Sections of Gadolinium-155 and Gadolinium-157 Between 1.1 and 220 keV

Yutaka Nakajima, Izumi Tsubone*, Motoharu Mizumoto, Yutaka Furuta, Makio Ohkubo, Masayoshi Sugimoto, and Yuuki Kawarasaki

The neutron capture cross sections of ^{155}Gd and ^{157}Gd have been measured for incident neutron energies between 1.1 keV and 235 keV using a pulsed neutron source and the time-of-flight technique. Capture gamma rays were detected by a 500 l liquid scintillator located at the end of a 54.45 m flight path. The incident neutron flux was measured by a ^{6}Li-glass scintillator. The cross sections were normalized by the saturated resonance technique. Deviation from other measurements is within the uncertainties of the experimental errors in the overlap energy region. The average resonance parameters were obtained by statistical model analysis of the capture cross sections to be: $10^4 S_0 = 3.00 \pm 0.28$, $10^4 S_1 = 3.66 \pm 1.06$, $\langle \Gamma_\gamma^s \rangle = 119 \pm 29$ meV, $\langle \Gamma_\gamma^p \rangle = 138 \pm 55$ meV for ^{155}Gd, and $10^4 S_0 = 2.23 \pm 0.57$, $10^4 S_1 = 2.18 \pm 0.65$, $\langle \Gamma_\gamma^s \rangle = 115 \pm 28$ meV and $\langle \Gamma_\gamma^p \rangle = 129 \pm 25$ meV for ^{157}Gd.

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* On leave from Kyushu University as research student in JAERI

Neutron Total Cross Sections of Tatalum-181 and Uranium-238 from 24.3 keV to 1 MeV and Average Resonance Parameters

Izumi Tsubone*, Yutaka Nakajima, Yutaka Furuta and Yukinori Kanda**

A paper on this subject will be published in Nucl. Sci. Eng. with the following abstract:

The neutron total cross sections of ^{181}Ta and ^{238}U have been obtained in the energy range from 24.3 keV to 1 MeV by means of neutron transmission measurements using the Japan Atomic Energy Research Institute linac. The measurements were carried out with the iron-filtered neutron beam technique and the time-of-flight method, using an NE-110 plastic scintillator as a neutron detector at a 100 m station. For ^{238}U, correction for the resonance self-shielding effect was taken into account below 270 keV by measuring the transmission of four samples of different thicknesses. By fitting average R-matrix calculations to the observed total cross sections, the neutron strength functions S_ℓ for p- and d-wave, and distant level parameters R_ℓ^∞ for s-, p-, and d-wave were deduced to be: R_0^∞ =-0.003±0.03, $S_1 x10^4$= 0.57±0.31, R_1^∞=-0.01±0.03, $S_2 x10^4$=1.22±0.12,and R_2^∞=-0.15±0.3 for ^{181}Ta, and R_0^∞=-0.072±0.028, $S_1 x10^4$= 1.68±0.28 ,R_1^∞=0.23±0.08, $S_2 x10^4$=0.70±0.34 and R_2^∞=-0.33±0.13 for ^{238}U. The effective s-wave scattering radii were 7.90±0.03 and 9.30±0.04 fm for ^{181}Ta and ^{238}U, respectively.

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* On leave from Kyushu University as research student in JAERI.

** Department of Energy Conversion Engineering, Kyushu University, Kasuga, Fukuoka 816

III-A-3

Neutron Resonance Parameters of Rubidium-85 and Rubidium-87

Makio Ohkubo, Motoharu Mizumoto and Yuuki Kawarasaki

A paper on this subject was published in "Journal of Nuclear Science and technology" in Vol 21, p254-265 (Aplil 1984) with the following abstract.

High resolution neutron transmission and low background capture measurements were carried out on the separated rubidium isotopes, using the time-of-flight facility of the linear accelerator of Japan Atomic Energy Research Institute. Resonance parameters and associated quantities were deduced as follows:

For ^{85}Rb, $g\Gamma_n$ values were determined for 138 resonance levels in the energy region below 18.5 keV. s-wave strength function was obtained to be $S_0=(0.94 \pm 0.11)\times10^{-4}$, average level spacing $\langle D\rangle = 133 \pm 11$ eV and the average radiation width $\langle\Gamma_\gamma\rangle = 328 \pm 18$ meV. For ^{87}Rb, $g\Gamma_n$ values were determined for 30 resonance levels in the energy region below 48.6 keV and the following quantities were deduced: $S_0=(1.15 \pm 0.3)\times10^{-4}$, $\langle D\rangle = 1380 \pm 250$ eV and $\langle\Gamma_\gamma\rangle = 166 \pm 30$ meV.

For ^{85}Rb average properties of resonances are in good agreement with the prediction of the statistical model. On the other hand, for ^{87}Rb the average properties of resonances deviate from the prediction of the statistical model: four strong s-wave resonances cluster within an energy interval of 5 keV, and they carry about 37 % of s-wave strength below 48.6 keV.

III-A-4

Neutron resonance parameters of Silver-107 and Silver-109

M. Mizumoto, M. Sugimoto, Y. Nakajima, M. Ohkubo,

Y. Furuta and Y. Kawarasaki

A paper on this subject has been published in J. Nucl. Sci. Technol. 20 (1983) 883 with the following abstract:

Neutron transmission measurements were carried out on the separated isotopes of silver using the time-of-flight facility at the Japan Atomic Energy Research Institute electron linear accelerator. Neutrons were detected with the ^{6}Li-glass detectors at 56 and 191 m. The samples used were metallic powder enriched to 98.2 % for ^{107}Ag and 99.3 % for ^{109}Ag. Transmission data were analyzed with the multi-level Breit-Wigner formula incorporated in a least squares fitting program. Resonance energies and neutron widths were determined for the large number of resolved resonances in the neutron energy region of 400 eV - 7 keV. The s-wave strength functions and average level spacings were obtained to be; $S_0=(0.43 \pm 0.05)\times10^{-4}$ $D_0=20 \pm 2$ eV for ^{107}Ag and $S_0=(0.45 \pm 0.05)\times10^{-4}$, $D_0= 20 \pm 2$ eV for ^{109}Ag.

III-A-5

Measurements of Neutron Resonance Parameters of ^{122}Sn

Yutaka Nakajima, Makio Ohkubo, Yutaka Furuta,
Masayoshi Sugimoto and Yuuki Kawarasaki

Neutron transmission measurements have been carried out on an enriched isotope of ^{122}Sn (92.20%) with the Japan Atomic Energy Research Institute linac time-of-flight facility. Electrons accelerated to 120 MeV impinged on a water cooled tantalum target to produce pulsed neutron beam. The linac was operated at a repetition rate of 300 pps, an electron burst width of 30 ns and an average beam current of $\sim$30 μA. The neutrons were detected by a ^{6}Li-glass scintillation detector at a 100 m station. A sample was oxide powder (SnO_2) encapsulated in a thin-walled aluminum case. The background was determined by the use of black resonances of thick Al and Bi plates.

The resonance parameters were deduced by the shape analysis with the computer program SIOB up to 30 keV neutron energy. The s-wave average resonance parameters obtained from individual resonance parameters are the following: $S_0 x10^4 = 0.30^{+0.12}_{-0.08}$, $D = 1.17^{+0.27}_{-0.17}$ keV, and $R' = 0.60 \pm 0.05$ fm.

III-A-6

Resonance parameters of Barium isotopes.

M. Mizumoto, M. Sugimoto, M. Ohkubo, Y. Nakajima

Y. Furuta and Y. Kawarasaki

Transmissions and capture cross sections of Barium isotopes (^{135,137,138}Ba) have been measured at 55 m time-of-flight station of the JAERI linac facility. The transmission data are analyzed with a multi-level Breit-Wigner formula to obtain neutron widths of resonances in combination with capture data taken with a 500 l large liquid scintillation detector.

III-A-7

Neutron Resonance Parameters of ^{142}Ce

M. Ohkubo, M. Mizumoto, Y. Nakajima,
Y.Furuta, M.Sugimoto, and Y.Kawarasaki

Neutron total cross section measurements on separated isotope ^{142}Ce and natural Ce have been made using a TOF spectrometer of the JAERI linac from 0.1 to 100 keV. Resonance analyses on ^{142}Ce and also ^{140}Ce are in progress.

III-A-8

A 500 l large liquid scintillation detector for neutron capture cross section measurements

Motoharu Mizumoto, Masayoshi Sugimoto and Tokio Shoji

A paper on this subject will be published as JAERI-M report with the following abstract:

A large liquid scintillation detector has been constructed for the purpose of measuring neutron capture cross sections. The detector is installed at a 55 m time-of-flight station at the JAERI electron linear accelerator. The detector tank is filled with 500 l scintillator liquid (NE224) and 20 l tri-methylborate. The tank is optically separated into halves by thin aluminized mylar so that background counts are reduced by operating the two halves of the tank in coincidence. The gamma pulse height resolution is found to be 24 % (FWHM) for 2.5 MeV sum peak of Co-60 source and the overall time resolution is 4.3 ns (FWHM).

The gamma-ray response function of the detector was investigated in order to determine the efficiency in either its conincidence or non-coincidence operation. Comparison was made between the observed pulse height distributions and calculations with a new Monte-Carlo code for various gamma-ray sources and neutron capture gamma-rays.

This report will describe the characteristic of the detector and the preliminary experiments for demonstrating the detector performance.

B. Nuclear Data Center, Department of Physics and Working Groups of Japanese Nuclear Dada Committee

III-B-1 Evaluation of Neutron Nuclear Data for ^{6}Li

Keiichi Shibata

A paper on this subject will be published as JAERI-M report with the following abstract:

Neutron nuclear data of ^{6}Li have been evaluated for JENDL-3 in the energy range from 10^{-5} eV to 20 MeV. Evaluated quantities are the total, elastic and inelastic scattering, radiative capture, photon-production, (n,2n), (n,p) and (n,α) reaction cross sections and the angular and energy distributions of neutrons. The total, elastic scattering and (n,α) cross sections below 1 MeV were calculated on the basis of the R-matrix theory. Two discrete levels were taken into account for the inelastic scattering. The double-differential cross sections for the (n,2n) reaction and the inelastic scattering to the continuous levels were obtained from the phase-space model calculations.

Figures 1 and 2 show the evaluated total and (n,α) reaction cross sections, respectively.

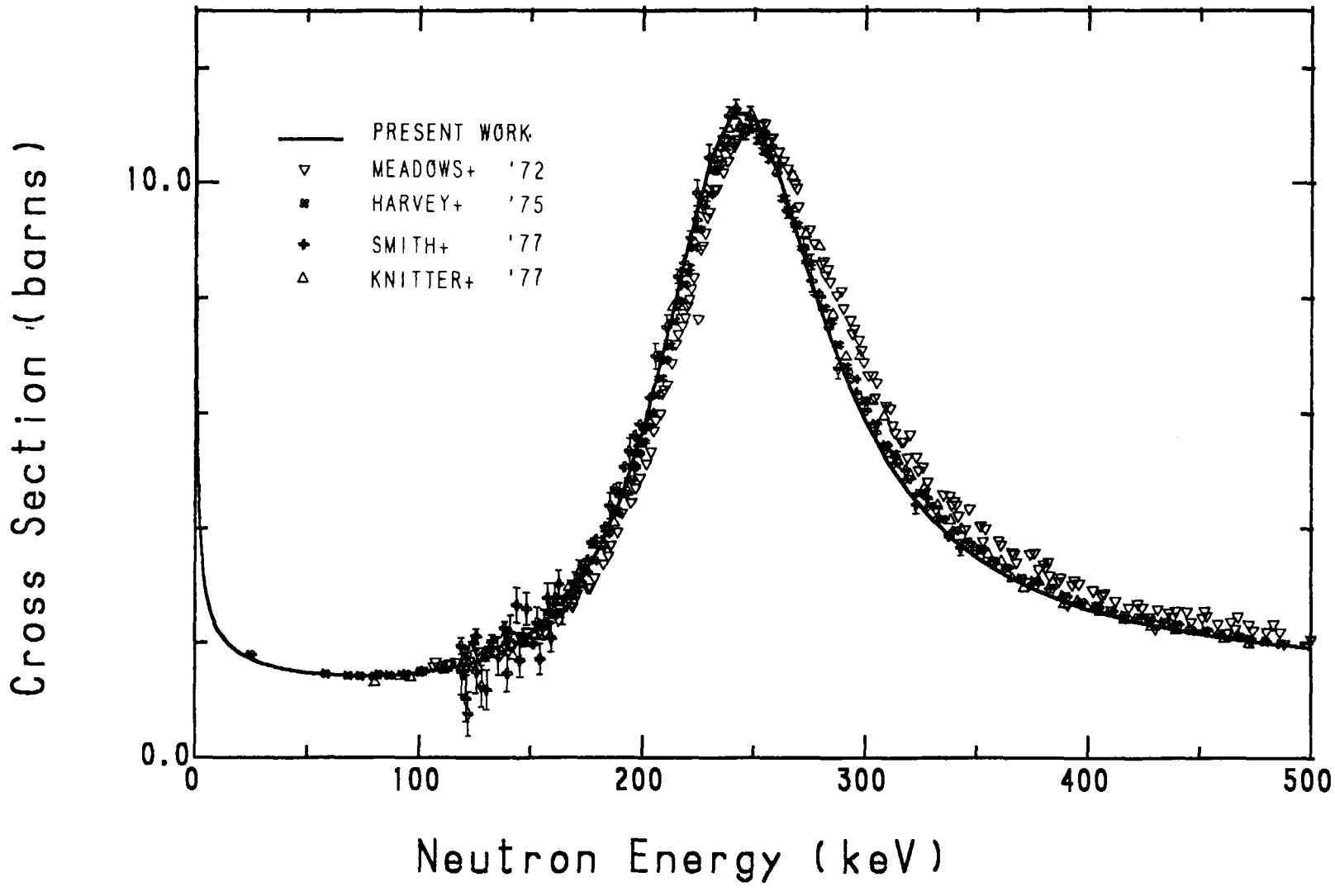

Fig. 1 Measured and evaluated total cross sections of ^{6}Li.

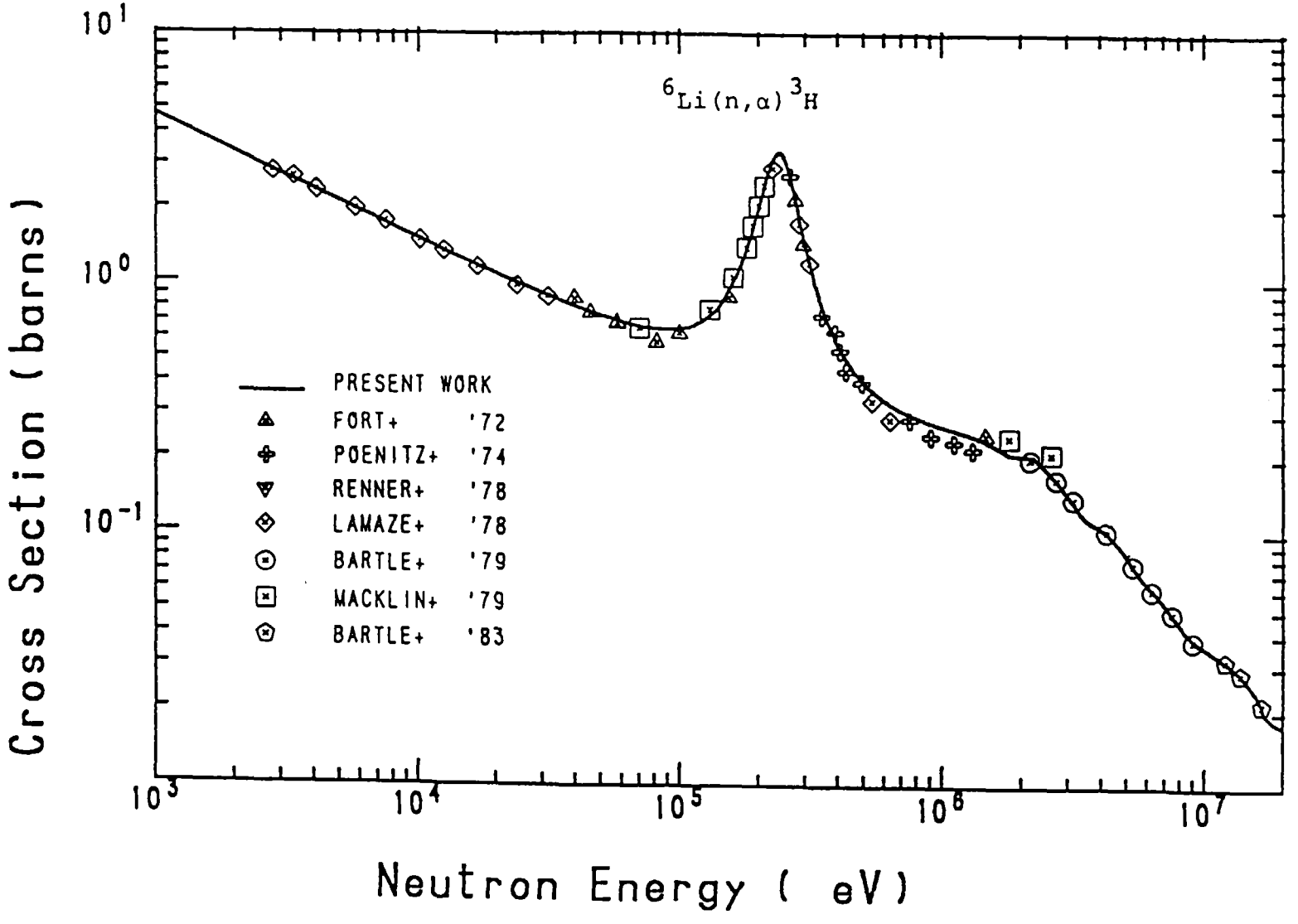

Fig. 2 Measured and evaluated ^{6}Li(n,α) cross sections.

III-B-2 Evaluation of Neutron Nuclear Data for ^{16}O

Y. Kanda*, T. Murata**, S. Tanaka,

Y. Nakajima, T. Asami and K. Shibata

A paper on this subject will be published as JAERI-M report with the following abstract:

Neutron nuclear data of ^{16}O have been evaluated for JENDL-3 in the energy range from 10^{-5} eV to 20 MeV. Evaluated quantities are the total, elastic and inelastic scattering, (n,2n), (n,γ), (n,p), (n,d) and (n,α) reaction cross sections and the angular and energy distributions of neutrons. The total cross section below 3 MeV was calculated on the basis of the R-matrix theory. The inelastic scattering cross section was obtained from the statistical model calculation.

Figures 1 and 2 show the evaluated total cross sections.

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* Interdisciplinary Graduate School of Engineering Sciences, Kyushu University

** NAIG Nuclear Research Laboratory, Nippon Atomic Industry Group Co., Ltd.

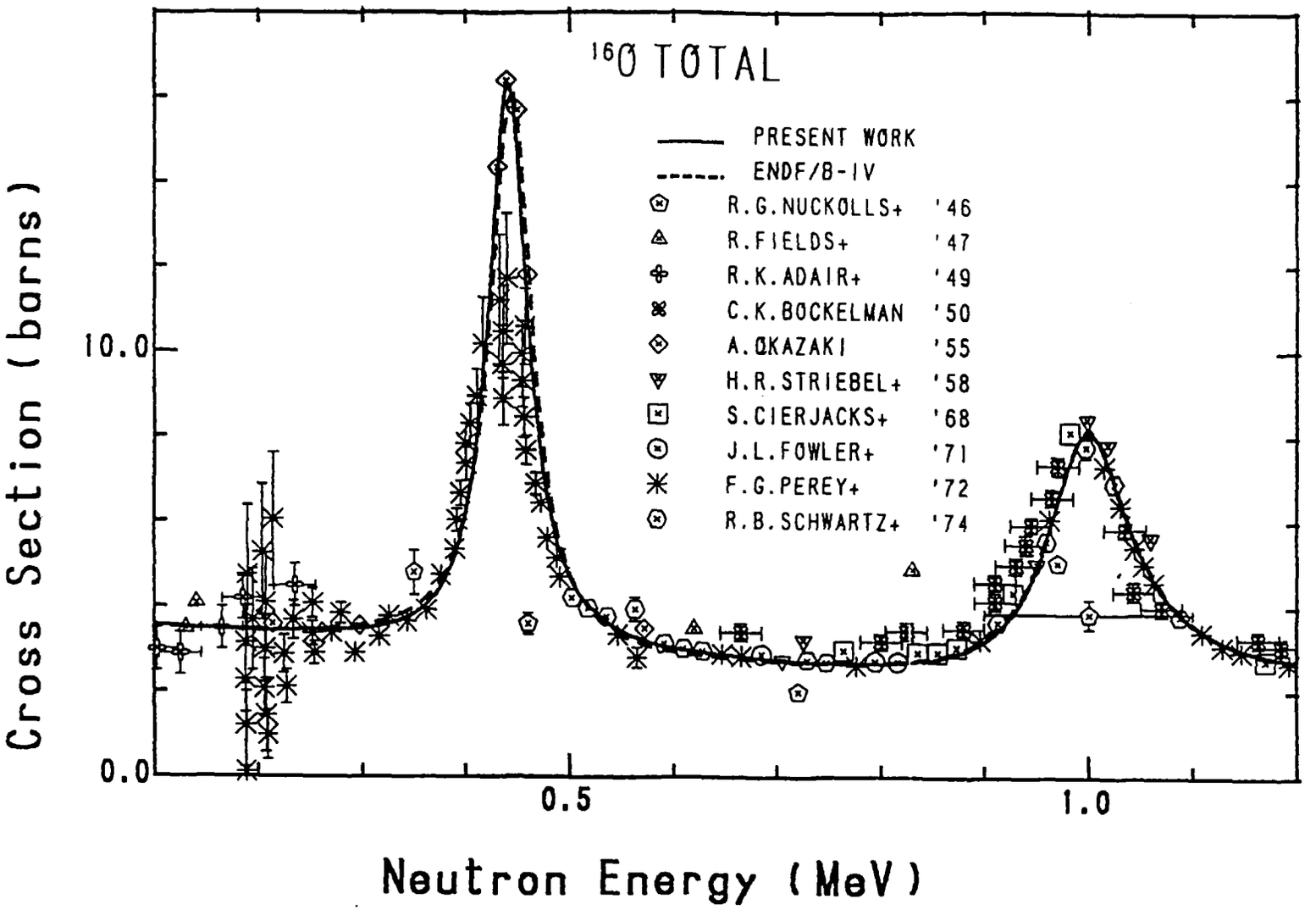


Fig. 1 Measured and evaluated total cross sections of ^{16}O below 1.2 MeV.

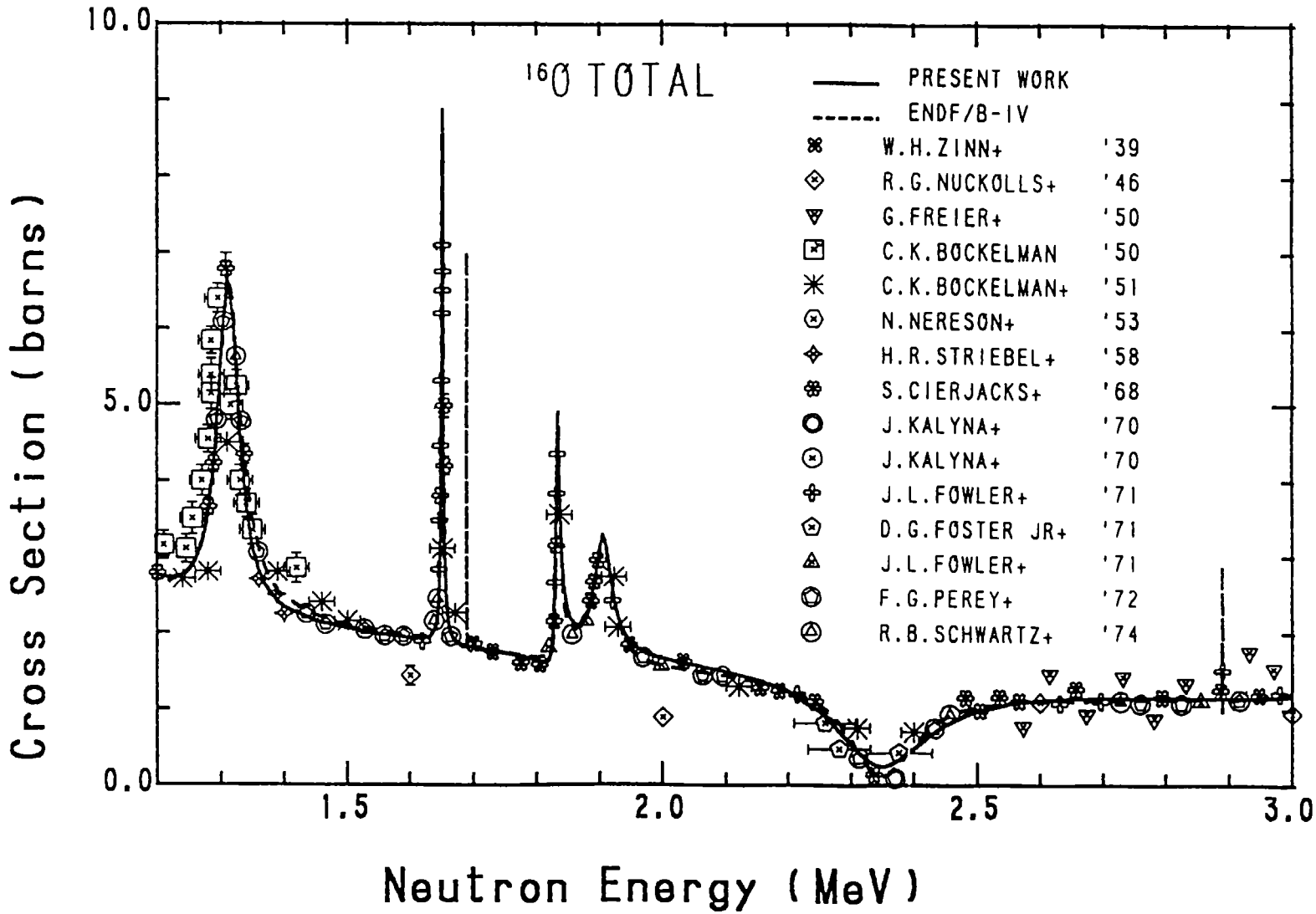


Fig. 2 Measured and evaluated total cross sections of ^{16}O between 1.2 MeV and 3 MeV.

III-B-3

Evaluation of Neutron Nuclear Data of ^{241}Pu for JENDL-2

Yasuyuki KIKUCHI and Nobuo SEKINE*

A paper on this subject was published as JAERI-M 84-111 with the following abstract:

Neutron nuclear data of ^{241}Pu were newly evaluated for JENDL-2. Evaluated quantities are the total, elastic and inelastic scattering, fission, capture, (n,2n), (n,3n) and (n,4n) reaction cross sections, the resolved and unresolved resonance parameters, the angular and energy distributions of emitted neutrons, and the average number of neutrons emitted per fission. The simultaneous evaluation method was adopted for the fission cross section so as to keep the consistency among the main fissile and fertile material nuclides. The theoretical calculations based on the spherical optical model and the statistical model were also used, when the experimental data were not sufficient. Discussion is given on the evaluation method.

* Present Address : Hitachi Engineering Co. Ltd.

III-B-4

Evaluation of Neutron Nuclear Data for ^{248}Cm and ^{249}Cm

Yasuyuki KIKUCHI and Tsuneo NAKAGAWA

A paper on this subject was published as JAERI-M 84-116 with the following abstract:

Neutron nuclear data of ^{248}Cm and ^{249}Cm have been evaluated. Evaluated quantities are the total, elastic and inelastic scattering, fission, capture, (n,2n), (n,3n) and (n,4n) reaction cross sections, the resolved and unresolved resonance parameters, the angular and energy distributions of the emitted neutrons, and the average number of neutrons emitted per fission. The fission cross section of ^{248}Cm was evaluated mainly on the basis of measured data and that of ^{249}Cm was estimated from the systematic trends. The other cross sections were calculated with the optical and statistical models because of scarce measured data.

This work was performed under contracts between Power Reactor and Nuclear Fuel Development Corporation and Japan Atomic Energy Research Institute.

C. Project Engineering Division

Department of JMTR Project

III-C-1

Covariance Effect in JMTR Neutron Spectrum Adjustment

K. Sakurai

The method and the preliminary result of the uncertainty analysis with adjustment code NEUPAC[1] were described in the previous paper[2]. The covariance effect in JMTR neutron spectrum adjustment has been evaluated in detail. The result is summarized as follows.

1) M. Sasaki and M. Nakazawa; PNC N941 80-192Tr(1981).

2) K. Sakurai; Nucl. Instr. and Methods 213(1983)359.

Guess Spectrum		Adjusted Spectrum Variance (%)		Neutron Flux (n/cm² sec) and Uncertainty (%)			
Variance (%)	Covariance (%)	6.5~10.5 MeV	10^{-9}~15 MeV	>1.0 MeV	Uncertainty	>0.1 MeV	Uncertainty
100	1	30	87	1.76×10^{8}	5.59	4.27×10^{8}	22.2
50	1	18	45	1.73×10^{8}	5.36	4.26×10^{8}	11.8
30	5	13	28	1.62×10^{8}	4.89	3.89×10^{8}	7.45
30	1	13	28	1.66×10^{8}	4.70	4.09×10^{8}	6.85
20	1	10	18	1.74×10^{8}	4.48	3.89×10^{8}	5.73
10	1	5	9	1.77×10^{8}	3.18	3.89×10^{8}	3.26
5	1	3	5	1.91×10^{8}	1.90	4.01×10^{8}	1.75

JMTRC J-11 neutron spectrum.
Cross section and covariance data from ENDF/B-V or IRDF-82.

III-C-2

Three Dimensional Analysis of Gamma-Heating Rates with MCACE and MCNP Codes for the JMTR Core

K. Sakurai and N. Yamano*

Gamma-heating rates for the JMTR core are calculated with three dimensional radiation transport codes MCACE[1] and MCNP[2]. For MCACE calculation, the neutron cross sections(100 groups) and the secondary gamma production cross sections(20 groups) are produced in RADHEAT-V4[1,3,4] by using ENDF/B-IV.

The calculations are performed on the standard core configurations with HEU(high enriched uranium), MEU(medium enriched uranium) and LEU(low enriched uranium). The absolute values of gamma-heating rates for each case are compared with the experimental values and the two dimensional analysis with DOT-3.5 . The gamma-heating rates for MEU and LEU cores are 6 and 15 % smaller than the values for HEU core, respectively.

1) N. Yamano et al.; Proc. 6th Int. Con. on Radiation Shielding, May 16-20, 1983, Vol. 1(1983)331.

2) LASL Group X-6; LA-7396-M, Revised(1979).

3) N. Yamano; JAERI-M84-038(1984).

4) N. Yamano; JAERI-M84-053(1984).

* Nuclear Fuel Facility Safety Evaluation Laboratory, Department of Nuclear Safety Evaluation, JAERI.

III-C-3

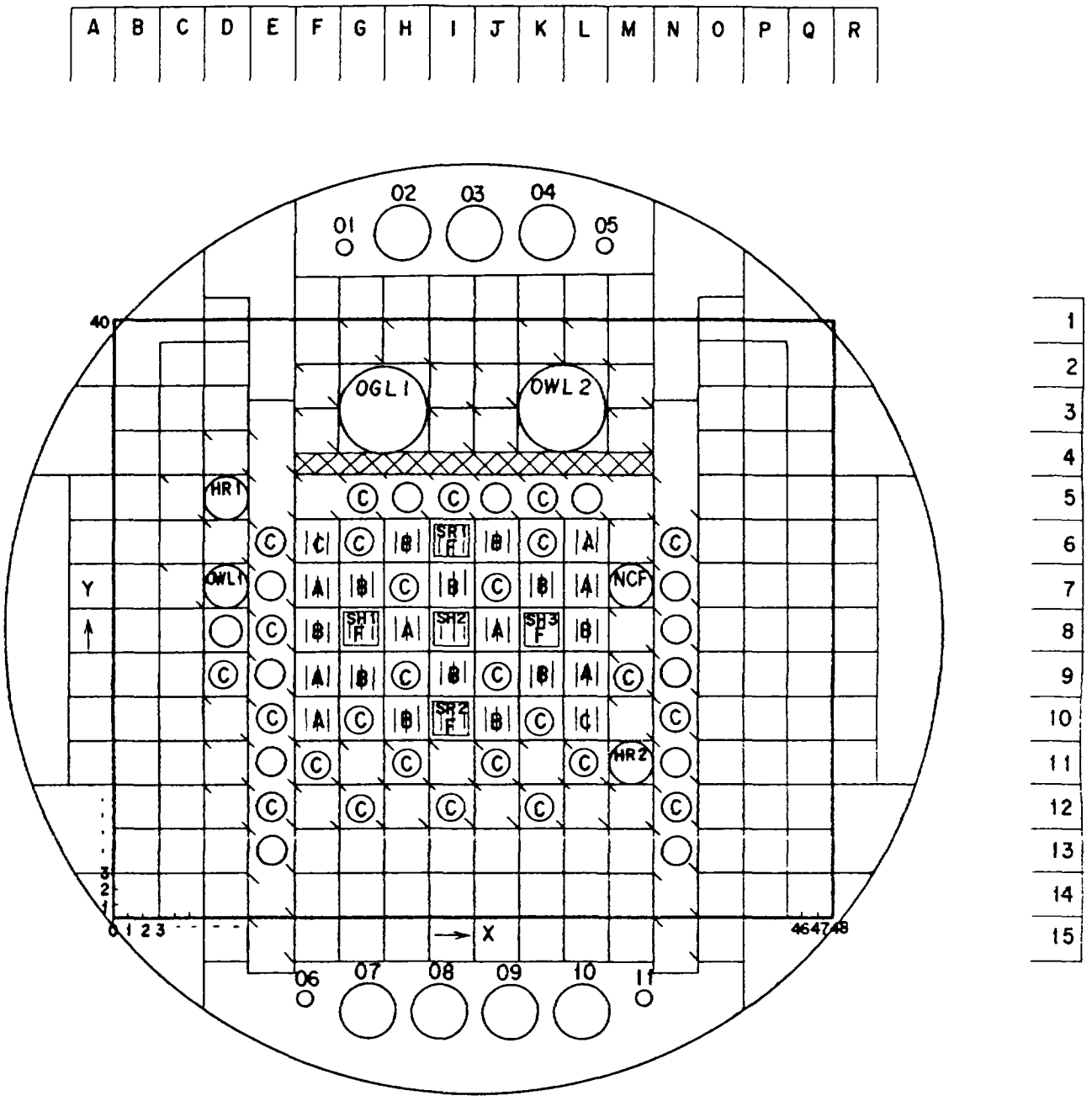
Dependence of Gamma-Heating Rates on Core Configurations in the JMTR

K. Sakurai and N. Yamano*

This paper will be submitted to the Fifth ASTM-EURATOM Symposium on Reactor Dosimetry held at the GKSS Research Centre(Geesthacht, Federal Republic of Germany, Sep. 24-28,1984).

Abstract; Gamma-heating rates for the JMTR core are calculated with two dimensional radiation transport code DOT-3.5 . The neutron cross sections(100 groups) and the secondary gamma production cross sections(20 groups) are produced in RADHEAT-V4 by using ENDF/B-IV and JENDL-2 libraries. The JMTR core is modelled with X-48 and Y-40 meshes. The calculations are performed on the standard core configuration and the recent operation core configurations. Especially, the dependence on the core configurations is carefully evaluated. And also, the absolute values of gamma-heating rates are compared with the experimental values, which were measured with TLD for the standard core configuration in the critical facility JMTRC. The C/E is about 1.0-1.3 for almost irradiation holes in the fuel region, Be-1, Be-2 and Al-1 reflector regions.

* Nuclear Fuel Facility Safety Evaluation Laboratory, Department of Nuclear Safety Evaluation, JAERI.



Fuel Element A B C
Fuel Follower F

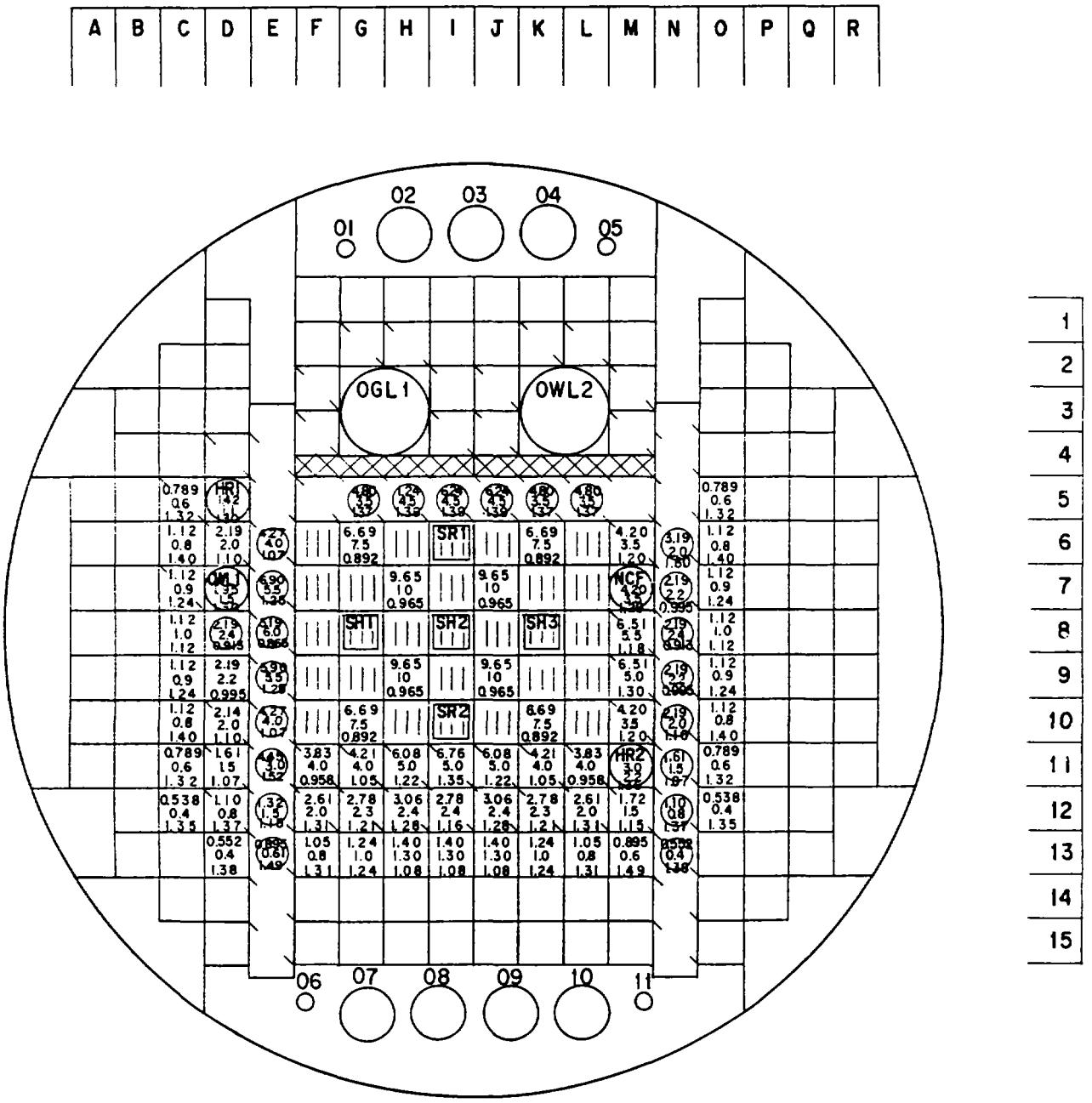
Beryllium Reflector Element

Aluminum Reflector Element

Standard Capsule

Unit Cell

Calculational model



Gamma-heating rates in W/g (SUS equivalent)

Upper; calculated vaue

Middle; Experimental value

Lower; C/E

III-C-4

Use of New Threshold Detector $^{204}Pb(n,n')^{204m}Pb$ for Reactor Neutron Dosimetry

K. Sakurai

The $^{204}Pb(n,n')^{204m}Pb$ reaction is important as a neutron dosimeter, especially to a nuclear reactor. The isomeric state at 2.2 MeV of ^{204}Pb decays with a half-life of 66.9 minutes[1]. The branching ratio is 99.18 % for 899 keV gamma-rays. The neutron cross sections of the reaction was reported by D. L. Smith[2]. The compilation of the energy dependent cross section for reactor neutron dosimetry and the irradiation experiment are in progress.

1) M. C. Lederer and V. S. Shirley; Table of Isotopes(7th ed.), wiley, New York(1978).

2) D. L. Smith et al.; ANL/NDM-37(1977).

III-C-5

Application of JENDL-2 for JMTR Neutron Dosimetry

K. Sakurai

The neutron fluence for each irradiation capsule has been evaluated by using neutron dosimetry or the result of nuclear calculations for the JMTR core[1,2].

The neutron dosimeter $^{54}Fe(n,p)^{54}Mn$ has been used to measure the neutron fluence above 1.0 MeV for the material capsule and the neutron dosimeter $^{59}Co(n,\gamma)^{60}Co$ has been used to measure the thermal neutron fluence for the

fuel capsule in the JMTR.

The evaluation of the neutron spectra of the JMTR has been performed by using the critical facility of the JMTR and the combination of the multi-foil activation method and the adjustment codes SAND-II and NEUPAC.

The neutron cross section library was compiled from ENDF/B-IV, -V, UKNDL and IRDF-82. At present, based on JENDL-2, the library has been compiled.

The thermal cross section of the $^{59}Co(n,\gamma)^{60}Co$ reaction in JENDL-2 agree with the one in ENDF/B-IV. However, the $^{54}Fe(n,p)^{54}Mn$ effective cross sections above 1.0 MeV for the JMTR neutron spectrum are 6 % smaller than those calculated with same spectrum and ENDF/B-IV , -V.

1) I. Kondo and K. Sakurai; J. Nucl. Sci. Technol. 18(1981)12.

2) K. Sakurai; Nucl. Instr. and Methods 213(1983)359.

III-C-6

Evaluation of Neutron Spectra and Gamma-Heating Rates for the JMTR Core -Difference on HEU, MEU and LEU Cores

K. Sakurai

This paper will be submitted to JAERI Report.

This paper consists of Capter 1 Introduction, Chapter 2 Evaluation of neutron spectra(neutron spectrum measurement and unfolding for core region, pressure vessel surveillance dosimetry), Capter 3 Evaluation of gamma-heating rates, Capter 4 Discussion and Capter 5 Conclusion.

The neutron spectrum unfolding was performed by using SAND-II and NEUPAC codes[1,2]. The neutron spectrum near pressure vessel was calculated

with PALLAS-2DCY[3]. The gamma-heating rates was calculated with two dimensional code DOT-3.5[4] and three dimensional codes MCACE and MCNP. The neutron cross sections and the secondary gamma production cross sections was mainly compiled from ENDF/B-IV for DOT-3.5 and MCACE calculations.

1) I. Kondo and K. Sakurai; J. Nucl. Sci. Technol. 18(1981)12.

2) K. Sakurai; Nucl. Instr. and Methods 213(1983)359.

3) K.Sakurai; Newsletter(petten), No.16(1981)18.

4) K. Sakurai and N. Yamano;Dependence of Gamma-Heating rates on Core Configuration for the JMTR Core, The Fifth ASTM-EURATOM Symposium on Reactor Dosimetry held at the GKSS Research Centre(Geesthacht, Federal Republic of Germany, Sep. 24-28,1984).

IV. KYOTO UNIVERSITY

Research Reactor Institute

IV-1 Determination of Pn value of ^{95}Rb by a β-γ Spectroscopic Method

K. Okano, Y. Kawase and Y. Funakoshi

Delayed neutron emission probability of ^{95}Rb has been measured utilizing a β-γ spectroscopic method[1] and the on-line isotope separator, KUR-ISOL. The Pn value of ^{95}Rb was determined from the yields of the 756.7 keV γ-ray of 64.0d ^{95}Zr produced by the decay chain of mass 95 and the 1427.7 keV γ-ray of ^{94}Sr produced after the neutron emission of ^{95}Rb. The value obtained is 8.59±0.57%, which is compared with previous values in the Table below.

Details of the experimental apparatus and procedure are described in another publication[2].

References:

1) K. Okano, Y. Funakoshi and Y. Kawase, Annu. Rep. Res. Reactor Inst. Kyoto Univ. Vol. 16 (1983) 47.

2) K. Okano, Y. Kawase and Y. Funakoshi, Annu. Rep. Res. Reactor Inst. Kyoto Univ. Vol. 17 (1984) (in press)

Table Pn value of ^{95}Rb

Reported value(%)	ISOL	Reference
7.10±0.93	ORSAY On-line mass spectrometer	I. Amarel et al., J. Inorg. Nucl. Chem. 31 (1969) 577.
8.54±0.91	CERN and LOUVAIN On-line mass spectrometer	E. Roeckl et al., Nucl. Phys. A222 (1974) 621.
8.4 ±0.5	LOHENGRIN	M. Asghar et al., Nucl. Phys. A247 (1975) 359.
11.0 ±0.8	SOLAR	P. L. Reeder et al., Phys. Rev. C15 (1977) 2108.
8.6 ±0.5	OSTIS	C. Ristori et al., Z. Physik A290 (1979) 311.
8.9 ±0.6	OSIRIS	E. Lund et al., Z. Physik A294 (1980) 233.
8.2 ±0.8	SOLIS	G. Engler et al., Nucl. Phys. A367 (1981) 29.
8.59±0.57	KUR-ISOL	Present result

IV-2 Measurement and Analysis of Energy Spectra of Neutrons in Structural Materials for Reactors

Itsuro Kimura, Shu A. Hayashi, Katsuhei Kobayashi,
Shuji Yamamoto, Ahmet Saim Selvi*,
Hiroshi Nishihara**, Satoshi Kanazawa**,
Takamasa Mori*** and Masayuki Nakagawa***

In order to assess evaluated nuclear data of main structural materials for fission and fusion reactors, measurement and analysis of energy spectra of neutrons in sample piles or scattered by sample slabs have been continuously carried out.

(1) The final result of the neutron spectrum in the titanium pile was published recently[1].

(2) The measurement and analysis of the neutron spectra in the iron, nickel and chromium piles were presented at the Consultants' Meeting on Evaluated Neutron Cross Section Data for Structural Materials held by IAEA at Vienna in November, 1983.

(3) The neutron spectrum in a spherical pile of manganese was measured and analysed recently. Manganese powder, whose purity was 99.95%, was packed into a steel vessel. The inner diameter and the thickness of the vessel were 60cm and 4.5mm, respectively. A photoneutron target was placed at the center of the pile and the neutrons at r=15cm (from the center) and μ=0 (90° to the radial direction) were extracted to the flight tube and the neutron detector. We measured the energy spectrum of the neutrons

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by the time-of-flight method. The details of the experimental arrangement can be seen elsewhere[1]. The measured and calculated spectra and their ratio are shown in Fig. 1. In general, both spectra agree from a few keV to a few MeV, over 3 decades of energy. It can be seen that the prediction with the ENDF/B-IV data is closer to the measured value than that with the JENDL-2 data, which does not have any resonance data between 100 keV and 800 keV.

The paper on this subject was submitted to Atomkernenergie.

(4) A paper on the measurement and analysis of neutron distribution in lithium fluoride and polytetrafluoroethylene piles was also submitted to J. Nucl. Sci. and Technol. recently.

(5) A paper on the measurement and analysis of neutron spectrum in lithium assembly is now in print to the publication in Annual Reports, Res. Reactor Inst., Kyoto University.

Reference:

(1) T. Mori, et al. : Assessment of Neutron Cross Sections for Titanium with Neutron Spectrum in Titanium Pile, J. Nucl. Sci. Technol., 20, 991-1005 (1983)

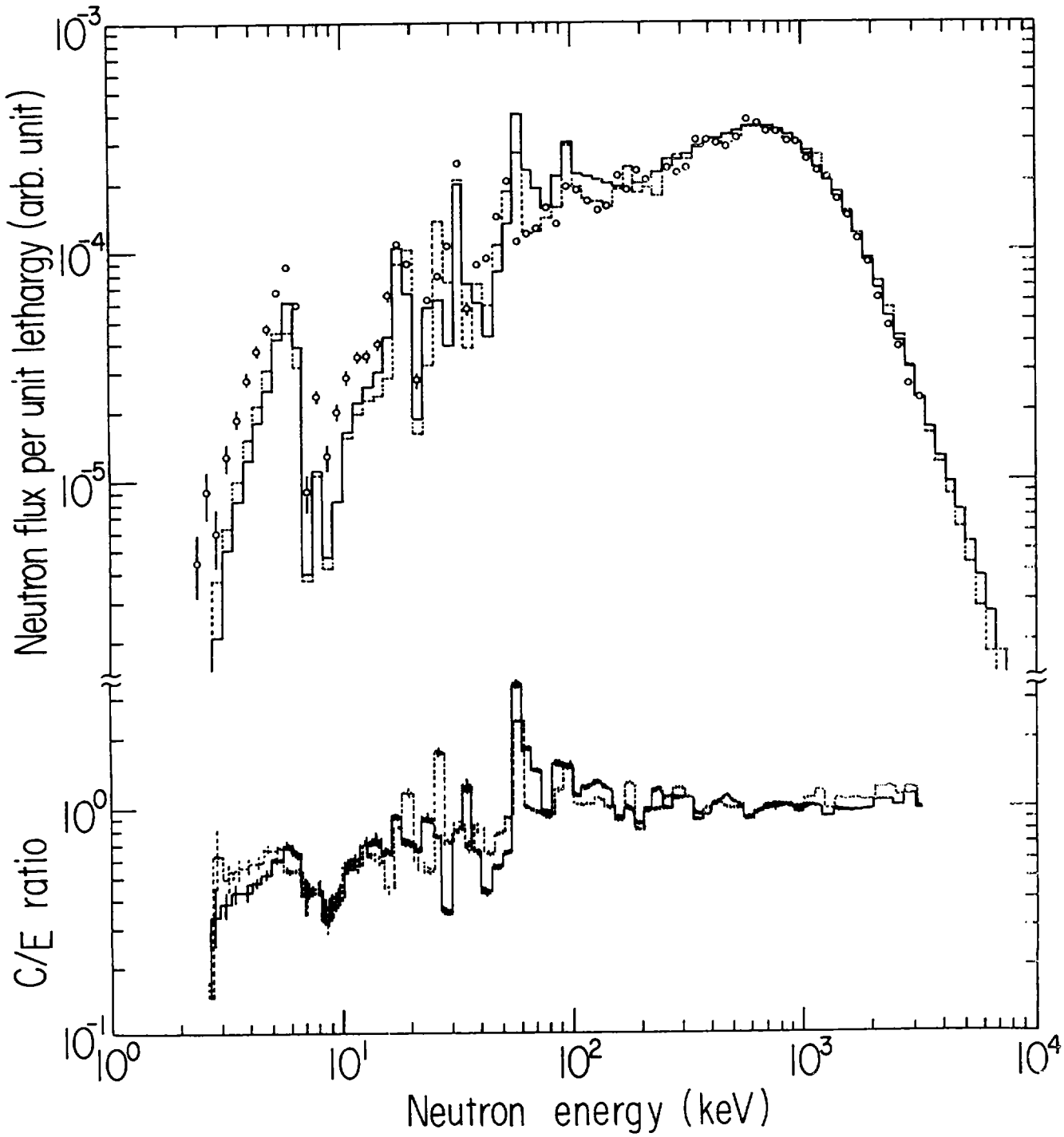

Figure (Top) Fast neutron spectra in a spherical manganese pile, ϕϕ : experimental points, ⌉⌊ : calculated with ENDF/B-IV, ⌉⌊ : calculated with JENDL/2.
(Bottom) The ratio of the calculated spectrum to the measured. The symbols are the same as the top figure.

IV-3

Neutron Total Cross Section Measurement of ^{232}Th in the Off-resonance Region below 300 eV

Katsuhei Kobayashi*, Yoshiaki Fujita*, and Nobuhiro Yamamuro***+

A paper on this subject was submitted to the Ann. Nucl. Energy with the following abstract:

The neutron total cross section of ^{232}Th at the off-resonance energies from thermal neutron to 300 eV has been measured by the linac time-of-flight method. Neutrons transmitted through a Th sample were detected with a ^{6}Li glass scintillator, 12.7 cm in diameter and 1.27 cm thick, placed at the 22 m station. Below 20 eV, the present result is in good agreement with the recent measurements at RPI, ORNL and BNL, and is close to BNL's data in the higher energy region. The evaluated nuclear data of ENDF/B-IV are distinctly lower in the energy region from thermal neutron to 300 eV than the present values. The JENDL-2 data are, however, close to the present result.

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IV-4 Measurement of Average Cross Sections for Some Threshold Reactions of Ti, Cr, and Pb in the Californium-252 Spontaneous Fission Neutron Spectrum Field

Katsuhei Kobayashi*, Itsuro Kimura*
Hiroshi Gotoh** and Hiroshi Tominaga***

A paper on this subject was submitted to the Ann. Repts. of the Res. Reactor Inst., Kyoto University with the following abstract:

The average cross sections for the $^{46,47,48}Ti(n,p)^{46,47,48}Sc$, $^{52}Cr(n,p)^{52}V$ and $^{204}Pb(n,n')^{204m}Pb$ reactions have been measured in the Cf-252 spontaneous fission neutron field by the activation method relative to the cross section for the $^{27}Al(n,\alpha)^{24}Na$ reaction. In the data processing, correlations between the experimental data have been considered and an off-diagonal weighted least squares fit has been applied to normalize the measured data to the reference value. The present results are combined with the author's data in the past, and the specific variance-covariance matrix of eighteen reactions has been obtained. Comparison of the measured and calculated data for the Cf-252 spectrum averaged cross sections has been performed to evaluate the validity of the neutron cross sections

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in the ENDF/B-IV, ENDF/B-V files and ANL-evaluation. A marked discrepancy more than 20 % can be seen between the measured and calculated average cross sections for the $^{47}Ti(n,p)^{47}Sc$ reaction, however, for the other reactions the calculated values are close to the measured ones, in general.

Table 1 The final results of eighteen average cross section measured in the Cf-252 spontaneous fission neutron field

No.	Reaction	Cross section (mb)	Uncertainty (mb)	(%)
1	$^{24}Mg(n,p)^{24}Na$	1.940	0.093	4.79
2	$^{27}Al(n,p)^{27}Mg$	4.891	0.179	3.66
3	$^{27}Al(n,\alpha)^{24}Na$	1.006	0.022	2.17
4	$^{32}S(n,p)^{32}P$	72.52	2.96	4.08
5	$^{51}V(n,p)^{51}Ti$	0.7126	0.0587	8.24
6	$^{54}Fe(n,p)^{54}Mn$	87.63	4.35	4.97
7	$^{56}Fe(n,p)^{56}Mn$	1.440	0.070	4.86
8	$^{58}Ni(n,p)^{58}Co$	118.5	4.1	3.45
9	$^{59}Co(n,\alpha)^{56}Mn$	0.2176	0.0140	6.44
10	$^{64}Zn(n,p)^{64}Cu$	41.84	1.75	4.18
11	$^{113}In(n,n')^{113m}In$	169.7	8.1	4.77
12	$^{115}In(n,n')^{115}In$	201.0	8.2	4.08
13	$^{197}Au(n,2n)^{196}Au$	5.267	0.226	4.30
14	$^{46}Ti(n,p)^{46}Sc$	14.04	0.61	4.36
15	$^{47}Ti(n,p)^{47}Sc$	21.58	1.16	5.38
16	$^{48}Ti(n,p)^{48}Sc$	0.4153	0.0158	3.80
17	$^{52}Cr(n,p)^{52}V$	1.470	0.098	6.64
18	$^{204}Pb(n,n')^{204m}Pb$	20.84	0.92	4.43

Table 2 Correlation matrix of the present result given in Table 3. The correlation coefficients have been multiplied by 100.

ROW/COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	100																	
2	40	100																
3	44	57	100															
4	41	45	52	100														
5	14	26	25	16	100													
6	46	41	42	40	16	100												
7	47	42	43	41	16	53	100											
8	39	55	62	50	24	40	41	100										
9	19	31	33	23	17	20	21	28	100									
10	29	46	51	36	23	30	30	42	29	100								
11	48	46	44	39	20	49	50	45	22	30	100							
12	56	54	52	46	24	60	61	53	26	36	66	100						
13	28	49	50	31	29	32	33	46	32	45	39	47	100					
14	21	28	49	25	12	20	21	30	16	25	21	25	24	100				
15	18	23	40	21	10	17	17	25	13	20	18	21	20	47	100			
16	25	33	57	29	14	24	24	35	19	29	25	29	28	61	51	100		
17	14	19	33	17	8	14	14	20	11	17	14	17	16	19	17	18	100	
18	21	28	49	25	12	20	21	30	16	25	21	25	24	26	23	28	18	100

V. KYUSYU UNIVERSITY

A. Department of Nuclear Engineering
Faculty of Engineering

V-A-1 Preequilibrium Emission of Protons from ^{93}Nb(n,p) Reaction at 14 MeV

N. Koori, Y. Ohsawa and I. Kumabe

A paper on this subject was published in Nuclear Science and Engineering 87 (1984) 34 with an abstract as follows:

The energy spectrum and angular distributions of protons emitted from the ^{93}Nb(n,p) reaction have been measured at a bombarding energy of 14.1 MeV with a position-sensitive counter-telescope. The energy spectrum is well explained by the sum of the spectra calculated on the basis of the preequilibrium and statistical evaporation models. The angular distributions are successfully reproduced by means of the generalized exciton model. The multistep direct reaction model indicates a little discrepancy in the absolute cross section in spite of general agreement in the shape of the angular distributions.

V-A-2 New Method of Precise Measurement of Activation Cross-Sections Induced by 14 MeV Neutrons

Y. Inenaga, A. Morita, M. Hyakutake and I. Kumabe

Recently Janczyszyn[1] proposed the activation method for cross section determination, in which the reaction leading to the same radionuclide as the investigated reaction is used as a reference reaction, and for the measurement of the cross sections of (n,α) reaction he used (n,p) reaction as a reference reaction.

We propose a new method which is an extension of Janczyszyn's method.[1] In the present work, (n,2n) reaction has been adopted as a reference reaction to determine (n,p) and (n,α) reaction cross sections.

On heavier nuclei, the cross sections of (n,p) and (n,α) reactions are very small, while those of (n,2n) reactions are several hundreds times as large as those of (n,p) or (n,α) reactions. Therefore (n,2n) reaction cross section can be easily and accurately measured.

The present method was tested using ^{124}Sn(n,2n), ^{123}Sb(n,p) and ^{126}Te(n,α) reactions. All the samples were metallic disks 14mm in diameter and about 1.6g/cm^2 thick. Thin Sn-foils (61mg/cm^2) were placed in the front and back of each sample to monitor the neutron flux. Each sample with the monitor foils was irradiated independently in the same position with respect to the neutron source for period of about 10m with 14 MeV neutrons.

We tried also to use a digital integrating circuit to monitor the neutron flux. This circuit is followed to the detector for the recoil α-particle in the T-D reaction and has the time constant equal to the mean life of produced ^{123}Sn nuclides. The γ-activities (E_γ=159.7 KeV) of produced ^{123}Sn($T_{1/2}$=40.1m) were measured with a Ge(Li) detector.

The experimental results are shown in Table I. The cross section ratio and the cross section for each reaction were determined with an error of about 3% and about 5%, respectively.

There are only a few data of (n,p) and (n,α) reaction cross sections of several millibarns measured with an accuracy better than 10%. Therefore it turns out that the present method is superior one for determining accurately (n,p) and (n,α) reaction cross sections.

Reference

1) J. Janczyszyn, Proc. Int. Conf. on Nuclear Data for Science and Technology, Antwerp (1982) p.869

Table I Cross section

	cross section		
	ratio	experimental(mb)	reference(mb)
$^{124}Sn(n,2n)$	1.00	547±23	547±23
$^{123}Sb(n,p)$	$(5.26\pm0.12)\times10^{-3}$	2.88±0.14	2.8±0.9
$^{126}Te(n,\alpha)$	$(2.74\pm0.09)\times10^{-3}$	1.50±0.08	0.8±0.4

V-A-3 Shell and Odd-Even Effects on Alpha-Particle Energy Spectra from (p,α) Reaction on Nuclei around N=50

I. Kumabe, Y. Mito, M. Hyakutake, N. Koori,
H. Sakai and Y. Watanabe

We have undertaken to measure systematically and accurately the double differential cross sections of the (p,α) reaction which is analogous one with the (n,α) reaction in order to clarify the shell effect and the odd-even effect in the pre-equilibrium process on the (p,α) reaction. By the analogy with the (p,α) reaction, we expect to clarify the shell effect and the odd-even effect on the 14 MeV (n,α) reaction.

The energy spectra of α-particles emitted from the (p,α) reaction on ^{90}Zr, $^{92,94,96,98,100}Mo$, ^{93}Nb, ^{106}Pd and Ag for 18 MeV protons and on some of them for 15 MeV protons have been measured. The 15 and 18 MeV proton beams from the tandem Van de Graaff accelerator at Kyushu University were analyzed by a beam analyzing magnet and brought into a scattering chamber. The α-particle detecting system was mounted on a turntable inside the scattering chamber. The detecting system consisted of a ΔE-E counter telescope of two silicon surface barrier detectors having a thickness of 15μm and 300μm, respectively. Emitted α-particles were identified and separated from other reaction products by means of an Osaka Denpa MPS-1230 Particle Identifier.

For the (p,α) reactions on the odd-mass target nuclei ^{93}Nb and Ag low lying states, to which the unpaired proton relates, of the residual nuclei are weakly excited. This experimental result indicates that the unpaired nucleon acts as a spectator not only for near magic nuclei with one more nucleon outside the magic shell but also for ordinary odd-mass

nuclei which are far apart from the magic number. Therefore it may be concluded that the (p,α) reaction for 15-18 MeV protons is the knock-on reaction of an α-cluster in target nuclei.

The experimental energy spectra for the odd-even pair of Ag and ^{106}Pd are reproduced well by the calculated ones using the effective Q-values which is smooth functions of mass number and atomic number and has no odd-even effect. From this fact it can be said that there exists no appreciable odd-even effect on the target nucleus for the (p,α) reaction in this energy region.

The energy spectra for ^{90}Zr and ^{92}Mo which are magic nuclei fall sharply to zero near 16 MeV for the 18 MeV (p,α) reactions. The energy spectra for ^{94}Mo and ^{96}Mo which are near magic nuclei with a few nucleons outside the magic shell fall sharply near 16 MeV and have some sharp structures above 16 MeV which seem to correspond to discrete levels or groups of levels of the residual nuclei. Similar features to those for $^{94,96}Mo$ are also seen for ^{98}Mo and ^{100}Mo, but the flattened cross sections above 16 MeV increase gradually with increasing mass-number.
These energy spectra can be reproduced very well by the calculated ones using the effective Q-values and the modified shell model in which the uniform spacing shell model was modified so as to have wide spacing at the magic number under the assumption of the knock-on reaction of an α-cluster in target nucleus. The calculated energy spectra for 15 MeV protons reproduce well also the experimental ones which show the similar shell effect to those for 18 MeV protons.

V-A-4 Analysis of 14 MeV (n,n') Scattering with Hybrid Model

Y. Watanabe, M. Hyakutake and I. Kumabe

The particle emission from states of exciton number n=3 in the pre-equilibrium exciton model is considered to correspond to a one-step direct reaction. Therefore we have undertaken to analyze 14 MeV (n,n') data, on the basis of the multi-step direct reaction (MSDR) theory[1] or the statistical multi-step direct emission (SMDE) theory[2] as a one-step process and on the basis of the generalized exciton model (GEM)[3] as multi-step processes. In this paper preliminary results of the analysis of 14 MeV (n,n') data are presented.

Comparison of the experimental angular distributions[4] measured in Kyushu University with calculated ones is shown in Fig.1. The calculated results using the GEM theory are indicated by broken curves.

The calculated results using the present hybrid model are indicated by solid curves for MSDR + GEM and by dotted curves for SMDE + GEM. The calculated results are in fairly good agreement with the experimental data, and an underestimation for high-energy neutrons at backward angles was improved very nicely. However a little underestimation is seen for high-energy neutrons at forward angles.

Comparision of the experimental angular distributions[5] measured in Osaka University with calculated ones is shown in Fig.2. The calculated energy spectra using the present hybrid model are in fairly good agreement with experimental ones except for high-energy neutrons at forward angles.

References:

1) T. Tamura et al., Phys. Lett. 66B (1977) 109.

2) H. Feshbach et al., Ann. Phys. 125 (1980) 429.

3) H. Gruppelaar et al., Proc. Int. Conf. on Nuclear Data for Science and Technology, Antwerp (1982) p. 537,
Costa et al., Lettere al Nuovo Cimento 36 (1983) 431.

4) Y. Irie et al., Mem. Fac. Eng. Kyushu Univ. 37 (1977) 19.

5) A. Takahashi et al., Proc. Int. Conf. on Nuclear Data for Science and Technology, Antwerp (1982) p. 360,
OKTAVIAN Report A-83-01.

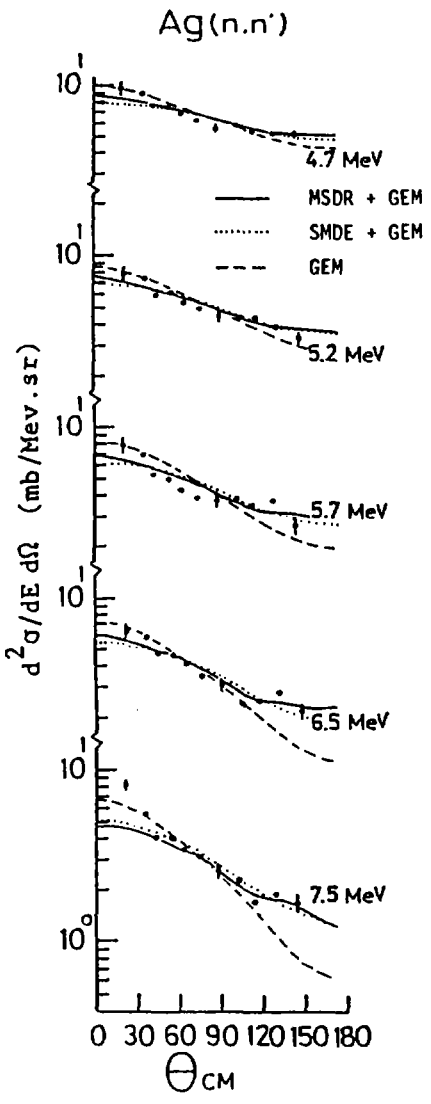

Fig.1

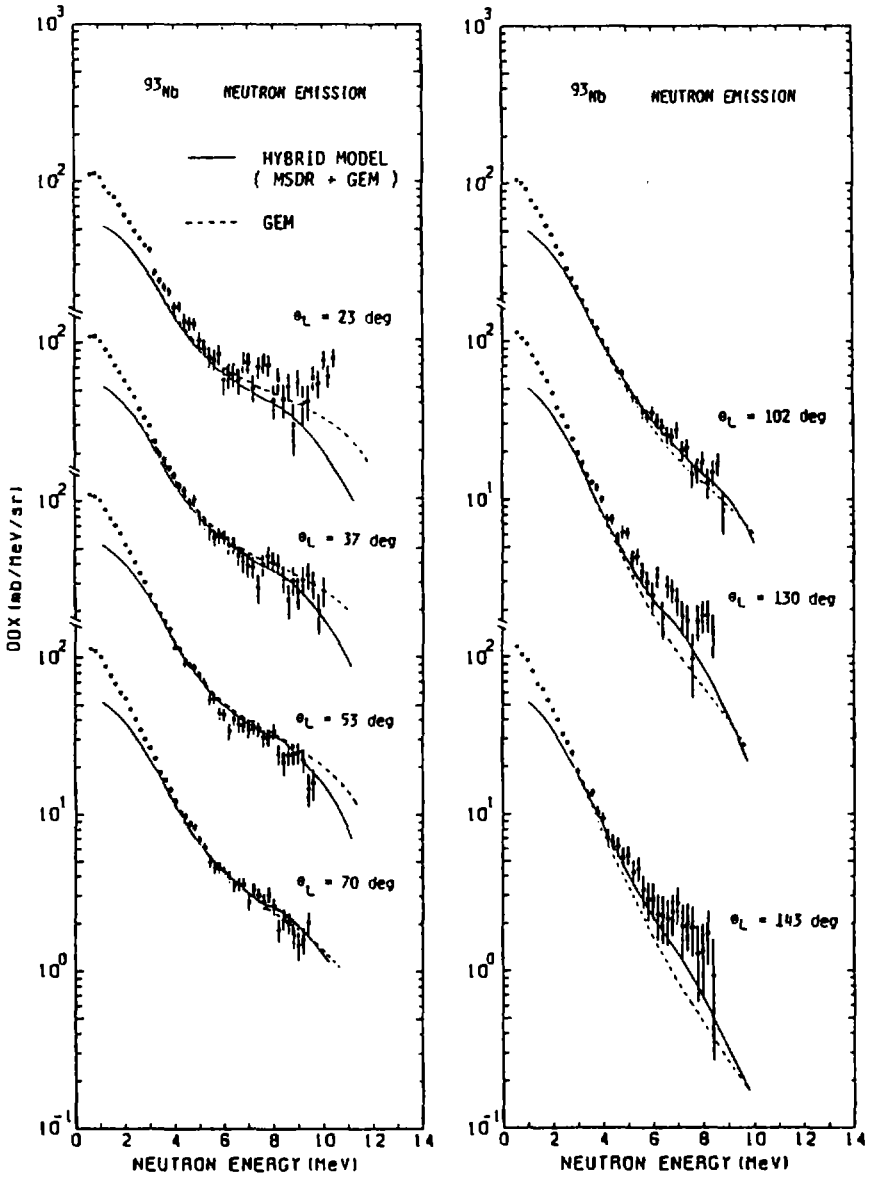

Fig.2

B. Energy Conversion Engineering
Interdisciplinary Graduate School of Engineering Sciences

V-B-1 Estimation of level density parameters with Bayesian method

Y. Uenohara and Y. Kanda

A several kinds of nuclear reaction models have been utilized for evaluations of neutron cross sections. The models are characterized by their parameters. Estimation of the parameters is significant for the evaluation. Parameters have been usually obtained intuitively by checking agreement between calculated cross sections and measured ones except optical model parameter search. Such a method, however, cannot yields the optimal parameters.

We applied a Bayesian method to estimate the optimal nuclear reaction model parameters. The level density parameters required of calculation of ^{60}Ni, ^{58}Ni, ^{59}Co(n,x) cross sections were estimated practically.

Hauser-Feshbach model calculation code "GNASH" was used for our study. The level density formula and initial guesses were taken from Gilbert-Cameron's formula and parameters, respectively. The level density parameters were estimated by fitting ^{60}Ni(n,p), ^{58}Ni(n,p), (n,2p), ^{59}Co(n,p), (n,α), (n,2n) cross sections, and proton and α-particle parduction spectra induced 14.8 MeV neutron on ^{60}Ni and ^{58}Ni. The cross sections calculated using estimated parameters agreed with the measured ones fairly well.

The estimated parameters improved the calculated cross sections more than Gilbert-Cameron's ones.

V-B-2

Significance of Covariance Matrices in Nuclear Data Evaluation

Y. Uenohara and Y. Kanda

Covariances of evaluated nuclear data are found useful in applications of nuclear data. We demonstrated that the covariances for the evaluated nuclear data are valuable also in the nuclear data evaluation itself. As an example, evaluations of fission cross sections for ^{235}U and ^{238}U were chosen for the demonstration.

Since major parts of experiments for $^{238}U(n,f)$ cross sections are relative measurements to $^{235}U(n,f)$, it is inevitable to refer to ^{235}U (n,f) cross sections as the standard cross sections in order to evaluate $^{238}U(n,f)$ cross sections. In our demonstration, the cross sections for ^{238}U were evaluated simultaneously by using the evaluated $^{235}U(n,f)$ cross sections (ENDF/B-V), the measured $^{238}U(n,f)$ cross sections, and the measured cross section ratios of $^{238}U(n,f)$ and $^{235}U(n,f)$. The evaluation method is based on a Bayes estimation. We take logarithms of ^{238}U, ^{235}U (n,f) cross sections and their ratios in order to apply a linear least square method to the evaluations. The logarithmic excitation functions were represented with a first order B-spline function. The covariances of $^{235}U(n,f)$ cross sections were taken from the standard file of ENDF/B-V. The others were estimated on the basis of each item concerning the orgins of errors in the individual reports.

By the present method, the simultaneous evaluation which includes a few reactions can easily be extended to the simultaneous evaluation which covers more reactions by chaining the data for the other reactions. The covariance matrices for the evaluated cross sections make it sure

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to construct the evaluated nuclear data file which is optimized to whole available experimental data.

VI. NAGOYA UNIVERSITY

Department of Nuclear Engineering

Faculty of Engineering

VI-1 Measurement of Neutron Activation Cross-sections of Fusion Reactor Materials at 14.6 MeV

H. Atsumi, H. Miyade, M. Yoshida, T. Ishii, H. Yamamoto, K. Kawade, T. Katoh, A. Takahashi* and T. Iida*

Neutron activation cross-sections of fusion reactor materials at 14.6 MeV were measured to provide basic data for the assessment of damage and activation of materials due to the high flux fast neutrons.

Sample materials were irradiated with the fast neutrons generated from the Intense 14 MeV Neutron Source(OKTAVIAN) at Osaka University by the D(T,n)α reaction. The neutron flux was about 10^9 neutron/cm^2/s. Gamma-rays from produced radioactive elements were measured with a Ge detector to obtain the cross-sections.

The absorption of neutron in the sample materials was measured. In Fig. 1, the relative neutron flux obtained from the activity of Nb foils in the stacked foils is shown. The broken line shows the estimated flux in the air. Obtained flux was definitely reduced from the estimated flux in the air. The loss in the sample is about 0.2 percent for 100 mg. The angular dependence of source neutron energy was

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measured by sandwich sets of Nb and Zr foils. Measured angular dependence was in good agreement with the calculated one based on the kinematics of reaction products. The result is shown in Fig. 2.

Sets of sample foils were irradiated together with monitor foils(Nb) by the fast neutron with the energy of 14.6 MeV. Activation cross-sections were determined by using the standard cross-section of the $^{93}Nb(n, 2n)^{92}Nb$ reaction, which is taken as 464 $\pm$ 14 mb. Measured cross-sections of molybdenum isotopes are shown in Table 1.

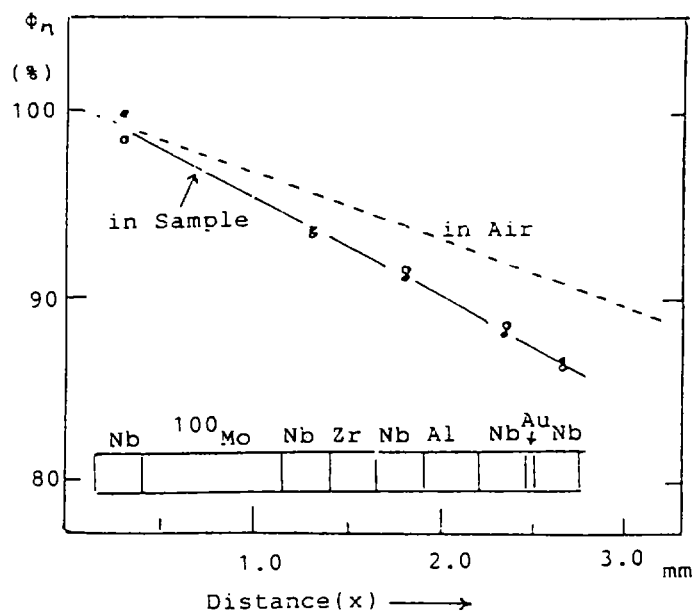

Fig. 1 Absorption of neutron in the sample

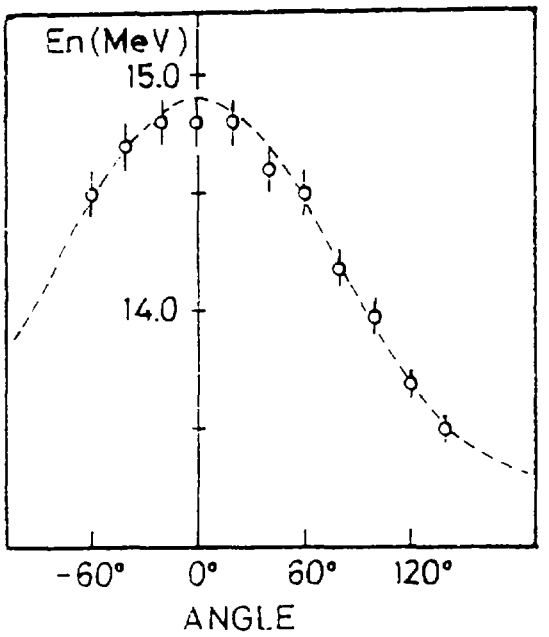

Fig. 2 Angular dependence of source neutron energy

Table 1 Activation cross-sections of molybdenum isotopes

reaction	cross-section (mb)	reaction	cross-section (mb)
$^{100}Mo(n,2n)^{99}Mo$	1500	$^{95}Mo(n,p)^{95m}Nb$	5.8
$^{100}Mo(n,\alpha)^{97}Zr$	2.7	$^{95}Mo(n,p)^{95g}Nb$	32
$^{98}Mo(n,\alpha)^{95}Zr$	5.8	$^{92}Mo(n,p)^{92m}Nb$	68
$^{97}Mo(n,np)^{96}Nb$	4.2	$^{92}Mo(n,\alpha)^{89}Zr$	27
$^{96}Mo(n,p)^{96}Nb$	24		
$^{96}Mo(n,np)^{95m}Nb$	1.7		
$^{96}Mo(n,np)^{95g}Nb$	4.6		

VII. RIKKYO (ST. PAUL'S) UNIVERSITY

Department of Physics

VII-1 Backward Cross Section for the $^6Li(n,d)^5He$ Reaction at 14.1 MeV

Y. Ando, S. Shirato and H. Yamada*

The differential cross section for the $^6Li(n,d)^5He$ reaction at 14.1 MeV was experimentally obtained at the backward c.m. deuteron angles Θ_d = 110°, 117°, 130° and 143°.

The emitted deuterons were measured with a counter telescope, which consists of two gas proportional counters and two silicon detectors of 16 μm ("ΔE detector") and 270 μm ("E detector") in thickness. The measurements of 130° and 143° (i.e., the telescope setting angles θ_1 = 115° and 130°, respectively) were performed with a ^6Li-metal target of 2.78 mg/cm^2 thick, in coincidence with the associated α-particles from the ^3H-d neutron source reaction in order to reduce background particles emitted from the E detector in the direction of the ^6Li target, while the 110° and 117° measurements and another 143° one (i.e., θ_1 = 93°, 100° and 130°, respectively) were done without the d-α coincidence using a ^6Li target of 2.36 mg/cm^2 thick.

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Both results with and without the d-α coincidence were confirmed to be consistent in the present case, but it should be noted that the careful background subtraction was necessary to determine the backward cross section without using the d-α coincidence.

The present experimental data are shown in Fig. 1, together with the published forward data[1,2] and the exact finite-range (EFR) DWBA calculation[1]. The present backward data are in agreement with the prediction of the EFR-DWBA calculation. The disagreement at around $\Theta_d = 50^o$ would be due to taking into consideration only the incoherent sum (the solid line in Fig. 1) of the proton pickup and α-particle pickup amplitudes.

References:

1) S. Higuchi, K. Shibata, S. Shirato and H. Yamada, Nucl. Phys. A384 (1982) 51.

2) V. Valković, G. Paić, I. Slaus, P. Tomas, M. Cerineo and G. R. Satchler, Phys. Rev. 139 (1965) B331.

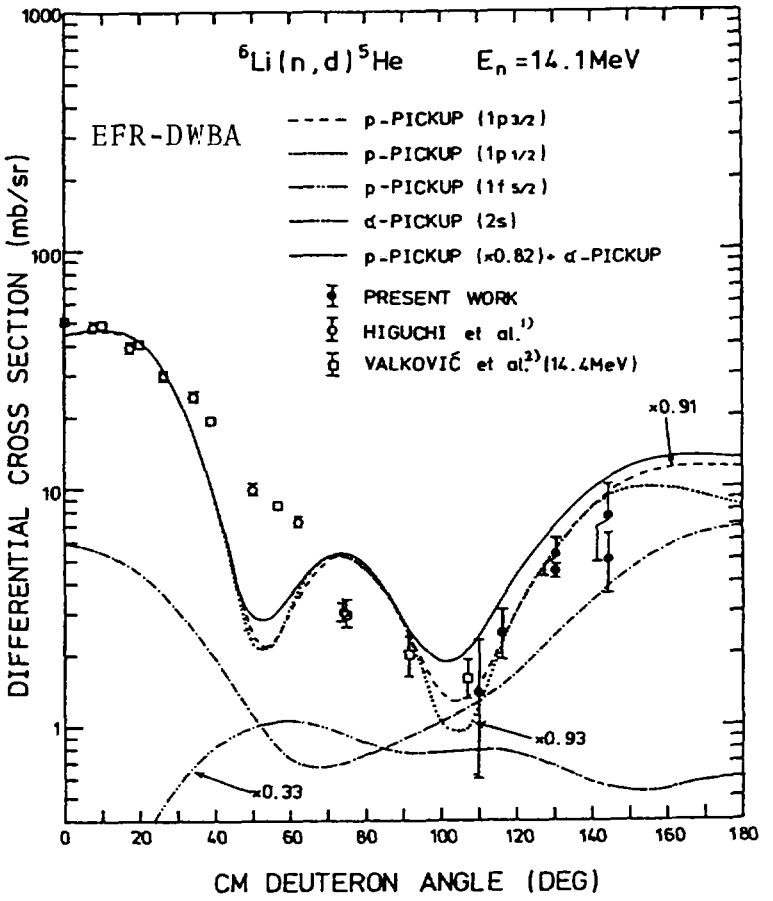

Fig. 1. Measured and calculated angular distributions of deuterons.

VIII. TOHOKU UNIVERSITY

Department of Nuclear Engineering

Faculty of Engineering

VIII-1

Measurements of double-differential neutron emission cross sections for ^{6}Li and ^{7}Li

S.Chiba,M.Baba,H.Nakashima,M.Ono,N.Yabuta,S.Yukinori and N.Hirakawa

The energy and angular distributions of emitted neutrons from ^{6}Li and ^{7}Li were measured by use of the time-of-flight method for incident neutrons of 14.2, 5.4, 4.2 MeV for ^{6}Li and of 14.2, 6.0, 5.4 MeV for ^{7}Li. Tohoku University Dynamitron accelerator provided primary neutrons via the d-T and d-D reactions. The experimental method and the results have been described in ref.1.

Typical results for 14.2 MeV neutrons are presented in Fig.1. The data were obtained at 10 or 8 angles between 30° and 150°, and the differential elastic and inelastic cross sections as well as continuum cross sections were derived. Care was taken in background determination and in multiple scattering correction.

The differential cross sections obtained for elastic scattering and for inelastic scattering to the 2.18 MeV state of ^{6}Li and the 4.63 MeV state of ^{7}Li, were in good agreement with those by other experiments and by recent evaluation for JENDL-3PR1[2]. The differential cross sections for 14.2 MeV were successfully interpreted in terms of the coupled-channel optical model.

The results of emission spectra for the neutron continuum were compared with those by JENDL-3PR1[2], where the energy distribution of the neutron continuum resulting from the (n,nα) and (n,2n) reactions were presented with phase-space model. For MeV region, the agreement is fairly well. However, for 14.2 MeV, present results indicate significant contribution of higher levels in the inelastic scattering process, leading to remarkable deviation from the phase-space model. Such a trend was more evident for ^{6}Li. The energy-angular integrated cross sections were in reasonable agreement with those by JENDL-3PR1.

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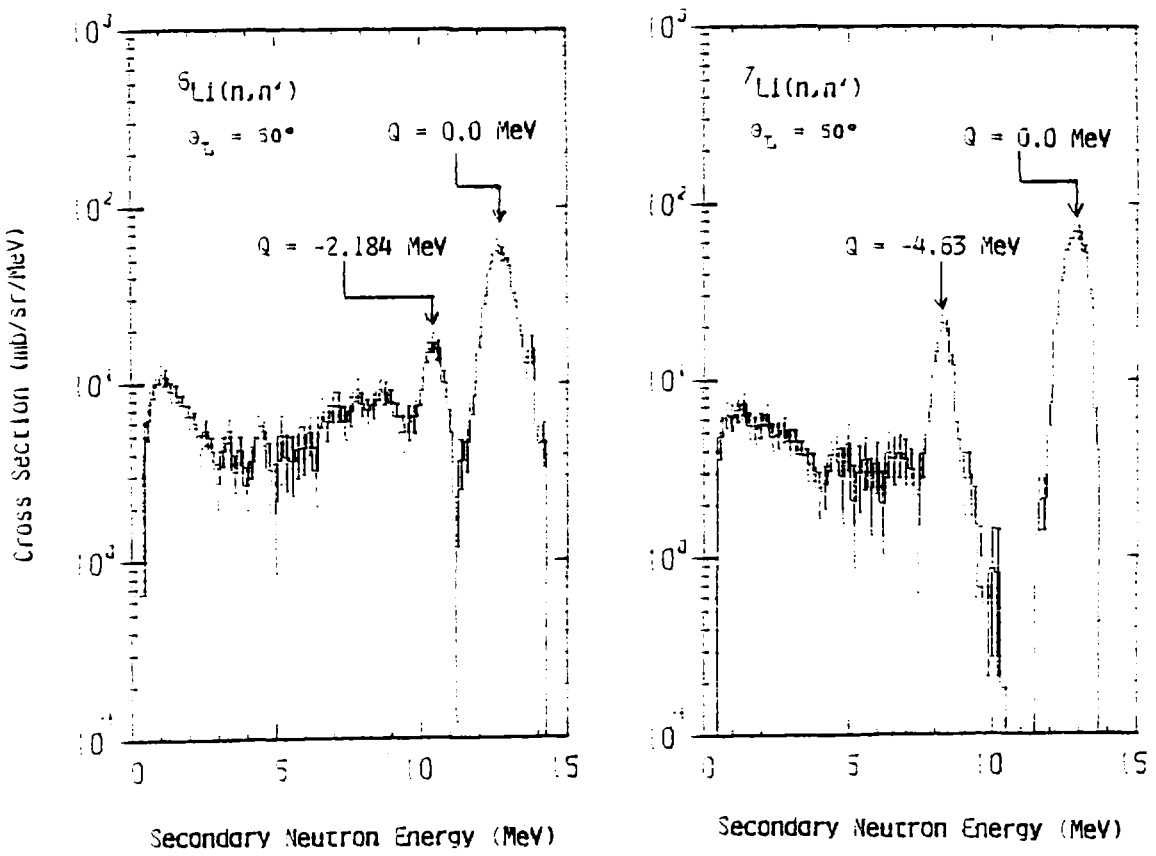

Fig.1 Neutron emission spectra from Li(n.n'x) reactions for 14.2 MeV neutrons

VIII-2

Measurement of Fission Neutron Spectrum from Th-232

H.Nakashima,M.Baba,S.Chiba,M.Ono,S.Yukinori,N.Yabuta and N.Hirakawa

The prompt fission neutron spectrum was measured at incident neutron energy of 2 MeV, using the time-of-flight technique. The solid sample of metallic thorium (2cm in dia. and 5cm long) was employed as a fission sample. Care was taken in background and energy-scale determination. The experiment and result have been described in ref.1.

The result for fission spectrum is shown in Fig.1, along with that given by JENDL-2.[2]. Agreement between the data is good except for slight deviation in the energy region around 4MeV. In Fig.1 are also shown the best fit curves obtained by fitting the present results with the Maxwell or Watt type functional form. The Maxwellian temperature obtained is 1.24 ± 0.016 (MeV) and is consistent with Terrel's formula[3] as shown in Fig.2, if we assume $\upsilon = 2.15$[2].

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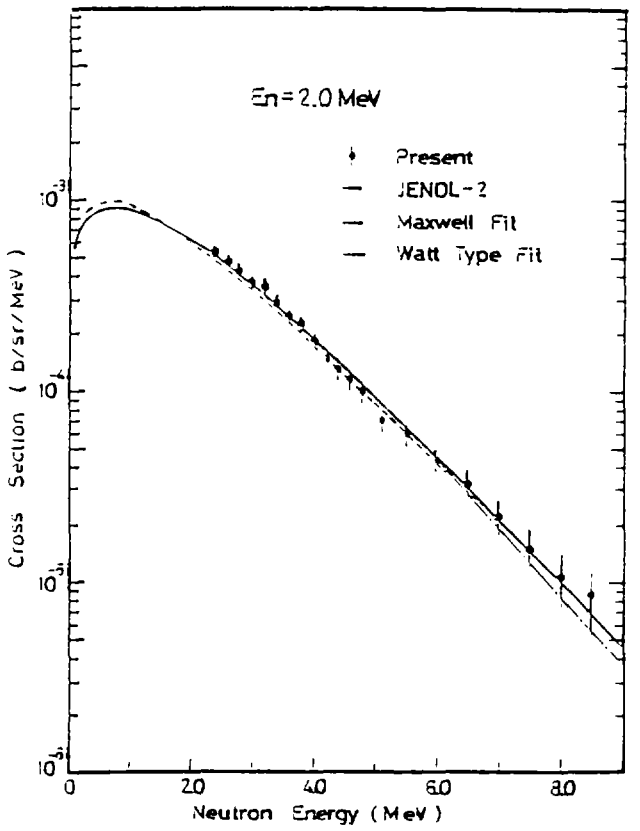

Fig.1 Energy distribution of prompt fission neutrons from Th-232

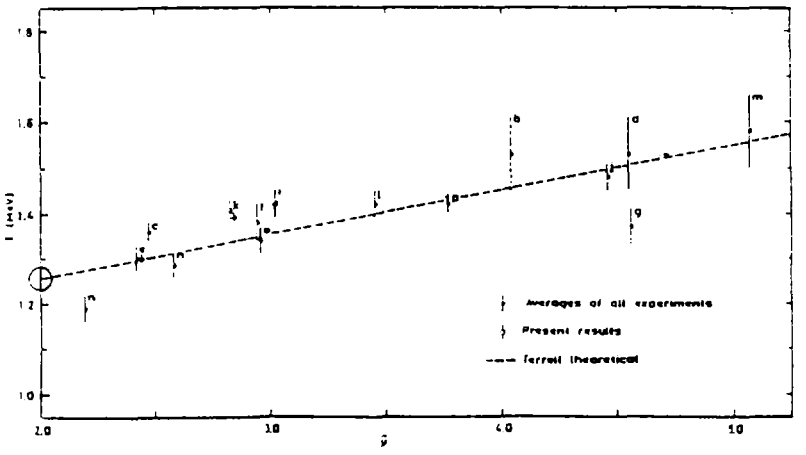

Fig.2 Relationship between the Maxwellian temperature(T) and the number of neutrons from fission (υ)

VIII-3

Neutron Scattering from Th-232 at MeV incident energies

H.Nakashima,M.Baba,S.Chiba,M.Ono,S.Yukinori,N.Yabuta and N.Hirakawa

The energy and angular distributions of secondary neutrons from Th-232 were measured for 1.6, 2.0, 4.5 and 6.0 MeV incident neutrons. The time-of-flight spectrometer at Fast Neutron Laboratory, Tohoku University was employed for the measurements. The experiments and results have been described in ref.1.

Partial cross sections for the "elastic" scattering (including the 1-st 2^+ and 2-nd 4^+ states contributions), and the inelastic scattering were obtained as well as the evaporation temperature for the neutron continuum. The inelastic cross sections and continuum emission cross sections obtained were in good agreement with those by previous measurements[2] and by Batchelor[3], but are remarkably larger than JENDL-2 values[4]. If we evaluate the 2^+ and 4^+ states contribution by the coupled channel calculation, the total inelastic cross sections are nearly equal with the values obtained in ANL evaluation[5], and is larger than JENDL-2 values by 30%. Present results for evaporation temperature support the results by previous measurements[1] and by Batchelor[3], and differ considerably from JENDL-2 values.

References;

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IX. TOKYO INSTITUTE OF TECHNOLOGY

Research Laboratory for Nuclear Reactors

IX-1 Gamma Rays from 27.7-keV s-Wave Neutron Resonance Capture by ^{56}Fe

H. Komano, M. Igashira, M. Shimizu, and H. Kitazawa

We have measured distinguishable gamma rays for the transition to the ground state and to the first excited state following 27.7-keV s-wave neutron resonance capture by ^{56}Fe with a good signal-to-noise ratio, using a 60-cm^3 pure Ge detector. Partial radiation widths have been obtained for both transitions. It has been found that those widths are not comprehensible in the valency capture model. The results suggest that there is some possibility of core excitation in s-wave neutron resonance capture by ^{56}Fe.

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IX-2 Neutron Capture Gamma-Ray Spectra of Nuclei with N = 82 - 118 at the Neutron Energies of 10 - 800 keV

M. Igashira, M. Shimizu, H. Komano, H. Kitazawa, and N. Yamamuro*

We have measured capture gamma-ray spectra of Pr, Tb, Ho, Ta and Au at the neutron energies of 10 - 800 keV with an anti-Compton NaI(Tl) detector, using a time-of-flight technique. The small resonance, well known as pygmy resonance, was clearly observed in all these spectra. Observed gamma-ray spectra were compared with the statistical model calculation, using the Brink-Axel gamma-ray strength function with a small resonance. Remarkable features of the pygmy resonance were found to be that the resonance energy and the electric dipole strength exhausted in the resonance increase with neutron number.

Contributed to the 5th International Symposium on Capture Gamma-Ray Spectroscopy and Related Topics, Knoxville (1984).

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* Present Adress : Nippon Atomic Industry Group Co. Ltd.

IX-3 Gamma Rays from 565-keV p-Wave Neutron Resonance and Off-Resonance Capture by ^{28}Si

M. Shimizu, M. Igashira, H. Komano, and H. Kitazawa

We have measured gamma-ray spectra from the 565-keV p-wave neutron resonance capture by ^{28}Si and from the off-resonance capture at 485 keV, using an anti-Compton NaI(Tl) detector and a time-of-flight technique. Partial radiation widths were obtained for the transitions to the final states, ground(1/2+), 1273 keV(3/2+), 2028 keV(5/2+), 2425 keV(3/2+) and 3067 keV(5/2+), following the p-wave neutron capture. Comparison between the calculated and observed for these widths, especially for the transitions to both 3/2+ states, might not be understood within a framework of the valency capture model, suggesting some possibility of the core-excitation in the resonance capture process. On the other hand, the off-resonance neutron capture can be fairly well explained by the direct capture theory.

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IX-4 Excitation of Isovector M1 States in p-Wave Neutron Resonance Capture Reactions on ^{56}Fe

H. Kitazawa, H. Komano, M. Igashira, and M. Shimizu

At the neutron energies of 20-100 keV, we have measured gamma rays for the transitions to low excited states of the residual nucleus below 1.5 MeV following p-wave neutron resonance capture by ^{56}Fe, using a 60-cm^3 pure Ge detector and a time-of-flight technique. Three p-wave neutron resonance states at 34.21, 38.39 and 59.19 keV were completely discriminated from other resonances. Strong anormalous M1 transitions leading from these resonance states to either ground(1/2-) or first excited(3/2-) state have been observed with much better signal-to-noise ratio than previous works. In addition, partial radiation widths were obtained for the transitions to both final states. These transitions are comprehensible in the semidirect model, assuming excitation of isovector M1 states in the target nucleus and using a reasonable spin-isospin dependent force in the two-body nucleon interaction.

Contributed to the 5th International Symposium on Capture Gamma-Ray Spectroscopy and Related Topics, Knoxville (1984).

IX-5 Proton Strength Functions in the Mass Region of 30 to 70

E. Arai and T. Matsuzaki*

The strength function of compound-nucleus formation is one of the good tools to study the role of the nuclear shell-model effect in compound nuclear system. For neutrons, abundant experimental data are present in the mass range of 40~240. For protons, however, a very small number of theoretical works have so far been performed, partly because of the shortage of experimental data.

Using high-resolution proton beams, proton excitation functions were measured to search for proton resonance levels. Proton strength functions were determined from average proton reduced widths and average spacings of proton resonance levels.

Theoretical values for s- and p-wave proton strength functions are calculated by employing an optical potential. Proton transmission coefficients are calculated for incident protons with a given angular momentum by means of the code "DWUCK 4". The used optical potential parameters were searched so as to reproduce experimental proton strength functions. Using the proton transmission coefficients, cross sections are deduced for a compound nuclear system with a given spin-parity in the manner of statistical compound nuclear theory. Finally s- and p-wave proton strength functions are obtained from the compound-nucleus formation cross sections.

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