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INDC(JAP)-70/U

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PROGRESS REPORT

(July 1981 to June 1982 inclusive)

September 1982

Editor
S. Kikuchi
Japanese Nuclear Data Committee

Japan Atomic Energy Research Institute
Tokai Research Establishment
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 of research.

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This edition covers a period of July 1, 1981 to June 30, 1982. 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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H	2	EVALUATION	10-5	20+7	JAE	EVAL-PROG	NEANDC-J83U		19	SEP 82	SHIBATA.FOR JENDL-2
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TI	48	N, PROTON	FISS		KTO	EXPT-PROG	NEANDC-J83U		45	SEP 82	KOBAYASHI+.REL TO AL(N,A).SIG+COVAR.
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FE	56	N, PROTON	15+7		JAP	EXPT-PROG	NEANDC-J83U		1	SEP 82	KUDO.T-D,SSD.110.9+-1.4 MB
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MO		N, PROTON	15+7		NAG	EXPT-PROG	NEANDC-J83U	63		SEP 82	AMEMIYA+.ACTIVATION SIG.NDG
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ELEMENT S A	QUANTITY	ENERGY MIN	ENERGY MAX	LAB	TYPE	DOCUMENTATION REF	VOL	PAGE	DATE	COMMENTS
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HF 178	EVALUATION	10-5	20+7	JAE	EVAL-PROG	NEANDC-J83U	24		SEP 82	HIDA+.FOR JENDL-2.TBL FIG FOR SIG-NG
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TA 181	STRNTH FNCTN	24+4	10+6	JAE	EXPT-PROG	NEANDC-J83U	14		SEP 82	TSUBONE+.TOT-SIG FIT.S1,S2,R0,R1,R2
AU 197	SPECT N,GAMM	30+3	80+4	TIT	EXPT-PROG	NEANDC-J83U	72		SEP 82	YOSHINARI+.BGO SCINTI.SPECT IN FIG
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TH 232	INELAST GAMM	10+6	22+6	TOH	EXPT-PROG	NEANDC-J83U	65		SEP 82	ITAGAKI+.DYNAMITRON,GE(LI) AT 125DEG
U 233	FISS PROD GS	FAST		TOK	EXPT-PROG	NEANDC-J83U	85		SEP 82	AKIYAMA+.TBP IN AEJ,24,NO.9(82)
U 233	FISS PROD BS	FAST		TOK	EXPT-PROG	NEANDC-J83U	82		SEP 82	AKIYAMA+.TBP IN AEJ,24,NO.10(82)
U 233	RESON PARAMS	NDG		JAE	EVAL-PROG	NEANDC-J83U	32		SEP 82	KIKUCHI+.PUB IN INDC(NDS)-129,309
U 233	RESON PARAMS	10-5	20+7	JAE	EVAL-PROG	NEANDC-J83U	31		SEP 82	NAKAGAWA+,PUBLISHED IN JAERI-M 9823
U 235	FISS PROD GS	FAST		TOK	EXPT-PROG	NEANDC-J83U	85		SEP 82	AKIYAMA+.TBP IN AEJ,24,NO.9(82)
U 235	FISS PROD BS	FAST		TOK	EXPT-PROG	NEANDC-J83U	82		SEP 82	AKIYAMA+.TBP IN AEJ,24,NO.10(82)
U 235	RESON PARAMS	NDG		JAE	EVAL-PROG	NEANDC-J83U	32		SEP 82	KIKUCHI+.PUB IN INDC(NDS)-129,309
U 235	RESON PARAMS	10-5	20+7	JAE	EVAL-PROG	NEANDC-J83U	31		SEP 82	NAKAGAWA+,PUBLISHED IN JAERI-M 9823
U 238	TOTAL	24+4	10+6	JAE	EXPT-PROG	NEANDC-J83U	14		SEP 82	TSUBONE+.LINAC,TOF,IRON FILTER,NE110
U 238	RESON PARAMS	NDG		JAE	EVAL-PROG	NEANDC-J83U	33		SEP 82	NAKAGAWA+.PUB.IN INDC(NDS)-129,282

ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF	VOL	PAGE	DATE	COMMENTS
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U	238	STRNTH FNCTN	24+4	10+6	JAE	EXPT-PROG	NEANDC-J83U	14		SEP 82	TSUBONE+.TOT-SIG FIT.S1,S2,R0,R1,R2
PU	239	FISS PROD GS	FAST		TOK	EXPT-PROG	NEANDC-J83U	85		SEP 82	AKIYAMA+.TBP IN AEJ,24,NO.9(82)
PU	239	FISS PROD BS	FAST		TOK	EXPT-PROG	NEANDC-J83U	82		SEP 82	AKIYAMA+.TBP IN AEJ,24,NO.10(82)
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PU	240	RESON PARAMS	10-5	20+7	JAE	EVAL-PROG	NEANDC-J83U	31		SEP 82	NAKAGAWA+,PUBLISHED IN JAERI-M 9823
PU	241	RESON PARAMS	NDG		JAE	EVAL-PROG	NEANDC-J83U	32		SEP 82	KIKUCHI+.PUB IN INDC(NDS)-129,309
PU	241	RESON PARAMS	10-5	20+7	JAE	EVAL-PROG	NEANDC-J83U	31		SEP 82	NAKAGAWA+,PUBLISHED IN JAERI-M 9823
PU	242	RESON PARAMS	NDG		JAE	EVAL-PROG	NEANDC-J83U	31		SEP 82	NAKAGAWA+.PUBLISHED IN OAERI-M 9823
PU	242	RESON PARAMS	NDG		JAE	EVAL-PROG	NEANDC-J83U	33		SEP 82	NAKAGAWA+.PUB.IN INDC(NDS)-129,282
AM	IJO	EVALUATION	10-5	20+7	JAE	EVAL-PROG	NEANDC-J83U	28		SEP 82	KIKUCHI,PUBLISHED IN JAERI-M 82-096
AM	241	EVALUATION	10-5	20+7	JAE	EVAL-PROG	NEANDC-J83U	28		SEP 82	KIKUCHI,PUBLISHED IN JAERI-M 82-096
MANY		DIFF INELAST	14+7		KYU	THEO-PROG	NEANDC-J83U	55		SEP 82	KUMABE.PRE-COMPOUND
MANY		N, PROTON	14+7		KYU	THEO-PROG	NEANDC-J83U	51		SEP 82	KUMABE.PUBLISHED IN SNT,18,563(81)
MANY		N, PROTON	14+7		KYU	THEO-PROG	NEANDC-J83U	59		SEP 82	HARUTA.PRE-COMPOUND
MANY		N, ALPHA	14+7		KYU	THEO-PROG	NEANDC-J83U	59		SEP 82	HARUTA.PRE-COMPOUND
MANY		STRNTH FNCTN	NDG		HOS	THEO-PROG	NEANDC-J83U	13		SEP 82	FURUOYA.PUBLISHED IN PTP,67,1456(82)

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

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I. ELECTROTECHNICAL LABORATORY

Radiation Metrology Section

I-1 $^{56}Fe(n,p)^{56}Mn$ Cross Section at 14.60 MeV

Katsuhisa Kudo

The neutron (n,p) cross section of ^{56}Fe has been re-measured more precisely at the neutron standard field of Electrotechnical Laboratory. The new measuring system of associated alpha particles from T(d,n)α reactions has been improved to evaluate the mean energy of neutrons emitted to the direction of the Fe foil and also to determine the neutron emission rate from the target simultaneously. Figure 1 shows the experimental arrangement of the associated alpha particle method. The alpha fluences at 89° and 131° to the incident deuteron beam were measured by the Si surface barrier detectors, which were positioned at (999.3±0.5) mm from the target with a tantalum diaphram of (5.000±0.005) mm diameter. The total counts of alpha spectra were obtained by adjusting the lower discrimination level of the single channel analyzer at the midpoint of the tail part following to the main alpha peak. The solid angle conversion factor(SAF) from the LAB to the CM system was determined corresponding to the measured

mean energy of neutrons. The ratio of the alpha and the neutron SAF values, $J_\alpha(89°)/J_n(45°)$, was estimated as 1.039±0.002 for the mean neutron energy of 14.60 MeV. In order to obtain the neutron emission rate per solid angle, the alpha fluence only at 89° was adopted for the thick target. The measurements at 131° were applied to evaluate the mean neutron energy by coupling with those at 89°. The mean energy was also measured by Ryves's method[1] at the beginning and the end of the experiments for each Ti-T target. Figure 2 shows the mean energy of neutrons measured at 45° to the deuteron beam as a function of total beam charge received by the Ti-T target. It is evident that the mean energy decreases gradually with the increase of the total beam charge. The contribution of protons from D(d,p)T reaction was separated from the alpha spectrum by locating a Mylar film of 0.82 mg/cm^2 thickness on the way to the detector from the target, and they were subtracted. The neutron attenuations in the cppper backing and the air for the direct neutrons were estimated as (0.9±0.4)% using PALLAS code[2]. Iron foils of 99.99% purity having 25.4 mm diameter and 0.1 mm thickness were irradiated at a distance 153.30± 0.25 mm from the neutron source at 45° to the direction of the incident deuteron beam. The absolute activities of iron foils were measured by the 4πβ-γ coincidence method[3]. The correction factor adopted in activity measurement was the same value of 0.0177±0.0009 precisely determined in the last experiments[4].

As a result, the $^{56}Fe(n,p)^{56}Mn$ cross section has been determined as 110.9±1.4 mb, and the square root of the quadratic sum of errors in this experiments has been ±1.3%. The cross section obtained in the measurements was re-calculated to compare with that of Ryves's recent evaluation 109.2±1.0 mb at 14.73 MeV with the use of $d\sigma_{Fe}/dE$ = (-0.0123±0.006) %/keV[5]. The value at 14.73 MeV was evaluated as 109.3±1.5 mb and agreed very well with the result of the Ryves's evaluation.

References:

1) T.B. Ryves, Nucl. Instr. and Meth. 167(1979)449.

2) K. Takeuchi et al., JAERI-M9014 (1980).

3) Y. Kawada, Researches of the Electrotechnical Laboratory No.730(1972).

4) K. Kudo, Nucl. Instr. and Meth. 141(1977)325.

5) T.B. Ryves et al., Int. Conf. on Nucl. Cross Sections for Technol. at Univ. of Tenessee, Oct. 22~26(1979).

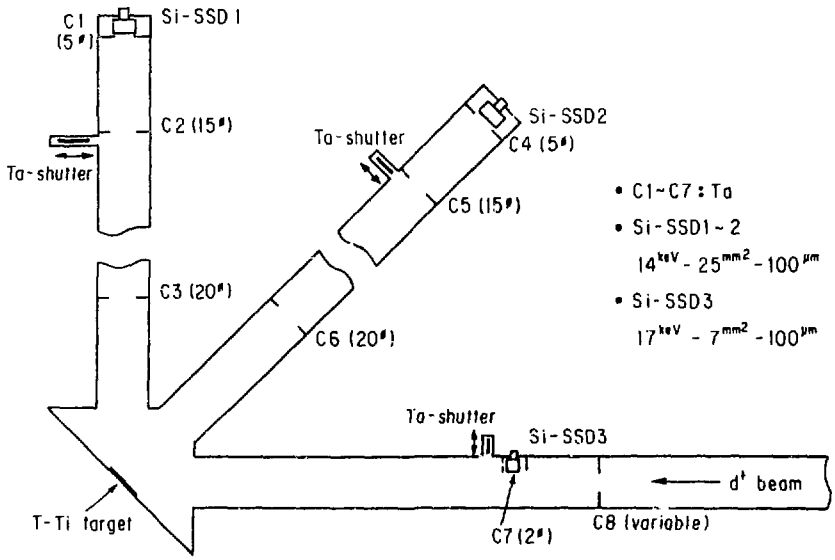

Fig. 1. Experimental arrangement of associated alpha particle method

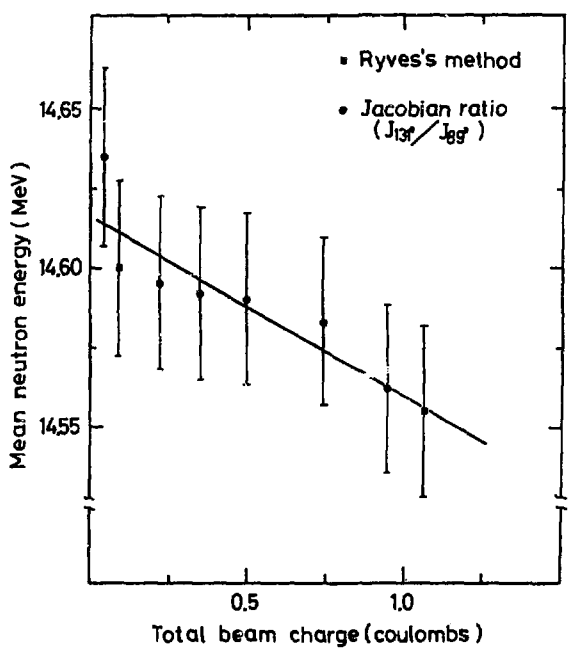

Fig. 2. Mean neutron energy as a function of total beam charge received by Ti-T target

I-2 Thermal Cross Section Ratio σ_H / σ_{Mn}

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

Manganese to hydrogen thermal neutron cross section ratio σ_H/σ_{Mn} has been determined more acurately by variation of the solution of a circulated manganese sulphate bath technique[1]. The cross section ratio is derived from a following straight line equation with the use of the ratio of the slope to the intercept[2].

$$\frac{\eta_i(1-L_i)(1-S_i)(1-O_i)}{A_i} = \frac{1}{Q}\left\{1+\frac{\sigma_s}{\sigma_{Mn}(1+\bar{p})}\right\} + \frac{\sigma_H}{Q\,\sigma_{Mn}} \times \frac{N_H}{N_{Mn}(1+p_i)} ,$$

where the subscript i is introduced to denote a certain chemical concentration, and

Q: neutron emission rate (n/s)

A_i: saturation counting rate (cps)

η_i: efficiency of bath monitor (cps/Bq/cm^3)

L_i: fraction of leakage neutrons from the tank

S_i: fraction of neutrons captured in the source and source mounting

O_i: fraction of neutrons absorbed in oxygen and sulphur

p_i: manganese resonance correction

$\bar{p}$: averaged value of manganese resonance correction among several concentrations of the solution

σ_{Mn}, σ_S, σ_H: 2200 m/s neutron absorption cross sections of manganese, sulphur and hydrogen

N_H, N_{Mn}: atomic number densities of hydrogen and oxygen.

The measurements were performed in a spherical SUS316 vessel, 1.5 mm thick and internal diameter 98.4 cm, filled with a solution of manganese sulphate. The Cf source(5.4 mCi) was mounted at the center of a thin aluminum spherical shell of 9.1 cm in diameter positioned at the center of the vessel. The solution pumped from the bath was introduced into a cylindrical bath monitor vessel which provides two separate monitors, 2.5 cm^{ϕ} x 2.5 cm^{L} and 5. cm^{ϕ} x 5.1 cm^{L} NaI crystals coupled with temperature compensated photomultiplier base. All gamma-rays exceeding a threshold of about 20 keV were integrated and the gain drift was checked with a ^{60}Co source before and after each measurement. For precise determination of the efficiencies of the bath monitors for each concentration, an intense ^{56}Mn solution of high purity was divided into several portions by weight, some of which were used to determine the bath efficiencies and others were measured in the $4\pi\beta$-γ coincidence equipment to determine the specific activity in the same instant.

The standard long counter of Hanson and Mckibben type was used to evaluate the neutron escape from the manganese bath and a BF_3 counter was also used to measure the thermal neutrons at the surface of the bath (3),(4). Furthermore, the correction factor was also

evaluated using a discrete ordinates computer code PALLAS[5]. The both results agreed within a discrepancy of 20%. Thermal neutron absorption in the source and the source mounting was determined to measure the thermal neutron flux at the surface of the cavity boundary with gold foils for each concentration of manganese sulphate. The compositions of the source capsule were treated as SUS304L, the weight 2.9 g. The cross sections for the composite elements were taken from BNL325 2nd or 3rd edition. The thermal neutron flux and the cross sections described above were used to calculate thr thermal neutron absorption. On the other hand, the effects of thermal neutron absorption were measured by changing the covering area of the 0.02 mm thick cadmium foil around the source. The saturated counting rates were normalized to the value for the cadmium uncovered source and finally the correction was determined by extrapolating to cross section zero. The results measured by means of the two technique indicated in good agreement within a discrepancy of 10%. The absorption of neutrons by (n,p) and (n,α) reactions with oxygen and sulphur was calculated using PALLAS code. The cross sections for O(n,p), O(n,α) and S(n,p) were taken from ENDF/B-IV and the S(n,α) cross section from Troubetzkoy[6]. The correction for non-1/v activation in the energy region of epithermal resonances was calculated for each concentration of manganese by using the PALLAS code. The reaction cross section was

taken from the ENDF/B-IV library.

As a result, the manganese to hydrogen thermal neutron cross section ratio σ_H/σ_{Mn} has been evaluated as 0.02500 ± 0.00008.

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1) K. Kudo, J. At. Energy Soc. 23(1)(1980)62.

2) E.J. Axton, NBS Special Pub. 493(1977).

3) E.J. Axton et al., J.Nucl. Energy 15(1961)22.

4) K.W. Geiger et al., Can. J. Phys. 43(1965)373.

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

6) E.S. Troubetzkoy et al., Report N.D.A. 2133-4(1961).

II. HIROSHIMA UNIVERSITY

Department of Physics, Faculty of Science

II-1 Precision Measurements of Gamma-Ray Energies and Intensities

Y. Yoshizawa, Y. Iwata, J. Jin*, H. Kumahora and H. Inoue

1. Intensity Measurements

Relative gamma-ray intensities emitted from ^{75}Se, ^{125}Sb, ^{133}Ba, ^{160}Tb and ^{168}Tm were measured with a Ge(Li) detector. The detector was calibrated by using standard sources and cascade gamma rays. [1] Uncertainties of the relative intensities for strong gamma rays are about 0.5 % in the region higher than 280 keV and about 1 % in the region lower than 280 keV. Intensities per decays were calculated by using relative intensities and internal conversion coefficients. The results are listed in Tables I, II, III, IV and V, respectively.

2. Energy Measurements

Energies of five gamma rays were measured in the range 450-600 keV with Ge(Li) spectrometers which were calibrated by using gamma-ray energy standards of ^{198}Au and ^{192}Ir. These standards were accurately determined by Kessler et al. [2] Our observed energies are shown in Table VI. These gamma rays are useful for energy standards.

References :

1) Y. Yoshizawa, Y. Iwata, T. Kaku, T. Katoh, J. Ruan, T. Kojima and Y. Kawada, Nucl. Instr. and Meth. 174 (1980) 109

2) E. G. Kessler, R. D. Deslattes, A. Hennis and W. C. Sauder, Phys. Rev. Lett. 40 (1978) 171

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* Present address : Geological Institute of Hopei, Shuanhua, Hopei, China

Table I. Relative intensities and intensities per decay of gamma rays for ^{75}Se

Gamma-ray energy (keV)	Relative intensity (%)	Intensity per decay (%)
96.7	5.78 ± 0.17	3.35 ± 0.11
121.1	29.24 ± 0.29	17.0 ± 0.3
136.0	99.2 ± 0.9	57.8 ± 1.0
198.6	2.51 ± 0.04	1.46 ± 0.04
264.7	100.0 ± 0.5	58.0 ± 0.9
279.5	42.43 ± 0.20	24.6 ± 0.4
303.9	2.234 ± 0.017	1.296 ± 0.023
400.7	19.42 ± 0.13	11.28 ± 0.18
419.0	0.0231 ± 0.0021	0.0134 ± 0.0012
572.3	0.0634 ± 0.0029	0.0368 ± 0.0018
617.6	0.0078 ± 0.0021	0.0045 ± 0.0012

Table II. Relative intensities and intensities per decay of gamma rays for ^{125}Sb

Gamma-ray energy (keV)	Relative intensity (%)	Intensity per decay (%)
109.3	(0.241 ± 0.024)	(0.071 ± 0.007)
117.0	0.867 ± 0.025	0.257 ± 0.008
172.6	0.69 ± 0.04	0.205 ± 0.012
176.3	22.62 ± 0.21	6.70 ± 0.09
178.8	0.11 ± 0.04	0.032 ± 0.013
198.6	0.030 ± 0.011	0.009 ± 0.003
204.1	1.08 ± 0.03	0.320 ± 0.011
208.1	0.788 ± 0.021	0.233 ± 0.007
227.9	0.433 ± 0.012	0.128 ± 0.004
321.0	1.391 ± 0.024	0.412 ± 0.008
380.4	5.06 ± 0.04	1.500 ± 0.019
408.0	0.608 ± 0.021	0.180 ± 0.006
427.9	100.0 ± 0.7	29.6 ± 0.3
443.5	0.989 ± 0.023	0.293 ± 0.007
463.4	35.23 ± 0.14	10.44 ± 0.12
497.4	0.009 ± 0.008	0.0025± 0.0023
600.6	59.54 ± 0.22	17.64 ± 0.20
606.6	16.94 ± 0.07	5.02 ± 0.06
635.9	37.87 ± 0.14	11.22 ± 0.13
671.4	6.039 ± 0.024	1.790 ± 0.021

Table III. Relative intensities and intensities per decay of gamma rays for ^{133}Ba

Gamma-ray energy (keV)	Relative intensity (%)	Intensity per decay (%)
160.6	1.035 ± 0.026	0.642 ± 0.017
223.1	0.756 ± 0.024	0.468 ± 0.010
276.4	11.57 ± 0.06	7.17 ± 0.04
302.9	29.55 ± 0.14	18.31 ± 0.10
356.0	100.0 ± 0.6	61.96 ± 0.15
383.9	14.36 ± 0.09	8.90 ± 0.05

Table IV. Relative intensities and intensities per decay of gamma rays for ^{160}Tb

Gamma-ray energy (keV)	Relative intensity (%)	Intensity per decay (%)
93.3	0.181 ± 0.010	0.055 ± 0.003
197.0	17.06 ± 0.24	5.18 ± 0.08
215.6	13.37 ± 0.14	4.06 ± 0.05
230.6	0.280 ± 0.011	0.085 ± 0.003
242.5	0.033 ± 0.011	0.010 ± 0.003
246.5	0.069 ± 0.011	0.021 ± 0.003
298.6	87.8 ± 0.4	26.64 ± 0.17
299.6	2.877 ± 0.025	0.873 ± 0.009
337.3	1.129 ± 0.024	0.343 ± 0.007
349.9	0.047 ± 0.007	0.0142 ± 0.0021
379.4	0.040 ± 0.007	0.0122 ± 0.0022
392.5	4.48 ± 0.03	1.361 ± 0.012
432.7	0.073 ± 0.007	0.0221 ± 0.0022
486.1	0.289 ± 0.008	0.0878 ± 0.0026
682.3	1.97 ± 0.16	0.60 ± 0.05
765.3	7.18 ± 0.10	2.18 ± 0.03
872.0	0.71 ± 0.04	0.216 ± 0.011
879.4	100.0 ± 0.3	30.35 ± 0.08
962.3	32.03 ± 0.14	9.72 ± 0.04
966.2	82.57 ± 0.29	25.06 ± 0.07
1002.9 } 1005.0	3.571 ± 0.029	1.084 ± 0.009
1069.1	0.309 ± 0.011	0.094 ± 0.003
1102.6	1.906 ± 0.018	0.579 ± 0.005
1115.1	5.099 ± 0.023	1.548 ± 0.007
1177.9	49.26 ± 0.16	14.97 ± 0.05
1199.9	7.84 ± 0.03	2.379 ± 0.010
1251.3	0.357 ± 0.008	0.1084 ± 0.0025
1271.9	24.72 ± 0.08	7.505 ± 0.027
1285.6	0.046 ± 0.003	0.0140 ± 0.0009
1299.3	0.0051 ± 0.0019	0.0015 ± 0.0006
1312.1	9.35 ± 0.04	2.838 ± 0.012

Table V. Relative intensities and intensities per decay of gamma rays for ^{168}Tm

Gamma-ray energy (keV)	Relative intensity (%)	Intensity per decay (%)
99.1 } 99.3 }	9.70 ± 0.21	4.8 ± 0.10
174.0	0.084 ± 0.020	0.041 ± 0.010
184.3	36.0 ± 0.4	17.75 ± 0.20
198.2	108.4 ± 1.5	53.4 ± 0.8
272.9	0.206 ± 0.020	0.101 ± 0.010
284.1	0.14 ± 0.03	0.070 ± 0.017
348.4	0.68 ± 0.020	0.335 ± 0.010
422.2	0.601 ± 0.022	0.296 ± 0.011
447.5	46.7 ± 0.3	23.01 ± 0.19
521.7	0.079 ± 0.021	0.039 ± 0.011
546.8	5.21 ± 0.05	2.568 ± 0.027
557.1	0.399 ± 0.028	0.197 ± 0.014
631.7	18.08 ± 0.09	8.91 ± 0.04
645.7	2.94 ± 0.03	1.449 ± 0.016
673.7	0.332 ± 0.014	0.164 ± 0.007
720.3	24.35 ± 0.10	12.01 ± 0.07
730.6	10.32 ± 0.06	5.088 ± 0.029
741.3	25.13 ± 0.10	12.39 ± 0.05
748.3	0.855 ± 0.013	0.421 ± 0.007
815.9	100.0 ± 0.4	49.31 ± 0.11
821.1	23.36 ± 0.10	11.51 ± 0.05
829.9	13.80 ± 0.06	6.81 ± 0.03
853.5	0.075 ± 0.004	0.0367 ± 0.0021
914.9	6.09 ± 0.03	3.002 ± 0.016
928.9	0.127 ± 0.005	0.0626 ± 0.0027
1014.2	0.134 ± 0.010	0.066 ± 0.005
1167.5	0.140 ± 0.006	0.0690 ± 0.0028
1172.6	0.020 ± 0.005	0.0101 ± 0.0025
1277.4	3.328 ± 0.021	1.641 ± 0.011
1323.8	0.041 ± 0.004	0.0200 ± 0.0021
1332.4	0.010 ± 0.004	0.0050 ± 0.0018
1351.6	0.172 ± 0.007	0.085 ± 0.003
1359.0	0.021 ± 0.004	0.0104 ± 0.0021
1461.7	0.412 ± 0.019	0.203 ± 0.009

Table VI. Observed gamma-ray energies

Nuclide	Energy (eV)
^{7}Be	477606.4 ± 2.6
^{106}Ru	511856.2 ± 2.3
^{85}Sr	514007.6 ± 2.2
^{147}Nd	531032.9 ± 2.4
^{207}Bi	569703.5 ± 4.1

III. HOSEI UNIVERSITY

Department of Physics

III-1 The p-Wave Strength Function

Izumi FURUOYA

A paper on this subject has been published in Progress of Theoretical Physics, Vol.67, No.5, May, 1982 with an abstract as follows:

The effect of the intermediate structure, the doorway state, on the overall aspect of the p-wave strength function plotted with respect to mass number is investigated. Our qualitative method is analogous to that used by Block and Feshbach in their investigation on the s-wave strength function. It is shown that low values in the p-wave strength function near A=50 and A=160 can be explained by our theory. In particular it is found that the change of the number of doorway states contributing to the strength function is responsible for the splitting of the 3-p giant resonance and a deep valley in the 3-p giant resonance can be reproduced.

IV. JAPAN ATOMIC ENERGY RESEARCH INSTITUTE

A. Linac Laboratory, Division of Physics

IV-A-1

Average Neutron Total Cross Sections of ^{181}Ta and ^{238}U at the Fe-filtered Neutron Energies

I. Tsubone, Y. Nakajima, Y. Furuta and Y. Kanda*

Average neutron total cross sections of ^{181}Ta and ^{238}U have been measured by using Fe-filtered neutron beam techniques with a NE-110 plastic scintillation detector at a 100-m station. The average total cross sections were obtained at 25 energy points from 24 keV to 1 MeV with a statistical accuracy of 0.2 to 2.0 %.

Fitting the formula $\langle\sigma_t(E)\rangle = 2\pi\lambda\!\!\!^{-2}\sum_{\ell}(2\ell + 1)(1 - \mathrm{Re}(\overline{U}(E,\ell))$ to these data, s-, p-, d-wave average resonance parameters were obtained as follows: $R_0^\infty = 0.014$, $S_1 = 0.74 \times 10^{-4}$, $R_1^\infty = 0.076$, $S_2 = 2.1 \times 10^{-4}$, $R_2^\infty = -0.27$ for ^{181}Ta, and $R_0^\infty = -0.058$, $S_1 = 2.0 \times 10^{-4}$, $R_1^\infty = 0.18$, $S_2 = 1.7 \times 10^{-4}$, $R_2^\infty = -0.13$ for ^{238}U. Covariance matrices in each parameter were also obtained, and show the strong correlation between R_0^∞ and S_1.

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*Kyushu University

Neutron Resonance Parameters of Bromine-79 and Bromine-81

M.OHKUBO, Y.KAWARASAKI and M.MIZUMOTO

A paper on this subject has been published in J.Nucl.Sci.Technol 18,745(1981) with an abstract as follows.

Neutron resonances of separated isotopes of bromine were measured using a TOF spectrometer of the Japan Atomic Energy Research Institute electron linear accelerator. Transmission and capture measurements were made with a ^{6}Li-glass and a Moxon-Rae detector respectively,on separated isotopes(~98%)of ^{79}Br and ^{81}Br. Resonance analyses were made on transmission data with an area analysis code,and on capture data with a Monte-Carlo program. For ^{79}Br $g\Gamma_n^0$ values of 156 levels below 10 keV are obtained, and for ^{81}Br 100 levels below 15 keV. The s-wave strength function S_0,average level spacing $\langle D \rangle$, and average radiation width $\langle \Gamma_\gamma \rangle$ are obtained; for ^{79}Br $S_0=(1.27\pm 0.14)10^{-4}$, $\langle D \rangle=45\pm5$ eV, $\langle \Gamma_\gamma \rangle=293\pm20$ meV,and for ^{81}Br $S_0=(0.86\pm0.14)10^{-4}$, $\langle D \rangle=70\pm12$ eV, $\langle \Gamma_\gamma \rangle=234\pm20$ meV. For ^{79}Br statistical properties of resonances are in good agreement with the predictions of the statistical model. Intermediate structures are observed in the resonances of ^{81}Br showing clusters of levels at 1.2,4.4,10.0,11.5 and 14.1 keV, where the curve of cumulative sum of $g\Gamma_n^0$ vs. neutron energy shows steep rises.

IV-A-3

Neutron resonance parameters of ^{107}Ag and ^{109}Ag

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

Neutron transmission measurements were carried out on the separated isotopes of silver using the time-of-flight facility at the JAERI electron linear accelerator. Neutrons were detected with the ^{6}Li-glass detectors at 56.319 m and 191.49 m. The samples used were metallic powder enriched to 98.2 % for ^{107}Ag and to 99.3 % for ^{109}Ag. Transmission data were analyzed with a multi-level Breit-Wigner formula incorporated in a least squares fitting program. Resonance energies and neutron widths were determined for a large number of resolved resonances in the neutron energy region up to 7 keV. The s-wave strength functions and average level spacings were obtained to be; $S_0 = (0.42 \pm 0.05) \times 10^{-4}$, $D_0 = 22 \pm 2$ eV for ^{107}Ag and $S_0 = (0.44 \pm 0.05) \times 10^{-4}$, $D_0 = 21 \pm 2$ eV for ^{109}Ag.

IV-A-4

Neutron Resonance Parameters of ^{123}Sb

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

Neutron Transmission measurements on ^{123}Sb were carried out at the JAERI linac TOF spectrometer with the maximum resolution of $\sim$1 nsec/m. Separated isotope of ^{123}Sb(99% enriched, metallic powder)was used for the sample. Resonance analyses were made to obtain $g\Gamma_n$ values for $\sim$80 levels below 4 keV. High resolution transmission measurements using 190 m flight path, and capture cross section measurements with scintillator tank are in progress.

IV-A-5 Neutron Resonance parameters of ^{133}Cs

Y. Nakajima, M. Mizumoto, Y. Kawarasaki, Y. Furuta
I. Tsubone, M. Ohkubo and Y. Kanda*

Transmission and capture measurements on ^{133}Cs were carried out at 200 m and 50 m stations of JAERI linac neutron time-of-flight facility, respectively. The capture and transmission data respectively were analyzed with a Monte Carlo area analysis method[1] to obtain capture widths up to 2 keV and with the Atta-Harvey area anlysis code[2] to obtain neutron widths up to 5.8 keV. The analysis is in progress.

References:

1) F. H. Fröhner, GA-6906 (1966)

2) A. E. Atta and J. A. Harvey, ORNL-3205 (1961)

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* Kyushu University

IV-A-6

A Normalization Standard for Neutron Capture Probability in the Resonance Region

M.Ohkubo

A paper titled above has been published in Nucl.Instr.Methods 184(1981)465-467 with an abstract as follows.

Saturation capture probabilities for neutrons, impinging onto thick samples at resonance energies, are proposed as a standard for capture probability,in the energy region of a few hundred eV. Capture probabilities for the 132 eV resonance of cobalt,are examined.

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

IV-B-1 Evaluation of Neutron Nuclear Data for ^2H

K. Shibata, T. Narita and S. Igarasi

Evaluation of neutron nuclear data for ^2H was performed in the neutron energy region from 10^{-5} eV to 20 MeV.

The total and (n,2n) cross sections were estimated from the experimental data by using the spline function. The capture cross section at 0.0253 eV was determined from the measurement by Ishikawa[1] and extrapolated as 1/v up to 1 keV. Above 1 keV the capture cross sections were obtained from the inverse reaction $^3H(\gamma,n)^2H$[2] by taking account of the detailed balance. The present calculation gives a value of one-third at 14.4 MeV as compared with that of Cerineo et al.[3] which was obtained from measurement of tritons using a counter telescope. The elastic scattering cross section was given by subtracting the (n,2n) and capture cross sections from the total cross section. Fig. 1 shows the present results.

The angular distributions for the elastic scattering and the double differential cross sections for the (n,2n) reaction were calculated on the basis of the Faddeev equation with s-wave separable potentials[4]. In Table I are shown the scattering length and effective range parameters used in the calculations. The calculated double differential cross sections well reproduce the shape of the measured neutron energy spectra.

The evaluated data are compiled in the ENDF/B format and to be stored in the second version of Japanese Evaluated Nuclear Data Library, JENDL-2.

References:

1) H. Ishikawa: Nucl. Instrum. Meth. 109 (1973) 493.

2) J. C. Gunn and J. Irving: Phil. Mag. 42 (1951) 1353.

3) M. Cerineo et al.: Phys. Rev. 124 (1961) 1947.

4) W. Ebenhöh: Nucl. Phys. A191 (1972) 97.

Table I. Scattering length and effective range parameters.

System	Scattering length (fm)	Effective range (fm)
n-p triplet	5.4	1.8
n-p singlet	-23.7	2.7
n-n	-16.0	2.8

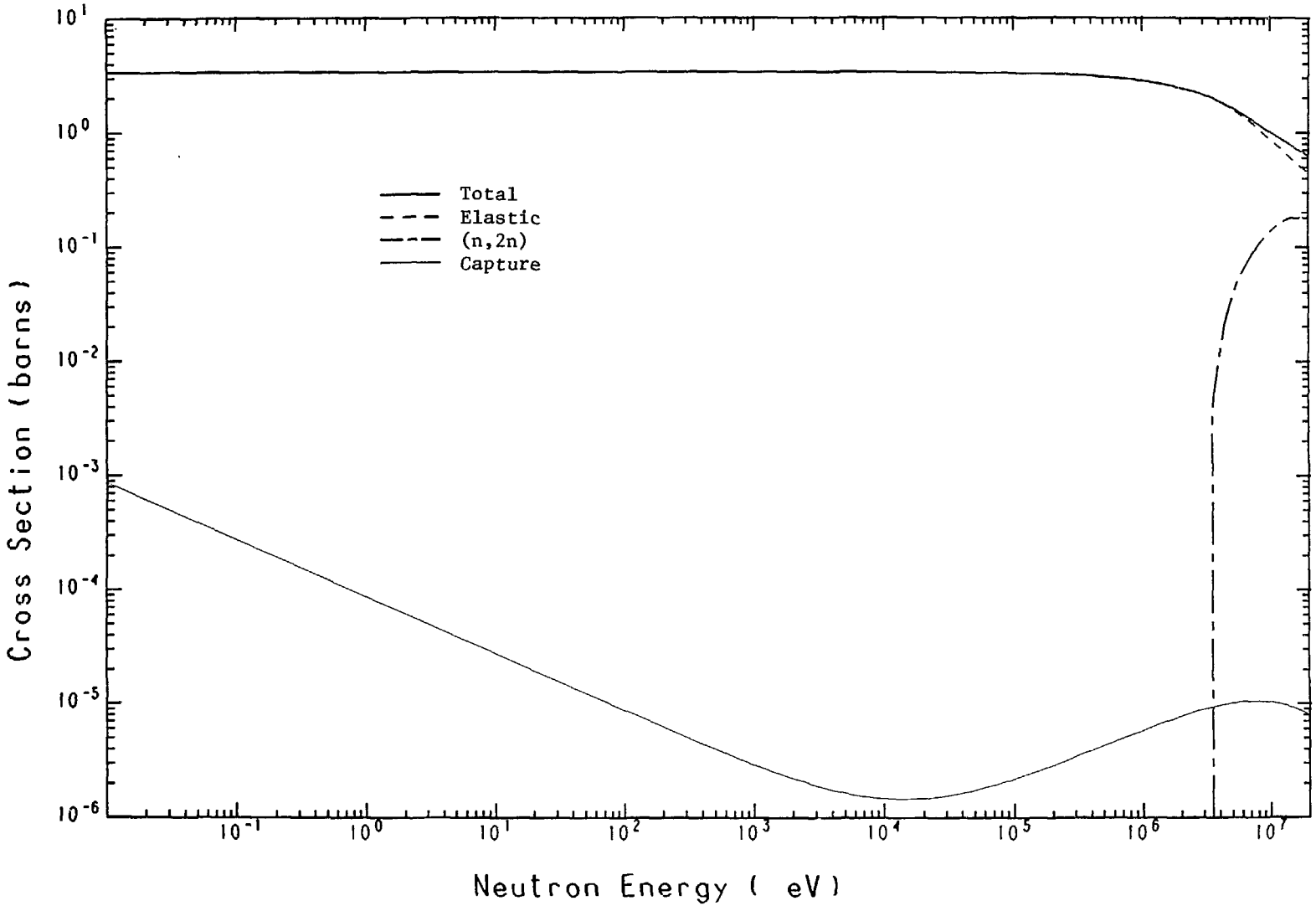

Fig. 1 Evaluated cross sections.

IV-B-2 Evaluation of Neutron Nuclear Data for ^{45}Sc

Y. OKA*, T. NAKAGAWA** and Y. KIKUCHI

A paper on this subject was published as JAERI-M 9981 with the following abstract:

Evaluation of neutron nuclear data for ^{45}Sc was performed in the energy range of thermal to 20 MeV. Evaluated quantities are the total, elastic and inelastic scattering, capture, (n,2n), (n,p) and (n,α) reaction cross sections, resonance parameters and angular distributions of emitted neutrons. Resonance parameters are recommended below 100 keV. Particular care was paid for the minimum value of the total cross section near 2 keV, since a mono-energetic neutron filter is now under design by using scandium metal at Fast Neutron Source Reactor YAYOI of The University of Tokyo. Optical and statistical model calculations are performed for the smooth cross sections above resonance region. The results were compiled in the ENDF/B format and they will be stored in the second version of Japanese Evaluated Nuclear Data Library JENDL-2.

Figure 1 shows the evaluated total cross section between 100 eV and 10 keV.

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** Data Bank, OECD-Nuclear Energy Agency

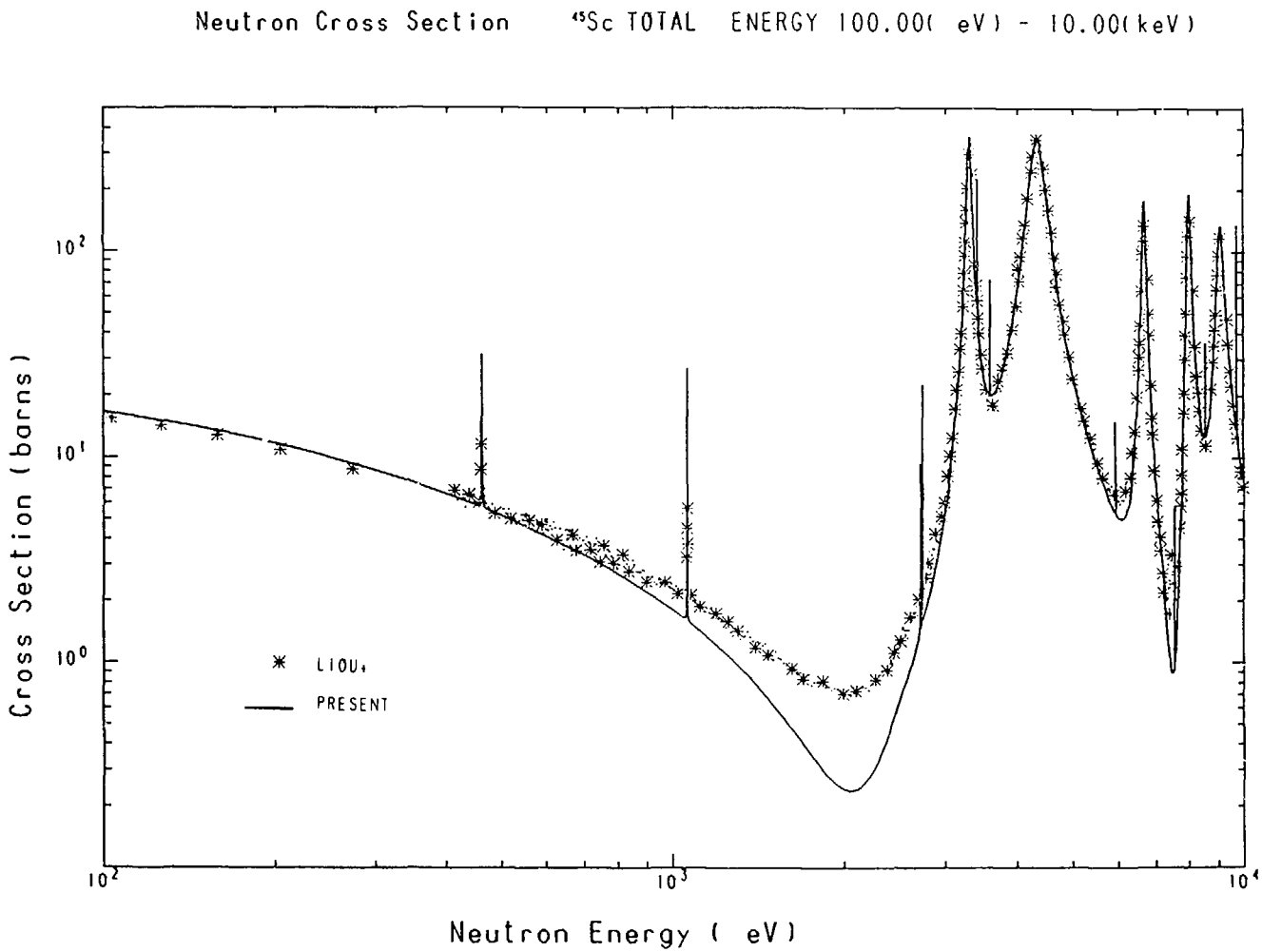

Fig. 1 The total cross section of ^{45}Sc between 100 eV and 10 keV.

IV-B-3 Evaluation of Hafnium Neutron Cross Sections

K. Hida,* H. Takano,** T. Yoshida,* S. Iijima,* T. Asami**

The neutron cross sections of the hafnium isotopes (A=174, 176~180) were evaluated for Japanese Evaluated Nuclear Data Library Version 2, JENDL-2. Although hafnium has good features as a reactivity control material of nuclear reactors, evaluated neutron data are scarce and are included neither in JENDL-1 nor in ENDF/B-IV.

The resonance parameters were adopted from the Drake's evaluation[1] and from BNL 325[2]. Background cross sections were introduced into the resonance region to reproduce the 2200 m/s values and to keep the consistency with measured total cross section data. The unresolved resonance region covers from the top of the resolved region up to 50 keV, the lower-end of the smooth cross section region.

The smooth cross sections were calculated on the basis of the statistical model with neutron penetration coefficient obtained by optical model.[3] The optical model parameters were determined so as to reproduce the total cross section of natural hafnium. The parameters are given in Table 1. The level density parameters for each isotope were determined from the measured resonance level spacings and the low-lying level scheme information. The value of the gamma strength S_γ was used as an adjustable parameter to obtain consistency with the measured capture cross section. A difficulty

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**) Japan Atomic Energy Research Institute, Takai Establishment

encountered in this procedure is that the abundance-weighted sum of the isotope-wise capture cross sections measured by Kapchigashev[4] does not agree with the measured cross section of natural hafnium.[5] The first priority was given to the consistency with natural hafnium cross sections. The adopted cross section curves are shown in Fig. 1 along with the Drake's evaluation for ENDF/B-V.

The cross sections for processes (n,2n), (n,3n), (n,p) and (n,α) were calculated with GNASH code[6] based upon the multi-step Hauser-Feshbach theory.

The 2200 m/s capture values and the resonance integrals of the present evaluation are listed in Table 2 with other evaluation values.

References

1) M.K. Drake, D.A. Sargis, T. Maung, EPRI NP-250 (1976)

2) S.F. Mughabghab, D.I. Garber, BNL 325, Third Edition (1972)

3) S. Igarasi, CASTHY code, private communication

4) S.P. Kapchigashev, Atomizdat, Moscow (1970), numerical values taken from the NESTOR data base

5) for example, D. Kompe, Nucl. Phys., A133, 513 (1969); M.C. Moxon, et al., AERE-PR/NP21 p.41 (1974) UKAEA

6) P.G. Young, E.D. Arthur, LA 6947 (1977) Los Alamos National Laboratory

TABLE 1 OPTICAL MODEL PARAMETERS AND STRENGTH FUCNTIONS

$V_0 = 38.0$, $W_s = 8.0 + 0.5\ E$, $V_{so} = 7.0$

$R_0 = R_s = R_{so} = 1.32$ fm (all in MeV)

$a_0 = a_{so} = 0.47$ fm, $a_s = 0.52$ fm

$S_0 = 2.0$,* $S_1 = 1.1$, $S_2 = 1.9$, $R' = 6.9$ fm

*) $\times 10^{-4}$ for S_0, S_1 and S_2

TABLE 2 CAPTURE CROSS SECTION AT 2200 M AND RESONANCE INTEGRAL

A	Abund %	σ_{2200}, barn		Res. Integral, barn		
		present	BNL-325	present	BNL-325	SAI
174	0.16	390	390±50	476	465±50	446
176	5.2	38	38±6	357	700±50	337
177	18.6	360	365±20	7230	7260±200	7220
178	27.1	86	86±10	1918	1950±100	1747
179	13.7	45	45±5	517	600±60	451
180	35.2	12.6	12.6±.7	36	43±8	29
nat		103	102±2	1972	2000±100	1900

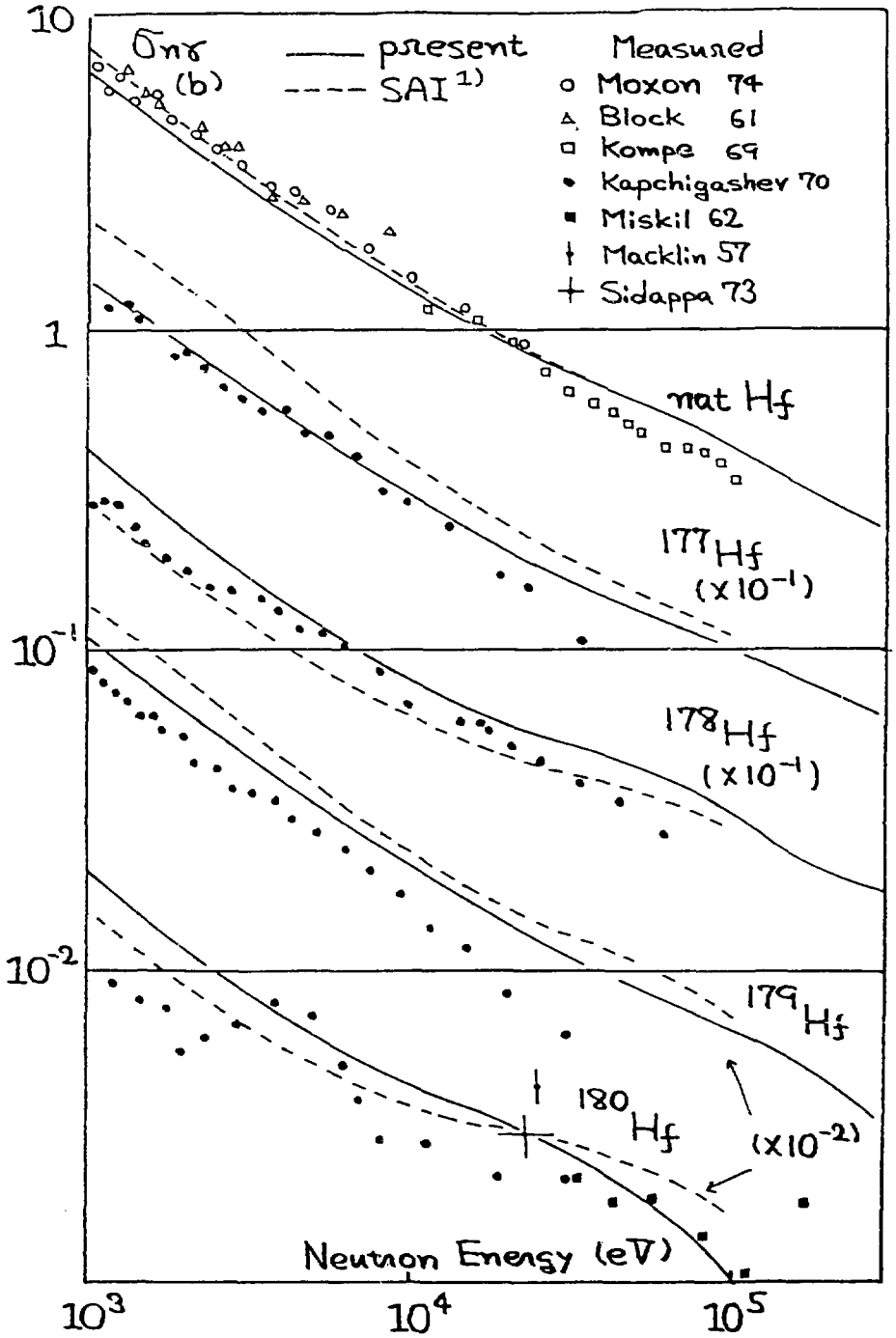

FIG 1 ADOPTED CAPTURE CROSS SECTIONS OF Hf ISOTOPES

IV-B-4

Evaluation of Neutron Nuclear Data for ^{241}Am and ^{243}Am

Y. KIKUCHI

A paper on this subject was published as JAERI-M 82-096 with the following abstract:

Neutron nuclear data of ^{241}Am and ^{243}Am were 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 or energy distribution of the emitted neutrons, and the average number of neutrons emitted per fission. The fission cross section was evaluated on the basis of newly measured data, and lower values than JENDL-1 were given in the subthreshold energy region. The reliability of the calculation parameters are also much improved, because experimental data became available for the total and capture cross sections of ^{241}Am in the high energy region. This work was made under contracts between Power Reactor and Nuclear Fuel Development Corporation and Japan Atomic Energy Research Institute.

Figures 1 and 2 show the evaluated cross sections of ^{241}Am and ^{243}Am, respectively.

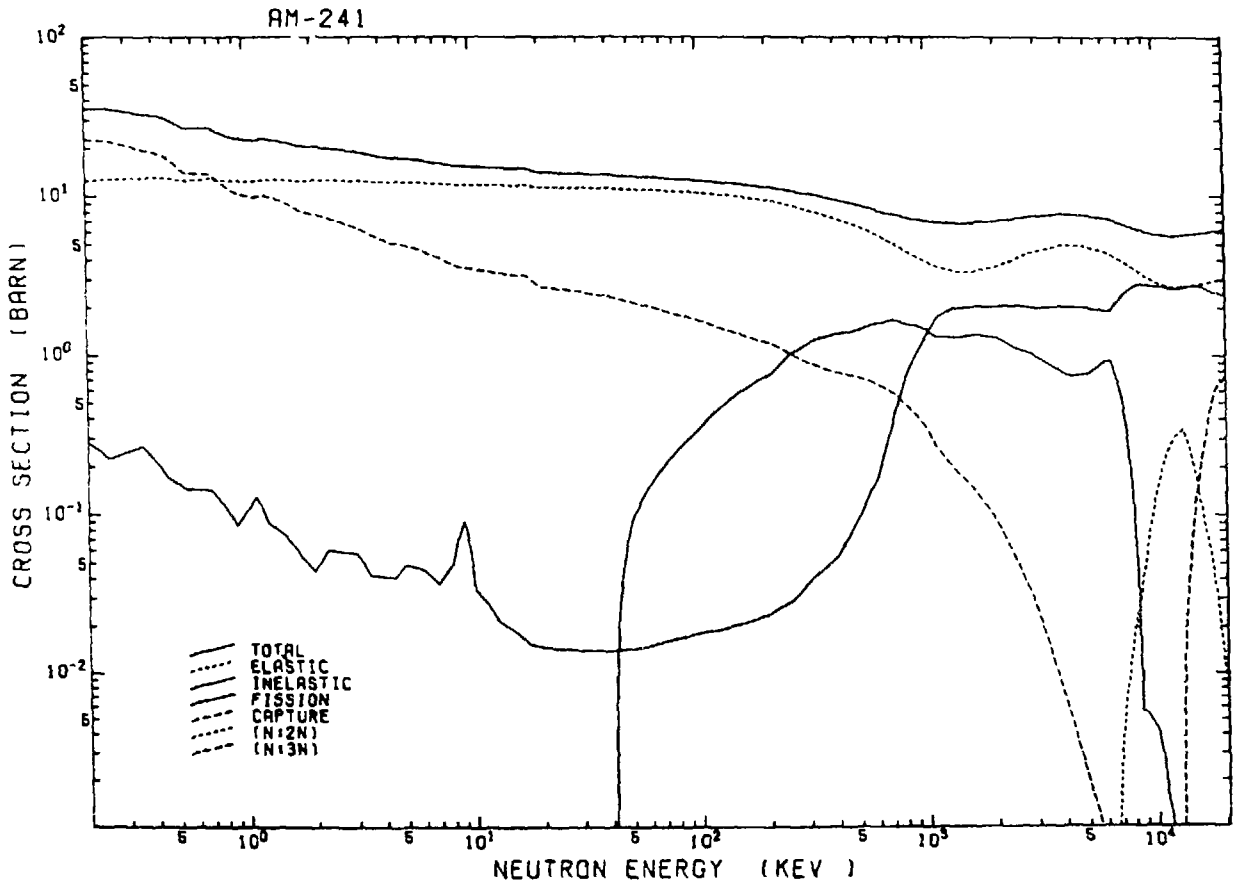

Fig. 1 Evaluated cross section of ^{241}Am.

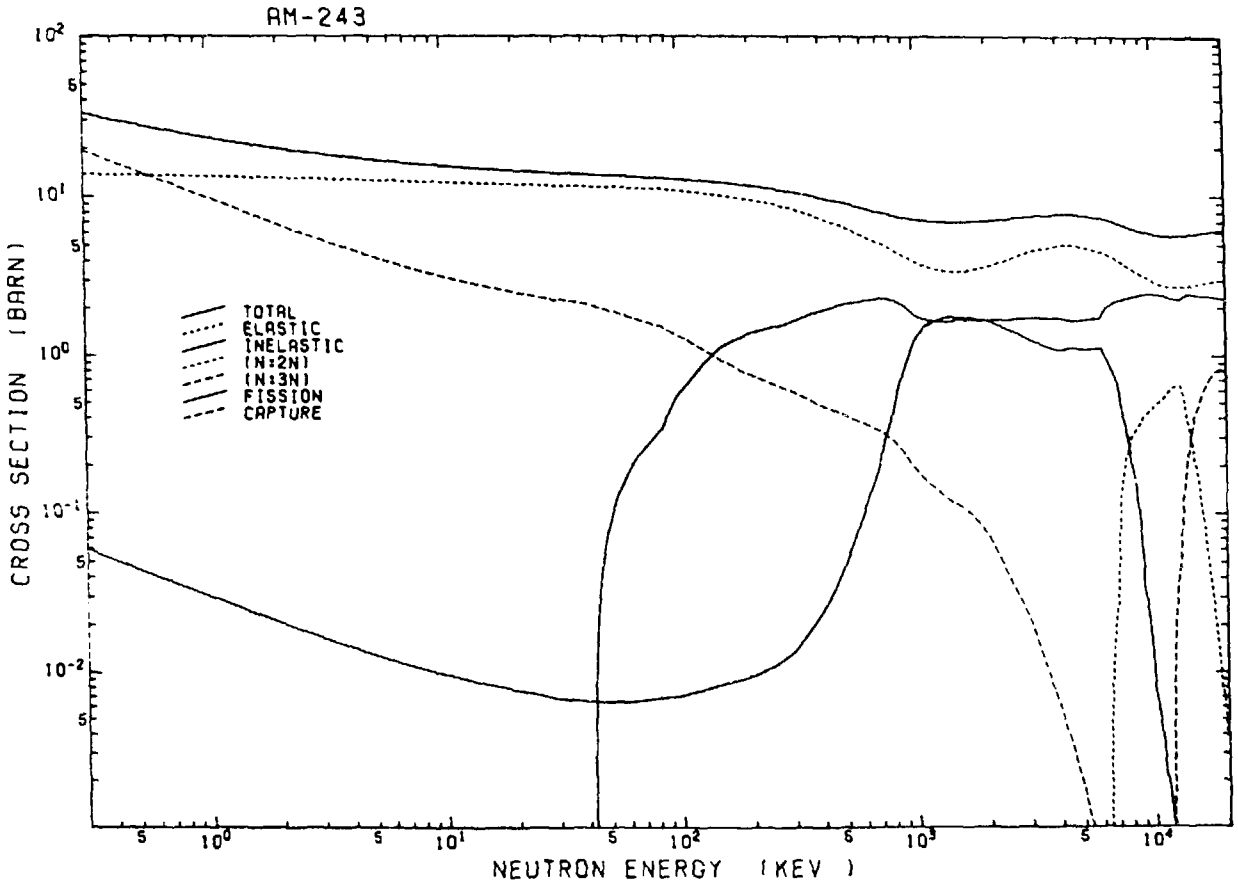

Fig. 2 Evaluated cross section of ^{243}Am.

IV-B-5

Evaluation of Resonance Parameters of ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Pu and ^{242}Pu

T. NAKAGAWA*, Y. KIKUCHI, A. ZUKERAN**

T. YOSHIDA***, M. KAWAI*** and A. ASAMI****

A paper on this subject was published as JAERI-M 9823 with the following abstract:

This report contains two papers entitled "Evaluation of Resonance Parameters of ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu" and "Evaluation of Resonance Parameters of ^{238}U, ^{240}Pu and ^{242}Pu", which were submitted to IAEA Consultants Meeting on Uranium and Plutonium Isotope Resonance Parameters held on the 28th Sept. - 2nd Oct., 1981 at Vienna as contributed papers. Summaries of the contributed papers will be quoted in the IAEA proceedings.

These two parts describe the evaluation of the resonance parameters of main fissile and fertile materials for JENDL-2, and discuss briefly the problems encountered in the evaluation. In part III of this report, the presently evaluated resonance parameters were tabulated.

* Data Bank, OECD-Nuclear Energy Agency

** Energy Research Laboratory, Hitachi, Ltd.

*** Nippon Atomic Industry Group Co., Ltd.

**** National Laboratory for High Energy Physics

IV-B-6

Evaluation of Resonance Parameters of ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu

Y. KIKUCHI, A. ASAMI* and T. YOSHIDA**

A paper on this subject was published in Proc. IAEA consultants Meeting on Uranium and Plutonium Isotope Resonance Parameters, 28 Sept. - 2 Oct., 1981, Vienna, p. 309:

The resonance parameters of ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu were evaluated for Japanese Evaluated Nuclear Data Library Version 2 (JENDL-2). The evaluation was made by two steps. At first, the parameters were evaluated on the basis of the reported measured data with a suitable method which depends on the status of measured data. The most reliable parameter set could be found after some simple examinations for ^{233}U, ^{239}Pu and ^{241}Pu, since total number of measured parameter sets is limited for these nuclides. On the other hand, numerous measurements exist for ^{235}U, and the evaluation was made by taking a suitable average, considering the fission and capture areas. Secondly, the cross sections were calculated with the parameters thus obtained, and were compared with the measured cross sections. Then the parameters were so modified that the calculated cross sections well reproduced the measured data. After modifying the resonance parameters, the remaining discrepancies between the calculated and measured cross sections, which are mainly caused by the interference among levels and are inevitable with the single-level Breit-Wigner formula, were corrected by applying slight background cross sections. The resonance integrals calculated from the presently evaluated parameters agree well with the measured data.

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* National Laboratory for High Energy Physics

** Nippon Atomic Industry Group Co., Ltd.

Evaluation of Resonance Parameters of ^{238}U, ^{240}Pu and ^{242}Pu

T. NAKAGAWA*, A. ZUKERAN** and M. KAWAI***

A paper on this subject was published in Proc. IAEA Consultants Meeting on Uranium and Plutonium Isotope Resonance Parameters, 28 Sept. - 2 Oct., 1981, Vienna, p. 282:

The evaluation of the resolved resonance parameters of ^{238}U, ^{240}Pu and ^{242}Pu was performed for the second version of Japanese Evaluated Nuclear Data Library JENDL-2. In this work, all the resonance parameters measured so far were compiled and examined. The evaluation was made by mainly using recent measurements for each isotope. The presently evaluated resonances are 183 s-wave and 265 p-wave resonance up to 4.73 keV for ^{238}U, 267 s-wave resonances up to 5.69 keV for ^{240}Pu and 95 s-wave resonances up to 1.89 keV for ^{242}Pu. For ^{238}U and ^{240}Pu, negative resonances were also recommended. The multi-level Breit-Wigner formula was applied, and their resolved resonance regions were chosen to be from 10^{-5} eV to 4 keV for ^{238}U and ^{240}Pu and from 10^{-5} eV to 1.29 keV for ^{242}Pu. Furthermore, background cross sections were determined to correct the cross sections calculated from the evaluated resonance parameters.

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* Data Bank, OECD-Nuclear Energy Agency

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IV-B-8

Benchmark Tests of JENDL-1

Y. KIKUCHI, A. HASEGAWA, H. TAKANO, T. KAMEI*

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A paper on this subject was published as JAERI-1275 with the following abstract:

Various benchmark tests were made on JENDL-1. At the first stage, various core center characteristics were tested for many critical assemblies with one-dimensional model. At the second stage, applicability of JENDL-1 was further tested to more sophisticated problems for MOZART and ZPPR-3 assemblies with two-dimensional model.

It was proved that JENDL-1 predicted various quantities of fast reactors satisfactorily as a whole. However, the following problems were pointed out:

1) There exists discrepancy of 0.9% in the k_{eff}-values between the Pu- and U-cores.
2) The fission rate ratio of ^{239}Pu to ^{235}U is underestimated by 3%.
3) The Doppler reactivity coefficients are overestimated by about 10%.
4) The countrol rod worths are underestimated by 4%.
5) The fission rates of ^{235}U and ^{239}Pu are underestimated considerably in the outer core and radial blanket regions.
6) The negative sodium void reactivities are overestimated, when the sodium is removed from the outer core.

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As a whole, most of problems of JENDL-1 seem to be related with the neutron leakage and the neutron spectrum.

It was found through the further study that most of these problems came from too small diffusion coefficients and too large elastic removal cross sections above 100 keV, which might be probably caused by overestimation of the total and elastic scattering cross sections for structural materials in the unresolved resonance region up to several MeV.

IV-B-9

Benchmark Tests on JENDL-2B

Y. KIKUCHI, T. NARITA, H. TAKANO,
Y. SEKI*, T. YOSHIDA** and T. KAMEI**

A paper on this subject was presented to the 2nd Analysis Meeting on JUPITER Program, Oct. 19 - 26, 1981, Tokyo, with the following abstract:

JENDL-2B is mixed library consisting of JENDL-2 for the most important nuclides, i.e., ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, Cr, Fe and Ni and of JENDL-1 for other nuclides. Complete reevaluation work was made for these eight nuclides. The simultaneous evaluation method was adopted in the evaluation for the five heavy nuclides. The resonance atructure was carefully studied for the structural materials in the unresolved resonance region up to several MeV.

Benchmark tests have been made on JENDL-2B. Various core center characteristics were tested with one-dimensional model for total of 27 assemblies. Satisfactory results were obtained as a whole. The results of spectrum indices, however, suggested some inconsistent spectrum prediction. Moremover, the reactivity worths were overestimated for most of materials, and apparent C/E discrepancies were observed between the Pu and U cores.

Applicablity of JENDL-2B was further tested to more sophisticated problems for MOZART and ZPPR-3 assemblies. The reaction rate distributions were better predicted with JENDL-2B than with JENDL-1. The positive sodium void reactivity worth was much overestimated with JENDL-2B due to too large moderation components. The control rod worths were well predicted in MOZART, but were considerably underpredicted in ZPPR-3.

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C. Project Engineering Section
Division of JMTR Project

IV-C-1 Experimental Evaluation of Neutron Cross Section for the $^{93}Nb(n,n')^{93m}Nb$ reaction in IRDF-82

K. Sakurai

Hegedüs' cross section for the $^{93}Nb(n,n')^{93m}Nb$ reaction[1] has been used for the neutron measurement[2] and the neutron spectrum unfolding[3]. But, the evaluated neutron cross section and the covariance data for the reaction are included in IRDF-82[4], which was released in Jan., 1982. Therefore, the data for the reaction in IRDF-82 are used for neutron spectrum unfolding with NEUPAC code[5]. For other reactions, the data in ENDF/B-V are used.

The neutron spectrum of the YAYOI glory-hole are unfolded with 7 reactions including the $^{93}Nb(n,n')^{93m}Nb$ reaction. The uncertainty of the unfolded spectrum is given in Table 1. The C/M of the reaction rate for the $^{93}Nb(n,n')^{93m}Nb$ reaction are 0.98 and 0.96 for the zeroth and final iteration, respectively.

References:

1) F. Hegedüs, EIR-BERICHT NR-195(1971)
2) K. Sakurai, Nucl. Technol.(in press)
3) K. Sakurai, Nucl. Instr. and Methods(in press)
4) D. E. Gullen et al., IAEA-NDS/R(1982)
5) M. Sasaki and M. Nakazawa, PNC N941 80-192 Tr(1981)

Table 1 Uncertainty of YAYOI glory-hole neutron spectrum with 7 reactions including $^{93}Nb(n,n')^{93m}Nb$ reaction

GROUP NO	ENERGY RANGE		GUESS FLUX	FINAL FLUX	ERROR(%)
1	1.50000E+01	1.05000E+01	2.55000E+08	2.55198E+08	2.84928E+01
2	1.05000E+01	6.50000E+00	1.96000E+09	1.88481E+09	1.25785E+01
3	6.50000E+00	4.00000E+00	8.12000E+09	7.72645E+09	1.86062E+01
4	4.00000E+00	2.50000E+00	1.64000E+10	1.45034E+10	2.86989E+01
5	2.50000E+00	1.40000E+00	3.44000E+10	3.28326E+10	2.95087E+01
6	1.40000E+00	8.00000E-01	5.23000E+10	5.36516E+10	2.81417E+01
7	8.00000E-01	4.00000E-01	5.68000E+10	6.65145E+10	2.44945E+01
8	4.00000E-01	2.00000E-01	3.57000E+10	3.57426E+10	2.37883E+01
9	2.00000E-01	1.00000E-01	8.15000E+09	5.98053E+09	2.76921E+01
10	1.00000E-01	4.65000E-02	4.32000E+09	3.45733E+09	2.84676E+01
11	4.65000E-02	2.15000E-02	1.84000E+09	1.81622E+09	2.92222E+01
12	2.15000E-02	1.00000E-02	5.05000E+08	5.41230E+08	2.96954E+01
13	1.00000E-02	4.65000E-03	1.05040E+08	1.06985E+08	2.99914E+01
14	4.65000E-03	2.15000E-03	1.87000E+07	1.67454E+07	2.97831E+01
15	2.15000E-03	1.00000E-03	3.02000E+06	3.02176E+06	2.99962E+01
16	1.00000E-03	4.65000E-04	7.05000E+05	7.05793E+05	2.99992E+01
17	4.65000E-04	2.15000E-04	1.44000E+05	1.44079E+05	2.99996E+01
18	2.15000E-04	1.00000E-04	3.25000E+04	3.25014E+04	3.00000E+01
19	1.00000E-04	4.65000E-05	7.51000E+03	7.51039E+03	3.00000E+01
20	4.65000E-05	2.15000E-05	1.59000E+03	1.59000E+03	3.00000E+01
21	2.15000E-05	1.00000E-05	4.37000E+02	4.37000E+02	3.00000E+01
22	1.00000E-05	4.65000E-06	1.15000E+02	1.15003E+02	3.00000E+01
23	4.65000E-06	2.15000E-06	1.30000E+02	1.30000E+02	3.00000E+01
24	2.15000E-06	1.00000E-06	2.42000E+01	2.42000E+01	3.00000E+01
25	1.00000E-06	4.65000E-07	4.20000E+00	4.20000E+00	3.00000E+01
26	4.65000E-07	1.00000E-07	1.15000E-01	1.15000E-01	3.00000E+01

IV-C-2 Use of New Threshold Detector $^{199}Hg(n,n')^{199m}Hg$ for Neutron Spectrum Unfolding

K. Sakurai

A paper on this subject was submitted to the Fourth ASTM-EURATOM Symposium on Reactor Dosimetry(Washington, March 22-26, 1982).[1)]

The validity of the $^{199}Hg(n,n')^{199m}Hg$ reaction for reactor neutron dosimetry has been examined through an irradiation experiment using the standard neutron field(glory-hole) in the YAYOI. The irradiation of foils in the YAYOI glory-hole was performed at a reactor power of 500 W and an irradiation time of 30 minutes. The reaction rates of the $^{199}Hg(n,n')^{199m}Hg$, $^{59}Co(n,\alpha)^{56}Mn$, $^{56}Fe(n,p)^{56}Mn$, $^{27}Al(n,p)^{27}Mg$, $^{27}Al(n,\alpha)^{24}Na$, $^{24}Mg(n,p)^{24}Na$, $^{23}Na(n,\gamma)^{24}Na$, $^{47}Ti(n,p)^{47}Sc$, $^{48}Ti(n,p)^{48}Sc$ and $^{115}In(n,n')^{115m}In$ reactions were used for neutron spectrum unfolding with SAND II code.

The neutron cross section for unfolding was compiled from Sakurai et al.[2)] and Hankla et al.[3)] The guess spectrum was calculated with a one dimensional transport code ANISN. The unfolded neutron spectrum is shown in Fig. 1. The characteristic neutron flux density value was calculated from the guess spectrum and from the unfolded spectrum. The total neutron flux density calculated from the guess spectrum is 1.614×10^{11} n/cm^2·sec. The value calculated from the unfolded spectrum is 1.826×10^{11} n/cm^2·sec. The value calculated from the evaluated spectrum[4)] is 1.875×10^{11} n/cm^2·sec. Using the $^{199}Hg(n,n')^{199m}Hg$ reaction rate, the total neutron flux density was 1 % smaller than that calculated from the neutron spectrum

unfolded without the $^{199}Hg(n,n')^{199m}Hg$ reaction rate.

We have used natural mercury sample. Therefore, the activity of the ^{199m}Hg is produced by the $^{198}Hg(n,\gamma)^{199m}Hg$ and $^{200}Hg(n,2n)^{199m}Hg$ reactions, and also generated by following decay of ^{199}Au that is produced by the $^{199}Hg(n,p)^{199}Au$ reaction. As the neutron spectrum of the YAYOI glory-hole is very hard, the influence of the $^{198}Hg(n,\gamma)^{199m}Hg$ reaction is negligibly small. The fission spectrum averaged cross section of the $^{200}Hg(n,2n)^{199m}Hg$ reaction is 5.5 mb.[5] Therefore, the influence of the $^{200}Hg(n,2n)^{199m}Hg$ reaction is about 2 %. The fission spectrum averaged cross section of the $^{199}Hg(n,p)^{199}Au$ reaction is 0.009 mb.[5] The influence of beta decay of the ^{199}Au is negligibly small.

The calculated fission spectrum averaged cross section for the $^{199}Hg(n,n')^{199m}Hg$ reaction is 238.3 mb.[2] The half-life of the isomer is 42.6 minutes. It means that the activity is easily produced by the irradiation with low level fast neutron flux. We have used the reaction in the experiment at the critical assembly of the JMTR. The threshold energy of the reaction is as low as that of the $^{115}In(n,n')^{115m}In$ reaction. Therefore, the $^{199}Hg(n,n')^{199m}Hg$, $^{115}In(n,n')^{115m}In$, $^{103}Rh(n,n')^{103m}Rh$ reactions should be useful threshold detector for the neutron dosimetry with low level fast neutron flux.

References:

1) K. Sakurai, Proceeding of the fourth ASTM-EURATOM Symposium on Reactor Dosimetry(to be published)

2) K. Sakurai et al., Nucl. Sci. and Technol.(to be published)

3) A. K. Hankla et al., Nucl. Phys., A180(1972)112

4) A. Sekiguchi et al., NUREG/CP-0004, 2(1977)1223

5) J. C. Roy and J. J. Hawton, CRC-1003(1960)

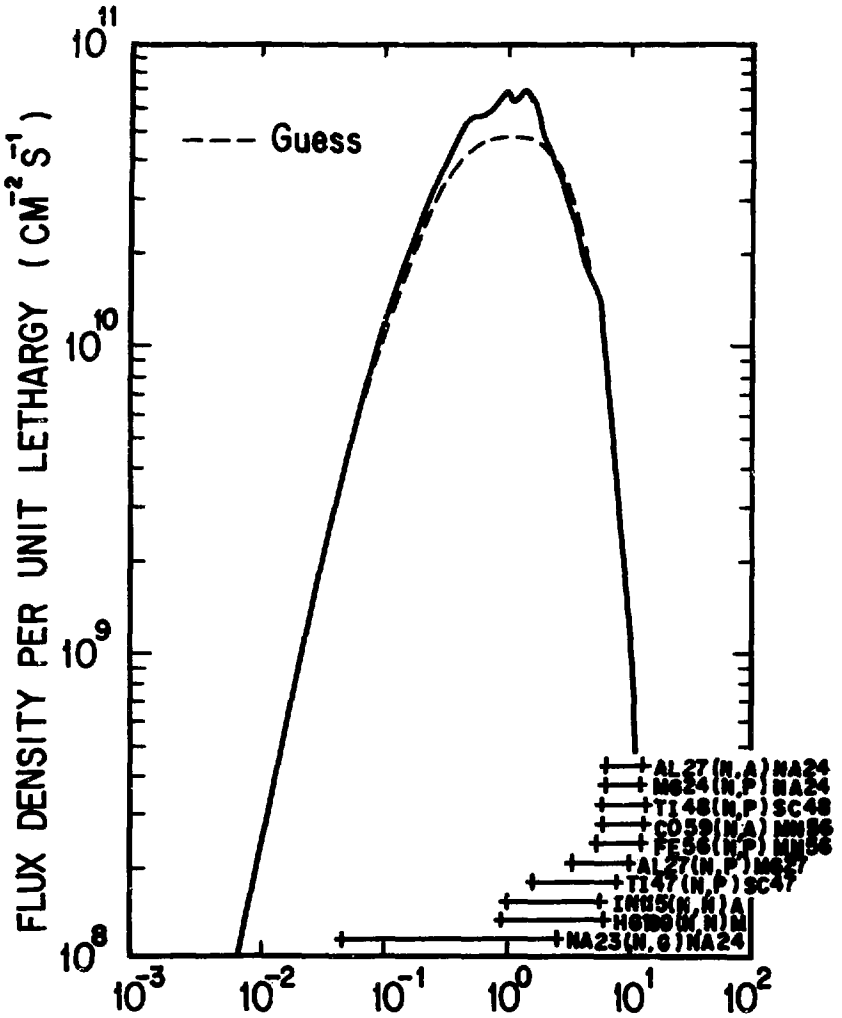

Fig. 1 Unfolded neutron spectrum of YAYOI glory-hole

IV-C-3 Uncertainty Analysis of JMTR(C) Fast Neutron Spectrum with NEUPAC code

K. Sakurai

The measurements of the neutron spectra of the JMTR have been performed by using the critical facility of the JMTR(JMTRC) and by the combination of the multi-foil activation method and the unfolding code SAND II[1)2)3)].

The uncertainties of the fast neutron spectra have been analyzed with NEUPAC code[4)]. The neutron cross section and the covariance data in IRDF-82 are used for the $^{103}Rh(n,n')^{103m}Rh$ reaction. For other reactions, the data in ENDF/B-V are used. The uncertainty of the neutron spectrum for the irradiation hole of J-11(first beryllium reflector region) is given in Table 1.

Table 1 Uncertainty of JMTR(C) neutron spectrum

GROUP NO.	ENERGY RANGE		ERROR(%)
1	1.50000E+01	1.05000E+01	2.98811E+01
2	1.05000E+01	6.50000E+00	8.66095E+00
3	6.50000E+00	4.00000E+00	2.33092E+01
4	4.00000E+00	2.50000E+00	2.34728E+01
5	2.50000E+00	1.40000E+00	1.19138E+01
6	1.40000E+00	8.00000E-01	1.98206E+01
7	8.00000E-01	4.00000E-01	2.29330E+01
8	4.00000E-01	2.00000E-01	2.48325E+01
9	2.00000E-01	1.00000E-01	2.50000E+01
10	1.00000E-01	4.65000E-02	2.49863E+01
11	4.65000E-02	2.15000E-02	2.49770E+01
12	2.15000E-02	1.00000E-02	2.49213E+01
13	1.00000E-02	4.65000E-03	2.47614E+01
14	4.65000E-03	2.15000E-03	2.47753E+01
15	2.15000E-03	1.00000E-03	2.46919E+01
16	1.00000E-03	4.65000E-04	1.89107E+01
17	4.65000E-04	2.15000E-04	1.52226E+01
18	2.15000E-04	1.00000E-04	2.49421E+01
19	1.00000E-04	4.65000E-05	2.34950E+01
20	4.65000E-05	2.15000E-05	2.48623E+01
21	2.15000E-05	1.00000E-05	2.49054E+01
22	1.00000E-05	4.65000E-06	2.46952E+01
23	4.65000E-06	2.15000E-06	5.35807E+00
24	2.15000E-06	1.00000E-06	2.38577E+01
25	1.00000E-06	4.65000E-07	2.26866E+01
26	4.65000E-07	1.00000E-09	3.00000E+01

References:

1) I. Kondo, NUREG/CP-0004, 1(1977)653

2) I. Kondo and K. Sakurai, J. Nucl. Sci. and Technol., 18, 6 (1981)461

3) K. Sakurai, Nucl. Instr. and Methods(in press)

4) M. Sasaki and M. Nakazawa, PNC N941 80-192 Tr(1981)

V. KYOTO UNIVERSITY

Research Reactor Institute

V-1 The measurement of the delayed neutron emission probability of ^{94}Rb

K. Okano, Y. Funakoshi and Y. Kawase

An on-line isotope separator of helium-jet type has been constructed for the study of neutron rich nuclei produced by thermal neutron fission. Several nuclear spectroscopic works on neutron rich Rb and Cs nuclei are now being performed using this separator. Measurements on the delayed neutron emission probabilities are also tried, utilizing a new method of measurements. The delayed neutron emission probability Pn of ^{94}Rb has been tentatively determined as 10.1±1.0%. Further measurements on ^{94}Rb and other delayed neutron emitters are now in progress.

Covariances in the Measurement of Californium-252 Spectrum Averaged Cross Sections for $^{46,47,48}Ti(n,p)^{46,47,48}Sc$ Reactions

Katsuhei Kobayashi and Itsuro Kimura

The ^{252}Cf fission spectrum averaged cross sections for the $^{46,47,48}Ti(n,p)^{46,47,48}Sc$ reactions have been measured relative to that of the $^{27}Al(n,\alpha)^{24}Na$ reaction. The experimental method is similar to the previous one[1]. The experimental uncertainties have been analyzed by using the form of a variance-covariance matrix. The detailed analytical method is described elsewhere[1]. The present result is summarized in Table 1.

As given in Table 2, the averaged cross sections for the $^{46,48}Ti(n,p)^{46,48}Sc$ reactions are in good agreement with those calculated with the energy dependent cross section. However, the calculated cross section for the $^{47}Ti(n,p)^{47}Sc$ reaction is larger by more than 10 percent in comparison with the measured one.

Reference :

1) K. Kobayashi, I. Kimura and W. Mannhart : J. Nucl. Sci. Technol., 19, 341 (1982).

Table 1 The Cf-252 spectrum averaged cross sections and the correlations between them

Reaction	Cross section(mb)	Std.dev.(%)	Correlation matrix (x 100)			
$^{27}Al(n,\alpha)^{24}Na$	1.006	2.19	100			
$^{46}Ti(n,p)^{46}Sc$	13.9	4.63	47	100		
$^{47}Ti(n,p)^{47}Sc$	21.6	5.47	39	46	100	
$^{48}Ti(n,p)^{48}Sc$	0.417	3.80	58	60	50	100

Table 2 Comparison of Cf-252 spectrum averaged cross section

Reaction	Experiment				Calculation	
	Present	Mannhart	Csikai	Kirouac	NBS-spectrum (B-V, IRDF-82)	Calc./Exp.
$^{46}Ti(n,p)^{46}Sc$	13.9 ± 0.6	13.8 ± 0.3	13.4±1.1	12.4±1.2	13.47	0.976
$^{47}Ti(n,p)^{47}Sc$	21.6 ± 1.2	18.9 ± 0.4	22.0±0.9	20.3±1.1	24.07	1.109
$^{48}Ti(n,p)^{48}Sc$	0.417±0.016	0.42 ± 0.01	0.38±0.02		0.4091	0.976

V-3

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

Katsuhei Kobayashi, Yoshiaki Fujita and Shigehiro Asano*

The neutron total cross section of ^{232}Th has been measured in the off-resonance region below about 300 eV by the linac TOF method. The transmission measurement and the experimental arrangement are similar to those in the previous measurement[1].

The preliminary experimental result, which is shown in Fig. 1, rather supports recent measurements at BNL[2], RPI[3] and ORNL[4] and the ENDF/B-V data. The ENDF/B-IV data is obviously lower than the present values. In recent years, Ohsawa surveyed and evaluated the thorium cross section[5], and the result will be incorporated in JENDL-2. The JENDL-2 data is rather close to the present values.

References :

1) K. Kobayashi, et al.: NEANDC(J)-75/U, p.25 (1981).

2) R. E. Chrien, et al.: Nucl. Sci. Eng., 72, 202 (1979).

3) R. C. Little, et al.: ibid., 79, 175 (1981).

4) D. K. Olsen and R. W. Ingle : ORNL/TM-7661 (1981).

5) T. Ohsawa and M. Ohta : J. Nucl. Sci. Technol., 18, 488 (1981).

* Kinki University, Kowakae, Higashi-osaka-shi, Osaka

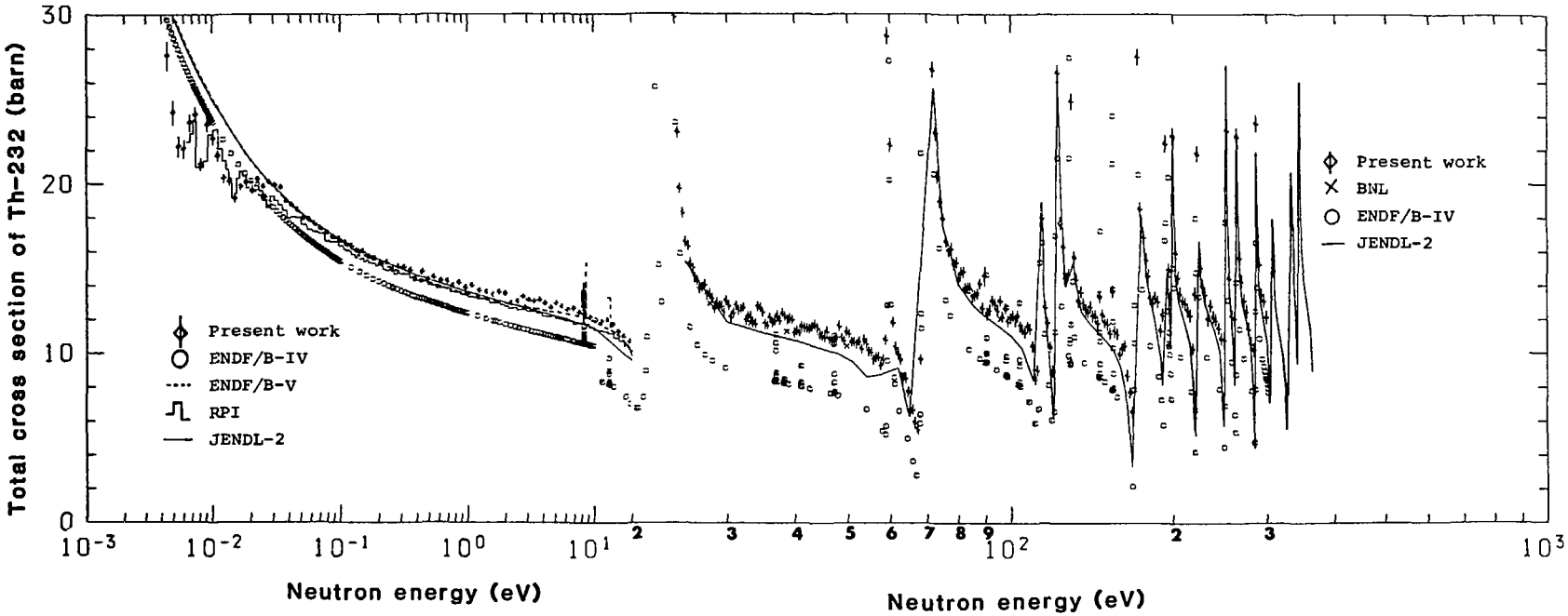

Fig. 1 Neutron total cross section of ^{232}Th

V-4 Mesurement and Analysis of Energy Spectra of Neutrons in Structural Materials for Reactors

Itsuro Kimura, Shu A. Hayashi, Katsuhei Kobayashi, Shuji Yamamoto, Hiroshi Nishihara *, Takamasa Mori **, Masayuki Nakagawa **

In order to assess neutron cross section data especially evaluated cross sections and group constants processed from the former, of main structural materials for fission and fusion reactors, measurement and analysis of neutron spectra in sample piles have been continuously carried out. The new results will be presented at the International Conference on Nuclear Data for Science and Technology at Antwerp in this September as a special invited paper [1].

(1) The final paper on molybdenum was recently published [2], in which we pointed out that the inelastic scattering cross section data for it in ENDF/B-IV caused a disagreement of the neutron spectrum in the pile with the measured spectrum.

(2) Intercomparison of the measured neutron spectra in the piles of main constituents of stainless steel (Fe, Ni and Cr) and the theoretically calculated with both ENDF/B-IV and JENDL-2 has been energetically carried out and the result will be shown at the Antwerp Conference.
Recently we measured a neutron spectrum in a spherical pile of iron 60cm in diameter, in addition to that in a big iron pile.

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(3) Very recently, the neutron spectrum in a spherical copper pile 60cm in diameter has been measured and analyzed. The result will be presented at the fall meeting of Atomic Energy Society of Japan in this October [3].

References:

1) Itsuro Kimura, et al., "The Integral Check of Neutron Cross Section Data for Reactor Structural Materials by Measurement and Analysis of Neutron Spectra" to be presented at the International Conference on Nuclear Data for Science and Technology at Antwerp in September 1982.

2) T. Mori, et al., J. Nucl. Sci. Technol., 19(1982) 427-437.

3) Shu A. Hayashi, et al., "Neutron Spectrum in Copper Pile", to be presented at the Fall Meeting of Atomic Energy Society of Japan.

VI. KYUSHU UNIVERSITY

Department of Nuclear Engineering
Faculty of Engineering

VI-1 Analysis of 14 MeV (n,p) Cross Sections with Pre-Equilibrium Model and Effective Q-Values

Isao Kumabe

A paper on this subject was published in J. Nucl. Sci. Technol. 18 (1981) 563 with an abstract as follows :

The measured cross sections of 14 MeV (n,p) reaction for nuclei with mass number larger than 90 are analyzed in terms of the pre-equilibrium exciton model and an effective Q-value, that is derived from a semi-empirical mass formula whose parameters are smooth functions of mass number and are free from fluctuations near closed shells. The deviations from 1.0 of the ratios of experimental to theoretical cross sections calculated using the effective Q-values are markedly reduced as compared with the use of the true Q-values. The use of the effective Q-values also gives a better agreement between the experimental and calculated cross sections in the calculations based on the geometry-dependent hybrid model.

VI-2 Analysis of (p,n) Reaction with Pre-Equilibrium Exciton Model and Effective Q-values

Yoshio Mito, Masatoshi Haruta and Isao Kumabe

One[1] of authors has analyzed the measured cross sections of 14 MeV (n,p) reaction for nuclei with mass number larger than 90 in terms of the pre-equilibrium exciton model[2] and an effective Q-value. The effective Q-value is derived from a semi-empirical mass formula whose parameters are smooth functions of mass number and are free from fluctuations near closed shells. The deviations from 1.0 of the ratios of experimental to theoretical cross sections calculated using the effective Q-values are markedly reduced as compared with the use of the true Q-values. We have demonstrated[1] that the use of the effective Q-value is reasonable for the pre-equilibrium process using the uniform spacing shell model modified by the shell effect.

In order to reconfirm the availability of the use of the effective Q-value, we have undertaken to analyze the experimental energy spectra[3] of neutrons emitted from the (p,n) reaction, which is the inverse reaction of the (n,p) reaction, at 18∿25 MeV using the pre-equilibrium exciton model and the effective Q-values.

The effective Q-values for the (p,n) reaction are easily derived from those for the (n,p) reaction.

The effective Q-values for the (p,n) reaction is expressed as

$$Q = -\{(M_n - M_H)C^2 + b[(Z+1) - Z_0 - 1/2]\} - 0.8 \text{ (MeV)},$$

where M_n and M_H are the masses of the neutron and hydrogen atom, respectively, and Z is the atomic number of the target nucleus. The values of Z_0 and b are expressed as

$$Z_0 = -0.0001838A^2 + 0.4255A + 2.372$$

$$b = 0.0001008A^2 - 0.03728A + 4.678,$$

where A is the mass number.

Fig. 1 shows the experimental[3] and calculated neutron spectra for Rh, Pd and Ag isotopes at an incident proton energy of 25 MeV. The energy spectra calculated using the true Q-values are shown by the dashed curves. The agreement between the experimental and calculated values is good for the even-even nuclei, but the agreement is not good for the odd nuclei.

The energy spectra calculated using the effective Q-values are shown by the solid curves.

The solid curves are in good agreement with the experimental data for both the shape and the magnitude of the cross sections for both the even-even and odd nuclei. Thus the availability of the use of the effective Q-values has also been confirmed for the (p,n) reaction.

References

1) I. Kumabe, J. Nucl. Sci. Technol. 18 (1981) 563.

2) G.M. Braga-Marcazzan et al., Phys. Rev., C6 (1972) 1398.

3) S.M. Grimes et al., Phys. Rev. C13 (1976) 2224.

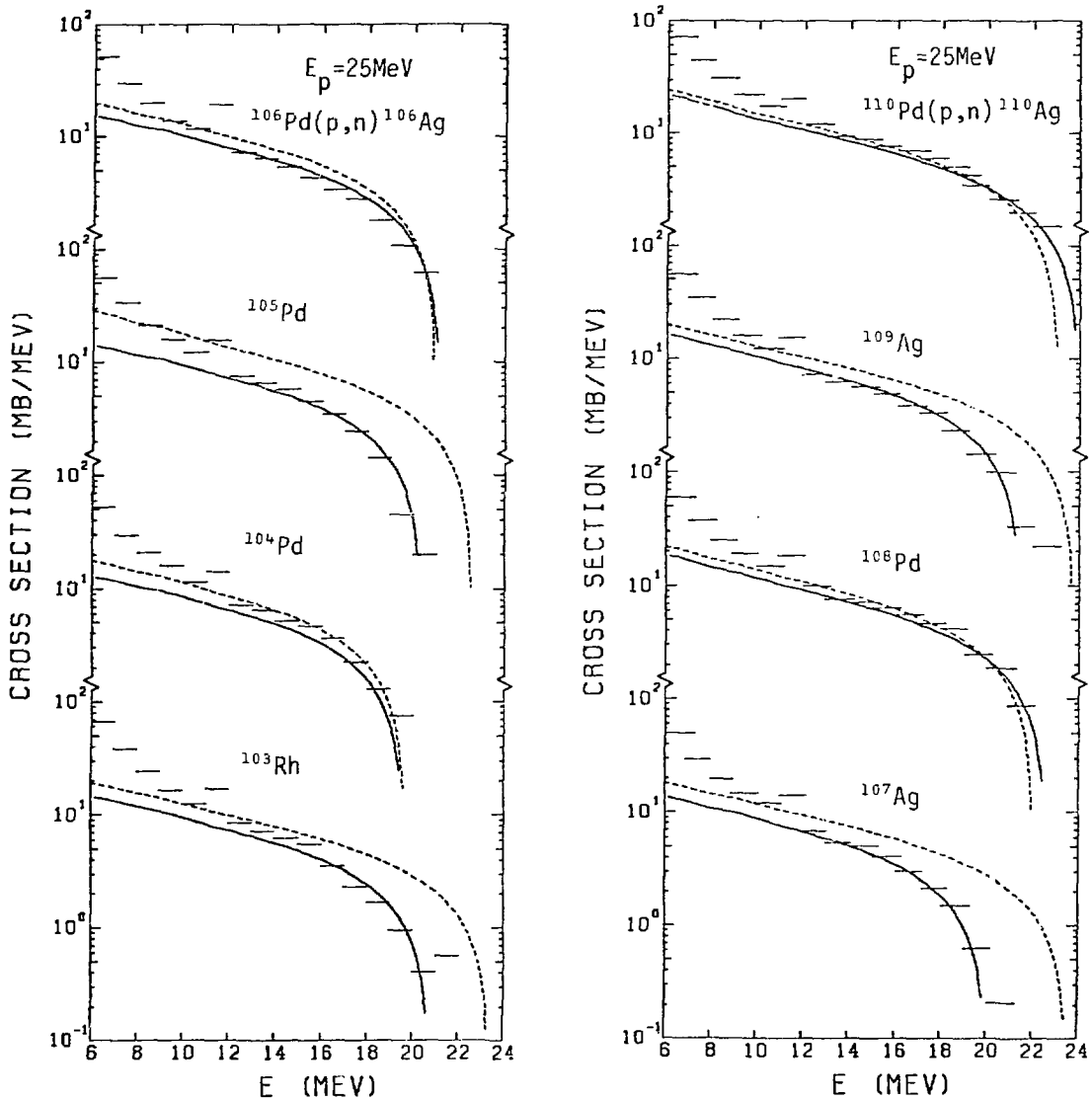

Fig. 1 Experimental and calculated neutron spectra for Rh, Pd and Ag isotopes at an incident proton energy of 25 MeV. The energy spectra calculated using the true Q-values and effective Q-values are shown by the dashed and solid curves, respectively.

VI-3 Shell Effects in Pre-Equilibrium Neutron Emission from Reaction of 14 MeV Neutrons

Isao Kumabe

Recently author[1] has analyzed the measured cross sections of 14 MeV (n,p) reaction for nuclei with mass number larger than 90 in terms of the pre-equilibrium exciton model[2] and an effective Q-value, that is derived from a semi-empirical mass formula whose parameters are smooth functions of mass number and are free from fluctuations near closed shells. The deviations from 1.0 of the ratios of experimental to theoretical cross sections calculated using the effective Q-values are markedly reduced as compared with the use of the true Q-values. We have demonstrated[1] that the use of the effective Q-value is reasonable for the pre-equilibrium process using the uniform spacing shell model modified by the shell effect.

The use of the effective Q-value corresponds to a shift of the true ground state to a fictitious ground state of the residual nucleus.

We examine experimental (n,n') spectra to determine whether a shell effect appears near the magic number and whether the difference between pre-equilibrium spectra for even-A and odd-A targets appears.

Fig. 1 shows the differential cross sections near 7 MeV of the emitted neutron energy E_n as a function of atomic number Z. The experimental cross sections were obtained by integrating the differential cross sections[3] over the solid angle. The cross sections for odd-mass targets are indicated by open circles, while those for even-mass targets are indicated by full circles.

The reason for the use of the cross sections near 7 MeV is as follows. In the region of $E_n < 7$ MeV, the contribution of the compound process is

larger. In the region of $E_n > 7$ MeV, the cross sections are smaller and have larger statistical errors.

As is seen in this figure, there exist a deep dip near $Z = 28$ and presumable shallow dips near $Z = 40$ ($N = 50$) and $Z = 50$. However no appreciable variation of the experimental cross sections between odd and even targets appear. These effects could be explained using a modified shell model mentioned below.

The unidorm spacing shell model is used in the pre-equilibrium model. It has been well known in the usually used shell model with spin-orbit coupling that the large energy jumps of orbit spacings occur at the magnic numbers. Taking this shell effect into account, we modify the uniform spacing shell model. This modified shell model is the same as that used for the (n,p) reactions[1].

Under the assumption of the one-step direct (n,n') reaction which corresponds to the neutron emission from states of exciton number $n = 3$, the reaction leads to the one-particle one-hole states of the residual nucleus. This situation is the same as that in the case of the (n,p) reaction[1]. Therefore, under the assumption of that the level density is linearly proportional to the exciton energy, an origin (a fictitious ground state) for the excited states of the residual nucleus at the magic number is shifted[1] by the gap energy from the true ground state, if states near the ground state are neglected. Since the ground-state Q-values for the (n,n') reaction are always zero, the origin for the level density in the case of the magic number is shifted by the gap energy from that in the ordinary case. Thus it can be explained that the shell effect appears near the magic number. On the basis of the theoretical consideration using the modified shell model mentioned above, we can explain that no odd-even effect appears in the pre-equilibrium neutron emission induced by 14 MeV

neutrons.

With respect to the difference between n-p and n-n effective interactions, free n-p and n-n cross sections at a neutron energy around the Fermi energy of 50 MeV are reffered[4] as

$$(\sigma_{np} / \sigma_{nn})^{1/2} = 1.7.$$

Therefore, taking this effect into account, it is predicted that the shell effect appears strongly near the proton magic number and appears weakly near the neutron magic number. Taking the pairing correlation into account, the gap energy at atomic number $Z = 28$ is about 3 MeV.

We have analyzed the energy spectra of neutrons emitted from the reaction of 14 MeV neutrons using the pre-equilibrium[2] and compound models, and compared with experimental data[3]. Figs. 2 and 3 show the experimental and calculated neutron spectra for ^{52}Cr and ^{58}Ni, respectively. The agreement between the experimental and calculated values is good for ^{52}Cr, but the agreement is not good for ^{58}Ni. If we use the ground-state Q-value of -3 MeV, a good agreement is obtained as is seen in Fig. 3.

References

1) I. Kumabe, J. Nucl. Sci. Technol., 18 (1981) 563.

2) G.M. Braga-Marcazzan et al., Phys. Rev., C6 (1972) 1398.

3) D. Hermsdorf et al., Zfk-277 (1974).

4) K. Kikuchi and M. Kawai, "Nuclear matter and nuclear reactions" (North-Holland, Amsterdam, 1968) ch. 2.

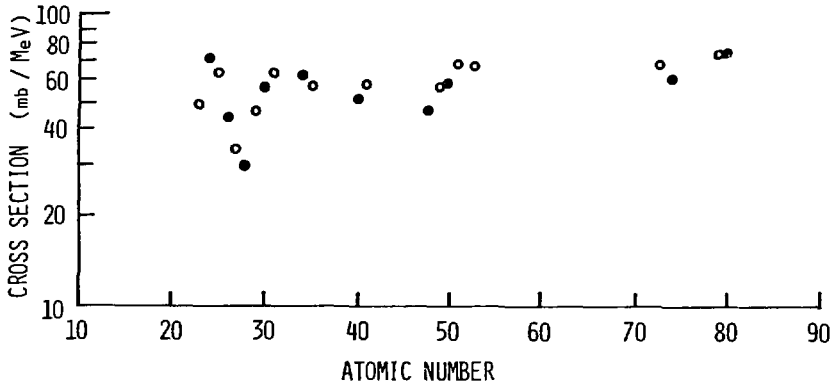

Fig. 1 Differential cross sections near 7 MeV of the emitted neutron energy as a function of atomic number.

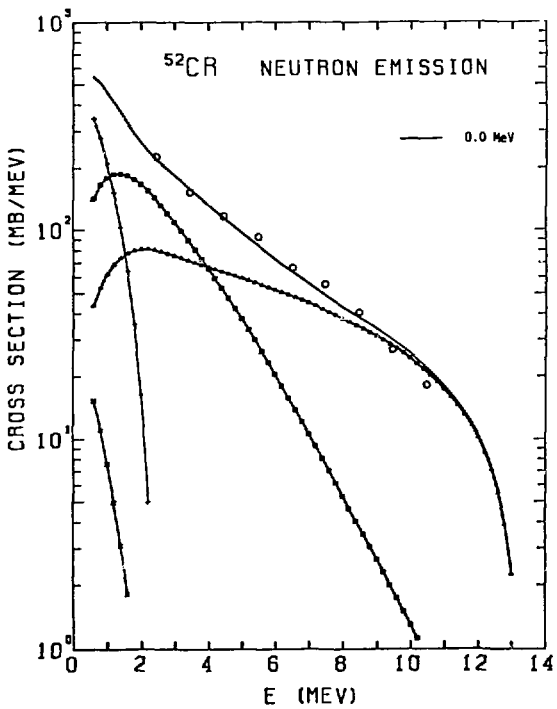

Fig. 2 Experimental and calculated neutron spectra for ^{52}Cr (n,n').

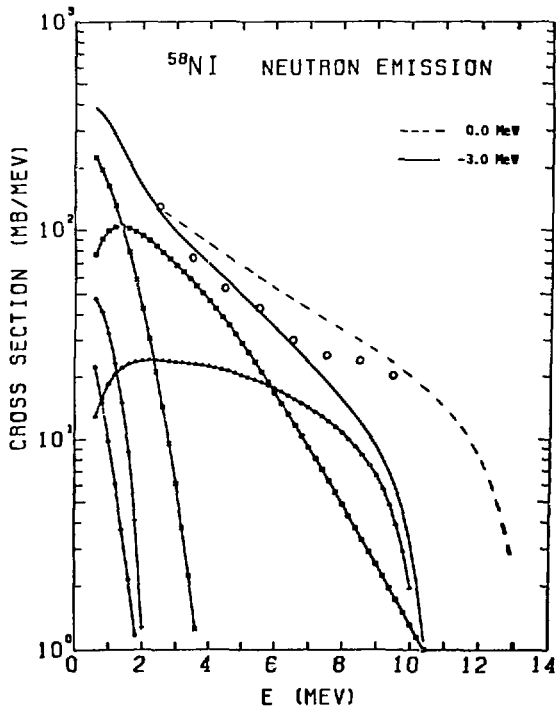

Fig. 3 Experimental and calculated neutron spectra for ^{58}Ni (n,n').

Analysis of energy spectra of charged particles emitted from the reaction of 14 MeV neutrons on nuclei with A∿90

M. Haruta, H. Murayama, M. Hyakutake and I. Kumabe

In the previous report[1] we have shown that the use of the effective Q-value[2] in the pre-equilibrium process is reasonable in the calculation of the energy spectra of particles emitted from the reaction of 14 MeV neutrons on nuclei with A=40∿70.

In the present report the analysis using the effective Q-value has been extended to the nuclei of other mass region. The calculations were done in a manner similar to that reported previously[1].

Experimental data (^{89}Y, ^{90}Zr, ^{93}Nb and ^{92}, ^{94}, ^{95}, ^{96}Mo) of Lawrence Livermore Lab.[3] were compared with the calculated values.

For proton emission in the pre-equilibrium process the effective Q-value was used. On the other hand for alpha particle emission in the pre-equilibrium process the averaged Q-value $Q'=(Q_e+Q_t)/2$ of the effective Q-value Q_e and the true Q-value Q_t was used. In Fig. 1 are shown typical proton and alpha-particle emission spectra calculated for ^{93}Nb and ^{89}Y. The agreement between the measured and calculated values is good.
A reasonable agreement between the measured and calculated values was also obtained for other nuclei. Thus it is confirmed that the effective Q-value is more effective in the calculations of the pre-equilibrium process for the nuclei of the mass region A∿90.

References

1) M. Hyakutake, M. Haruta and I. Kumabe, NEANDC/(J)-75/U p. 38 (1981)

2) I. Kumabe, J. Nucl. Sci. Technol. 18 (1981) 563 and I. Kumabe, NEANDC(J)-75/U p. 33 (1981)

3) R.C. Haight, S.M. Grimes, R.G. Johnson and H.H. Barschall, Phys. Rev. C23 (1981) 700 and references contained therein

4) N. Koori : to be published

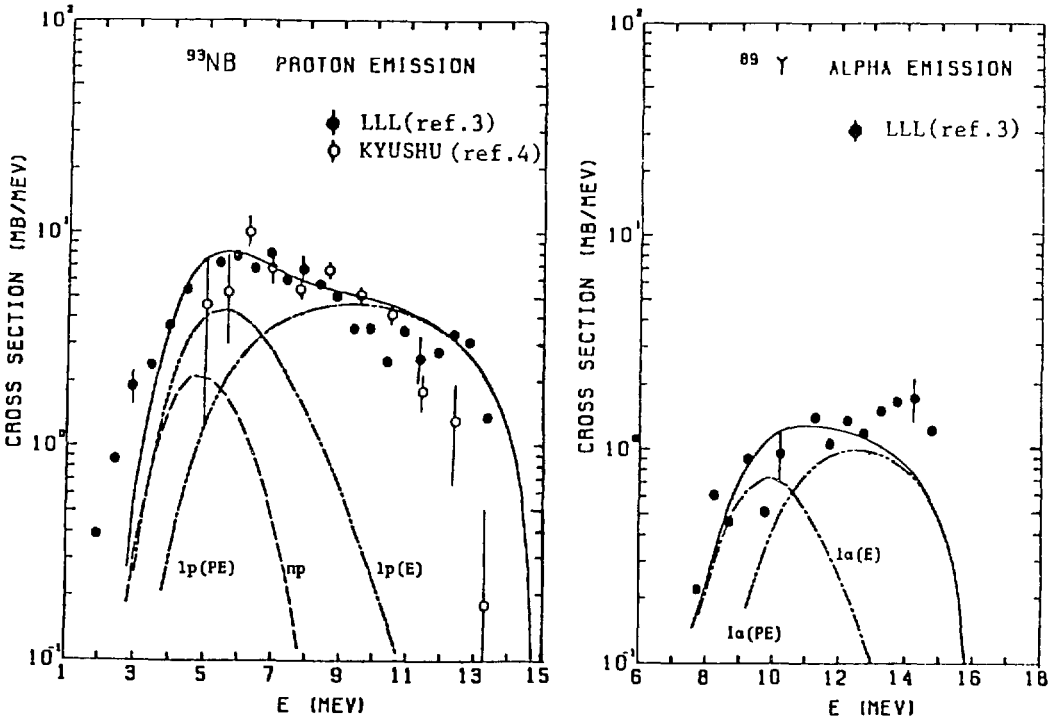

Fig. 1 Calculated and experimental proton and alpha-particle emission spectra from 14 MeV neutrons on ^{93}Nb and ^{89}Y. E: equilibrium process, PE : pre-equilibrium process, 1p(α) : 1-st proton (alpha) emission, np : protons after 1-st neutron emission.

VII. NAGOYA UNIVERSITY

Department of Nuclear Engineering
Faculty of Engineering

VII-1

Decay of ^{147}Ce to Levels of ^{147}Pr

M.Totsuka, S.Fujita, K.Mio, K.Kawade, H.Yamamoto,
T.Katoh and T.Nagahara*

A paper on this subject was submitted to J. Nucl. Sci. Technol.

The decay of a short-lived nucleus ^{147}Ce to levels of ^{147}Pr was investigated with Ge(Li) detectors in singles and coincidence modes. Radioactive sources were prepared by a chemical separation, a rapid paper electrophoresis, from the fission products of ^{235}U. The half-life of ^{147}ce is 57 $\pm$ 5 s. A total of 14 gamma-rays, including 4 new ones, were observed and 13 gamma-rays are incorporated in a level scheme of ^{147}Pr including a new level at 2.7 MeV.

Energies and relative intensities of gamma-rays in the decay of ^{147}Ce are shown in Table 1.

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Table 1.

Energies and relative intensities of gamma-rays in the decay of ^{147}Ce

E_γ (keV)	I_γ
92.9 ± 0.3	66 ± 6
175.0 ± 0.7	4 ± 1
199.0 ± 0.3	27 ± 3
269.2 + 0.5	100 ± 5
289.2 ± 0.5	29 ± 6
359.2 ± 0.5	17 ± 3
361.7 ± 0.5	9 ± 2
374.4 ± 0.3	51 ± 5
*452.0 ± 0.4	34 ± 4
465.0 ± 0.5	13 ± 2
467.7 ± 0.4	43 ± 4
799.6 ± 0.5	6 ± 2
802.5 ± 0.4	6 ± 2
832.2 ± 0.3	20 ± 3

* Not placed in the proposed decay scheme

VII-2

Neutron Activation Cross Section of Molybdenum Isotopes at 14.8 MeV

S. Amemiya, K.Ishibashi, T.Katoh

A paper on this subject was submitted to the J. Nucl. Sci. Technol.

The neutron activation cross sections of molybdenum isotopes have been measured for the 14.8 MeV neutron. The cross sections have been determined with reference to the known $^{27}Al(n,\alpha)^{24}Na$ and the $^{27}Al(n,p)^{27}Mg$ reactions. The cyclic activation method was employed for the gamma-ray measurement of short-lived nuclei. A 55 cm^3 Ge(Li) detector was used for the measurement of gamma-ray spectra. Cross section data are presented for (n,2n), (n,p) and (n,α) reactions on molybdenum isotopes. The cross sections of (n,np) reaction on ^{98}Mo are also presented. The exponential dependence on (N-Z)/A of the (n,p) reaction cross sections are discussed.

VIII. RIKKYO (ST. PAUL'S) UNIVERSITY

Department of Physics

VIII-1 Backward Cross Sections for the (n,d) and (n,t) Reactions of ^{6}Li at 14.1 MeV

H. Yamada, K. Ozawa and S. Shirato

The backward cross-sections for the reactions $^{6}Li(n,d)^{5}He$ and $^{6}Li(n,t)^{4}He$ at 14.1 MeV were measured with a counter telescope in order to compare with the exact finite-range DWBA results which were reported in a previous paper[1].

A ^{6}Li target of 2.36 mg/cm^{2} thick was positioned at a distance of 4 cm from the neutron-source point. The counter telescope consisted of two gas-proportional counters and two silicon detectors of 16 μm and 270 μm thick was set at an angle of 130° with respect to the incident neutron direction. The measured c.m. differential cross-sections at Θ = 143° were obtained to be 7.6 ± 3.2 mb/sr for (n,d) and 2.3 ± 1.0 mb/sr for (n,t). These preliminary data were consistent with the previous EFR-DWBA results. However, in order to reduce the background due to charged particles emitted from the E-detector toward the target, the measurement of the reaction products in coincidence with the associated α-particles from the ^{3}H-d neutron-source was required and prepared, as well as a detailed calculation taking into account the coherent sum of the direct and exchange amplitudes by a modified code of DWUCK-5.

Reference:

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

IX. TOHOKU UNIVERSITY

Department of Nuclear Engineering
Faculty of Engineering

IX-1 NEUTRON INELASTIC SCATTERING CROSS SECTIONS FOR ^{232}Th DETERMINED FROM THE (n,n'γ) REACTION

S. Itagaki, A. Takahashi, Y. Ose, M. Yoda and K. Sugiyama

Neutron inelastic cross sections of ^{232}Th have been deduced from gamma-ray measurements at incident energy range of 1.0 to 2.2 MeV. A pulsed source of neutrons was produced via the ^{7}Li(p,n)^{7}Be reaction using the Dynamitron accelerator at Tohoku University. The gamma-rays were observed with a 70 cm^{3} Ge(Li) detector at an angle of 125° in conjunction with a time-of-flight electronics. The neutron fluence was monitored by a NE-213 liquid organic scintillator with n-gamma discrimination.

The twelve excited levels of 714 to 1330 KeV and the decay scheme were derived from twenty-six gamma-rays. Based on these data, the cross sections of the gamma-ray production and the neutron inelastic scattering for each excited state were deduced. Present results show fairly agreement with the previous works[1] for the most part. The details will be published else where[2].

References:

1) J.J. Egan,et al.,Proc. Conf. Nuclear Cross Sections for Technology, Knoxville, Tenn. (1979), and W.R. McMurray, Southern Univ.Nucl.Inst. Annual Research Report (1976).

2) Annual Report of SCA and FNL, Tohoku University.

IX-2 DOUBLE DIFFERENTIAL CROSS SECTIONS FOR Mo AND Fe AT 15.2 MeV

S. Iwasaki, H. Uchida, H. Suwa
H. Tamura, K. Nakada, and K. Sugiyama

Double differential cross sections at 15.2 MeV for molibdenum and iron have been measured. The experiment has been perforemed using the 15.2 MeV source neutrons produced by the T+d reaction with the Dynamitron accelerator and the time-of-flight spectrometer of the 5"ø x2" NE213 detector[1]. Measurements have been made at eight angle positions ranging from 30 to 150 deg.

We have tried to reproduce the experimental curve for the molybdenum using the preequilibrium model code PREANG by Akkermans et al.[2], because their model was one of a few prerequilibrium models by which one could calculate not only the angle integrated energy spectrum of the emitted particles, but also the angular distribution of them. As well as the original scattering kernel of the two-body interaction, we have used the modefied kernel, which was introduced by themselves, with the same values of the parameters of the kernel as their ones[2]. Applied this modification, the trend of angular distributions exept for the high energy region above 10 MeV have been markedly improved at the backward angles, as discussed by them.

References

1) S. Iwasaki et al., Progress Report of the Fast Neutron Lab., Tohoku Univ., NETU-38, 49 (1981)
2) J. M. Akkermans et al., Phys. Rev. C, 22 p73 (1980)

X. TOKYO INSTITUTE OF TECHNOLOGY

Research Laboratory for Nuclear Reactors

X-1 Gamma-Ray Spectra from Capture of 400-keV Neutrons by Nb and Mo

M. Igashira, K. Hashimoto*, H. Kitazawa and N. Yamamuro

Capture gamma-ray spectra from Nb and Mo have been measured at the neutron energy of 420 ± 20 keV. The T.I.T. pulsed 3-MV Pelletron accelerator provided a proton burst of 1.5-ns width at 2-MHz repetition rate. The neutrons were produced by the $^{7}Li(p,n)^{7}Be$ reaction. A 7.5 cmϕ x 15 cm NaI(Tl)-detector centered in an annular NaI(Tl)-crystal, which was surrounded by a heavy shield consisting of paraffin, boric acid, and lead, was used as a gamma-ray detector. The detection efficiency and response function were determined with gamma-rays from calibrated radioactive sources and from the $^{27}Al(p,\gamma)^{28}Si$, $^{9}Be(p,\gamma)^{10}B$, and $^{19}F(p,\alpha\gamma)^{16}O$ reactions. Each target located at 15 cm from the neutron source was a 4.5 cmϕ x 4.5 cm natural sample. The distance between the sample and NaI(Tl)-detector was 109 cm. The detector axis made an angle of 125° with respect to the proton beam direction.

The capture gamma-ray spectra, shown in Figs. 1 and 2, were obtained after background subtraction, spectrum unfolding, and gamma-ray self-shielding correction. The figures show that both spectra consist of unresolved gamma-rays, discrete high-energy gamma-rays for the transitions leading to low lying states, and discrete low-energy gamma-rays. The histograms were calculated by the computer code CASTHY[1] based on the statistical model using the gamma-ray strength function of Brink and Axel[2] and using the level density distribution of Gilbert and Cameron[3]. The calculated spectrum of Nb is in an excellent agreement with the observed one in the energy region

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except for $E_\gamma < 1.5$ MeV where the strong peaks of gamma-rays are observed. For the case of Mo, the calculated spectrum agrees well with the observed one, and the strong peak of gamma-rays observed at 0.8 MeV is also explained well by the calculation. The comparison between experiment and theory shows that the gamma-ray spectra from capture of 420-keV neutrons by Nb and Mo can be understood by the statistical model, though some discrepancies still exist in the low-energy part of gamma-ray spectrum of Nb.

References:

1) S. Igarashi, J. Nucl. Sci. Technol., 12, 67 (1975).

2) P. Axel, Phys. Rev., 126, 671 (1962).

3) A. Gilbert and A. G. W. Cameron, Can. J. Phys., 43, 1446 (1965).

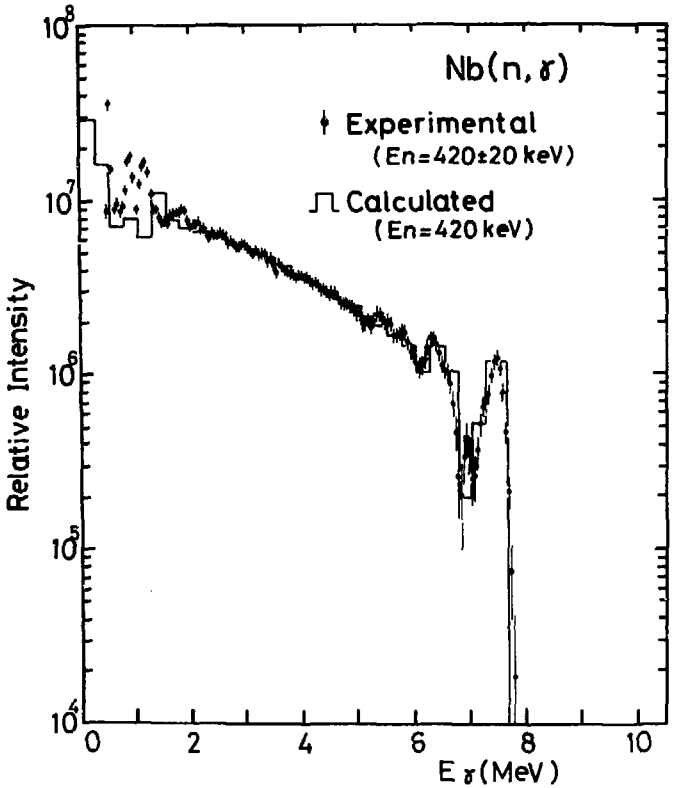


Fig. 1 Capture gamma-ray spectra from the Nb(n,γ) reaction.

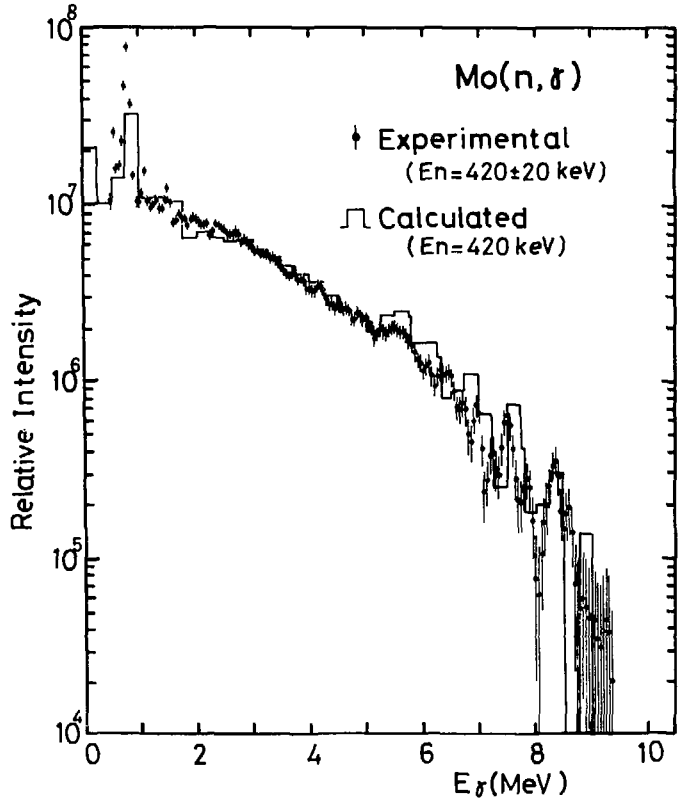


Fig. 2 Capture gamma-ray spectra from the Mo(n,γ) reaction.

X-2 Fast Neutron Capture Cross Section Measurement with Pulse-Height Weighting Technique

M. Shimizu, M. Igashira and N. Yamamuro

Neutron capture cross section measurement has been performed in the energy range from 200 to 610 keV with the pulse height weighting technique. Monoenergetic neutrons were generated by $^{7}Li(p,n)$ reactions which were induced by pulsed proton beam from the T.I.T. 3-MV pelletron accelerator. A sample was located at 185 cm from the neutron source, and capture gamma-rays emitted from the sample were detected with a hollow cylindrical NE-213 scintillation counter, which has 37 cm outer-diameter, 17 cm inner-diameter, and 13 cm thick. The volume of scintillator is about 10 liter. An annular graphite gamma-ray absorber with 7 cm inner-diameter and 19.5 cm length was inserted into the center of the detector as to make the weighting function of the detector a straight line as possible. The detector was mounted in the heavy shield consisting of 10-cm thick lead and 35-cm thick boric-acid and paraffin. To reduce the background, a cube of 40 cm boric-acid and paraffin surrounded the neutron source, and neutrons were led to 0° direction with respect to the proton beam by pre-collimators. The neutron flux impinging on the sample was measured by a thin ^{6}Li-glass scintillation counter and a ^{10}B slab-NaI scintillation counter. The preliminary result of ^{165}Ho capture cross sections at the neutron energies of 200, 300 460 and 610 keV was obtained from the relative values to the $^{197}Au(n,\gamma)$ cross sections which were quoted from the ENDF/B-V file. Because the corrections of neutron self-shielding and multiple scattering and of gamma-ray self-absorption in the reference sample of gold were slightly large, the error of results became about 10%. The values of cross section agree fairly well with the revised Macklin et al.'s data[1)] and Johnsrud et al.'s data[2)].

In figure, Brzosko et al.'s[3] and Czirr et al.'s[4] data are also plotted for comparison. The improvement of accuracy of data is possible by using a thin sample and a new Boron-NaI neutron monitor.

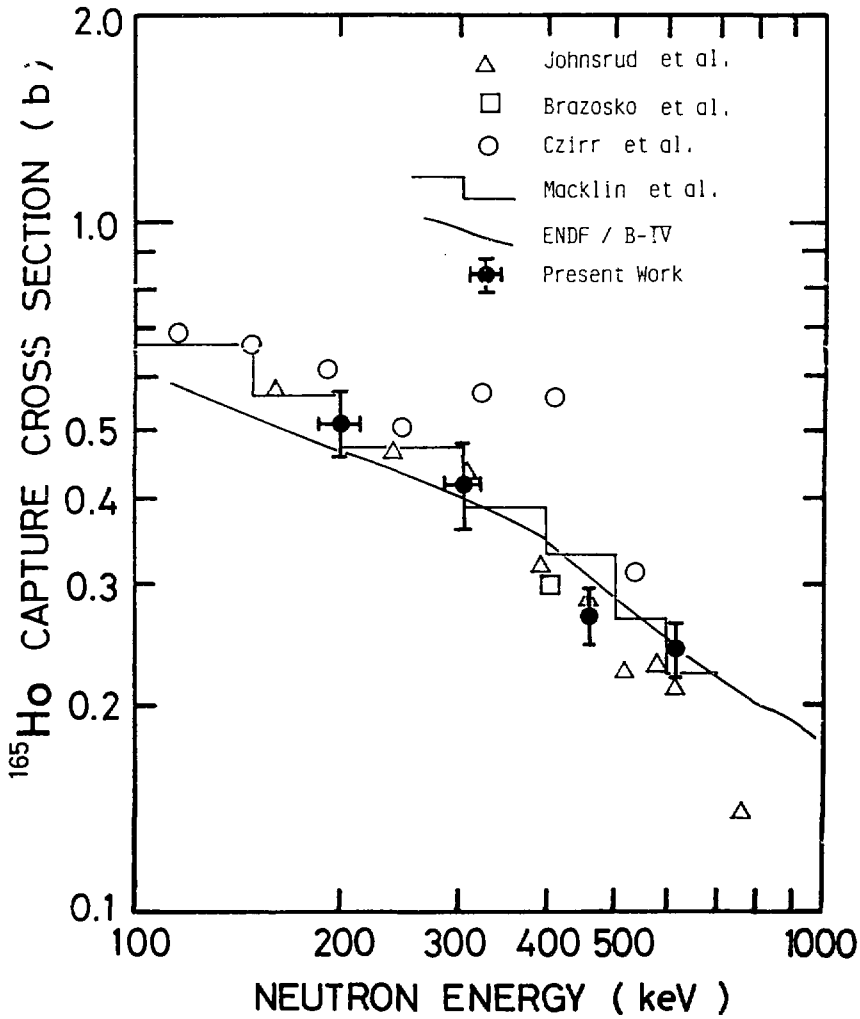
References:

1) R.L. Macklin and R.R. Winters, Nucl. Sci. Eng. 78, 110 (1981).

2) A.E. Johnsrud et al., Phys. Rev. 116, 927 (1959).

3) J.S. Brzosko et al., Acta Phys. Polonica B2, 489 (1971).

4) J.B. Czirr and M.L. Stelts, Nucl. Sci. Eng. 52, 299 (1973).



X-3 Measurement of Neutron Capture Gamma-ray Spectra with BGO Scintillator

T. Yoshinari*, M. Igashira and N. Yamamuro

Neutron capture gamma-ray spectra for $^{197}Au(n,\gamma)$ and $Pd(n,\gamma)$ reactions have been measured with a bismuth germanate (BGO) scintillator of 10 cm diam and 2 cm thick. Samples were placed in the neutron beam from the KUR electron linear accelerator, and the range of 3-80 keV is selected by TOF method. The measured gamma-ray spectra were unfolded with the response functions of BGO detector, which were determined from Monte-Carlo calculations and measured spectra using several monoenergetic gamma-ray sources.

The capture gamma-ray spectra obtained are shown in Figs. 1 and 2. For $^{197}Au(n,\gamma)$ spectrum, our data[1], in which gamma-rays were detected with the C_6D_6 liquid scintillator, and the Bergqvist and Starfelt's 15-keV neutron data[2] are plotted for the comparison. Some discrepancy are found between the BGO and C_6D_6 data, probably due to the error of the detection efficiency. The histogram in Fig. 2 shows the calculated one using CASTHY code, based on the statistical model, and the arrows indicate the neutron separation energy of compound nucleus for palladium isotopes. The agreement between experimental and caluculated is good in general.

References:

1) N. Yamamuro et al., Proc. Specialists' Mtg. Fast-neutron capture cross sections, Argonne, April 20-23, 1982.

2) I. Bergqvist and N. Starfelt, Nucl. Phys. 39, 353 (1962).

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* Present address: Hitachi Ltd.

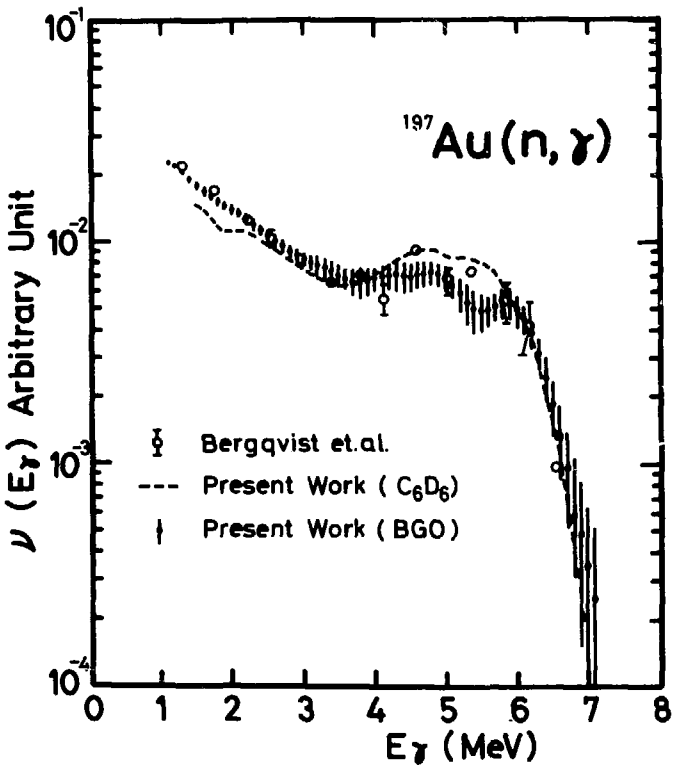

Fig. 1 Capture gamma-ray spectra from the ^{197}Au(n,γ) reaction.

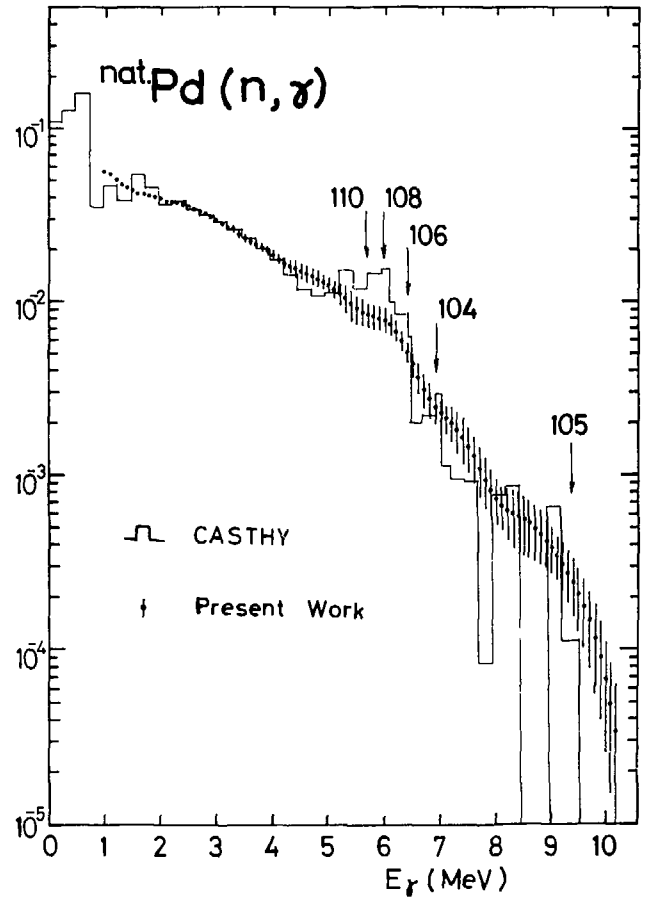

Fig. 2 Capture gamma-ray spectra from the Pd(n,γ) reaction.

XI. UNIVERSITY OF TOKYO

A. Institute for Nuclear Study

XI-A-1

Evaluation of Neutron Production Data Induced by 30- and 52-MeV Protons

T. Nakamura, M. Fujii*, and K. Shin**

A paper on this subject has been submitted to Nuclear Science and Engineering. The neutron energy spectra emitted in the direction of 0, 15, 30, 45, 75 and 135 deg to the beam axis were measured with a NE-213 scintillator, when the 30- and 52-MeV proton beams were injected into thick targets of C, Fe, Cu and Pb. The measured spectra were compared with the results calculated by the MECC-7 Monte Carlo code[1)], in order to evaluate the accuracy of the code integrally. The MECC-7 code treats the intranuclear-cascade and evaporation processes on the basis of the Fermi's free gas model and directly gives the nonelastic cross section and the neutron production cross section differential in energy and angle.

The thick-target neutron energy spectrum was calculated by dividing the target into thin slabs and summing up the neutrons produced in each thin slabs which are equal to the neutron production cross sections given by the MECC-7 code. Figures 1 and 2 show the comparison of the measured and calculated neutron energy spectra for thick C, Fe, Cu and Pb targets bombarded by

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30- and 52-MeV protons, respectively. These figures show that the calculated neutron spectra give 2 to 3 times larger values than the measured spectra in the forward direction and this big difference decreases with the emission angle, and the calculated results give the underestimation to the measured spectra in the backward direction. As a result, at around 75 deg, the agreement between experiment and calculation is very good in absolute value, except for carbon. For carbon target, the calculated spectra extend to the energy range above E_0-Q (E_0 is the incident proton energy.), because the calculation postulated the fixed binding energy of 7 MeV despite of the Q-value of -18.14 MeV of most probable $^{12}C(p,n)$ reaction.

These comparisons revealed that the calculated energy-angular distribution of neutron flux produced by a proton of energy below about 100 MeV does not give good agreement with the measured one and the discrepancy between calculation and experiment increases with lower proton energy and lighter target nucleus, and it was confirmed that the MECC-7 code has poor accuracy for neutron production calculation in this proton energy range, since the Fermi free gas model which postulates the free independent motion of nucleons in the nucleus is not adequate in this low energy region where the nuclear structure has a strong effect.

Reference:

1) RSIC Computer Code Collection, "Documentation for CCC-156/MECC-7 Code Package - Medium Energy Intranuclear Cascade Code System", Radiation Shielding Information Center, Oak Ridge National Laboratory (1973).

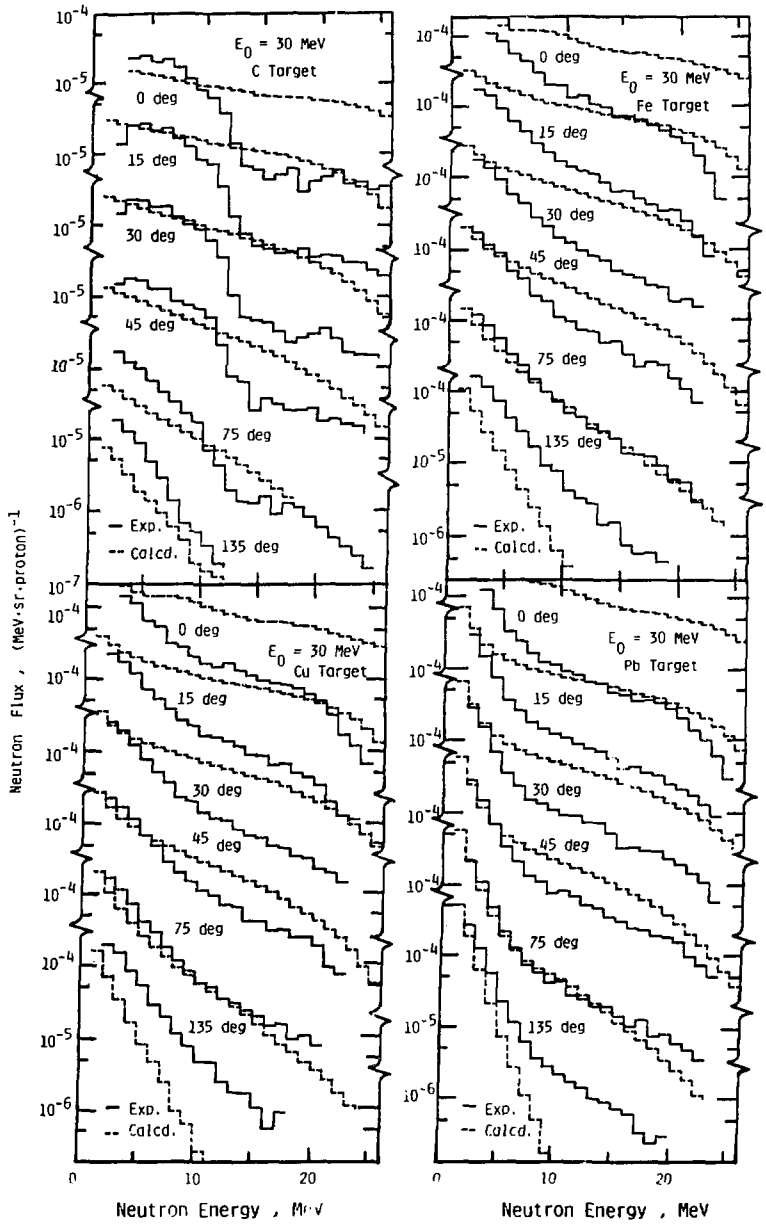

Fig. 1. Comparison of measured and calculated neutron energy spectra at several emission angles for thick C, Fe, Cu and Pb targets bombarded by one 30-MeV proton.

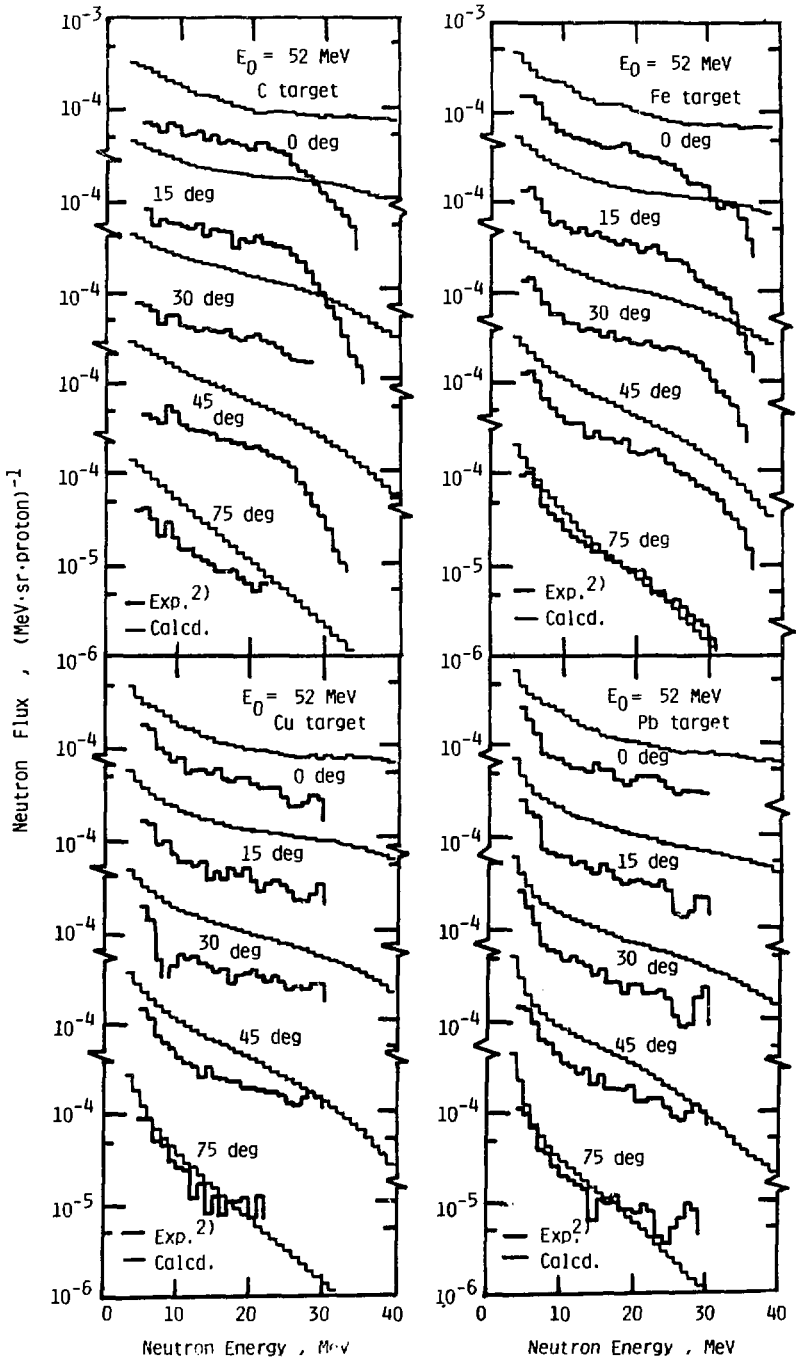

Fig. 2. Comparison of measured and calculated neutron energy spectra at several emission angles for thick C, Fe, Cu and Pb targets bombarded by one 52-MeV proton.

Neutron and Photon Production from Thick Targets by Light-Heavy Ion Bombardment

T. Nakamura, K. Shin*, M. Fujii**, H. Hibi*, and Y. Uwamino***

A paper on this subject is now in preparation to be submitted to Nuclear Physics. The neutron and photon energy spectra emitted in the direction of 0, 15, 30, 45, 75 and 135 deg to the beam axis were obtained by unfolding the pulse-height distributions measured simultaneously with the n-γ pulse shape discrimination of a NE-213 scintillator, when the 30-MeV p, 33-MeV d, 65-MeV ^{3}He and 65-MeV ^{4}He beams were injected into thick targets of C, Fe, Cu and Pb.

As examples of the observed results, the neutron energy spectra for a carbon target exposed to these four beams are shown in Fig. 1, by normalizing to one incident particle. For 0 degree incidence of a 33-MeV deuteron, our measured spectrum is compared with the TOF spectrum by Meulders et al.[1)] and showed good agreement each other. The figure shows the following tendency; 1) In the forward direction of d and ^{3}He beams, there can be seen a broad peak coming from the breaking-up of the projectile itself, and 2) the neutron spectra become softer with increasing the emission angle. Figure 2 shows the angular distribution of neutrons integrated the measured spectra above

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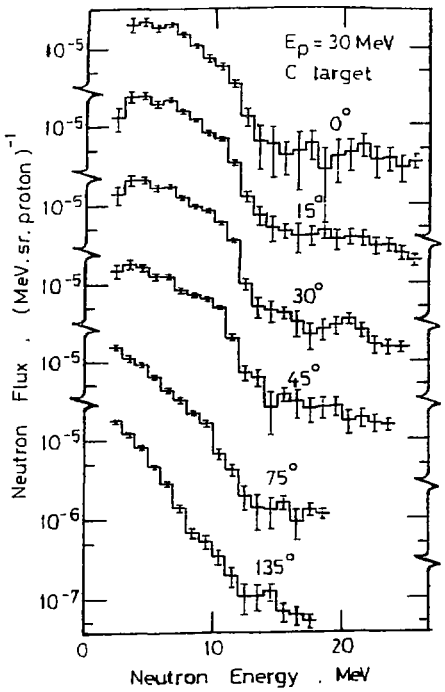
3 MeV for proton and 4 MeV for d, ^{3}He and ^{4}He. The figure shows that the forwardness becomes stronger in the order of p, ^{4}He, ^{3}He and d, reflecting a forwardness of stripping reaction and a higher momentum transfer from the heavier projectile to the target. Table I gives the neutron and photon yields above E_{cut} integrated in all directions to one incident particle, together with total neutron yield estimated the neutrons below E_{cut} by fitting the spectra measured above E_{cut} to the Maxwellian distribution.

Reference:

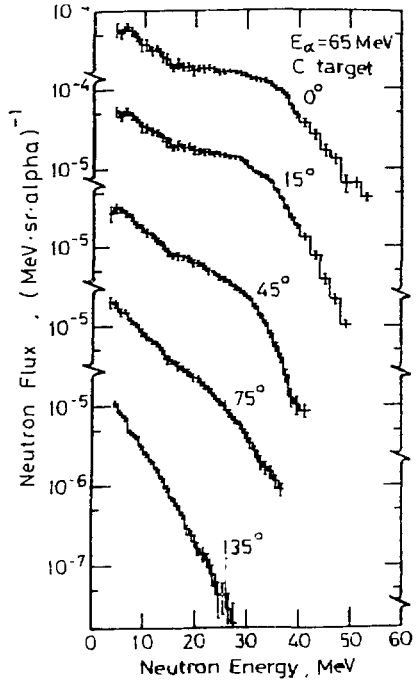
1) J. P. Meulders, P. Leleux, P. C. Macq and C. Pirart, Phys. Med. Biol., 20, 235 (1975).

Table I Total neutron and photon yields per one incident particle

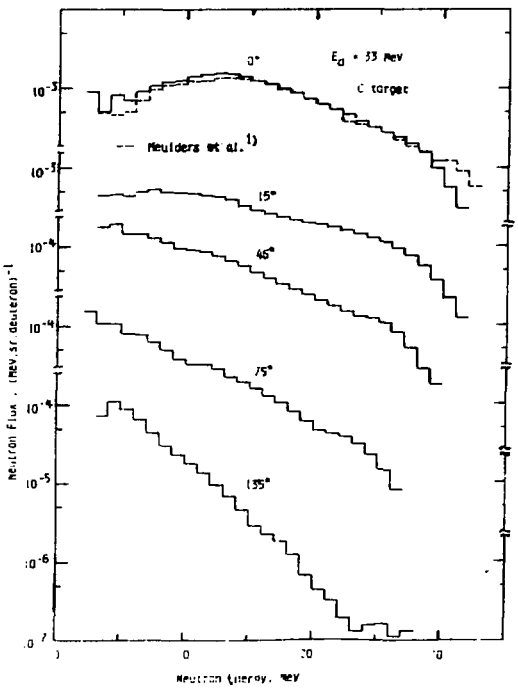
Projectile	Target	Neutron			Photon	
		$E \geqq 0$	$E \geqq E_{cut}$	E_{cut}	$E \geqq E_{cut}$	E_{cut}
		$\times 10^{-3}$		MeV	$\times 10^{-3}$	MeV
30-MeV proton	C	1.14	0.672	3	7.42	1.5
	Fe	9.90	3.87		12.8	
	Cu	12.1	4.96		13.8	
	Pb	17.3	3.53		9.39	
33-MeV deuteron	C	24.9	17.1	4	18.9	1.5
	Fe	19.6	7.64		23.2	
	Cu	21.7	7.68		25.3	
	Pb	12.4	3.39		6.80	
65-MeV ^{3}He particle	C	12.8	6.28	4	12.4	1.0
	Fe	13.3	5.85		13.8	
	Cu	14.2	5.98		13.2	
	Pb	14.8	3.54		12.4	
65-MeV ^{4}He particle	C	2.96	2.18	4	5.20	1.5
	Fe	6.68	2.91		9.22	
	Cu	7.00	3.80		9.05	
	Pb	6.11	1.66		5.13	



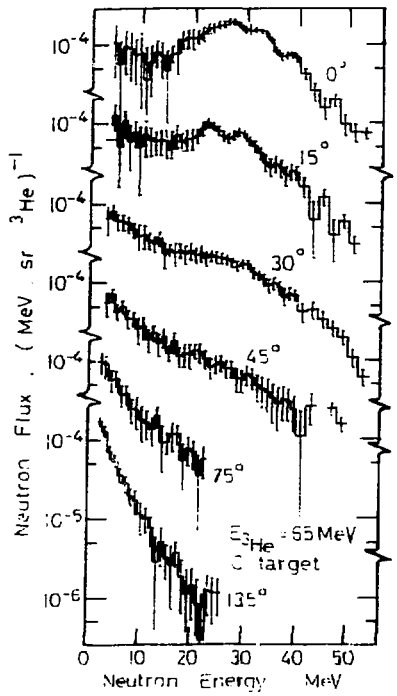
(a) 30-MeV proton injection



(b) 65-MeV alpha particle injection

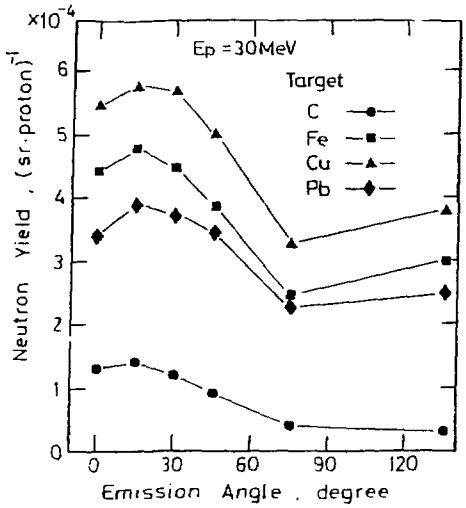


(c) 33-MeV deuteron injection

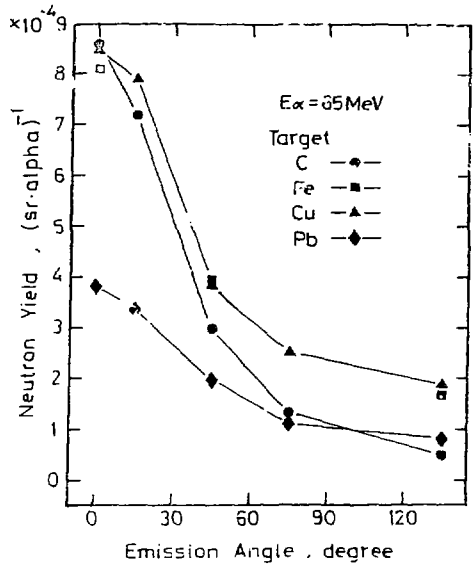


(d) 65-MeV He-3 particle injection

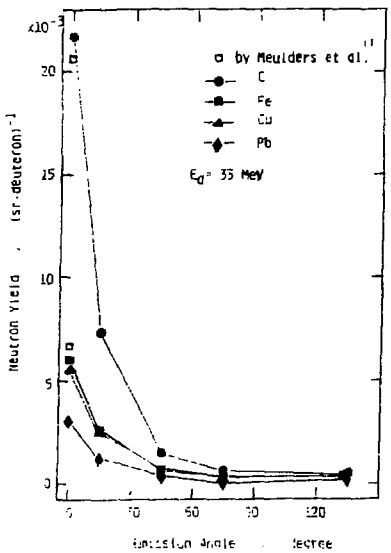
Fig. 1 Neutron energy spectra of C target



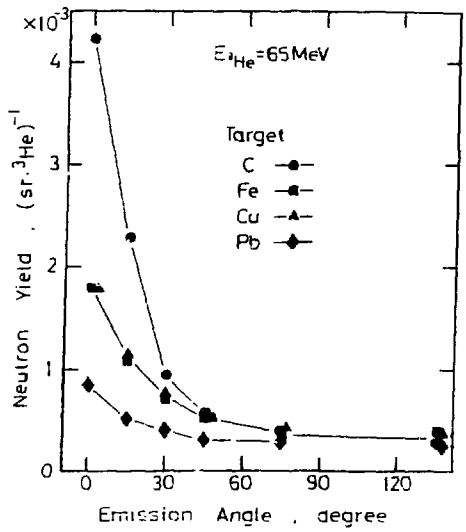
(a) 30-MeV proton-produced neutrons above 3 MeV



(b) 65-MeV alpha-produced neutrons above 4 MeV



(c) 33-MeV deuteron-produced neutrons above 4 MeV



(d) 65-MeV He-3-produced neutrons above 4 MeV

Fig. 2 Neutron angular distributions

B. Nuclear Engineering Research Laboratory, Faculty of Engineering

XI-B-1

Measurements of Beta-Ray Decay Heat of Fission Products for Fast Neutron Fission of ^{235}U, ^{239}Pu and ^{233}U

M. Akiyama, K. Furuta, T. Ida*, K. Sakata** and S. An

A paper on this subject will be published in the Journal of Atomic Energy Society of Japan 24, No.10 (1982).

Beta decay heat released from fission products (FPs) has been measured for fast-neutron fissions of ^{235}U, ^{239}Pu and ^{233}U using the radiation spectrometry method. The sample irradiations were for 10, 60 and 300s (10 and 100s for ^{233}U) in the fast neutron source reactor YAYOI of the University of Tokyo. Spectral data for beta-ray were obtained at post-irradiation time intervals ranging from 11s to 26000s using a plastic scintillation detector combined with a transmission type proportional counter to eliminate gamma-ray effects. The data were processed to the form of beta-energy release rates per fission for each set of time-interval parameters. The standard representation of the decay heat following fission pulse (in cooling times ranging from 19 to 24000s) was provided from the beta-energy release rates. The experimental uncertainties (1σ) of the decay heat data were within 5%.

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The present results are compared with three summation calculations using JNDC[1], TASAKA[2] and ENDF/B-IV[3] FP decay data libraries. As the results of these comparisons, it appears that the values calculated using JNDC FP decay data library are in well agreement with the measured values. The present results of decay heat for ^{235}U, ^{239}Pu and ^{233}U are shown in Fig.1, Fig.2 and Fig.3, respectively.

References:

1) T. Yamamoto, et al., JAERI-M 9357 (1981)
   H. Ihara, et al., JAERI-M 9715 (1981)
2) K. Tasaka, NUREG/CR-0705 (1979)
3) T. R. England, R. E. Schenter, LA-6116-MS (1975)

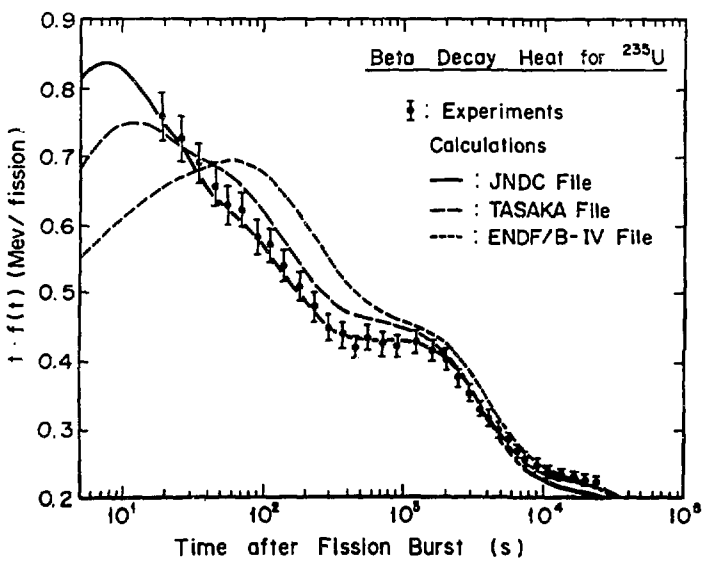

Fig. 1 Beta energy emission rate following an instantaneous pulse of fast-neutron fissions of ^{235}U. Comparison of the experimental results with three summation calculations.

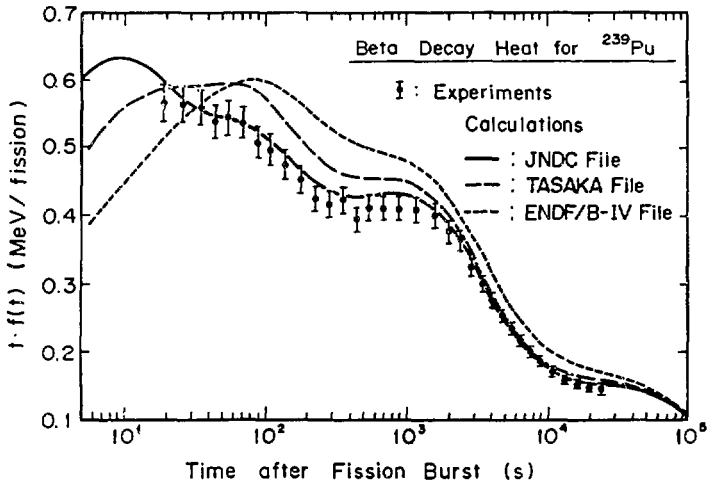

Fig. 2 Beta energy emission rate following an instantaneous pulse of fast-neutron fissions of ^{239}Pu. Comparison of the experimental results with three summation calculations.

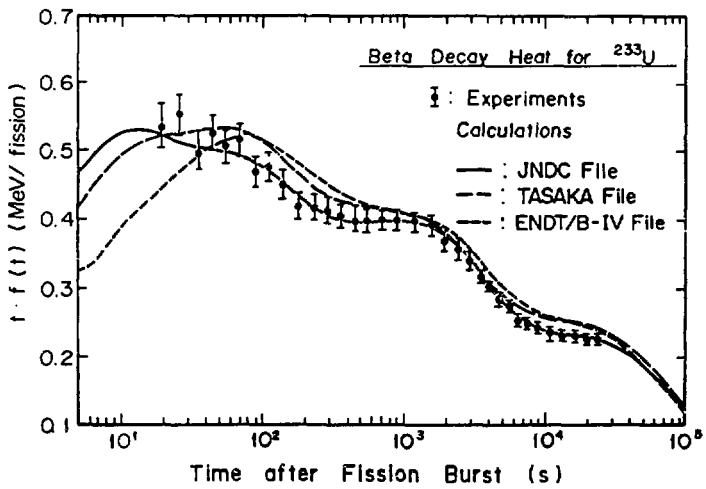

Fig. 3 Beta energy emission rate following an instantaneous pulse of fast-neutron fissions of ^{233}U. Comparison of the experimental results with three summation calculations.

Measurements of Gamma-Ray Decay Heat of Fission Products for Fast Neutron Fissions of ^{235}U, ^{239}Pu and ^{233}U

M. Akiyama, K. Furuta, T. Ida*, K. Sakata** and S. An

A paper on this subject will be published in the Journal of Atomic Energy Society of Japan 24, No.9 (1982).

Gamma decay heat released from fission products (FPs) has been measured for fast-neutron fissions of ^{235}U, ^{239}Pu and ^{233}U using the radiation spectrometry method. The sample irradiations were for 10 and 100s in the fast neutron source reactor YAYOI of the University of Tokyo. Spectral data for gamma rays were obtained at post-irradiation time intervals ranging from 11s to 25950s using a NaI(Tℓ) scintillation detector. The date were processed to the form of gamma-energy release rates per fission for each set of time-interval parameters. The standard representation of the decay heat following fission pulse (in cooling times ranging from 19s to 24000s) was provided from the gamma-energy release rates. The uncertainties (1σ) of the decay heat data ware about 5% for ^{235}U and ^{239}Pu and about 7% for ^{233}U.

The data obtained from the present experiments are compared with three summation calculations using JNDC[1], TASAKA[2] and ENDF/B-IV[3] decay data libraries, and with other experimental results. The summation calculation results using the JNDC FP decay data library are in better agreement with the present data

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**Present address : Mitsubishi Atomic Power Industries, Inc.

than the other calculations. The present results of decay heat for ^{235}U, ^{239}Pu and ^{233}U are shown in Fig.1, Fig.2 and Fig.3, respectively.

References:

1) T. Yamamoto, et al., JAERI-M 9357 (1981)
   H. Ihara, et al., JAERI-M 9715 (1981)
2) K. Tasaka, NUREG/CR-0705 (1979)
3) T. R. England, R. E. Schenter, LA-6116-MS (1975)
4) P. C. Fisher, L. B. Engle, Phys. Rev. 134, B796 (1964)
5) L. R. Bunney, D. Sam, Nucl. Sci. Eng. 29, 432 (1967)

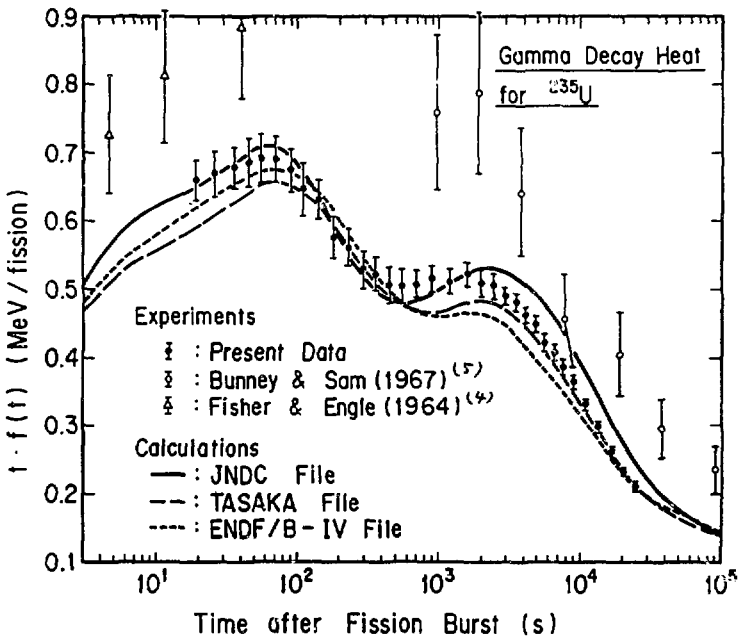

Fig. 1 Gamma energy emission rate following an instantaneous pulse of fast-neutron fissions of ^{235}U. Comparison of the experimental results with three summation calculations, and other experimental results.

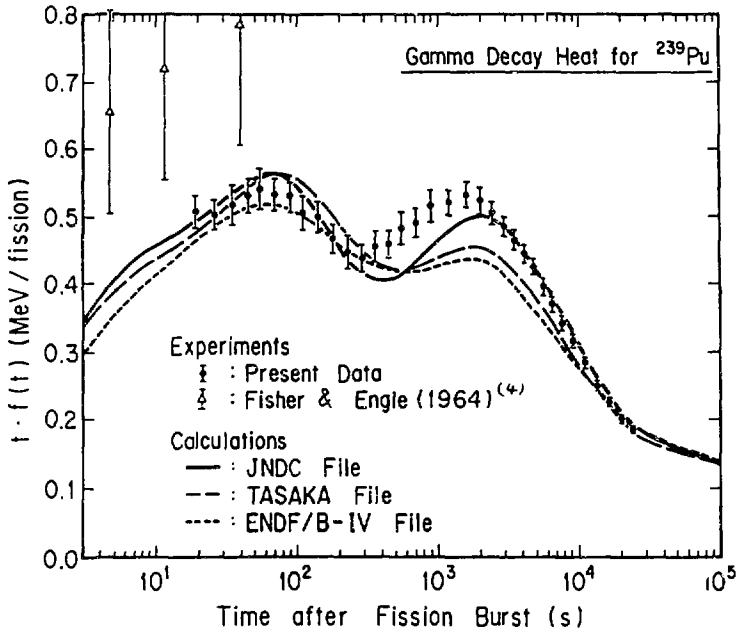

Fig. 2 Gamma energy emission rate following an instantaneous pulse of fast-neutron fissions of ^{239}Pu. Comparison of the experimental results with three summation calculatins, and other experimental results.

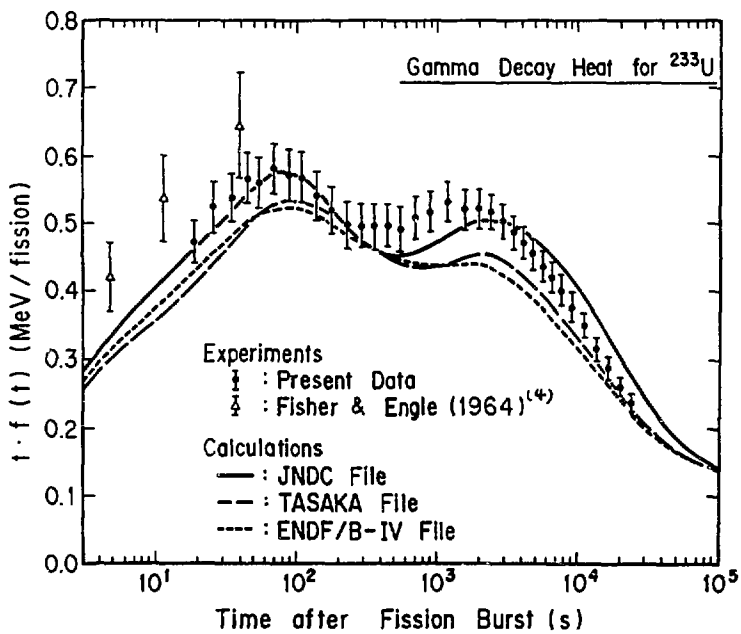

Fig. 3 Gamma energy emission rate following an instantaneous pulse of fast-neutron fissions of ^{233}U. Comparison of the experimental results with three summation calculations, and other experimental results.

XII. WASEDA UNIVERSITY

Department of Physics
and Applied Physics

XII-1 Semi-Empirical Estimation of Delayed Neutron Emission Probabilities

T.Tachibana and M.Yamada*

A semi-empirical method of estimating the β strength function from β-decay data on three neighboring nuclei has been devised. This method is most effective for the β^--decay of a nucleus with odd proton number ($Z=Z_1$) and even neutron number being equal to a magic number plus two ($N=N_1$); in this case, the three neighboring nuclei are (Z_1+1,N_1), (Z_1,N_1-2) and (Z_1+1,N_1-2).

The β^- strength functions of ^{87}Br and ^{137}I have been estimated by this method, data of the neighboring nuclei being taken from ref. 1). and the result represents the general trend of experimental data[2)] fairly well except for the regions of the lowest and highest excitation energies of daughter nuclei, where this method is either inapplicable or subject to large uncertainties.

The delayed neutron emission probabilities have been calculated for these nuclei by use of the estimated β^- strength functions. The competition factor between neutron and γ-ray emissions has been taken from ref. 3).

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Waseda University

Depending on various choices of the β^--decay Q-values and the depths of the average potentials for proton and neutron, the calculated values of the delayed neutron emission probabilities range from 2.2% to 3.0% for ^{87}Br, and from 3.2% to 4.7% for ^{137}I. These values are to be compared with the experimental values[4], (2.57±0.15)% for ^{87}Br, and (6.7±0.4)% for ^{137}I, respectively.

Application of this method to other nuclides is being planned.

References:

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

2) K.-L.Kratz, W.Rudolph, H.Ohm, H.Franz, M.Zendel, G.Herrmann, S.G.Prussin, F.M.Nuh, A.A.Shihab-Eldin, D.R.Slaughter, W.Halverson and H.V.Klapdor, Nucl. Phys. A317 (1979) 335

3) K.Takahashi, Prog. Theor. Phys. 47 (1972) 1500

4) E.Lund, P.Hoff, K.Aleklett, O.Glomset and G.Rudstam, Z. Phys. A294 (1980) 233