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Editor

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Japanese Nuclear Data Committee

Japan Atomic Energy Research Institute
Tokai Research Establishment
Tokai-mura, Naka-gun, Ibaraki-ken, Japan

Editor's Note

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

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

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

This edition covers a period of January 1, 1999 to December 31, 1999. 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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IX. Osaka University

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LI	6	(N,GAMMA)	NDG		TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	OHSAKI+.P96.KEV NEUTRON CAPTURE
LI	6	(N,GAMMA)	NDG		TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	OHSAKI+.P97.AT STELLER ENERGY
C	12	DIFF INELAST	2.0+7	4.0+7	JAE	THEO-PROG	INDC(JPN)-186U	MAR 00	SUKHOVITSKIJ+.P20.SOFT ROTATOR MDL.
O	16	(N,GAMMA)	NDG		TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	OHSAKI+.P96.KEV NEUTRON CAPTURE
O	16	(N,GAMMA)	NDG		JPN	THEO-PROG	INDC(JPN)-186U	MAR 00	KITAZAWA+.P63.DIRECT CAPT.FOLD MDL
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NE	20	(N,GAMMA)	NDG		TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	OHSAKI+.P96.KEV NEUTRON CAPTURE
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NA	23	RESON PARAMS	3.5+4	5.3+4	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	HORI+.P98.PARTIAL+TOTAL WG.
AL	27	EVALUATION	2.0+7	2.0+9	JAE	EVAL-PROG	INDC(JPN)-186U	MAR 00	LEE+.P15.CALC WITH GNASH+QMD CODES
AL	27	(N,P)	2.0+6	7.0+6	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SENGA+.P55.ACTIVATION METHOD
AL	27	(N,P)	3.0+6	7.0+6	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	FURUTA+.P56.ACTIVATION METHOD
AL	27	(N,ALPHA)	3.0+6	7.0+6	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	FURUTA+.P56.ACTIVATION METHOD
AL	27	A EMISSION	1.4+7		OSA	EXPT-PROG	INDC(JPN)-186U	MAR 00	TAKAHASHI+.P67.OKTAVIAN.CSI(TL) DET
TI	47	(N,P)	3.0+6	7.0+6	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	FURUTA+.P56.ACTIVATION METHOD
TI	47	(N,P)	2.0+6	7.0+6	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SENGA+.P55.ACTIVATION METHOD
FE	56	(N,P)	3.0+6	7.0+6	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	FURUTA+.P56.ACTIVATION METHOD
NI	58	(N,P)	3.0+6	7.0+6	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	FURUTA+.P56.ACTIVATION METHOD
NI	58	(N,P)	2.0+6	7.0+6	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SENGA+.P55.ACTIVATION METHOD
NI	58	(N,ALPHA)	NDG		KYU	EVAL-PROG	INDC(JPN)-186U	MAR 00	KAWANO+P51.STATMDL + WIDTH FLUCT.

ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF VOL PAGE	DATE	COMMENTS
ZN	64	(N,P)	3.0+6	7.0+6	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	FURUTA+.P56.ACTIVATION METHOD
SR	90	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
SR	90	RES INT CAP	5.0-1		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
MO	100	(N,NP)	1.3+7	1.5+7	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SAKANE+.P56.TO META.ACTIVATION METH.
MO	95	(N,NP)	1.3+7	1.5+7	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SAKANE+.P56.TO META.ACTIVATION METH.
TC	99	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
TC	99	RES INT CAP	5.0-1		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
CD	116	(N,NP)	1.3+7	1.5+7	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SAKANE+.P56.TO GS.ACTIVATION METHOD
TE	123	(N,NP)	1.3+7	1.5+7	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SAKANE+.P56.TO META.ACTIVATION METH.
I	127	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
I	127	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	KATOH+.P28.SIG=6.40+-0.29 B
I	127	RES INT CAP	5.0-1		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
I	127	RES INT CAP	5.0-1		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	KATOH+.P28.RI=162+-8 B
I	129	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
I	129	RES INT CAP	5.0-1		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
CS	133	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
CS	133	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P29.MS,GS.(M+G)=29.0+-1.0B
CS	133	RES INT CAP	5.0-1		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
CS	133	RES INT CAP	5.0-1		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P29.MS,GS.(M+G)=298+-16 B
CS	134	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD

ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF VOL PAGE	DATE	COMMENTS
CS	134	(N,GAMMA)	MAXW		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	KATOH+.P27.TRIPLE N CAP.140.6+-8.5 B
CS	135	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
CS	135	RES INT CAP	5.0-1		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
CS	137	(N,GAMMA)	2.5-2		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
CS	137	RES INT CAP	5.0-1		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	NAKAMURA+.P31.ACTIVATION METHOD
ND	143	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
ND	143	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
ND	145	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
ND	145	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
ND	146	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
ND	146	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
SM	147	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
SM	147	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
SM	148	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
SM	148	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
SM	149	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
SM	149	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
SM	150	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
SM	150	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
SM	152	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.

ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF VOL PAGE	DATE	COMMENTS
SM	152	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
SM	154	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
SM	154	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
DY		TOTAL	2.0-3	1.0+5	KTO	EXPT-PROG	INDC(JPN)-186U	MAR 00	CHO+.P39.LINAC,TOF.TRNS METHOD.FIG
DY	161	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
DY	161	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
DY	162	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
DY	162	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
DY	163	(N,GAMMA)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.REL AU197.
DY	163	SPECT (N,G)	1.0+4	5.5+5	TIT	EXPT-PROG	INDC(JPN)-186U	MAR 00	IGASHIRA+.P95.ANOMALOUS BUMP OBS.
YB	176	(N,NP)	1.3+7	1.5+7	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SAKANE+.P56.ACTIVATION METHOD
YB	176	(N,ALPHA)	1.3+7	1.5+7	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SAKANE+.P56.ACTIVATION METHOD
HF		TOTAL	2.0-3	1.0+5	KTO	EXPT-PROG	INDC(JPN)-186U	MAR 00	CHO+.P39.LINAC,TOF.TRNS METHOD.FIG
OS	190	(N,P)	1.3+7	1.5+7	NAG	EXPT-PROG	INDC(JPN)-186U	MAR 00	SAKANE+.P56.TO GS.ACTIVATION METHOD
TH	229	FISSION	1.0-2	1.0+4	KTO	EXPT-PROG	INDC(JPN)-186U	MAR 00	KOBAYASHI+.P41.PB SLOWING DOWN SPEC.
PA	231	FISSION	1.0-1	1.0+4	KTO	EXPT-PROG	INDC(JPN)-186U	MAR 00	KOBAYASHI+.P41.PB SLOWING DOWN SPEC.
U	233	FISSION	3.0+4	2.0+7	JAE	EVAL-PROG	INDC(JPN)-186U	MAR 00	KAWANO+P18.SIMULTANEOUS EVALUATION
U	233	FISS YIELD	2.5-2		OSA	EXPT-PROG	INDC(JPN)-186U	MAR 00	TAKAMIYA+.P71.DOUBLE-V AND -E MEAS.
U	233	FRAG SPECTRA	2.5-2		OSA	EXPT-PROG	INDC(JPN)-186U	MAR 00	TAKAMIYA+.P71.DOUBLE-V AND -E MEAS.
U	235	FISSION	3.0+4	2.0+7	JAE	EVAL-PROG	INDC(JPN)-186U	MAR 00	KAWANO+P18.SIMULTANEOUS EVALUATION

ELEMENT S	A	QUANTITY	ENERGY MIN	MAX	LAB	TYPE	DOCUMENTATION REF VOL PAGE	DATE	COMMENTS
U	235	DELAYD NEUTS	2.5-2	FAST	NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	OYAMATSU.P57.SUMMATION CALCULATION
U	235	FISS PROD GS	FAST		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	OHKAWACHI+.P33.WITH YAYOI REAC.NDG
U	235	FISS PROD BS	FAST		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	OHKAWACHI+.P33.WITH YAYOI REAC.NDG
U	235	FISS YIELD	2.5-2		OSA	EXPT-PROG	INDC(JPN)-186U	MAR 00	TAKAMIYA+.P71.DOUBLE-V AND -E MEAS.
U	235	FRAG SPECTRA	2.5-2		OSA	EXPT-PROG	INDC(JPN)-186U	MAR 00	TAKAMIYA+.P71.DOUBLE-V AND -E MEAS.
U	238	DIFF INELAST	3.5+5	8.6+5	TOH	EXPT-PROG	INDC(JPN)-186U	MAR 00	MIURA+.P76.45KEV LEVEL. TOF
U	238	FISSION	1.0+5	2.0+7	JAE	EVAL-PROG	INDC(JPN)-186U	MAR 00	KAWANO+P18.SIMULTANEOUS EVALUATION
U	238	DELAYD NEUTS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	OYAMATSU.P57.SUMMATION CALCULATION
NP	237	(N,GAMMA)	1.0-2	1.0+3	KTO	EXPT-PROG	INDC(JPN)-186U	MAR 00	KOBAYASHI+.P40.PB SLOWING DOWN SPEC.
NP	237	SPECT FISS N	6.2+5		TOH	EXPT-PROG	INDC(JPN)-186U	MAR 00	THAN WIN+.P75.PROMPT N.WATT DIST.
NP	237	FISS PROD GS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
NP	237	FISS PROD GS	FAST		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	OHKAWACHI+.P33.WITH YAYOI REAC.NDG
NP	237	FISS PROD BS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
NP	237	FISS PROD BS	FAST		JNC	EXPT-PROG	INDC(JPN)-186U	MAR 00	OHKAWACHI+.P33.WITH YAYOI REAC.NDG
PU	239	FISSION	3.0+4	2.0+7	JAE	EVAL-PROG	INDC(JPN)-186U	MAR 00	KAWANO+P18.SIMULTANEOUS EVALUATION
PU	239	DELAYD NEUTS	2.5-2	FAST	NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	OYAMATSU.P57.SUMMATION CALCULATION
PU	239	FISS YIELD	2.5-2		OSA	EXPT-PROG	INDC(JPN)-186U	MAR 00	TAKAMIYA+.P71.DOUBLE-V AND -E MEAS.
PU	239	FRAG SPECTRA	2.5-2		OSA	EXPT-PROG	INDC(JPN)-186U	MAR 00	TAKAMIYA+.P71.DOUBLE-V AND -E MEAS.
PU	240	FISSION	1.0+5	2.0+7	JAE	EVAL-PROG	INDC(JPN)-186U	MAR 00	KAWANO+P18.SIMULTANEOUS EVALUATION
PU	241	FISSION	3.0+4	2.0+7	JAE	EVAL-PROG	INDC(JPN)-186U	MAR 00	KAWANO+P18.SIMULTANEOUS EVALUATION

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ELEMENT S A	QUANTITY	ENERGY MIN	ENERGY MAX	LAB	TYPE	DOCUMENTATION REF VOL PAGE	DATE	COMMENTS
AM 241	FISS PROD GS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
AM 241	FISS PROD BS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
AM 243	FISS PROD GS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
AM 243	FISS PROD BS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
CM 242	FISS PROD GS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
CM 242	FISS PROD BS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
CM 244	FISS PROD GS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
CM 244	FISS PROD BS	FAST		NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	TAKEUCHI+.P59.HYBRID METHOD
MANY	(N,NP)	1.3+7	1.5+7	NAG	EVAL-PROG	INDC(JPN)-186U	MAR 00	SAKANE+P55.SYSTEMATICS OF SIG

Prepared by JNDC CINDA Group.

I. Hokkaido University

A. Division of Physics

I-A-1

Analysis of proton induced reactions with High Energy Nuclear Reaction Model

HIRATA YUICHI, OHNISHI AKIRA, NARA YASUSHI, OTSUKA NAOHIKO,
NIITA KOUJI, CHIBA SATOSHI, TAKADA HIROSHI

A paper on this subject was presented at the Meeting of Hokkaido branch of the Atomic Energy Society of Japan, on December 15, 1999, with following abstract.

We incorporate Percolation Model into the High Energy Cascade Model JAM. And we apply JAM with Percolation Model to fragmentation phenomena in the proton induced reaction and we confirm its validity on the description of fragmentation phenomena. Through the comparison between JAM with Percolation Model and simple Percolation Model, we show the good ability of JAM with Percolation Model to reproduce the experimental fragment production cross section.

I-A-2

Nuclear Reaction Database on Meme Media

Yosihide OHBAYASI [a], Hiroshi MASUI [a],
Shigeyoshi AOYAMA [b], Kiyoshi KATÔ [c] and Masaki CHIBA [d]

A Paper of this subject was presented at 1999 Symposium on Nuclear Data and will be published in the proceedings:

We have shown a new type of nuclear data retrieval system, in which NRDF (Nuclear Reaction Data File), a kind of charged particle nuclear data (CPND) compilation in Japan, is applied as an example. To get benefits from recent computer and network technologies, we adopt the IntelligentPad architecture as a framework of the present system. This software architecture has many useful features for handling multimedia, media-based system construction, and graphical user interface. IntelligentPad is not only a specific software package, but also the fundamental environment architecture to support the effective utilization of computerized resources. It is called Meme media architecture. Meme media is the environment that shares and re-uses the resources of all over the world connected to the Internet[1].

For effective utilization of nuclear data, seamless linkages between measured experimental data and its application should be important. Considering these linkages, it is essential to link accumulation, evaluation and circulation on the same system. Furthermore, there are interdependences among them: evaluation of accumulated data, circulation of evaluated data, and re-accumulation evaluated data. Therefore, we should consider constructing the framework so as to achieve this continuous cycle. In addition, we should consider integrating the different databases which have different compilation policy or evaluation policy. Using the integrated database, we can retrieve and utilize the various resources concerned with nuclear data. With the above background and motivation, we discuss the aim of the framework of the utility system for nuclear reaction data with future computer facilities.

References

[1] Tanaka,Y.: International Conference on Multimedia Modeling '98, Lausanne P. 1(1998).
Ohbayasi, Y.: Journal of Information Science, 26(1) 2000, pp. 29-37

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I-A-3

Development of a Search System of NRDF on WWW

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A paper on this subject was presented at 1999 Symposium on Nuclear Data and also will be published in JAERI-Conf with the following abstract:

We develop a data search system and a data entry system for the Nuclear Reaction Data File (NRDF), which is the one of the charged-particle reaction database organized by Japan Charged Particle Reaction Group (JCPRG). Using a WWW browser, we can easily search, retrieve and utilize the data of NRDF. Moreover, now the (charged-particle) nuclear reaction data can be accumulated from the data entry page on WWW.

1. NRDF Data Search System

Address of the Search System: http://nrdf.meme.hokudai.ac.jp/tools/nrdf_search.html

Recent years, WWW is getting the most popular way to investigate and retrieve data form huge amounts of resources around the world, not only for academic use but also commercial use. In such a situation, at first, we develop a new NRDF data search system on WWW with simple operations and graphical data plots. In this system, We can search the data of charged-particle nuclear reaction with some query keywords namely, a projectile, a target, authors, a reference and the year of the publication. The search results are listed as usual WWW search page. Each data is assigned with "d-number" and each d-numbered file can be browsed by the *data-browsing* page.

The data file of NRDF contains informations of the bibliography, experimental setups, numerical data for plots, parameters of the evaluation and so on. However, the data file itself is not suitable to be read, since we have to know the words of the data cord and the structure of the data format. Therefore, the *data-browsing* page is designed so that we do not have to know the words and the structure. To overlook the all graphs in the data file, the thumb-nails of the graphs are displayed in that page. Then, each graph is showed precisely in each *graph-display* page.

2. NRDF Data Entry System

We also develop a data entry system to accumulate the nuclear reaction data directly from the researcher of the experiment. With this system, the accuracy and the reliability of the data will be rising up compared with the data which is accumulated by paper-published one, and more, the circulation of the nuclear reaction data would be quicker and more comfortable.

II. Hosei University

A. College of Engineering and Research Center of Ion Beam Technology

II-A-1

Photoluminescence from transmuted impurities in neutron-transmutation-doped semi-insulating GaP

K. Kuriyama, K. Ohbora and M. Okada *

In this paper, we report that the transmuted Ge atoms are incorporated as both donor and acceptor impurities for a relatively low doping level of ~10^{17} cm^{-3}, forming a Ge_{Ga}-Ge_P complex defect. We suggest that the electrical activation of neutron transmutation doped (NTD)-GaP is restricted in the presence of the complex defect.

Materials used in this study were undoped (111)-oriented semi-insulating GaP ($\rho \geq 10^7 \Omega$ cm) grown by the liquid-encapsulated Czochralski method. Samples were irradiated with thermal and fast neutrons at fluxes of 8.15×10^{13} and 3.9×10^{13} cm^2s^{-1}, respectively. The fluences of thermal and fast neutrons were 4.4×10^{18} and 2.1×10^{18} cm^{-2} for the irradiation time t=15 h, respectively. The net concentration of transmuted impurities (N_{NTD}) is expressed as

$$N_{NTD} = \phi t \Sigma n_i \sigma_c^i, \qquad (1)$$

where ϕ is the thermal neutron flux, t the irradiation time, n_i the concentration of the ith isotope, and σ_c^i its capture cross section. These values are listed in Table 1. The value of $\Sigma n_i \sigma_c^i$ in GaP is estimated to be 7.46×10^{-2} atoms/cm^3/neutrons/cm^2. Therefore, the doping concentration is determined precisely by the thermal neutron fluence (ϕt). For t=15h, $N_{NTD} = 3.3\times10^{17}$ cm^{-3}. Unfortunately, after the transmutation reactions, the transmuted atoms are usually not in their original positions but displaced into interstitial positions due to the recoil produced by the γ and β particles in the nuclear reactions. In addition, the defects induced by the fast neutron irradiation disturb the electrical activation of transmuted impurities. However, Frenkel type defects [1,2] in NTD-GaP were annealed out between 200 and 300℃, while P antisite (P_{Ga}) defects [1] of ~10^{18} cm^{-3} annihilated at annealing temperatures between 600 and 650 ℃. Therefore, transmuted impurities, Ge and S, would be substituted on Ga and/or P lattice sites by annealing at around 650℃. The photoluminescence (PL) measuring system used here has been used for the

Table 1. The parameter of each element for NTD and calculated NTD concentration.

Element	Thermal neutron capture cross section (10^{-24} cm)	Natural abundance	Transmuted element (concentration)[a]
^{69}Ga	1.4	0.602	^{70}Ge (9.2×10^{16} cm^{-3})
^{71}Ga	5.0	0.398	^{72}Ge (2.2×10^{17} cm^{-3})
^{31}P	0.19	1.00	^{32}S (2.1×10^{16} cm^{-3})

[a] The values for neutron irradiation time t=15 h.

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identification of cation antisite defects in semi-insulating GaP [3]. The 488 nm line of a 100 mW Ar^+ laser was used as the excitation source. To minimize the background noise of the photodetector a photomultiplier cooler was also used. Samples for annealing were capped by SiO_2 film, formed by the spin-on method [4] using the OCD (Ohka coating diffusion; Tokyo Ohka Kogyo Co., Ltd.), which is an alcohol solution of sianol, and annealed for 30 min at the desired temperatures.

Figure 1 shows the PL spectra of unirradiated and NTD-GaP. The PL spectrum (peak 1) of unirradiated samples shows signatures of the donor-accepter (DA) pair recombination involving S donor and carbon acceptors [5]. Two (peaks 2 and 3) of the replicas occur at energies consistent with electronic transitions accompanied by zone-center optical phonons with energies 50.1 meV (LO_Γ) and 100.2 meV ($2LO_\Gamma$). Sulfur, silicon and carbon in GaP are the most common as the residual impurities [6]. In samples annealed at 600℃, a weak broad emission was observed at around 1.7 eV. This emission may be assigned to donor-acceptor complexes of the $[P_{Ga}{}^+Si_P{}^-]$ type [7] in GaP, since the 600℃-annealed samples contain the P_{Ga} antisite defects[1] of 4×10^{17} cm^{-3}. A broad emission at 1.65 eV appears in 640℃-annealed samples and a slight hump was observed at around 1.87 eV in 660℃-annealed samples. This hump was observed clearly by annealing at 700℃ and annihilates at an ambient temperature ~50 K. The 1.87 eV emission [8,9] is attributed to the DA pair recombination arising from the transmuted S_P and Ge_P atoms. On the other hand, although the 1.65 eV emission has been interpreted as DA pairs of Ge_{Ga}-Ge_P type [10,11], the emission is somewhat broad (half width ~270 meV) and lies at lower energy by ~220 meV than an energy position $[E_g - (E_A+E_D)+e^2/\varepsilon R = 1.87$ eV for a pair separation $R\to\infty$, where E_g is the (indirect) energy gap (=2.388 eV at 15 K), e the electronic charge and ε the low-frequency dielectric constant (=11.1)] of discrete Ge_{Ga}-Ge_P DA pairs. Furthermore, the transition energy for a simple nearest-neighbour pair(no-phonon coupling) should lie at 2.42 eV using a nearest-neighbour distance R~2.36 Å. However, in NTD-GaP the main transition energy observed here was 1.65 eV. Since Ge in GaP is the amphoteric impurity with deep acceptor and donor levels, strong phonon co-operation will also occur, but optical transition rates will be significant only for associates. Similar situation has been proposed for Si in GaP [5], forming a nearest-neighbour Si_{Ga}-Si_P complex. Therefore, the broad emission would be expected to arise from a nearest-neighbour Ge_{Ga}-Ge_P coupled strongly to the lattice.

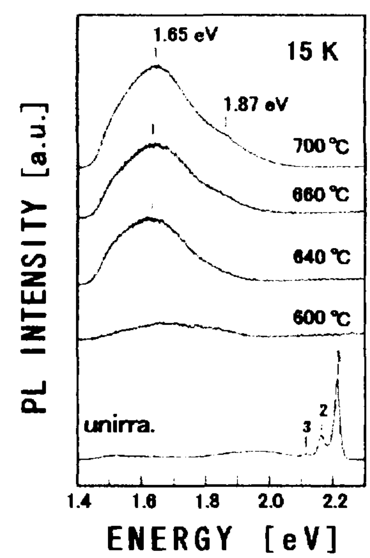

FIG. 1. Photoluminescence spectra taken at 15 K for unirradiated and NTD-GaP. PL peaks 1, 2, and 3 in unirradiated GaP represent S_P-C_P DA pair recombination, its LO-phonon replica, and 2LO-phonon replica, respectively. 1.65 eV and 1.87 eV emissions in NTD-GaP are attributed to Ge_{Ga}-Ge_P complex and S_P-Ge_P DA pair recombinations, respectively.

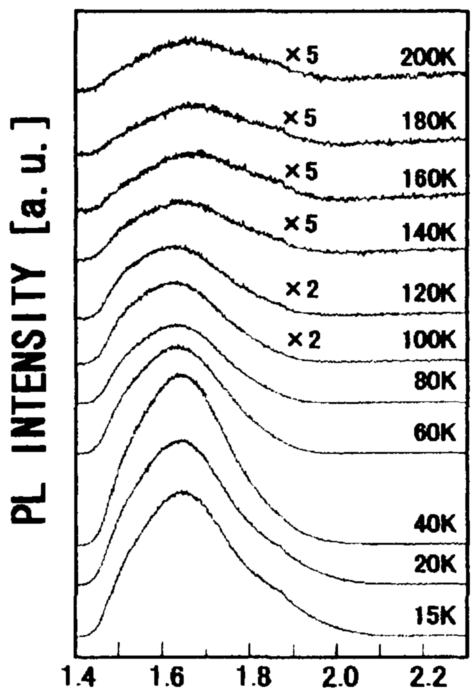

FIG. 2. Temperature dependence of the photoluminescence spectra for 700℃-annealed NTD-GaP.

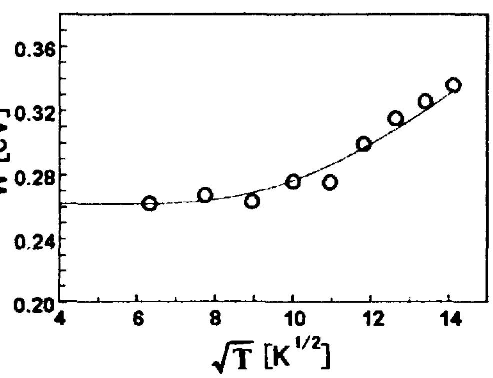

FIG. 3. Variation of the half-width W with the square root of the temperature T for the 1.65 eV band in NTD-GaP. Theoretical curve is a plot of Eq. (2), with $h\nu = 0.025$ eV.

To confirm the presence of the Ge_{Ga}-Ge_P complex, the temperature dependence of the half-width, W, of the broad emission was measured. If the localized electron transitions from the excited state to the ground state of this complex center produce the characteristics luminescence, the dependence would appear to follow the configuration-coordinate(CC) [12] model equation,

$$W = A[\coth(h\nu/2kT)]^{1/2}, \qquad (2)$$

where A is a constant whose value is equal to W as the temperature approaches 0 K and $h\nu$ is the energy of the vibrational mode of the excited state. Figure 2 shows the temperature dependence of the PL emission for 700℃-annealed NTD-GaP. The emission peak shifted to higher energies by about 25 meV. The shift is opposite to the band gap when the excited-state vibrational energy is larger than or equal to the ground-state vibrational energy and when the CC curves do not change shape with temperature. In Fig.3, Eq. (2) has been fitted to the experimental value for NTD-GaP. For the estimation of W, the spectrum of the 1.65 eV band was subtracted from that of the 1.87 eV band. The value of $h\nu$ used was 0.025 eV. The good fit to this equation that was found for the Ge_{Ga}-Ge_P center in NTD-GaP shows the validity of applying the CC model.

In NTD-GaP the transmuted Ge atoms were incorporated as both donor and acceptor impurities for the relatively low doping of $\sim 10^{17}$ cm^{-3}, while in conventional doping method[11], Ge donor was introduced for the high concentration of $> 10^{19}$ cm^{-3}. This indicates that NTD method is useful one for introducing Ge donor, resulting from a fact that Ge atoms are transmuted from Ga lattice sites in GaP. A possible explanation for the formation of the Ge_{Ga}-Ge_P complex is based on the assumption that Ga_P antisite defects are introduced simultaneously by neutron irradiation as well as the P_{Ga} antisite defects [1]. The NTD process transmutes Ga atoms in Ga_P lattice sites into Ge_P antisite defects. Finally the Ge_P defect would combine with the nearest-neighbour Ge_{Ga} transmuted from the Ga lattice sites. However, although Ga_{As} antisite defects have been observed in neutron irradiated GaAs[13], Ga_P antisite defects in GaP have not yet been identified experimentally [14].

In conclusion, we have observed the broad emission band at 1.65 eV accompanied by a hump at ~1.87 eV in NTD-GaP annealed above 640℃. These emissions were attributed to Ge_{Ga}-Ge_P complex and S_P-Ge_P DA pair recombination, respectively. The complex defect was confirmed using the configuration coordinate model. The electrical activation of NTD-GaP was restricted by the presence of the complex defect, forming a localized state.

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III. Japan Atomic Energy Research Institute

A. Nuclear Data Center and Working Groups of Japanese Nuclear Data Committeee

III-A-1
Evaluation of Neutron- and Proton-induced Nuclear Data on ^{27}Al up to 2 GeV

Lee Y.-O.*, Chang J.*, Fukahori T. and Chiba S.;

A paper on this subject was published in J. Nucl. Sci Technol., 36(12), 1125 (1999) with following abstract:

We have evaluated neutron and proton nuclear data of ^{27}Al for energies up to 2 GeV. The best set of optical model parameters were obtained from 20 MeV for neutrons and from reaction threshold for protons up to 250 MeV with the phenomenological non-relativistic potential forms incorporating effects of dispersion relationship and results of the Dirac phenomenology. The transmission coefficients for neutrons and protons derived from the optical models were fed into the GNASH code system to calculate angle-energy correlated emission spectra for light ejectiles and gamma rays. For energies between 250 MeV and 2 GeV, the total, reaction and elastic scattering cross sections were evaluated by an empirical fit and systematics. Emitted nucleon and pion spectra were estimated by use of QMD+SDM (Quantum Molecular Dynamics + Statistical Decay Model).

* Korea Atomic Energy Research Institute

III-A-2

JENDL PKA/KERMA File for IFMIF Project

Fukahori T., Chiba S., Shibata K., Ikeda Y., Aruga T.,
Watanabe Y.[1], Murata T.[2], Yamano N.[3] and Kawai M.[4]

A paper on this subject will be published in Proc. the Tenth International Symposium on Reactor Dosimetry, Sep.12-17, 1999, Osaka, Japan with following abstract:

In the Japanese Nuclear Data Committee, the JENDL PKA/KERMA file is prepared from the evaluated nuclear data file, for radiation damage calculations used to such as the International Fusion Material Irradiation Facility (IFMIF). The file contains primary knock-on atom (PKA) spectra, KERMA factors and displacement per atom (DPA) cross sections for 78 isotopes of 29 elements in the energy range between 10^{-5} eV and 50 MeV. The processing code system, ESPERANT, was developed to calculate quantities of PKA, KERMA and DPA from evaluated nuclear data for medium and heavy elements by using an effective single particle emission approximation (ESPEA). For light elements such as Li, Be, B, C, N and O, the PKA spectra are evaluated by the SCINFUL/DDX and EXIFON codes, simultaneously with other neutron cross sections.

[1] Kyushu University
[2] Aitel Co.
[3] Sumitomo Atomic Energy Industries, Ltd.
[4] High Energy Accelerator Research Organization

III-A-3
Status of JENDL Photonuclear Data File and Intercomparison with Other Libraries

Fukahori T., Kishida N., Chiba S., Murata T.[1], Asami T.[2], Hida K.[3] and Maki K.[4]

A paper on this subject will be published in Proc. the Ninth International Conference on Radiation Shielding, Oct. 17-22, 1999, Tsukuba International Congress Center, Tsukuba, Japan with following abstract:

The Japan Atomic Energy Research Institute (JAERI) Nuclear Data Center has started evaluation work in cooperation with Japanese Nuclear Data Committee (JNDC) to produce a JENDL Photonuclear Data File. The JENDL Photonuclear Data File is provided for applications such as electron accelerator shielding and radiation therapy, and given for gamma-ray induced reactions up to 140 MeV. The photon absorption cross section is evaluated with the giant dipole resonance model and the quasi-deuteron model, and the decaying processes are estimated with the statistical model with preequilibrium correction by using MCPHOTO and ALICE-F codes. The intercomparison has been made of JENDL Photonuclear Data File with other evaluated photonuclear data files such as BOFOD, CNDC, EPNDL, and LANL as well as experimental data available for the important elements.

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[1] Aitel Co. Ltd.
[2] Data Engineering Co. Ltd.
[3] Toshiba Co.
[4] Hitachi Co, Ltd.

III-A-4

Nuclear Data Sheets for A=125

J. Katakura

The new evaluation of A=125 mass chain was published in Nucl. Data Sheets 86, 955 (1999) with the following abstract:

The 1993 evaluation for A=125 mass chain has been revised using experimental results from decays and reactions Adopted values for the level and decay properties are tabulated. Inconsistencies and discrepancies are noted. All data available before February 1999 have benn considered.

III-A-5

Evaluation of Fission Cross Sections and Covariances for ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, and ^{241}Pu

T. Kawano, H.Matsunobu, T.Murata, A.Zukeran, Y.Nakajima, M.Kawai, O.Iwamoto, K. Shibata, T.Nakagawa, T.Ohsawa, M.Baba and T.Yoshida

A report on this subject was published as JAERI-Research 2000-004 with the following abstract:

A simultaneous evaluation code SOK (Simultaneous evaluation on KALMAN) has been developed, which is a least-squares fitting program to absolute and relative measurements. The SOK code was employed to evaluate the fission cross sections of ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu and ^{241}Pu for the evaluated nuclear data library JENDL-3.3. Procedures of the simultaneous evaluation and the experimental database of the fission cross sections are described. The fission cross sections obtained were compared with evaluated values given in JENDL-3.2 and ENDF/B-VI.

B. Research Group for Inovative Nuclear Science

III-B-1

Efficiency calibration of a Ge detector in the 0.1-11.0MeV region

S. Raman*,**, C. Yonezawa**, H. Matsue**, H. Iimura** and N. Shinohara**

A paper on this subject was submitted to the Nuclear Instruments and Methods with the following abstract.

An efficiency curve was constructed for a large-volume Ge detector located at the thermal-neutron beam line of the JRR-3M reactor at the Japan Atomic Energy Research Institute. The calibrations for γ-ray energies below 2754 keV were accomplished with a large number of radioactive sources and above 2754 keV with the $^{12}C(n,\gamma)$ and $^{14}N(n,\gamma)$ reactions. This detector and its efficiency curve were subsequently used to determine accurately the photon emission probabilities of γ rays from the decays of ^{56}Co ($T_{1/2}$=77d) and ^{66}Ga (9.5 h) and from the $^{35}Cl(n,\gamma)$ reaction. These radiation sources can serve as secondary standards for efficiency calibrations.

Research supported in part by the US Department of Energy under contract with Lockheed Martin Energy Research Corporation.

*Oak Ridge National Laboratory
**Japan Atomic Energy Research Institute

C. Research Group for Hadron Science

III-C-1

Relationship between the isovector optical potential and Direct Urca process in high-density neutron star matter in the relativistic mean-field theory

Tomoyuki Maruyama and Satoshi Chiba

A report on this subject was published as JAERI-Research 99-006 with the following abstract:

We have derived a relationship in terms of the relativistic mean-field theory between the isovector optical model potential for nucleon-nucleus interactions and the possibility of Direct Urca process in neutron star matters which leads to an anomalously fast cooling of neutron stars. It became obvious that the possibility for the Direct Urca to occur in neutron stars, i.e., whether or not the proton mixing ratio exceeds the threshold value of 1/9, is highly connected with the symmetry energy coefficient of high-density nuclear matter and the energy dependence of the isovector optical potential at the medium energy region. We hope such data would be measured in near future because they would be also important for understanding the nuclear reaction mechanisms and generating the medium-energy nuclear data.

III-C-2

Coupled-channels optical model calculations with account of nuclear volume conservation

Efrem Sh. Sukhovitskiĭ, Satoshi Chiba and Osamu Iwamoto

A paper on this subject was published in Nucl. Phys. **A646**, 19(1999) with the following abstract:

A coupled-channel formalism based on the soft-rotator model is proposed which allows conservation of the nuclear volume for dynamically deformable nuclei. The extra coupling term due to the volume conservation contributes to a stronger coupling between levels of same spin and parity. The effect is demonstrated for the case of n + ^{12}C interaction leading to the 0_2^+ state located at 7.65 MeV for incident neutron energies of 20 to 40 MeV.

III-C-3

New Options of Coupled Channels Optical Model Code OPTMAN Version 6 (1999)

Efrem Sh. Sukhovitskiĩ, Satoshi Chiba, Osamu Iwamoto and Keiichi Shibata

A report on this subject was published as JAERI-Data/Code 99-028 with the following abstract:

This report is a supplement to JAERI-Data/Code 99-019, describing new options of soft-rotator CC code OPTMAN installed on computers at JEARI Nuclear Data Center. Due to the new options, the code is now applicable for analysis of neutron and proton induced reactions simultaneously up to projectile energy of around 200 MeV.

III-C-4

^{238}U Optical Potential up to 100 MeV Incident Nucleon Energies

Efrem Sh. Sukhovitskiĩ, Satoshi Chiba, Osamu Iwamoto and Tokio Fukahori

A report on this subject was published as JAERI-Research 99-040 with the following abstract:

A coupled-channel formalism based on the axial rigid-rotor model built on a saturated coupling scheme as used for estimation of optical model potential of ^{238}U for the nucleon incident energies from 0.1 to 100 MeV. Suggested best fit parameters allow description of experimental neutron and proton scattering angular distributions and neutron total cross section data almost within experimental errors. Predicted absorption cross section for neutron above 10 MeV is 10% higher than adopted earlier. Use of the saturated coupling scheme allows reliable prediction of neutron transmissions for nucleon interaction with excited nuclear states (necessary for the statistical model calculation) as well as for interaction with the ground-state band.

III-C-5

Development of JQMD (Jaeri Quantum Molecular Dynamics) Code

K. Niita, Tos. Maruyama, Y. Nara, S. Chiba and A. Iwamoto

A report on this subject was published as JAERI-Data/Code 99-048 (1999) with the following abstract:

QMD (Quantum Molecular Dynamics) model has been proposed at the latter 80's and widely used to analyze various aspects of the heavy-ion reactions. We have developed the original QMD code (JQMD; JAERI QMD) in Advanced Science Research Center of JAERI and applied it not only to the heavy-ion reactions but also to the proton-induced reactions fo teh energy range from several 10 MeV up to 3 GeV per nucleon. Many important results obtained by using JQMD code, which have been already published in the several papers of nuclear physics and nuclear data, show that JQMD has its originality and good quality. In this report, we summarize physical models included in JQMD, explain the source code of JQMD, and describe the method to run JQMD in computers showing some examples.

III-C-6

Analysis of the Proton-induced Reactions at 150 MeV ~ 24 GeV by High Energy Nuclear Reaction Code JAM

K. Niita, Y. Nara, H. Takada, H. Nakashima, S. Chiba and Y. Ikeda

A report on this subject was published as JAERI-Tech 99-065 with the following abstract:

We are developing a nucleon-meson transport code NMTC/JAM, which is an upgraded version of NMTC/JAERI. NMTC/JAM implements the high energy nuclear reaction code JAM for the intra-nuclear cascade part. By using JAM, the upper limits of the incident energies in NMTC/JAERI, 3.5 GeV for nucleons and 2.5 GeV for mesons, are increased drastically up to several hundreds GeV.

We have modified the original JAM code in order to estimate the residual nucleus and its excitation energy for nucleon or pion induced reactions by assuming a simple model for target nucleus. As a result, we have succeeded in lowering the applicable energies of JAM down to about 150 MeV.

In this report, we describe the main components of JAM code, which should be implemented in NMTC/JAM, and compare the results calculated by JAM code with the experimental data and with those by LAHET2.7 code for proton induced reactions from 150 MeV to several 10 GeV.

It has been found that the results of JAM can reproduce quite well the experimental double differential cross sections of neutrons and pions emitted from the proton induced reactions from 150 MeV to several 10 GeV. On the other hand, the results of LAHET2.7 show the strange behavior of the angular distribution of nucleons and pions from the reactions above 4 GeV.

III-C-7

Nuclear matter structure studied with quantum molecular dynamics

Tos. Maruyama, K. Niita, K. Oyamatsu, Tom. Maruyama, S. Chiba and A. Iwamoto

A paper on this subject was published in Nucl. Phys. **A654**, 908c(1999) with the following abstract:

Quantum molecular dynamics is applied to study the ground state properties of nuclear matter at subsaturation densities. Clustering effects are observed as to soften the equation of state at these densities. The structure of nuclear matter at subsaturation density shows some exotic shapes with variation of the density.

III-C-8

Equation of State of neutron-star matter and the isovector nucleon optical model potential

Tomoyuki Maruyama and Satoshi Chiba

A paper on this subject was published in J. Phys. G.: Nucl. Part. Phys. **25**, 2361(1999) with the following abstract:

Employing the relativistic mean-field theory, relationship between the Equation of State (EoS) of neutron-star matter and the isovector optical model potential for nucleon-nucleus interaction is discussed. By utilizing such a relationship, the possibility for the Direct URCA, which is determined by the proton fraction of the neutron-star matter and gives a rapid cooling of neutron stars, is connected with the energy dependence of the isovector optical potential at the medium energy region. Therefore, the present result suggests that uncertainties in the EoS and cooling mechanism of neutron-star matter can be reduced in principle by a precise determination of the nucleon optical potential.

III-C-9

Magnetic Field Effect on Nuclear Shell Structure and Implications to Physics of Neutron Stars

V.N. Kondratyev, T. Maruyama and S. Chiba

A report on this subject was published as JAERI-Research 99-065 with the following abstract:

The effect of the magnetic field on the shell structure of nuclei is considered by employing the shell-correction treatment. Ths shift of a phase in shell-oscillations is shown to represent the main feature of the field effect. Such a phase-change is originating from the Pauli-magnetic response associated with the relative shift of spin-up and spin-down energy levels. The neutron shell-correction energy behaves almost periodically as a function of the field strength with a slightly enhanced amplitude of the shell-oscillations at a large field. The period of the sign change is determined by the energy difference between neighbour levels. The proton shell-correction energy displays an anomalous dependence on the field. The proton orbital magnetism enhances the nuclear shell effect especially when the field influence is comparable to the spin-orbit coupling. The nuclear magic numbes are demonstrated to depend considerably on the magnetic field on the strength scale $B \sim 10^{16} - 10^{17}$ G relevant for neutron stars and supernovas. Such a field is found to shift significantly nuclear magics of the iron region towards smaller mass numbers.

III-C-10

Vacuum discharge as a possible source of gamma-ray bursts

Guangjun Mao, Satoshi Chiba, Walter Greiner and Kazuhiro Oyamatsu

A report on this subject was published as JAERI-Research 99-072 with the following abstract:

We propose that spontaneous particle anti-particle pair creations from the discharged vacuum caused by the strong interactions in dense matter are major sources of γ-ray bursts. Two neutron star collisions or black hole-neutron star mergers at cosmological distance could produce a compact object with its density exceeding the critical density for pair creations. The emitted anti-particles annihilate with corresponding particles at the ambient medium. This releases a large amount of energy. We discuss the spontaneous $p\bar{p}$ pair creations within two neutron star collision and estimate the exploded energy from $p\bar{p}$ annihilation processes. The total energy could be around $10^{51} - 10^{53}$ erg depending on the impact parameter of colliding neutron stars. This value fits well into the range of the initial energy of the most energetic γ-ray bursts. We suggest to measure the anti-proton spectra from the identical sources of γ-ray bursts to test the scenario.

III-C-11

Analysis of Neutron Spectra from Thick Targets Bombarded with 710-MeV Alpha Particles by Quantum Molecular Dynamics plus Statisitcal Decay Model

Shin-ichiro Meigo, Satoshi Chiba and Kazuo Shin

A paper on this subject was published in J. Nucl. Sci. Technol. **36**, 250(1999) with the following abstract:

The spectra of neutrons produced from thick targets (water, carbon, iron and lead) bombarded with 710-MeV α-particles were calculated by using quantum molecular dynamics (QMD) plus statistical decay model (SDM). The calculation was compared with experiments. For all targets, the calculated results reproduced the experimental data much better than those calculated with the intra-nuclear cascade-evaporation (INCE) code HETC-KFA1. It was found that the neutron transport effect was important for the prediction of spectra of neutrons produced at backward angles for targets thicker than the mean free path of the neutron observed with the lowest energy in the experiment.

IV. Japan Nuclear Cycle Development Institute

A. Waste Management and Fuel Cycle Research Center

IV-A-1

Measurement of the Effective Neutron Capture Cross Section of ^{134}Cs by Triple Neutron Capture Reaction Method

Toshio KATOH[*1], Shoji NAKAMURA, Hideo HARADA,
Yuichi HATSUKAWA[*2], Nobuo SHINOHARA[*2], Kentaro HATA[*2],
Katsutoshi KOBAYASHI[*2], Shoji MOTOISHI[*2] and Masakazu TANASE[*2]

A paper on this subject was published in J. Nucl. Sci. Technol. , 36, 635(1999) with the following abstract.

The measurement of effective neutron capture cross section(σ) of ^{134}Cs was carried out with a method using a triple neutron capture reaction, $^{133}Cs(n, \gamma)^{134}Cs(n, \gamma)^{135}Cs(n, \gamma)^{136}Cs$. The target used for the experiment was natural cesium(^{133}Cs), and was irradiated for 23 days and 17 hours in the reactor JRR-3 at Japan Atomic Energy Research Institute(JAERI). The neutron field of the reactor was monitored by Au/Al and Co/Al alloy wires. A high purity Ge detector was employed for the measurement of γ-rays from the irradiated target and monitor wires. Gamma-rays emitted in the decay of ^{134}Cs and ^{136}Cs nuclides induced by single and triple neutron capture reactions of ^{133}Cs were seen at the energies of 563, 569, 605, 796, 802, 819, 1039, 1048, 1168 and 1235 keV. Decays of the 819 and the 1048 keV γ-ray intensities were followed; it was confirmed that these γ-rays originated in the ^{136}Ba, the decay product of ^{136}Cs. Data obtained were analyzed with values of neutron capture cross sections of ^{133}Cs and ^{135}Cs. The σ of ^{134}Cs obtained is 140.6 ± 8.5 barns and agrees with the value measured by Bayly et al. with a mass analysis method within the limits of error.

*1 Japan Nuclear Cycle Development Institute and
Gifu College of Medical Technology
*2 Japan Atomic Energy Research Institute

IV-A-2

Measurement of Thermal Neutron Capture Cross Section and Resonance Integral of the Reaction $^{127}I(n, \gamma)^{128}I$

Toshio KATOH[*1], Shoji NAKAMURA, Hideo HARADA, Yoshimune OGATA[*2],

A paper on this subject was published in J. Nucl. Sci. Technol., 36, 223(1999) with the following abstract.

The thermal neutron(2,200 m/s neutron) capture cross section(σ_0) and the resonance integral(I_0) of the reaction $^{127}I(n, \gamma)^{128}I$ were obtained. The targets of the iodine were irradiated within and without a cadmium capsule at Rikkyo University Research Reactor. Characteristic features of neutron field were monitored by Co/Al and Au/Al wires. Gamma-rays from the irradiated targets were measured by a high purity Ge detector. The γ-ray spectra were taken successively and the decay of peak-area counts of the 443 keV γ-ray of ^{128}I was followed. A half-life of ^{128}I obtained was 24.72 ± 0.03 min. The σ_0 and I_0 of the reaction $^{127}I(n, \gamma)^{128}I$ were deduced from the analysis of obtained γ-ray spectra according to the Westcott's convention and were 6.40 ± 0.29 barns and 162 ± 8 barns, respectively. The previous measurements of the σ_0 and I_0 of the reaction $^{127}I(n, \gamma)^{128}I$ were reviewed and differences between the present values and the previous results were discussed with special emphasis on the experimental results by Friedmann et al., whose experiment was the same as the present simultaneous measurement of the σ_0 and I_0.

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[*2] Radioisotope Center, Nagoya University

IV-A-3

Measurement of Thermal Neutron Capture Cross Section and Resonance Integral of the Reaction $^{133}Cs(n,\gamma)^{134m,134g}Cs$

Shoji NAKAMURA, Hideo HARADA and Toshio KATOH

A paper on this subject was published in J. Nucl. Sci. Technol., 36, 847(1999) with the following abstract.

The measurements of the thermal neutron (2,200 m/s neutron) cross section (σ_0) and the resonance integral (I_0) of the $^{133}Cs(n,\gamma)$ reaction were performed by an activation method to obtain fundamental data for research on the transmutation of nuclear wastes. The cross sections for the formations of the isomeric state ^{134m}Cs and the ground state ^{134g}Cs were measured respectively by following the behavior of the γ-ray counting rate after the irradiation.

The thermal neutron capture cross sections and the resonance integrals of the $^{133}Cs(n,\gamma)$ reaction were determined to be 2.70 ± 0.13 b and 23.2 ± 1.8 b for the formation of the isomeric state ^{134m}Cs, and 26.3 ± 1.0 b and 275 ± 16 b for the formation of the ground state of ^{134g}Cs. The results for the reaction $^{133}Cs(n,\gamma)^{134m+g}Cs$ were 29.0 ± 1.0 b and 298 ± 16 b, respectively. As for the thermal neutron capture cross section for the formation of $^{134m+g}Cs$, the evaluated value (29.00 b) of JENDL-3.2 agreed with the present result. The reported value by Baerg et al. was in good agreement with the present result within the limits of error on the thermal neutron capture cross section for ^{134m}Cs. On the other hand, the resonance integral for $^{134m+g}Cs$ was 32% smaller than the experimental value by Steinnes et al.

IV-A-4

Performance of n-γ pulse-shape discrimination with simple pile-up rejection at high γ-ray count rates

T. Okuda[1], H. Yamazaki[1], M. Kawabata[1], J. Kasagi[1], and H. Harada

A paper on this subject was published in Nucl. Instr. Methods., A426, 497(1999) with the following abstract.

The performance of n-γ pulse-shape discrimination for a liquid scintillation detector has been investigated for γ-ray count rate up to 50 kcps. A method in which the ratio of the total to partial charge in the anode pulse is directly measured has shown much improved quality of the pulse-shape discrimination when pile-up events are rejected; it can discriminate neutron events of 50 cps from γ-ray events of 29 kcps. The method with simple pile-up rejection has the advantage that only general purpose electronics are required.

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IV-A-5

Precise Measurements of Neutron Capture Cross Sections for FP

Shoji NAKAMURA, Hideo HARADA and Toshio KATOH

A paper on this subject was published in Proc. the 1999 Nuclear Data Symposium with the following abstract.

The thermal neutron capture cross sections (σ_0) and the resonance integrals (I_0) of some fission products (FP), such as ^{137}Cs, ^{90}Sr, ^{99}Tc, ^{129}I and ^{135}Cs, were measured by the activation and γ-ray spectroscopic methods. Moreover, the cross section measurements were done for other FP elements, such as ^{127}I, ^{133}Cs and ^{134}Cs. This paper provides the summary of the FP cross section measurements, which have been performed by authors.

IV-A-6

HIGH RESOLUTION MEASUREMENT OF TOTAL PHOTONUCLEAR CROSS SECTIONS

Hideo HARADA, Kazuyoshi FURUTAKA
Hideaki OHGAKI[1] and Hiroyuki TOYOKAWA[1]

A paper on this subject was published in Proc. the 1999 Nuclear Data Symposium with the following abstract.

A high-resolution photo-absorption spectroscopic method has been developed in order to investigate the fine structures in photonuclear reactions. To achieve an energy resolution of about 0.1% for high-energy photons (10-30 MeV), a new type of a photon spectrometer has been developed. To enhance a quality of data, the beam of laser Compton photon has been utilized. Recent progress of this new spectroscopic method is reviewed.

*1 Electrotechnical Laboratory

IV-A-7

A β-γ Coincidence Measurement System for Precise Determination of γ-ray Emission Probabilities of Short-Lived FP Nuclides

K. Furutaka, S. Nakamura, H. Harada and T. Katoh

A paper on this subject was published in Proc. the 1999 Nuclear Data Symposium with the following abstract.

For the precise determination of γ-ray emission probabilities of short-lived FP nuclides, a β-γ coincidence measurement system has been developed, which utilizes a thin plastic scintillation detector as a β-ray detector. To demonstrate the performance of the developed system, it was applied to the measurement of absolute γ-ray emission probability I_γ of short-lived nuclide, ^{28}Al ($T_{1/2}$= 2.24 (min)), whose I_γ is well known.

B. Reactor Physics Research Group

IV-B-1

Decay Heat Measurement of Minor Actinides at YAYOI

Yasushi OHKAWACHI, Akira SHONO
Reactor Physics Research Group, System Engineering Technology Division, OEC, JNC

Fission-product decay heat has been measured for fast neutorn fissions of U-235, Np-237 for beta-ray and gamma-ray. The samples were irradiated at fast neutron source reactor YAYOI, and returned to a counting room. Beta-ray energy spectra were measured using a plastic scintillation detector combined with a proportional counter to eliminate gamma-ray effects. Gamma-ray energy spectra were measured using a NaI scintillation detector. The measurements were made covering times following irradiations from 11 to 24000 seconds. And, the number of fissions were evaluated from measured gamma spectra by Ge detector.

In the future, for both beta and gamma rays, the background count will be subtracted from the pulse height distribution of 1024 channels measured. The results will be grouped by 340 channels to match the response matrix of the detector. This distribution will be converted to energy spectra using the FERDO code and the response matrix of the detector. Normalized decay heat by the number of fissions can be obtained by integration of the energy spectra for each time step. These results will be compared with the results of summation calculations using JNDC-V2 decay data file.

TAble 1. Decay Heat Measurement of Minor Actinides at YAYOI

Nuclide	Spectrum Measurement	Irradiation Time (sec)	Reactor Power (W)
U-235	β	10 , 100	500
	γ	10 , 100	500
Np-237	β	10*	1500*
		100*	1900(MAX)
		500	1900(MAX)
	γ	100*	1900(MAX)
		500	1900(MAX)

Fission Counts Measurment by Ge Detector ; All Samples before/after Irradiation.
*Irradiation Time & Reactor Power were insufficient for Fission Counts Estimation. (Tentative)

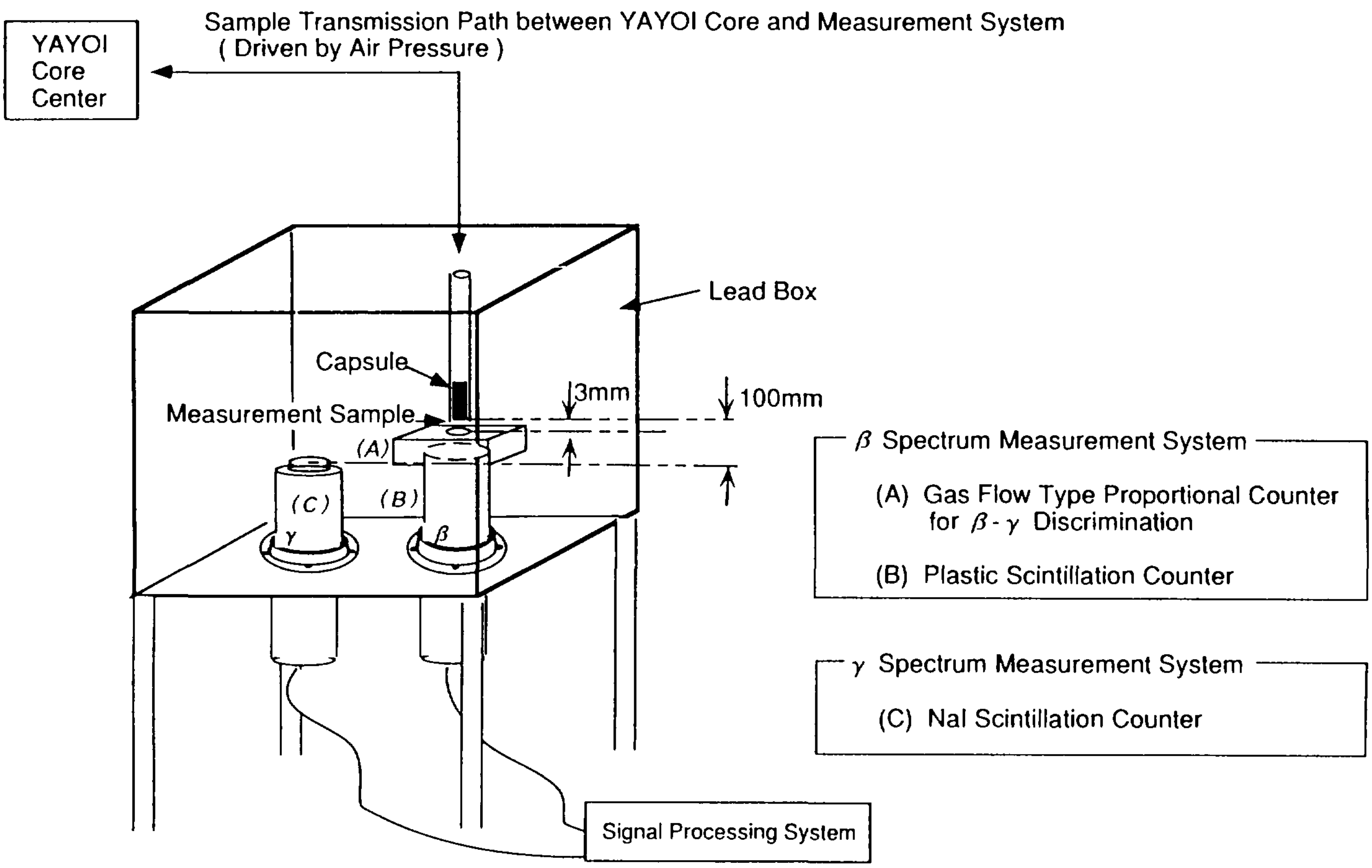

Fig 1. Conceptual View of Decay Heat Measurement

V. Kyoto University

A. Department of Nuclear Engineering

V-A-1

Modification of Photo-nuclear Cascade Evaporation Code PICA95 at Energies below 150 MeV

T. Sato, K. Shin
Department of Nuclear Engineering, Kyoto University
S. Ban, Y. Namito, H. Nakamura, H. Hirayama
KEK, High Energy Accelerator Research Organization

A paper on this subject was published in Nuclear Instruments & Methods in Physics Research A[1].

In our previous works, it was found that the photo-nuclear reaction yields evaluated by the combination of PICA95 and EGS4 tended to overestimate the experimental ones. In order to solve the discrepancy, we modified the PICA95 in following four points.

The calculation method for the cross section of quasi-deuteron disintegration (QDD) was changed without using the normalized parameter. The giant resonance was taken into account by using its cross section fitted by Lorentz curve. The parameterized in-medium nucleon-nucleon scattering cross section was substituted for that in free space. The mass formula and level density parameter used in the calculation process of evaporation was updated. The yields calculated by the modified PICA95 agreed better with experiment than with the values obtained from the original PICA95 code.

V-A-2

Experimental Setup for Measurements of High Energy Photo-Neutron Spectra from Thick Targets

T. Sato, K. Shin, R. Yuasa
Department of Nuclear Engineering, Kyoto University
S. Ban
KEK, High Energy Accelerator Research Organization
H. Lee, G. Kim
Pohang Accelerator Laboratory, POSTECH

A paper on this title was reported in 9th International Conference of Radiation Shielding, held in Oct.17-22, 1999, Tsukuba, Japan, and is to be published as a paper of J. Nuclear Science and Technology: Supplement.

Photo-neutron spectra produced by 2.04 GeV electron incident on thick Al, Cu, Sn and Pb targets were measured by TOF method. The experimental arrangement is showed in Fig. 1. An efficiency of used detector POLOT-U was calculated by SCINFUL and Cecil's code. The efficiency was also measured for neutron energies at 14.9, 35, 70, 90 and 135 MeV to confirm the calculated results. However, there is a discrepancy between those two results. A lead attenuator was placed at th e middle point of the flight path to suppress gamma flash signals. The thickness of the attenuator was changed from 10 cm to 30 cm for each target, and the effects of the attenuator on the neutron spectra were calculated by a combination of slightly changed LAHET code and ENDF- HE/VI data.

Obtained neutron spectra from each attenuator case agreed with each other for neutron energy from 10 MeV to 300 MeV. As an example of neutron spectra, those from the10-radiation length lead target obtained with two flight path lengthsare compared with modified PICA95/EGS4 calculation in Fig. 2.

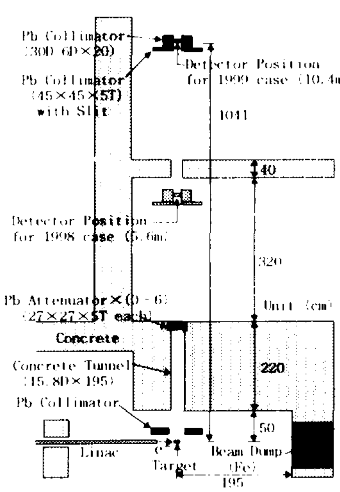

Fig. 1 Experimental setup

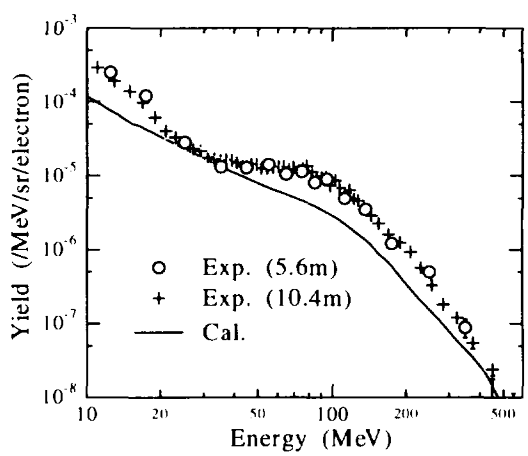

Fig. 2 Neutron spectra for lead target

Reference
1. Nuclear Instruments & Methods in Physics Research A 437, 471-480 (1999).

B. Research Reactor Institute

V-B-1

Measurement of Neutron Total Cross-Sections of Dy and Hf in the Energy Region from 0.002 eV to 100 keV

Hyun-Je Cho[1*], Katsuhei Kobayashi[1], Shuji Yamamoto[1], Yoshiaki Fujita[1], Youngseok Lee[2], Guinyun Kim[2], and Seung Kook Ko[3]

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3 Department of Physics, University of Ulsan
San 1, Mooge-dong Nam-gu, Ulsan 680-749, Korea

A paper on this subject was presented at the 1999 Symposium on Nuclear Data at Tokai-mura, JAERI held on Nov. 18-19, 1999.

The neutron total cross-sections of Dy and Hf have been measured in the energy region from 0.002 eV to 100 keV by the neutron time-of-flight method with a 46 MeV electron linear accelerator (linac) of the Research Reactor Institute, Kyoto University. A ^{6}Li glass scintillator has been used as a neutron detector and metallic plates of Dy and Hf samples, 0.5 to 5.0 mm thick, have been applied to the neutron transmission measurement. The neutron flight path from the water-cooled Ta target to the ^{6}Li glass scintillator is 22.1±0.01 m. The background level has been determined by the block-off method and/or by using notch-filters of Co (132 eV), Ag (5.2 and 16.3 eV) and Mn (336 eV) and a Cd sheet. The figures show the present measurements, the previous data and the evaluated data in ENDF/B-VI.

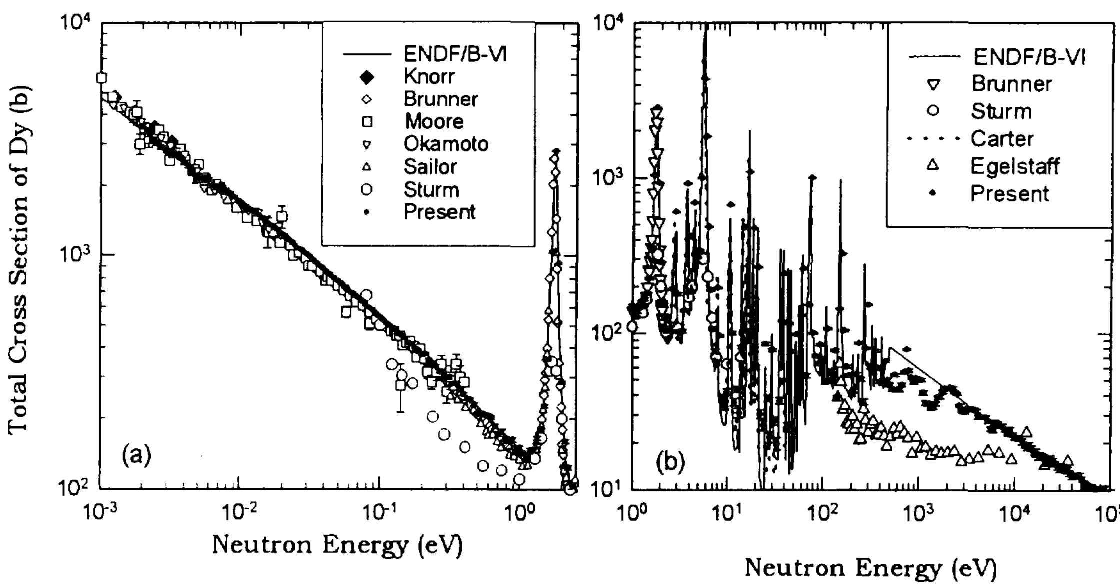

Figure. Comparison of neutron total cross section of Dy.

V-B-2

Capture Cross Section Measurement of Np-237 below 1 keV with Lead Slowing-down Spectrometer

Katsuhei Kobayashi[1], Hyun-Je Cho[1*], Shuji Yamamoto[1], Takaaki Yoshimoto[1], Yoshiaki Fujita[1], and Yasushi Ohkawachi[2]

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Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan
* Visiting Scientist from University of Ulsan, Korea
2 Oarai Engineering Center, Japan Nuclear Cycle Development Institute
Narita, O-arai, Ibaraki 311-1393, Japan

A paper on this subject was presented at the 1999 Symposium on Nuclear Data at Tokai-mura, JAERI held on Nov. 18-19, 1999.

Making use of a lead slowing-down spectrometer (KULS) driven by a 46 MeV electron linear accelerator (linac), the relative capture cross section of Np-237 has been measured in the neutron energy region from 0.01 eV to 1 keV with energy resolution of about 40 % (FWHM) in the KULS. The oxide powder of neptunium NpO_2 was packed in an aluminium can and the effective size of the sample was 20 mm in diameter and 1.4 mm thick. The capture cross section measurement has been carried out by measuring prompt capture gamma-rays from the neptunium sample using an Ar-gas proportional counter. The neutron flux/spectrum at the irradiation position in the KULS has been monitored with a BF_3 proportional counter. The $^{10}B(n,\alpha)$ reaction is a well-known cross section showing a good 1/v energy dependency. The result has been normalized to the reference value of the $^{237}Np(n,\gamma)$ ^{238}Np reaction at 0.0253 eV, and compared with the experimental/evaluated data. The figure shows the present measurement, the previous data and the evaluated data broadened by the resolution function of the KULS.

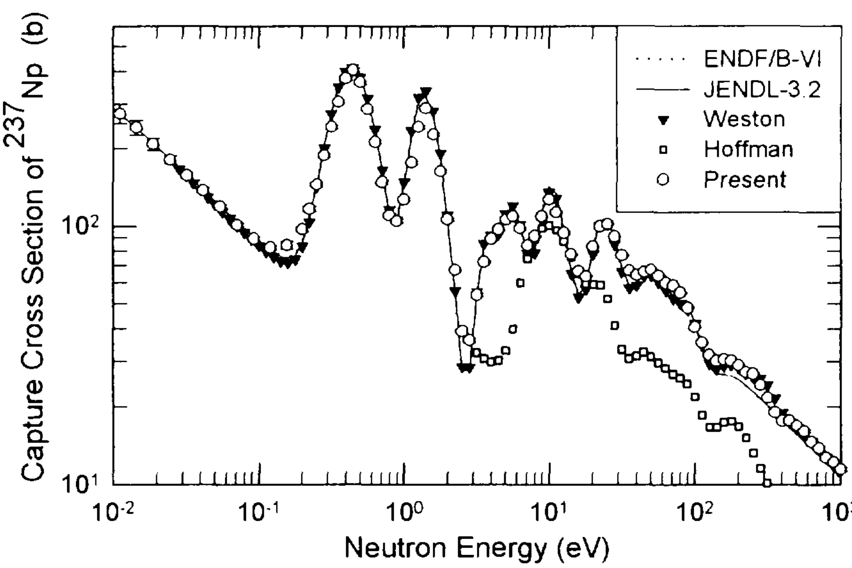

Figure. Comparison of the capture cross sections for the $^{237}Np(n, \gamma)$ reaction.

V-B-3

Fission Cross Section Measurements of Th-229 and Pa-231 using Linac-driven Lead Slowing-down Spectrometer

Kobayashi, K.[1], Yamamoto, S.[1], Kai, T.[1*], Cho, H.J.[1**], Yamana, H.[1], Fujita, Y.[1], Mitsugashira, T.[2] and Kimura, I.[3***]

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2 The Oarai-branch, Institute for Material Research, Tohoku University
3 Department of Nuclear Engineering, Kyoto University
* Present address: Japan Atomic Energy Research Institute
** Visiting scientist from University of Ulsan, Korea
*** Present address: Institute of Nuclear Technology, Institute of Nuclear Safety System, Inc

A paper on this subject was present at the 1999 Symposium on Nuclear Data at Tokai-mura, JAERI held on Nov. 18-19, 1999.

Making use of a back-to-back type double fission chamber and Kyoto University Lead slowing-down Spectrometer (KULS) driven by a 46 MeV electron linear accelerator (linac) at the Research Reactor Institute, Kyoto University (KURRI), the neutron-induced fission cross sections of Th-229 and Pa-231 have been measured relative to the $^{235}U(n,f)$ reaction from ~0.1 eV to 10 keV with energy resolution (FWHM) of about 40 %. Each of the measured result has been compared with the evaluated data in ENDF/B-VI, JENDL-3.2 and JEF-2.2, whose data were broadened by the energy resolution of the KULS. The experimental data for the fission cross sections of Th-229 and Pa-231 have scarcely been obtained before in the relevant energy region.

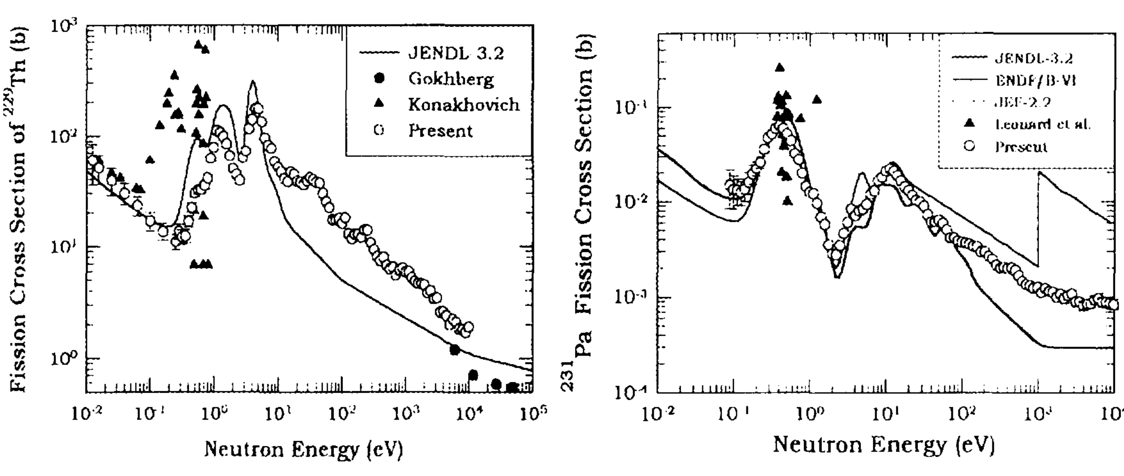

Figure. Comparison of the current measurement and the experimental/evaluated fission cross sections of Th-229 and Pa-231. The evaluated data are broadened by the energy resolution of the KULS.

VI. Kyushu University

A. Department of Advanced Energy Engineering Science

VI-A-1

The $^{12}C(p, p'3\alpha)$ breakup reaction induced by 14, 18 and 26 MeV protons

M. Harada, Y. Watanabe, A. Yamamoto, S. Yoshioka, K. Sato, T. Nakashima, H. Ijiri, H. Yoshida*, Y. Uozumi*, N. Koori**, S. Meigo†, O. Iwamoto†, T. Fukahori†, and S. Chiba†

A paper on this subject was published in *J. Nucl. Sci. and Technol.*, **36**, 313 (1999) with the following abstract:

Double-differential cross sections (DDXs) of emitted protons and α particles were measured for proton-induced reactions on ^{12}C at 14, 18, and 26 MeV in order to investigate the $^{12}C(p, p'3\alpha)$ breakup reaction. The experimental DDXs were analyzed on the assumption that the $(p, p'3\alpha)$ reaction proceeds through two major processes, a three-body simultaneous breakup (3BSB) process (*i.e.*, $p + {}^{12}C \rightarrow p + \alpha + {}^{8}Be^{*}_{2.94\mathrm{MeV}}$) and sequential decay processes from unstable nuclei produced by (p, p') and (p, α) reactions (*i.e.*, ^{12}C, ^{9}B, ^{8}Be and ^{5}Li). Partial cross sections for the various reaction channels was extracted from the measured DDXs by a least square method with two fitting functions: a three-body phase distribution function for the 3BSB process and a Breit-Wigner function for the transition to a discrete level in the first step of the sequential decay process. The result showed that the $^{12}C(p, p'3\alpha)$ reaction took place predominantly *via* nearly isotropic particle emission in the 3BSB process, and emission of protons and α particles with low energies was explained well by the sequential decay *via* $^{12}C^{*}$ and $^{9}B_{g.s.}$. Experimental (p, p) and (p, p') scattering cross sections at 26 MeV were reproduced well by the coupled-channels calculation with the soft-rotator model. The experimental DDXs were compared with a Monte Carlo claculation based on the SCINFUL/DDX code and the latest intermediate energy nuclear data evaluation library LA150.

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**Faculty of Integrated Arts and Sciences, The University of Tokushima
†Japan Atomic Energy Research Institute

VI-A-2

Measurement of Double Differential Cross Sections of Secondary Charged-Particles Produced by Proton-Induced Reaction at Several Tens of MeV

M. Harada, Y. Watanabe, A. Yamamoto, Y. Tanaka, Sun Weili, K. Shin*, S. Meigo†, O. Iwamoto†, H. Nakashima†, H. Takada†, S. Chiba†, T. Fukahori†, T. Sasa†, and S. Tanaka†

A paper on this subject was presented at the Ninth Int. Conf. on Radiation and Shielding (ICRS-9), Oct. 17-22, 1999, Tsukuba, Japan, with the following abstract:

Double differential cross secitons (DDXs) were measured for light-charged particles production in proton-induced reactions on ^{12}C and ^{27}Al at two incident energies of 42 and 68 MeV. The measured DDXs were in generally good agreement with the LA150 evaluation, except for the (p, xd) reaction. The experimental angular distributions of proton elastic and inelastic scattering from ^{12}C showed fairly good agreement with a coupled-channels calculation based on the soft-rotator model.

*Department of Nuclear Engineering, Kyoto University
†Japan Atomic Energy Research Institute

VI-A-3

Semiclassical distorted wave model analysis of multistep direct $(p, p'x)$ and (p, nx) reactions to the continuum

Y. Watanabe, R. Kuwata, Sun Weili, M. Higashi, H. Shinohara,
M. Kohno*, K. Ogata**, and M. Kawai**

A paper on this subject was published in *Phys. Rev. C* **59**, 2136 (1999) with the following abstract:

The semiclassical distorted wave (SCDW) model is extended to include three-step process in multistep direct (MSD) processes in nucleon-induced preequilibrium nucleon-emission reactions. The extended SCDW model is applied to analyses of MSD processes in ^{58}Ni$(p,p'x)$, ^{90}Zr$(p,p'x)$, ^{90}Zr(p,nx), and ^{209}Bi$(p,p'x)$ in the incident energy range of 62 – 160 MeV. SCDW calculations with no adjustable parameter give overall good agreement with experimental double differential cross sections, except at very small and large angles. The nonlocality of distorting potentials is taken into account in terms of the Perey factor, and is found to be essential for reproducing the absolute magnitude of the cross sections. Effects of the density and momentum distributions of target nucleons and the use of in-medium N-N cross sections on the SCDW calculation are discussed. Comparison with other models is made, in particular regarding the contributions of individual multistep processes to the calculated cross sections. Validity of the local semiclassical approximation to distorted waves, which is essential to SCDW is discussed on the basis of a numerical test.

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**Department of Physics, Kyushu University

VI-A-4

Theoretical modification on semiclassical distorted wave model and its application to the study of spin observables

K. Ogata*, M. Kawai*, Y. Watanabe, Sun Weili, and M. Kohno**

A paper on this subject was published in *Phys. Rev. C* **60**, 054605 (1999) with the following abstract:

The semiclassical distorted wave (SCDW) model of nucleon inelastic and charge exchange scattering at intermediate energies is modified to take accurate account of off-the-energy-shell matrix elements of the in-medium N-N interaction and explicit account of the exchange of colliding two nucleons, making use of the G matrix parameterized in coordinate representation. The effects of the modification on the double differential inclusive cross sections are discussed for the case of $(p,p'x)$ and (p,nx) reactions on ^{90}Zr at 160 MeV. The modification enables the SCDW model to calculate spin observables. The depolarizations in ^{58}Ni$(p,p'x)$ at 80 MeV, ^{90}Zr$(p,p'x)$ and ^{90}Zr(p,nx) at 160 MeV by one- and two-step processes are calculated, and the result for ^{58}Ni$(p,p'x)$ is compared with experimental data. The calculated spin flips for $(p,p'x)$ and (p,nx) on ^{90}Zr are analyzed in terms of the effects of in-medium modification of the N-N interaction and the contributions of individual components of the effective interaction.

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**Physics Division, Kyushu Dental College

VI-A-5

Semiclassical distorted wave model with Wigner transform of one-body density matrix

Sun Weili, Y. Watanabe, M. Kohno*, K. Ogata**, and M. Kawai**

A paper on this subject was published in *Phys. Rev. C* **60**, 064605 (1999) with the following abstract:

A semiclassical distorted wave (SCDW) model with realistic single particle wave functions in a finite range single particle potential is presented for multistep direct processes in nucleon inelastic scattering and charge exchange reactions to the continuum, making use of the Wigner transform of one-body density matrix. The higher momentum components of target nucleons are properly taken into account in comparison with the previous SCDW model with a local density Fermi gas model. The new SCDW model still gives a simple closed-form expression for the cross section with no free adjustable parameter which allows a simple intuitive interpretation, just as in the previous SCDW model. This model is applied to the analyses of multistep direct processes of $^{90}\mathrm{Zr}(p,p'x)$ reactions at incident energies of 80 and 160 MeV. The calculated double differential cross sections including up to three-step processes are compared with experimental data. The calculated cross sections at backward angles are larger than those given by the previous calculations, and the agreement with experimental data is much improved. Discussions on the mechanism of this improvement are given in terms of the momentum distribution of target nucleons.

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**Department of Physics, Kyushu University

VI-A-6

Estimation of Energy Dependence of the Optical Potential Parameters for ^{209}Bi

T. Kawano

A paper on this subject was published in *Nucl. Sci. Eng.*, **131**, 107 (1999) with the following abstract:

A parameter estimation method based on a Bayes' theorem is applied to the parameters of the neutron optical potential for ^{209}Bi. The potential parameters at a certain energy are determined according to an assumption that parameters vary gradually with the incident neutron energies, and it is demonstrated that the method can be used as an efficient tool for investigating the energy dependence of the optical potential parameters.

The derived potential parameters are expressed by both a polynomial function and a Brown-Rho parameterization, and the energy dependencies are interpreted by a dispersion relation theory. Both expressions of the energy dependent parameters give a good description of the experimental elastic scattering cross section and the total cross section.

VI-A-7

Evaluation of Covariance for Fission Neutron Spectra

T. Kawano, T. Ohsawa†, K. Shibata‡, and H. Nakashima

A paper on this subject was published in *JAERI-Research* 99-009, (1999) with the following abstract:

A covariance evaluation system for the evaluated nuclear data library JENDL-3.2 was established, and the covariance data for fission spectra of ^{233}U, ^{235}U, ^{238}U, ^{239}Pu were evaluated. Two methods were employed to evaluate the covariance. The first one is based on the experimental data, and the second one is based on a model calculation including some kinds of renormalizations. The later technique was adopted for the covariance evaluation for the evaluated fission spectra in JENDL-3.2. We performed an adjustment of the evaluated fission spectrum of ^{235}U using the spectrum averaged cross section of ^{27}Al(n,p), ^{46,47,48}Ti(n,p), ^{54,56}Fe(n,p), ^{58}Ni(n,p), ^{90}Zr$(n,2n)$ reaction. It was demonstrated that the adjusted sperctrum is normalized to unity.

† Department of Nuclear Engineering, Kinki University
‡ Japan Atomic Energy Research Institute

VI-A-8

Microscopic Calculation of the Multistep Compound Process

T. Kawano

A paper on this subject was published in *Phys. Rev.*, *C* **59**, 865 (1999) with the following abstract:

The Feshbach, Kerman, and Koonin model of statistical multistep compound (MSC) process is calculated microscopically, and comparisons of the microscopically calculated MSC process with a phenomenological phase space model are made. The microscopic model gives small particle emission probability in comparison with the constant wave function approximation, and a simple way to get rid of the difference is proposed. A $2p$-$1h$ doorway state formation cross section is calculated with the spherical Nilsson model, and a strength of the residual interaction V_0 is estimated from the doorway state formation cross section. The obtained V_0 is in the same magnitude as those derived in the previous MSD analyses. Comparisons of the microscopic MSC calculations with the experimental data show that the calculated particle emission spectra reproduce the measurements at backward angles.

VI-A-9

Analysis of ^{58}Ni(n, α) Reaction Cross Sections with the Hauser-Feshbach Statistical Theory and the Bayesian Parameter Estimation Method

T. Kawano, T. Sanami*, M. Baba*, and H. Nakashima

A paper on this subject was published in *J. Nucl. Sci. Technol.*, **36**, 256 (1999) with the following abstract:

Experimental data of ^{58}Ni(n,α) reaction cross sections are analyzed with the Hauser-Feshbach statistical model with the width fluctuation correction by Moldauer. A neutron optical potential which was derived from neutron induced reaction data is used for an entrance channel in order to fix the total reaction cross sections at reliable values. Global optical potentials are used for the proton and α-particle emission channels, and level density parameters of the residual nuclei are determined from the cumulative plot of discrete levels. These parameters are adjusted to the experimental data of ^{58}Ni(n,α) and (n,p) reaction cross sections, including the angular distribution of the emitted α-particles. The obtained parameters yield a good fit to the experimental cross sections of those reactions up to 8 MeV.

* Department of Quantum Science and Energy Engineering, Tohoku University

VI-B-1

Measurement of the continuum spectra from (p,p'x) reaction at 392 MeV

S. Aoki, Y. Uozumi, Cao Bin, J. Tanaka, H. Saiho, G. Wakabayashi, M. Matoba, M. Nakano *, T. Maki *, N. Koori †

We measured inclusive spectra of (p,p') reactions with a very wide emission energy range at RCNP under the program number E116. The measurements were carried out using a 392-MeV proton beam on four targets (^{12}C, ^{27}Al, ^{93}Nb and ^{197}Au) in December 1998. Each target was placed at the center of a scattering chamber with a 1 m diameter in the ES course. Two stacked GSO spectrometers [1] were set on a goniometer surrounding the 1 m chamber to measure angular distribution between 20 deg. and 104 deg.

Preliminary results of double differential cross sections for ^{12}C and ^{197}Au are displayed in Fig. 1 in comparison with QMD (Quantum Molecular Dynamics) [2] calculations. In the case of the ^{12}C(p,p'x) reaction, reasonable agreement are seen in the forward angle region < 90 deg. At the backward, $\theta = 104$ deg., the QMD goes down too quickly with increasing emission energy Ep'. By comparing the ^{197}Au(p,p'x) reaction data with QMD, we found that the QMD calculation gives very poor accounts. Large disagreement is observed at especially forward angles, by factors 5 − 6. As a conclusion, improvement of microscopic theories is indispensable to develop reliable calculations of radiation transport simulations.

References:

1) K. Anami *et al.*, Nucl. Instr. Meth. A 404 (1998) 327; H. Yoshida *et al.*, *ibid.*, A 411 (1998) 46.
2) K. Niita *et al.*, Phys. Rev. C 52 (1995) 2620.

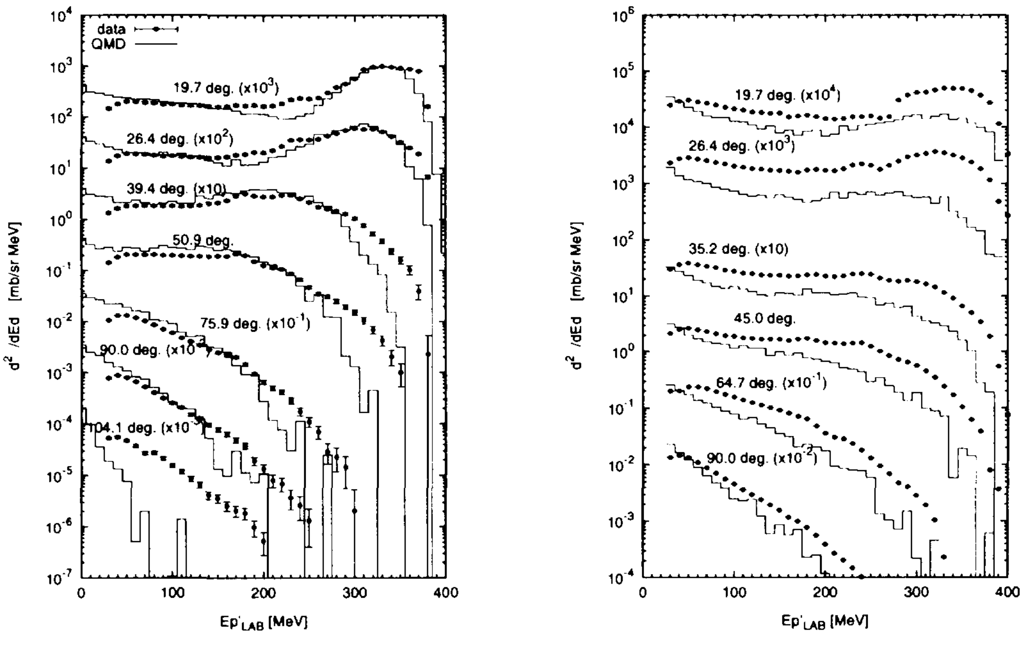

Figure 1: Double differential cross sections for the reaction of (p,p'x) at 392 MeV with ^{12}C (left hand side) and ^{197}Au (right hand side) targets.

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VII. Nagoya University

A. Department of Energy Engineering and Science

VII-A-1

Measurement of neutron activation cross sections in the energy range between 2 and 7 MeV by using a Ti-deuteron target and a deuteron gas target

T. Senga, H. Sakane, M. Shibata, H. Yamamoto, K. Kawade,
Y. Kasugai*, Y. Ikeda* and H. Takeuchi*

A paper on this subject will be published in Proceedings of the 1999 symposium on Nuclear Data, Nov. 18-19,1999, JAERI Tokai, with the following abstract.

Using a Ti-deuteron target in the neutron energy range between 2 and 4.5 MeV and a deuteron gas target between 4.5 and 7 MeV, mono-energetic neutrons could be generated enough for activation cross section measurements. The KN-3750 Van de Graaff accelerator at Nagoya University and the Fusion Neutronics Source (FNS) at Japan Atomic Energy Research Institute (JAERI) were used. Preliminary results of activation cross sections were obtained for reactions of $^{27}Al(n,p)^{27}Mg$, $^{47}Ti(n,p)^{47}Sc$, $^{58}Ni(n,p)^{58}Co$. The evaluation data of JENDL-3.2 showed reasonable agreement with our results.

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

VII-A-2

Systematics of (n,n'p) reaction cross sections by 14 MeV neutron

H. Sakane, M. Shibata, K. Kawade, Y. Kasugai* and Y. Ikeda*

A paper on this subject will be published in Proceedings of the 1999 symposium on Nuclear Data, Nov. 18-19,1999, JAERI Tokai, with the following abstract.

Systematics of (n,n'p) reaction cross section in the energy range between 13.4 and 14.9 MeV were studied on the basis of experimental data measured by the Nagoya and Fusion Neutronics Source groups. Our group have been measured 31 (n,n'p) reaction cross section. In present work, 8 (n,n'p) cross sections were newly measured in the neutron energy range between 13.4 and 14.9 MeV by using a high efficiency well-type HPGe detector. The measured isotopes were ^{113}Cd, ^{123}Te, ^{148}Nd, ^{160}Gd, ^{170}Er, ^{174}Yb, ^{184}W and ^{186}W. Preliminary empirical formulae of a cross section at 14.7 MeV based on 37 data were deduced as a function (N-Z+2)/A, where N, Z and A are neutron, proton and mass numbers of the target nuclei. Comparing the experimental data with the calculated value, we estimated that the accuracy of the proposed empirical formulae was ±50 %.

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

VII-A-3

Preparation of 3-7 MeV neutron source and preliminary results of activation cross section measurement

T. Furuta, H. Sakane, T. Masuda, Y. Tsurita, A. Hashimoto, N. Miyajima, M. Shibata, H. Yamamoto, and K. Kawade

A paper on this subject was published in Proceedings of the 1998 symposium on Nuclear Data, JAERI-Conf 99-002, pp.186-191, with the following abstract.

A d-D gas target producing monoenergetic neutrons has been constructed for measurement of activation cross sections in the energy region of 3 to 7 MeV at Van de Graaff accelerator of Nagoya university. Neutron spectra and neutron fluxes were measured as a function of the incident deuteron energy. Preliminary results of activation cross sections were obtained for reactions $^{27}Al(n,p)^{27}Mg$, $^{27}Al(n,\alpha)^{24}Na$, $^{47}Ti\ (n,p)^{47}Sc$, $^{56}Fe(n,p)^{56}Mn$, $^{58}Ni(n,p)^{58}Co$ and $^{64}Zn(n,p)^{64}Cu$. The results are compared with the evaluated values of JENDL-3.2. A well-type HPGe detector was used for highly efficient detection.

VII-A-4

Measurement of cross sections in the region of sub-mbarn by 14 MeV neutron with well-type HPGe detector

H. Sakane, M. Shibata, H. Yamamoto, K. Kawade, Y. Kasugai* and Y. Ikeda*

A paper on this subject was published in Proceedings of the 1998 symposium on Nuclear Data, JAERI-Conf 99-002, pp.210-215, with the following abstract.

Seven neutron activation cross sections were newly measured at energy range between 13.4 and 14.9 MeV by a high efficiency well-type HPGe detector. The cross sections of the $^{95}Mo(n,n'p)^{94m}Nb$, $^{100}Mo(n,n'p)^{99m}Nb$, $^{116}Cd(n,np)^{115g}Ag$, $^{123}Te(n,n'p)^{122m}Sb$ and $^{176}Yb(n,np)^{175}Tm$ reactions were obtained for the first time. The cross section of $^{176}Yb(n,\alpha)^{173}Er$ and $^{190}Os(n,p)^{190g}Re$ reactions were obtained at the six energy points between 13.4 and 14.9 MeV, although the previous results had been obtained at one energy point.

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VII-A-5

Precision of fission product yield and decay data required for practical delayed-neutron summation calculations

K. Oyamatsu
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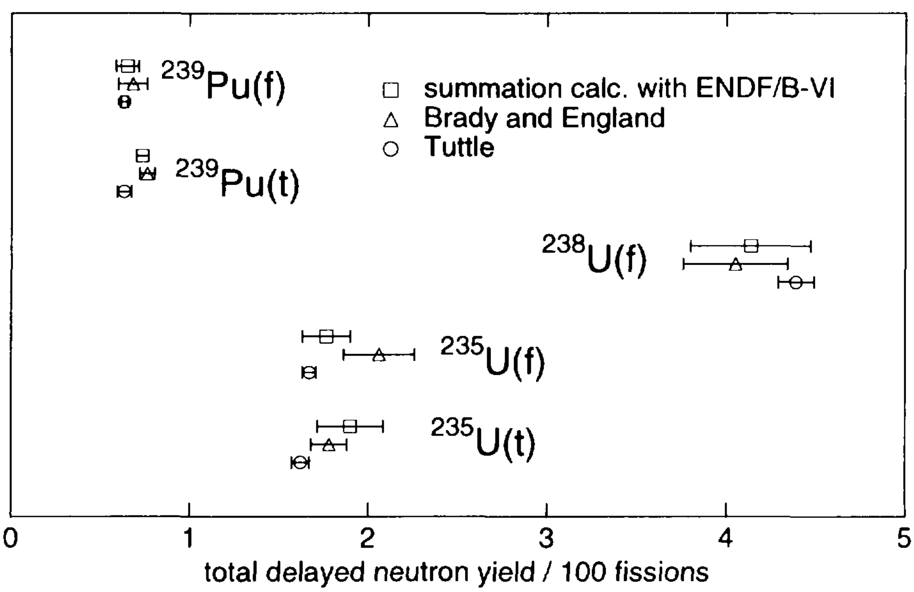
A paper on this subject was published in Proc. the Specialists' Meeting on Delayed Neutron Nuclear Data (JAERI-Conf 99-007, pp. 1-10, 1999).

This paper focuses on the precision of Fission Product (FP) yield and decay data required for delayed-neutron (DN) summation calculations. In this study, DN summation calculations and their sensitivity calculations to the input data are performed with fission yields and decay data in ENDF/B-VI. Uncertainties in the total delayed neutron yields are found to be about 10% even for ^{235}U, ^{238}U and ^{239}Pu. These values are much larger than the required precision (5%) to realize practical DN summation calculations. Their time dependence in the DN summation calculations seems to have similar behavior to Tuttle's evaluation. However, it is found that there exists marked difference between the two evaluations beyond their uncertainties for the DN activity after infinite irradiation at about 30 s. This differnce are found to stem primarily from the independent fission yields and secondly from the DN emission rates of ^{87}Br, ^{137}I, ^{136}Te, ^{88}Br and ^{138}I for ^{238}U(fast). It is concluded that the summation calculations would be greatly improved by precise determination of these values for the five nuclides.

Errata : In Fig. 3 of this paper, names of fissioning systems were printed incorrectly (in the reverse order). The correct figure is shown below.



VII-A-6
Key precursor data in aggregate delayed-neutron calculations

T.Sanami, K.Oyamatsu, Y.Kukita
Department of Energy Engineering and Science, Nagoya University

A paper on this subject was published in Proc. 1998 Nuclear Data Symposium (JAERI-Conf 99-002, pp. 120-123, 1999) with the following abstract.

The reactivity calculations with the delayed neutron (DN) six-group parameter sets in ENDF/B-VI were reported to give significant underestimates for long period (tens of seconds). The parameter sets were obtained form the summation calculations with ENDF/B-VI fission yields and decay data files. In this paper, we try to identify the precursor data that cause the significant underestimates. Because of the relatively long time scale, we examine the DN activity after infinite irradiation, and find that the summation calculation gives significantly smaller DN activity at about 30 s than the currently used six-group parameter set by Tuttle, although this feature does not looks important for the DN activity after a fission burst. From the time dependence of the DN activity, we find that the fission yields of ^{88}Br, ^{136}Te, and ^{137}I are the most probable sources for the underestimate. Furthermore, in order to achieve the required precision (5 %) for the DN activity, it is also necessary to perform precise measurements of their Pn values.

VII-A-7
Decay Heat Calculation for Minor Actinides in the Hybrid Method

H. Takeuchi, K. Oyamatsu, Y. Kukita
Department of Energy Engineering and Science, Nagoya University

A paper on this subject was published in Proc. 1998 Nuclear Data Symposium (JAERI-Conf 99-002, pp. 124-129, 1999) with the following abstract.

For evaluation of decay heat from the fission of minor actinides (MAs) we are currently forced to rely only on summation calculations since there has been no direct measurement for these nuclides. In this paper, we use an alternative approach (named "hybrid" method) to evaluate the MA decay heat power using the measured decay heat powers for major actinides at YAYOI. Results for the fast fissions of ^{237}Np, ^{241}Am, ^{243}Am, ^{242}Cm and ^{244}Cm are in support of the summation calculations for β decay heat, but suggest notable uncertainties in γ decay-heat summation calculations.

VII-A-8
Easy-to-use Application Programs to Calculate Aggregate Fission-Product Properties on Personal Computers

K. Oyamatsu

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e-mail : oyak@luna.nucl.nagoya-u.ac.jp

A paper on this subject was published in Proc. 1998 Nuclear Data Symposium (JAERI-Conf 99-002, pp. 234-239, 1999) with the following abstract.

Fission Products (FP) are dominant sources of activities in spent nuclear fuels over tens of years. Small Fortran programs for personal computers have been developed primarily to study the aggregate FP decay heat and delayed-neutron activities with the latest fission yield and decay data in Japanese, US and European Nuclear Data libraries. This paper describes how to use these programs together with two new features of our codes; i) unified front-end ii) capability of calculating the aggregate β and γ decay energy spectra.

VIII. National Defense Academy

A. Department of Mathematics and Physics

VIII-A-1

Folded-Potential Model Calculation of Low Energy Neutron Direct-Capture Cross Sections

Hideo Kitazawa, Masayuki Igashira[1], and Toshiro Ohsaki[1]

A paper of this title will be published in the Proc. 10th Int. Symp. on Capture Gamma-Ray Spectroscopy and Related Topics (Santa Fe, 1999) with the following abstract.

Low-energy neutron capture cross sections of ^{16}O are obtained from the direct-capture model, using the folded potential calculated with the nuclear density distribution and the effective nucleon-nucleon interaction DDM3Y. As a result, it is found that the model calculations reproduce the observed cross sections excellently.

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[1]Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology

IX. Osaka University

A. Department of Nuclear Engineering

IX-A-1

Measurement of Double Differential Cross Sections of Charged Particle Emission Reactions by Incident DT Neutrons
—Correction for Energy Loss of Charged Particle in Sample Materials—

A. Takahashi, H. Takagi, Y. Terada and I. Murata

A paper on this subject was presented at the 1999 Symposium on Nuclear Data and published in JAERI-Conf. 2000, with the following abstract.

Correction for the energy loss of charged particle in sample materials is a serious problem in measurement of charged particle emission spectrum induced by neutron. Recently, a new simple method has been developed for unfolding various measured radiation spectra by extending Bayes theorem [1]. In the present study, we have, thus, tried to apply this method to our experimental data of charged particle emission cross-section measured by the E-TOF two-dimensional analysis at OKTAVIAN of Osaka University [2].

In the past, our experimental data (double differential charged particle emission cross section (DDXc) induced DT neutrons) were corrected by the conventional method based on an assumption that any charged particle passes half thickness of sample material. This method was applicable if only the energy loss could be suppressed to very small value by using a thin sample foil. However, recently elements that cannot be supplied as an enough thin sample are planning to be used for cross section measurement, like light elements. In this study, focusing on a measurement containing remarkable energy loss in the sample material as a result of using a thick sample foil, we developed an unfolding code based on Bayes theorem to correct the energy loss.

Bayes' unfolding method is applicable to almost all kind of radiation measurement analysis. There are some variations in the Bayes' estimation method. In this work, we applied *spectrum type Bayes estimation method* to our charged particle spectrum unfolding problem. In the method, estimation calculation can be realized using just measured pulse height spectrum (histogram) data.

The estimation procedure is expressed as

$$est_j^{(l+1)} = \sum_i^m \left(d_i \times \frac{est_j^{(l)} \times r_{ij}}{\sum_j^n est_j^{(l)} \times r_{ij}} \right) \qquad ,(j = 1, n)$$

where r_{ij} called *likelihood* is the response of the detection system which provides the probability of a detection event giving pulse height h_i for the charged particle energy E_j. d_i is detected pulse height spectrum. $est_j^{(l)}$ is estimated spectrum revised by lth estimation calculation. The above formula is repeatedly used for the pulse height spectrum d_i in this work. Revised $est_j^{(l)}$ is used for prior information to next revise calculation.

In order to verify the above method in the charged particle spectrum unfolding problem, we applied this method to numerical simulation and practical measured results; i.e., α -particles measurement and spectrum unfolding for incident DT neutron in ^{27}Al samples (60mm ϕ × 10 μ m, 25 μ m, 100 μ m thick). α -particles were detected by a CsI(Tl) scintillator (2" ϕ ×2mm thick).
All the results showed the validity of this method. Although this method is very simple, it was found that the performance was not inferior to other methods at all. Thus, we confirmed that this method could be a powerful unfolding tool for charged particle spectrum measurement.

References:
[1] S. Iwasaki: "A New Approach for Unfolding Problems Based Only on the Bayes' Theorem", 9th International Symposium on Reactor Dosimetry, Prague, Chezk, Sep. 2-6, (1996).
[2] A. Takahashi, *et al.*: "A Time-of-Flight Spectrometer with Pulse-Shape Discrimination for Measurement of Double Differential Charged-Particle Emission Cross Section", Nucl. Instr. Meth., A401, 93(1997).

IX-A-2

Measurements of ^{9}Be(d,x) and ^{9}Be(p,x) Reaction Cross Sections at Low Energy

A. Takahashi, K. Ishii, K. Ochiai, H. Miyamaru and I. Murata

A paper on this subject was presented at the 1999 Symposium on Nuclear Data and published in JAERI-Conf. 2000, with the following abstract.

The DDXs of ^{9}Be(d,p_0),(d,t_0),(d,α_0) and (d,α_1) reactions were successfully obtained for deuteron energies between 90 and 290 keV[1]. And also the cross sections of ^{9}Be(p,α) and (p,d) reactions were measured for proton energies between30 and 300 keV. At low energy region, it seemed that all the obtained S-values of ^{9}Be(d,x) were enhanced by electron screening effect. As for the ^{9}Be(d,p_0)^{8}Be reaction, a backward-oriented angular distribution was seen. It is presumed that this can be understood by the effect of direct nuclear reaction when the incident beam energy is lower than the Coulomb barrier height of the target. We have measured preliminarily γ -ray spectra of ^{9}Be-d reaction to study the consistency between the γ -ray and charged-particle emissions.

References:

[1] K.Ochiai et al.: Proc. 10th Int. Symp. on Reactor Dosimetry, Osaka, JAPAN (1999), in press

IX-A-3

Secondary Gamma-ray Skyshine from 14MeV Neutron Source Facility(OKTAVIAN) -Comparison of Measurement with its Simulation-

S. Yoshida, R. Morotomi, T. Kondo, I. Murata, A. Takahashi and T. Yamamoto[(1)]

A paper on this subject was presented at the 1999 Symposium on Nuclear Data, and published in JAERI-Conf. 2000, with the following abstract.

Evaluation of skyshine effect of radiation is important for estimating dose equivalent near nuclear facilities. Especially for a neutron source facility, though it was through that contribution of neutron is dominant on dose equivalent, recent study at TFTR by H. W. Kugel et al.[1] reports that dose equivalent due to secondary gamma-ray skyshine approaches that of neutron at distances below 200m from the facility. It seems that this tendency at TFTR depends on the geometry of the facility. This suggests that it is very important to take into account the facility building in dose equivalent evaluation around the facility, namely experimental approaches as well as their analysis are therefore quite important.

In the present study, we have performed measurements of secondary γ -rays around the 14MeV neutron source facility OKTAVIAN of Osaka University with an Hp-Ge and NaI scintillation detectors.[2] High energy-resolution spectra measured by the Hp-Ge detector were used to investigate the skyshine mechanism through identification of nuclear reaction. On the other hand, spectra measured by the NaI detector were used for evaluation of dose equivalents around the facility. To simulate the skyshine effect, calculations with Monte Carlo code MCNP-4B were carried out.

From the result of measurement, many discrete gamma-rays were observed in the spectrum measured with the bare Hp-Ge detector (total contribution). It was found that about half of the discrete peaks are from material of the facility building. The dose equivalent decreases proportional to $1/r^2$, where r is distance from the facility. But it was found that the contribution from the upper air decreases slightly slower than the total contribution. It was confirmed from the MCNP calculation that these tendencies could be reproduced with an acceptable accuracy.

References:

[1] H. W. Kugel et al. :'Measurements of Tokamak Fusion Test Reactor D-T Radiation Shielding Efficiency' Fusion Eng. and Des. 28 (1995) 534-544.

[2] S. Yoshida et al. :'Measurement of Secondary Gamma-ray Skyshine and Groundshine from Intense 14MeV Neutron Source Facility', Proc, 9th Int. Conf. Radiation Shielding (1999)to be appeared.

(1) Radio Isotope Research Center,Osaka University

IX-A-4

Benchmark Experiment on Structural Materials in a Fusion Reactor -Leakage Neutron and Gamma-ray Spectra Measurement-

A. Takahashi, T. Nishio, T. Kondo, H. Takagi, Kokooo(1), I. Murata, D. Nakano(2), F. Maekawa(3), Y. Ikeda(3) and H. Takeuchi(3)

The benchmark experiments were carried out for structural materials in a fusion reactor at Fusion Neutronics Source (FNS) in JAERI, Japan. The experiments have been undertaken under the collaboration of JAERI and Osaka University. We focused on ceramic materials including lithium such as $LiAlO_2$, Li_2TiO_3 and Li_2ZrO_3 and some structural materials of C, V, Cu, Pb, W, Fe and SUS-316. Especially $LiAlO_2$, Li_2TiO_3 and Li_2ZrO_3 are regarded as advanced solid breeder materials because of their inherent advantages such as chemical stability at high temperature, good tritium recovery characteristic and so on. However no integral experiments exit using three blanket materials until now. C, V, Cu, Pb, W, Fe and SUS-316 are important structural materials to be used in a fusion reactor.

Leakage neutron spectra from the slab assemblies were measured using an NE-213 scintillation detector by the time-of-flight (TOF) method for two emission angles of 0 and 24.9 degree. A high-energy-resolution measurement, ranging from 0.05 to 15 MeV, was achieved by the pulse-shape-discrimination technique with three delay–line amplifiers which were set to different gains. The detector efficiencies were determined by using three measurements of a leakage neutron spectrum from beryllium assembly, energy and angle differential cross section of hydrogen using a polyethylene sample, neutron spectrum of ^{252}Cf spontaneous fission neutron source with the TOF method and SCINFUL calculation[1][2].

Secondary gamma-ray spectra from the slab assemblies were measured by using an NaI scintillation detector. By employing the time-of-flight (TOF) method, gamma-ray and neutron were efficiently discriminated. In order to examine angular dependence of the nuclear data, gamma-ray spectra were measured for three emission angles of 0, 24.9 and 50.0 degree. Unfolding was performed with the unfolding code HEPRO using the response matrix derived from the Monte Carlo code MCNP-4B calculation.

The measured spectra from both experiments were compared with the calculated results obtained by using MCNP-4B in order to discuss the validation of the evaluated nuclear data files of JENDL-3.2, JENDL-fusion file, FENDL/E-1.0, FENDL/E-2.0 and ENDF/B-VI.

Reference:
[1] Kokooo, et al., Fusion Technol., 34, 980 (1998).
[2] Murata I., et al., "Benchmark Experiment on $LiAlO_2$, Li_2TiO_3 and Li_2ZrO_3 Assemblies with D-T Neutrons - Leakage Neutron Spectrum Measurement -" Proc. 5th Int. Symp. on Fusion Nucl. Technol., Roma, Sept. 19~24 (1999) to be published.

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(1) Department of Physics, University of Mawlamyine (2) Mitsubishi Electric Corp.
(3) Japan Atomic Energy Research Institute

IX-A-5

Measurement of Secondary Gamma-ray Production Cross Sections of Structural Materials for Fusion Reactor -Extraction of Discrete and Continuum Components-

I. Murata, T. Kondo, R. Morotomi, T. Nishio, and A. Takahashi

A paper on this subject was presented at the 1999 Symposium on Nuclear Dada, Nov. 18-19, 1999, JAERI, Tokai, Japan with the following abstract.

In a fusion reactor design, secondary gamma-ray production cross section data are important because of the necessity of estimations for nuclear heating, radiation damage, radiation exposure, and so on. The experimental data[1] are usually discrete gamma-rays obtained with a Ge detector or continuum energy spectrum with NaI detector. In nuclear data files, continuum spectra are mainly included considering the measured continuum spectra with an NaI detector. In this study, gamma-rays generated by D-T neutrons were measured by separating them into two components: One is the discrete component including relatively prominent discrete peaks, the other is the continuum component which includes continuous energy distribution as well as many small discrete peaks. The gamma-ray spectrum for the latter has not been obtained experimentally at all. These two data were extracted from the measured spectrum with a Ge detector. With the data, both of continuum and discrete production cross sections of secondary gamma-rays and could be evaluated separately for the evaluated nuclear data.

In experiments, two kinds of spectra were measured with the sample-in and the sample-out systems by theTOF method at OKTAVIAN facility of Osaka University, Japan. In the sample-in measurement, the foreground spectrum contained the time-dependent background component and the time-independent component as well as the net foreground spectrum. The time-independent background could be removed using the background spectrum obtained in the same TOF spectrum. The time-dependent background spectrum was obtained from the sample-out experiment. From these spectra, the net foreground spectrum was obtained. After removing the prominent discrete peaks and unfolding the continuum spectrum, the energy spectrum which had only the continuum component could be derived. The obtained discrete and continuum gamma-ray production cross sections were compared with the theoretical calculation result as well as the evaluated unclear data.

References:

[1] S.P. Simakov et al.: Report INDC(CCP)-413 IAEA (1998)

IX-A-6

Measurement of (n,2n) Reaction Cross Sections with a Beam DT Neutron Source -Establishment of the System of Measurement-

I. Murata, Y. Terada, T. Nishio, K. Ochiai, F. Maekawa[1], H. Takeuchi[1] and A. Takahashi

(n,2n) reaction cross sections are of importance in nuclear design of a fusion reactor. However, there are many nuclides, the (n,2n) reaction cross sections of which were not measured, because appropriate radioisotopes cannot be produced by neutron irradiation. In principle, the cross section can be obtained by means of coincidence measurement of simultaneously emitted two neutrons through (n,2n) reaction. It is well known, however, that it is very difficult to realize it using a point neutron source. In the present study, this critical measurement was realized using a beam type DT neutron source at FNS of JAERI, Japan.

A small sample was carefully fixed so as to be within the neutron beam. Two NE213 scintillation detectors were arranged at about 20 cm from the sample. Several spectrum measurements were carried out by changing the detectors position to obtain angular correlation data. Neutron pulse height spectra due to (n,2n) reactions in the sample were extracted from the raw detector signals by the coincidence measurement and n/g pulse shape discrimination techniques. In 1999, the experimental system has been developed and tested through the measurement of the (n,2n) spectrum for a Mn sample. It is planning to carry out experiments for nuclides, the (n,2n) reaction cross sections of which were not measured though it is thought that they are very important.

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(1) Japan Atomic Energy Research Institute

B. Department of Chemistry

IX-B-1

Fission fragment configurations at scission point of ^{233}U, ^{235}U and $^{239}Pu(n_{th},f)$

K.Takamiya*, T.Inoue*, K.Nakanishi*, A.Yokoyama*, N.Takahashi*, T.Saito*, H.Baba*, Y.Nakagome**

A paper on this subject was published in J. Radioanal.Nucl.Chem. 239 (1999) pp.117-122 with the following abstract.

Abstract:
In order to estimate the deformation rate of fission fragment at scission point for thermal-neutron-induced fission of $^{233,235}U$ and ^{239}Pu, the double-velocity and double-energy measurements were carried out. As the result of the estimation for the deformation rate, there were two types of scission point configurations. One type is composed of deformed light and heavy fragments, and the other type is a combination of deformed light and spherical heavy fragments. Mass and total kinetic energy distributions were decomposed to two distributions by means of the type of configuration.

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A.Department of Quantum Science and Energy Engineering

X-A-1

Measurement of Prompt Fission Neutron Spectrum of Neptunium-237 for 0.62 MeV Incident Neutrons

Than Win*, Mamoru BABA, Masanobu IBARAKI, Takako MIURA, Toshiya SANAMI, Tomohiko IWASAKI and Naohiro HIRAKAWA

A paper of the subject has been published in *J. Nucl. Sci. Technol.*, 36 (6) 486-492 (1999) with the following abstract:

The prompt fission neutron spectrum of ^{237}Np induced by 0.62 MeV neutrons has been measured by using a Time-of-Flight method with a heavily shielded NE213 scintillation detector. The 4.5 MV Dynamitron accelerator of Tohoku University was used to produce pulsed neutrons. The sample was NpO_2 powder enclosed in a stainless steel container.

The fission spectrum data were obtained in the energy range from 0.8 to 12 MeV. Best fit parameters the experimental data have been derived for the Maxwellian and the Watt type distribution functions.

The Maxwellian temperature Tm of the present work was 1.28 ± 0.04 MeV. It is smaller than the Maxwellian temperature 1.38 MeV given by JENDL-3.2, but is consistent with that derived by the Howerton-Doyas formula on the relation between the average energy or Maxwellian temperature and the average number of prompt fission neutrons (ν_f). The measured spectrum is well described in terms of the Watt distribution,

$$\chi_w = C_w \sinh(\sqrt{1.95E}) \exp(-1.01E).$$

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* Present Address: Yangon University, Myanmar

X-A-2

Measurement of Neutron Inelastic Scattering Cross Section for the first level of ^{238}U in hundreds of keV range

T. Miura, M. Baba, M. Ibaraki, T. Sanami, ThanWin,
Y. Hirasawa, N. Hirakawa.

A paper of the subject is in print for publication in *Annals of Nuclear Energy* with following abstract:

Neutron inelastic scattering cross section for the first level of ^{238}U (Ex=44.9keV) was measured at eight incident energy points from 350 to 855keV at laboratory angle of 120° by using a time-of-flight spectrometer. Care was taken for the peak separation of the first level from the ground state, and for the absolute normalization of the cross section. The peak separation was achieved by employing a thin neutron production target ($\Delta E \leq 10$keV), long flight path (4~6m), and by experimental simulation of the elastic scattering peak with a lead sample. Validity of the absolute value and internal consistency in the experiment was confirmed by measuring carbon with well-known cross section and ^{238}U at another emission angle, 135°. The angle-integration was performed by employing the angular distribution of JENDL-3.2. The present experimental data for the first level and the ground state are close to the JENDL-3.2 data.

B. Laboratory of Nuclear Science

X-B-1

Clusters in the Photodisintegration of ^{9}Be

K. Shoda and T. Tanaka[1]

A paper of this subject was published in Phys. Rev. C 59, 239 (1999), with the following abstract.

The ground-state cross sections and angular distributions of $^{9}Be(\gamma,p)$, $^{9}Be(\gamma,t)$, $^{9}Be(\gamma,{}^{3}He)$, $^{9}Be(\gamma,d)$ are reported, together with the cross section for the $^{9}Be(\gamma,d)$ reaction to the first excited state. Qualitative discussions of these cross sections are made on the basis of a simple model which assumes free clusters in ^{9}Be. This is similar to the two-cluster model used for ^{6}Li and ^{7}Li for which theoretical calculations have been made. Predictions on the basis of this model indicate the importance of clustering in the photodisintegration of ^{9}Be, ^{6}Li, and ^{7}Li. The observed angular distributions are consistent with contributions due to E1 and E2 transitions.

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X-B-2

Spin-Isospin Flip Giant Resonances and Shell Dependence in ^{7}Li and ^{9}Be by π^+ Photoproduction

K. Shoda, S. Tôyama[1], K. Takeshita[2], T. Kobayshi[3] and H. Tsubota[4]

A paper of this subject was published in Phys. Rev. C 59, 3196 (1999), with the following abstract.

The giant resonances of spin-isospin flip mode are studied by measuring the energy and angular distributions of π^+ electroproduced from ^{7}Li and ^{9}Be nuclei. Several strong π^+ groups are found and angular distributions of these groups are analyzed by distorted-wave impulse approximation calculations using the single particle shell model. The experimental cross section of the groups corresponds to an order of the charge exchange single particle transition strength, establishing them as spin-isospin flip giant resonances. The shell model nature of (γ, π^+) results for $1p_{3/2}$ shell nuclei are summarized and presented together with previously published data. The obtained results are compared to previously published data for (π^-, γ), (n, p), (e,e$'$p), and (p, 2p) reactions. Strong transitions consistent with the giant resonance excitations from the $1s_{1/2}$ shell in the core and from the $1p_{3/2}$ valence shell are observed.

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Neutron Decay of the Pygmy and Giant Resonances in the ^{13}C(e,e'n)^{12}C Reaction

S. Suzuki[1], T. Saito, K. Takahisa[2], C. Takakuwa[3], T. Nakagawa[4], T. Tohei[5] and K. Abe[6]

A paper of this subject was published in Phys. Rev. C 60, 034309 (1999), with the following abstract.

The cross sections and angular correlations for neutron emission to various states in the residual nucleus, following the ^{13}C(e,e'n) reaction, have been measured over the excitation energy range 8-27 MeV at the effective momentum transfer of 0.35 fm^{-1}. In the pygmy resonance, neutron emission leads predominantly to the ground and first excited states of ^{12}C, while in the giant resonance it leads to population of two higher excited states (12.71 MeV, $T = 0$; 15.11 MeV, $T = 1$). This is the first direct observation for neutron population of these states. The isospin assignments of the resonances are made as a result of the observed decays. The branching ratio of the transition to the $T = 1$ states compared to the total cross section for neutron emission is found to be 19±5%, which is inconsistent with the theoretical predictions of about 50%. Both isospin splitting and the relative $T_<$ and $T_>$ strengths of the giant resonance are obtained for the neutron decay. The angular-correlation parameters for the decay of the giant dipole resonance are very similar for ^{13}C and ^{12}C, which provides some support for a weak coupling model in which the giant resonance for ^{13}C proceeds via core excitations in ^{12}C.

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X-B-4

Out of Plane Measurements of the Decay Neutron from the Giant Resonance in the $^{12}C(e,e'n)^{11}C$ Reaction

M. Oikawa[1], T. Saito, K. Takahisa[2], Y. Suga[3], K. Kino, T. Nakagawa[4], T. Tohei[5], K. Abe[6] and H. Ueno[7]

A paper of this subject will be published in Phys. Rev. Lett. with the following abstract.

Out of plane measurements of the angular correlations for the $^{12}C(e,e'n)$ reaction have been performed for the first time in the giant resonance region. The cross sections were directly separated into the longitudinal and transverse, longitudinal-transverse, and transverse-transverse components. The cross section at the peak of the giant resonance (ω = 22.5 MeV) has been found to be almost all longitudinal. It was reproduced by the multipole expansion with E0 and E2 components besides E1. The longitudinal-transverse might have a maximum around 24 MeV. The transverse-transverse is very small over the giant resonance.

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X-B-5

Study of the Giant Resonance of ^{28}Si by the (e,e'n) Reaction

K. Kino, T. Saito, T. Nakagawa, T. Nakagawa[1], and H. Ueno[2]

The cross sections and angular correlations for the ^{28}Si(e,e'n) reaction have been measured in the excitation energy range 19~30 MeV at the three effective momentum transfers of 0.38, 0.49, and 0.60 fm^{-1}. From a multipole expansion of the cross sections, the E1 and E2(or E0) have been separated.

The experiment was performed using the continuous electron beam from the 1.2 GeV Tohoku University stretcher booster ring. A natural silicon target of thickness 119 mg/cm^2 was bombarded with electron of both energies 149.5 and 197.5 MeV. The scattered electrons were detected by a magnetic spectrometer at θ_e = 28° for 149.5 MeV incident electron and at both θ_e = 28° and 35° for 197.5 MeV one. The emitted neutrons were detected using eight NE213 liquid scintillator neutron detectors.

The angular correlations have been measured at eight points θ_n = 58° to θ_n = 263°. Figure 1 shows a missing energy spectrum summing up all data at θ_n = 83° and q_{eff} = 0.38 fm^{-1}. Neutrons from the giant resonance decay mainly to the ground, first and second excited states in ^{27}Si. The angular correlations for neutrons summed up for n_0, n_1, and n_3 are shown in Fig. 2. In the figure solid lines indicate the Legendre polynomial fits.

The total cross sections have been deduced from the angular correlations and separated into E1 and E2(or E0) components by the multipole expansion. The results are shown in Fig. 3. The obtained E1 component agrees well with the ^{28}Si(γ, n) data[1] below 23 MeV. A discrepancy is seen between both data above 24 MeV. It might be due to including decays to the higher excited states in (γ, n) data. A broad peak in the E2(or E0) components is found around in 25 MeV.

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1) J.T. Caldwell, R.R. Harvey, R.L Bramblett and S.C. Fultz: Phys. Lett. 6, 213 (1963).

[1] Department of Physics, Tohoku Univ.
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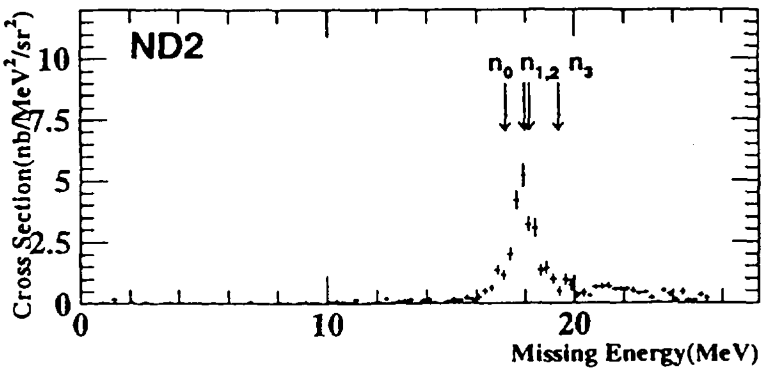

Fig. 1 Missing energy spectrum for the ^{28}Si(e,e'n) reaction. The allows indicate the enegies for n_0, n_1, n_2 and n_3 decays.

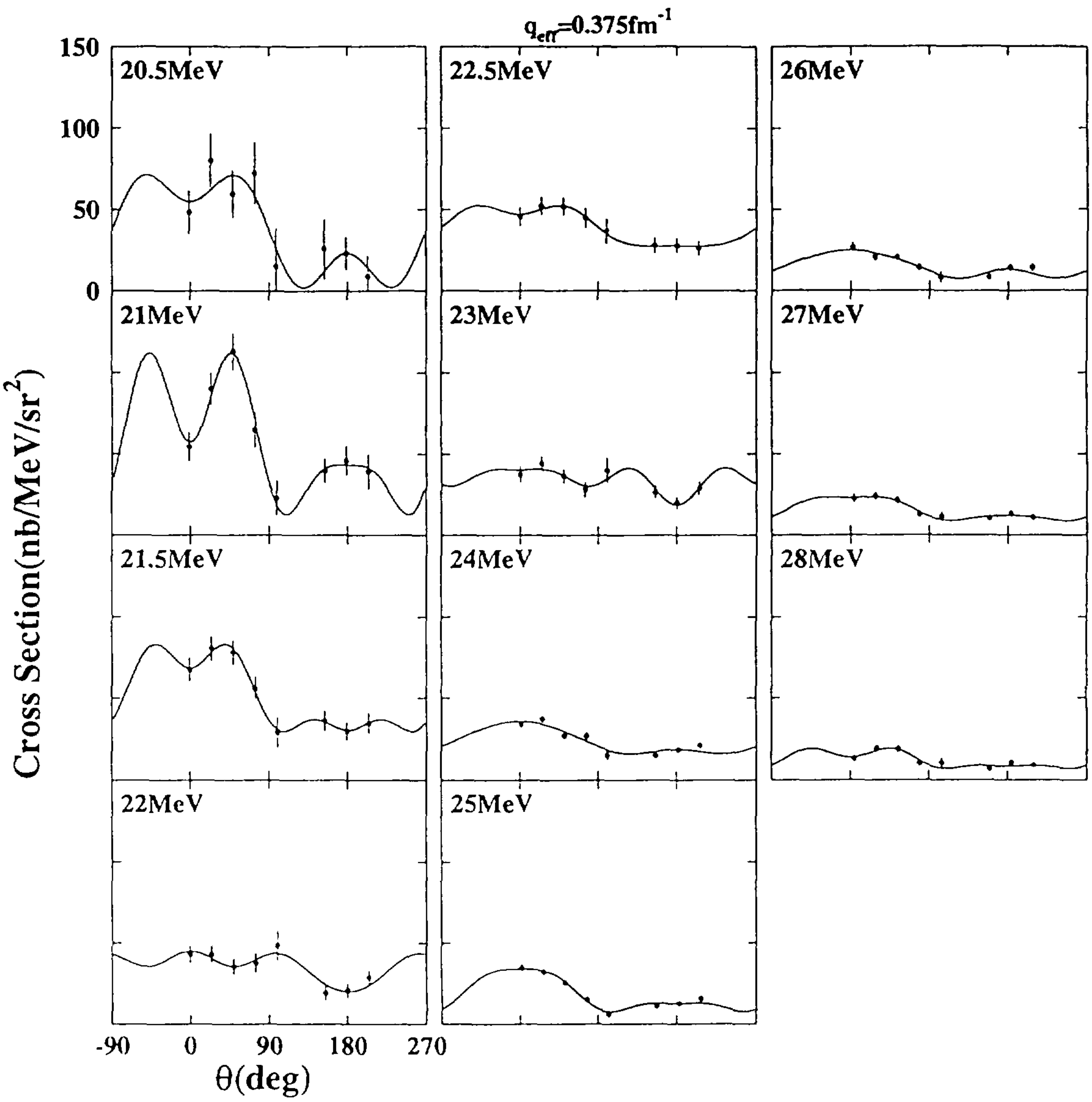

Fig. 2 The angular correlations for neutrons summed up for n_0, n_1, and n_3 at q_{eff} = 0.38 fm^{-1}. The solid lines are the Legendre polynomial fits.

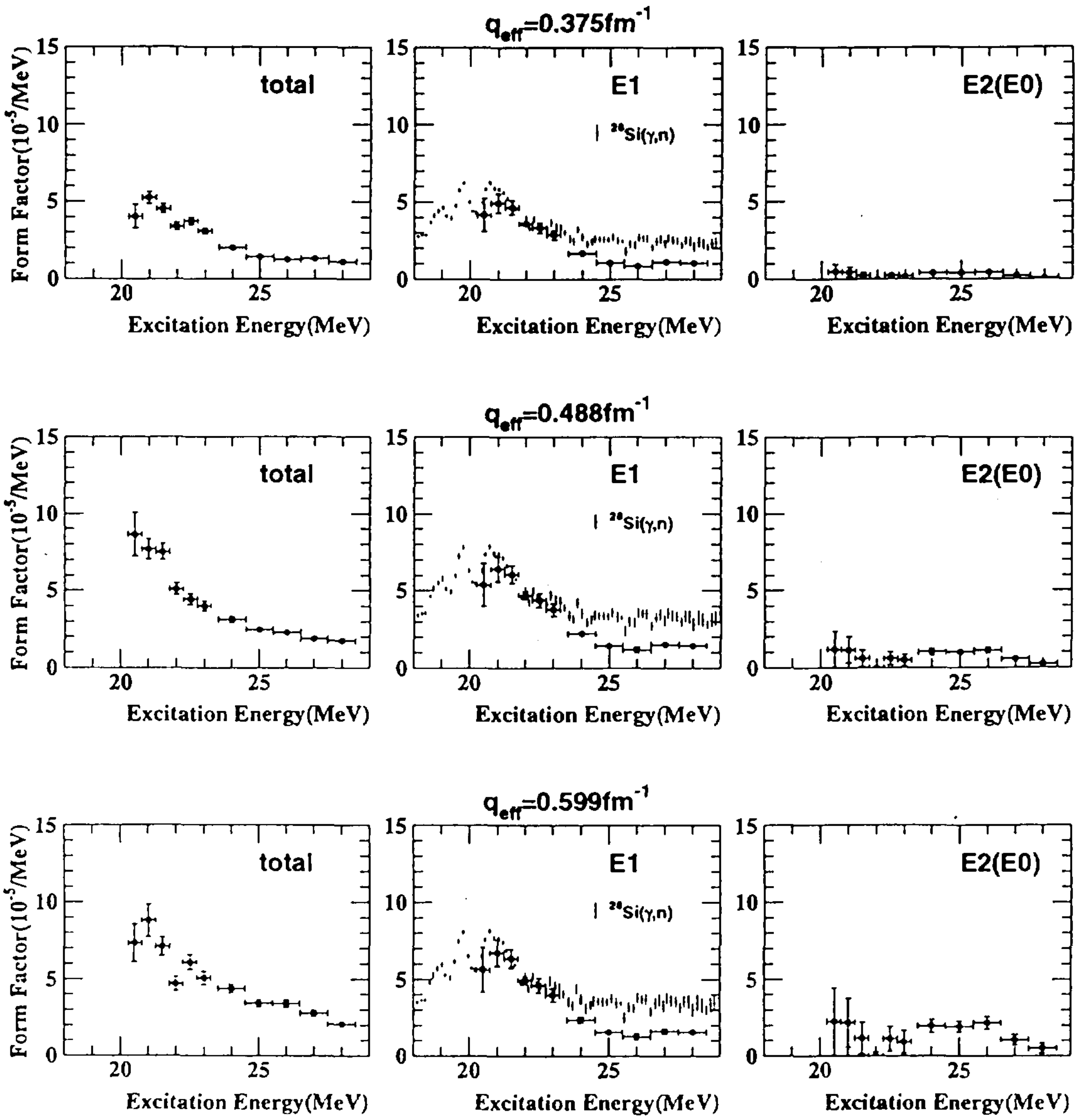

Fig. 3 Total cross sections and separated E1 and E2 (or E0) components at each momemtum transfer. The E1 components (filled circles) are compared with the $^{28}Si(\gamma, n)$ data (ref. 1).

C. Cyclotron and Radioisotope Center

X-C-1

Projectile Dependency of Radioactivities of Spallation Products Induced in Copper

H. Yashima, H. Sugita, T. Nakamura, T. Shiomi
Y. Uwamino, A. Fukumura

The reaction cross sections of spallation products in a Cu target by 230MeV/u C and Ne ions were obtained. Irradiation experiments were performed at HIMAC (Heavy Ion Medical Accelerator in Chiba), National Institute of Radiological Sciences. Gamma-ray spectra from activation samples were measured with a HPGe detector. From the gamma-ray spectra, we obtained the variation of reaction cross sections of Cl-38, Cr-49, Mn-55, Cu-60, Cu-61 and Co-62m in Cu sample with Cu target thickness, and compared it with the experimental data by Kim et al.. The results showed that the dependence of the cross sections to the projectile mass is very small for the same projectile energy per nucleon.

1. Introduction

Recently the high-energy and high-intensity accelerators have increasingly been used for nuclear physics, solid-state physics, radiotherapy, material damage study, and so on. Safety design consideration for the accelerator facilities requires reaction cross section data for high-energy ions to estimate the radioactivities induced in the accelerator components and in the shielding materials. We therefore irradiated 230MeV/nucleon C and Ne ions onto a Cu target, and investigated the projectile dependency of induced radioactivities of spallation products.

2. Experiment and Analysis

Irradiation experiments were performed at HIMAC (Heavy Ion Medical Accelerator in Chiba), National Institute of Radiological Sciences. A schematic view of the experimental set-up is shown in Fig.1. The Cu target was composed of a stack of 100mm $\times$100mm$\times$5mm Cu plates, and C, Al, Cr, Fe, Ni, Cu, Pb samples were inserted between the Cu plates. The thickness of Cu target is longer than the flight path of the projectile beam. The flight path of the projectile beam calculated by the SPAR code [1] is 10.5mm for 230MeV/u Ne and 17.4mm for 230MeV/u C. After irradiation, we measured the gamma-ray spectra from samples with a HPGe detector. Fig.2 shows a schematic view of the gamma-ray detection system. The reaction rates of radionuclides produced in samples which were identified from the gamma-ray spectra and the decay curves were estimated after being corrected for the peak efficiency of the HPGe detector and the coincidence-summing effect.

3. Results and Discussions

From the reaction rates, we obtained the reaction cross sections of Cl-38, Cr-49, Mn-56 Cu-60, Cu-61 and Co-62m in a Cu target by 230 MeV/u Ne and C ions. The results were compared with the data for 290, 400MeV/u C and 400MeV/u Ne ions by Kim [2].

Fig.3 shows the variation of reaction cross sections of Cl-38 produced in the Cu sample with Cu target thickness. In Fig.3, the reaction cross sections of Cl-38 are almost constant down to the beam flight path and rapidly decrease beyond it. The reaction cross sections of Cl-38 produced by 230MeV/u C and Ne ions are almost equal each other. Since the mass number difference between Cu and Cl-38 is large, Cl-38 is almost produced by a primary projectile beam. But, for 400MeV/u C and Ne ions, the cross sections by Ne ions are about 40% higher than those by C ions, which implies some contribution of secondary particles to the production of Cl-38.

Fig.4 shows the variation of reaction cross sections of Cr-49 produced in the Cu sample with Cu target thickness. In Fig.4, the reaction cross sections of Cr-49 increase down to the beam flight path and decrease beyond it. Since the mass number of Cr-49 becomes closer to Cu than that of Cl-38, the fraction of Cr-49 produced by secondary particles increases, but the projectile dependence of the reaction cross sections is very small for the same projectile energy per nucleon.

Figs.5 to 8 show the variation of reaction cross sections of Mn-56,Cu-60,Cu-61,Co-62m produced in the Cu sample with Cu target thickness, respectively. In these figures, the reaction cross sections of these nuclides show the similar tendency as that of Cr-49 although the cross section increase with the target thickness is much higher for lighter mass products .

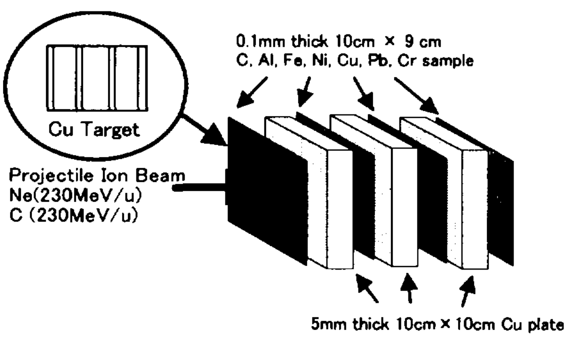

Fig.1 Schematic view of the experimental geometry.

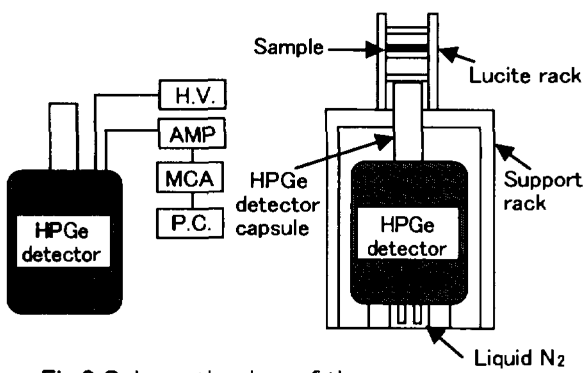

Fig.2 Schematic view of the gamma-ray detection system

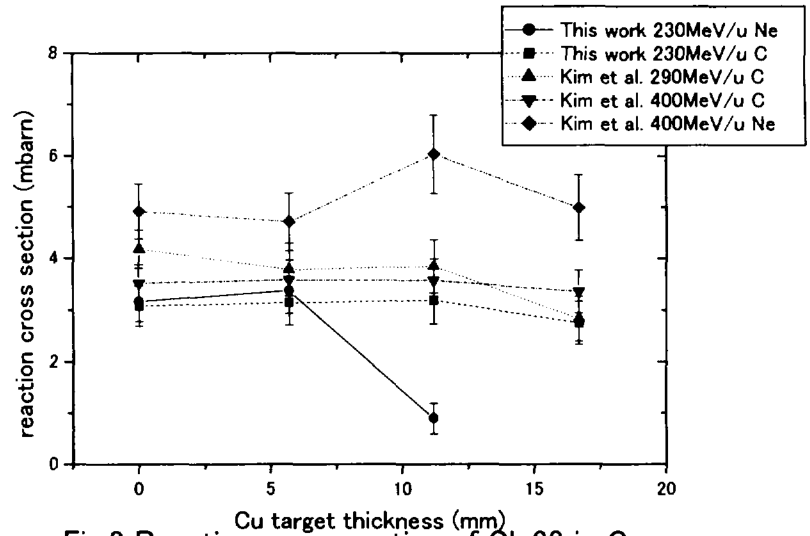

Fig.3 Reaction cross section of Cl–38 in Copper

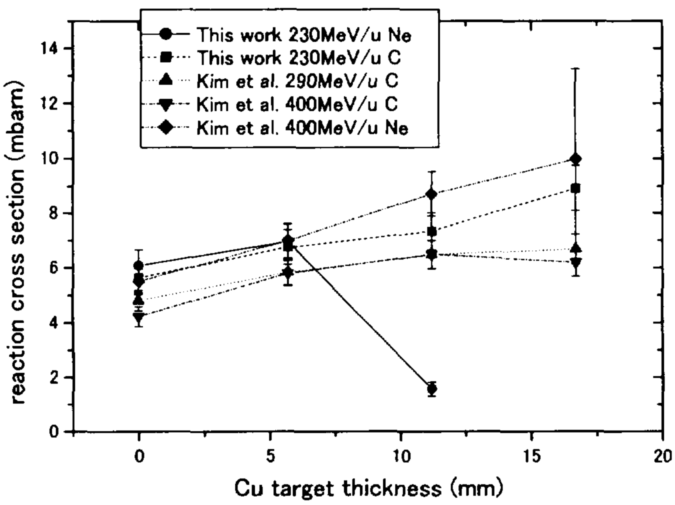

Fig.4 Reaction cross section of Cr–49 in Copper

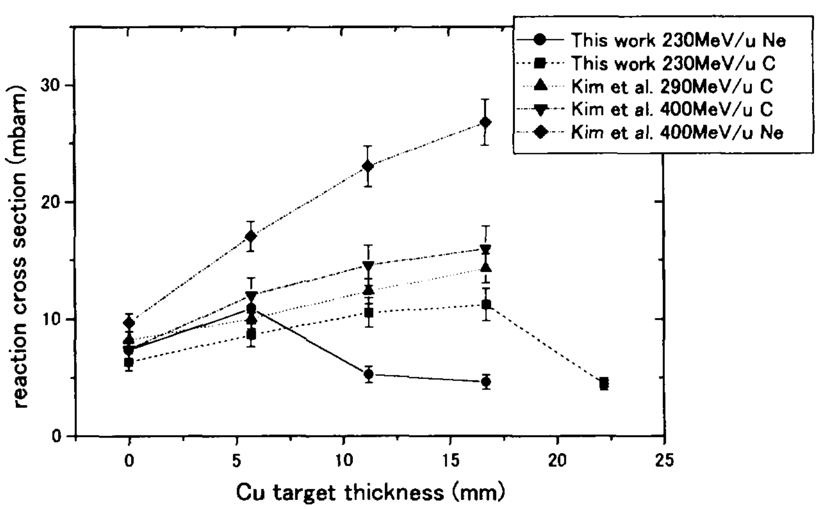

Fig.5 Reaction cross section of Mn–56 in Copper

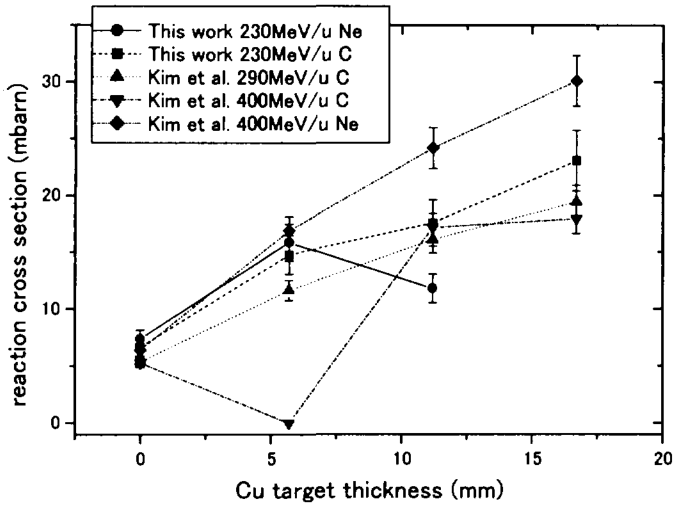

Fig.6 Reaction cross section of Cu-60 in Copper

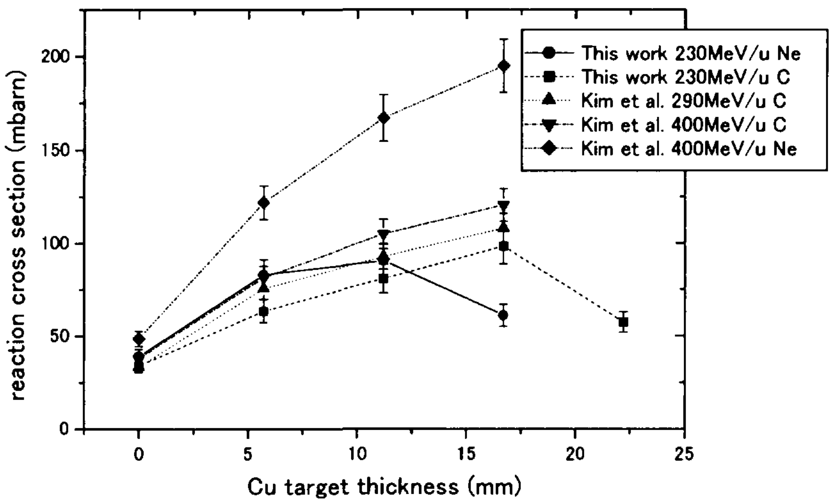

Fig.7 Reaction cross section of Cu-61 in Copper

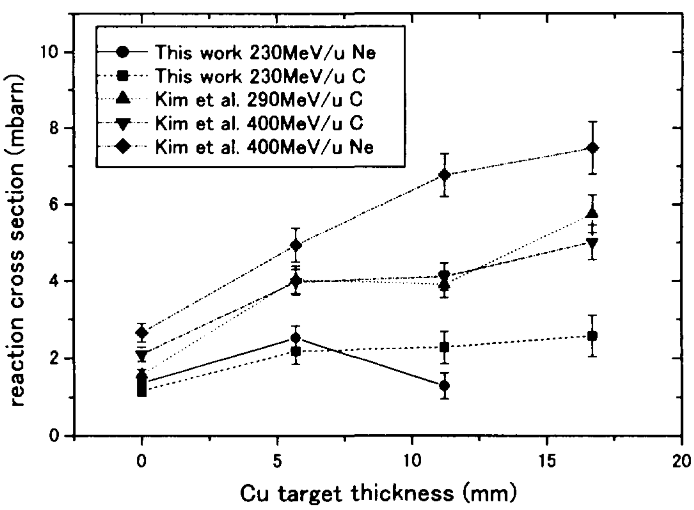

Fig.8 Reaction cross section of Co-62m in Copper

4. Conclusion

We performed the irradiation experiments by 230MeV/u Ne and C ions, and obtained the variation of reaction cross sections of nuclides produced in Cu sample with Cu target thickness. It was found that these cross sections have little dependence to the projectile mass having the same energy per nucleon. We are now analyzing the induced radioactivities produced in other samples.

Acknowledgments

We wish to thank the synchrotron machine group of HIMAC for synchrotron operation during the irradiation experiment. We are also very much obliged to the members of the Nakamura Laboratory of the Cyclotron and Radioisotope Center, Tohoku University.

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[1] T. Nakane, Nucl. Phys., A491, 130 (1989).

[2] E. Kim, Doctor Thesis, Tohoku University, Faculty of Engineering, Department of Quantum Science and Energy Engineering, March, 1999 (in Japanese)

X-C-2

Measurement of Neutron Production Cross Sections by High Energy Heavy Ions

Hisaki Sato, T.Kurosawa, H.Iwase, T.Nakamura, N.Nakao, Y.Uwamino

The double-differential cross section (DDX) of neutron production from thin C, Al, Cu, Pb targets bombarded by 135MeV/nucleon C ion were measured using the RIKEN Ring Cyclotron of the Institute of Physical and Chemical Research, Japan. The neutron energy spectra were obtained by using the time-of-flight method coupled with the ΔE-E counter telescope system. The ΔE counter of the NE102A plastic scintillator was used to discriminate charged particles from noncharged particles, neutrons and photons. The E counter of the NE213 liquid scintillator was used to measure the neutron energy spectra. The experimental spectra were compared with the calculation using the HIC and the QMD codes.

1. INTRODUCTION

Recently, the use of high-energy heavy ions have been increasing in various fields. To design the accelerator facility, it is important to protect workers from radiation, particularly penetrating neutrons produced by high energy heavy ions. There exist a few published data on the double-differential cross sections (DDX) of neutron production for 337 MeV/nucleon Ne ions on C, Al, Cu, U targets [1], but still very poor. In this work we present the double-differential cross sections (DDX) of neutron production from thin C, Al, Cu, Pb targets bombarded by 135MeV/nucleon C ion. These results will be useful as a benchmark experimental data to investigate the accuracy of high energy particle transport calculation code. Here, the measured spectra are compared with the calculation using the two heavy-ion Monte Carlo codes of internuclear-cascade and evaporation model (HIC) and the quantum molecular dynamics model (QMD).

2. EXPERIMENT

The measurements were carried out at the RIKEN Ring Cyclotron, the Institute of Physical and Chemical Research. A schematic view of the experimental set-up is shown in Fig.1. The NE213 liquid scintillator (12.7cm diameter by 12.7cm thick), which was designed to expand the dynamic range of output pulses for high energy neutron measurements, was used for E counter, and the NE102A plastic scintillator (15cm by 15cm square and 0.5cm thick) for ΔE counter was placed in front of the E counter to discriminate charged particles from noncharged particles, neutrons and photons. The target thicknesses are 1mm of C, 0.6mm of Al, 0.3mm of Cu, 0.3mm of Pb. The direction of incident beam was rotated around the target from 0 to 110 degrees through the beam swinger, for measuring the energy-angle distribution of neutrons produced from the target by the time-of-flight (TOF) method having the flight path of 847cm. In order to shield the spurious scattered neutrons, the neutrons from the target were introduced to the detector through the iron-concrete collimator of 120cm thickness. The measurements were carried out at 0 ° ,15 ° ,30 ° ,50 ° ,80 ° and 110 °

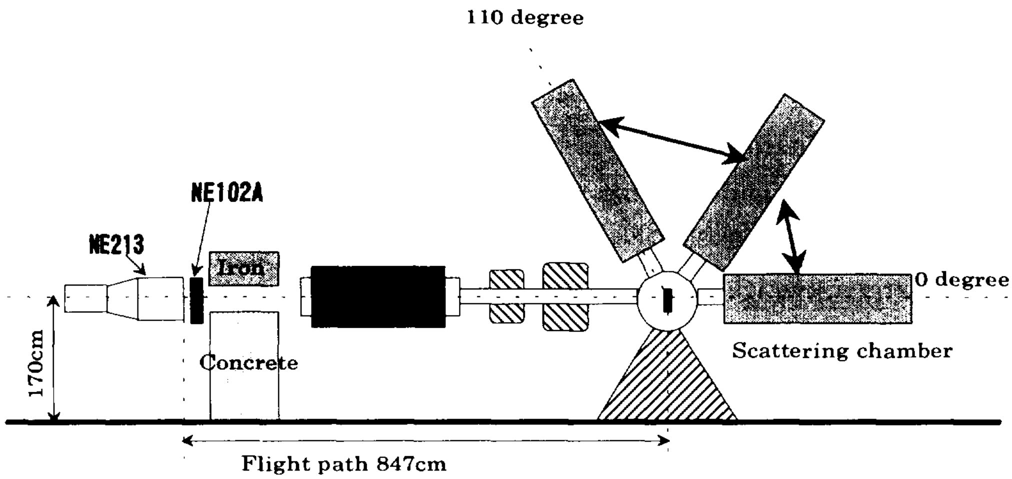

Fig.1 Schematic view of the experimental set-up

3. RESULTS AND DISCUSSIONS

We obtained neutron energy spectra for C,Al,Cu, and Pb targets bombarded by 135 MeV/nucleon C ion. These experimental results were compared with the calculation using the HIC [2] and the QMD [3] codes. Figs.2-5 show the experimental and calculated double differential cross sections of neutron production from C, Al, Cu, and Pb targets, respectively. Neutron energy spectra measured in the forward direction have a peak near the projectile energy per nucleon. This peak is due to a knock-on process in which a neutron is knocked out by the direct collision between the target nucleon and the projectile nucleon. This peak becomes more prominent in the forward direction and for a lighter target, since the momentum transfer from projectile to target nuclei is higher for lighter nucleus than for heavier nucleus [4]. The high energy end of neutrons in the forward direction reaches about 300-400MeV. This influences the Fermi motion of a nucleon in a nucleus. The neutron spectra have another two components based on cascade-preequilibrium emission process and evaporation-equilibrium emission process. At small angles, knock-on process is dominant, and at large angles, evaporation process is dominant. Two calculations of HIC and QMD show a tendency to underestimate the high energy neutron components beyond the peak at all angles. The HIC overestimates the peak, while the QMD underestimates the peak. At large angles, the calculated spectra become in good agreement with the measured spectra. In general, the QMD gives better agreement with the experimental results, especially for heavy target, than the HIC.

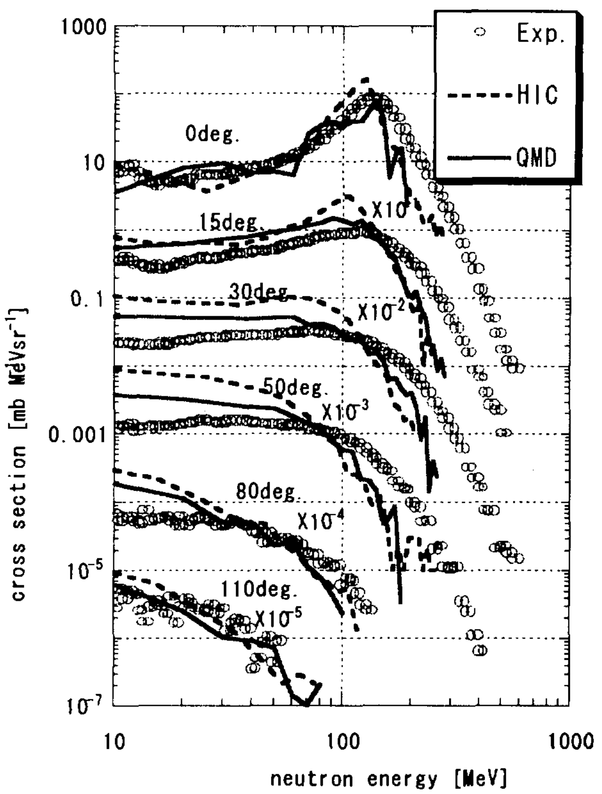

Fig.2 Neutron energy spectrum for C

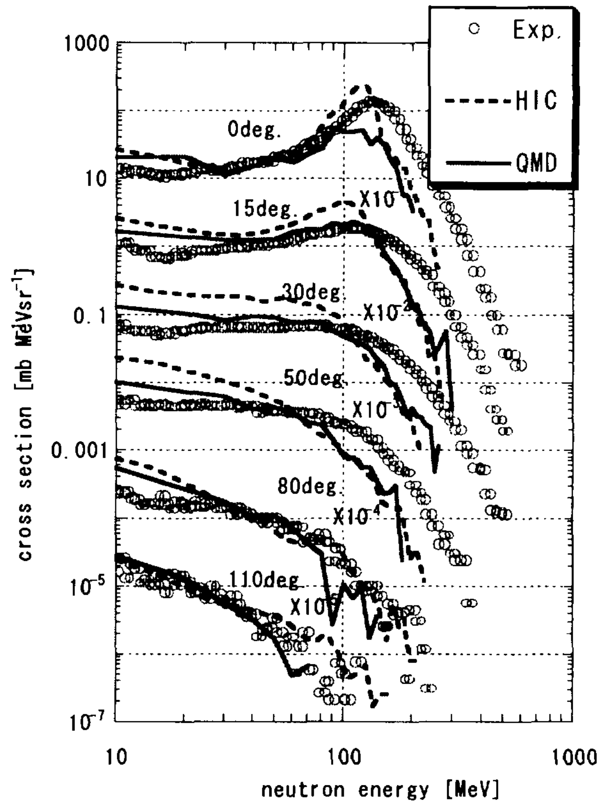

Fig.3 Neutron energy spectrum for Al

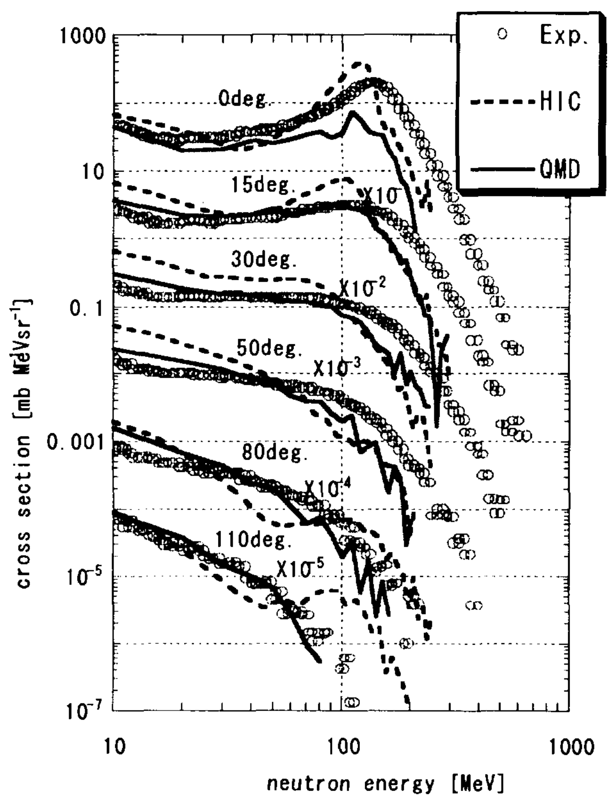

Fig.4 Neutron energy spectrum for Cu

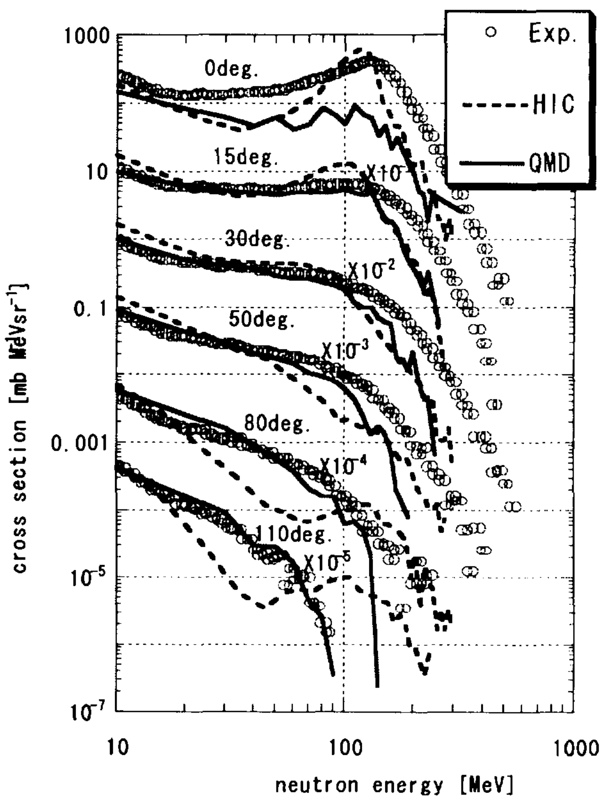

Fig.5 Neutron energy spectrum for Pb

4. CONCULUSIONS

We measured double-differential cross sections of neutron production from thin C, Al, Cu, Pb targets bombarded by 135 MeV/u C ion. The experimental spectra were compared with the calculation using the HIC and the QMD codes. The calculated spectra tend to underestimate the high energy neutron region. At large angles, the calculated spectra, particularly the QMD, are in rather good agreement with the measured spectra. These experimental results will be useful as the benchmark data for investigating the accuracy of high energy particle transport calculation code.

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XI. Tokyo Institute of Technology

XI-1

Measurements of keV-Neutron Capture Cross Sections and Capture Gamma-Ray Spectra of ^{143,145,146}Nd, ^{147,148,149,150,152,154}Sm and ^{161,162,163}Dy

M. Igashira, S. Mizuno, T. Ohsaki, K. Masuda, T. Veerapaspong, B. Duamet, M. Mizumachi and J. Hori

Three papers on this subject were published in J. Nucl. Sci. Technol., **36**, 493, 855, and 865 (1999). The abstracts of those paper are unified as follows:

The neutron capture cross sections and capture gamma-ray spectra of ^{143,145,146}Nd, ^{147,148,149,150,152,154}Sm, and ^{161,162,163}Dy were measured in the neutron energy region of 10 to 90 keV and at 550 keV. A neutron time-of-flight method was adopted with a ns-pulsed neutron source by the ^{7}Li(p,n)^{7}Be reaction and with a large anti-Compton NaI(Tl) gamma-ray spectrometer. A pulse-height weighting technique was applied to observed capture gamma-ray pulse-height spectra to extract capture yields. The capture cross sections were obtained with the error of about 5% by using the standard capture cross sections of ^{197}Au. The present results were compared with previous measurements and the evaluated values of JENDL-3.2 or ENDF/B-VI. The capture gamma-ray spectra were obtained by unfolding the observed capture gamma-ray pulse-height spectra. An anomalous shoulder or bump was observed in the region of 2 to 3 MeV in the gamma-ray spectrum of each nuclide, and the energy position of the shoulder or bump was consistent with the systematics obtained in our previous work.

XI-2

Measurements of Capture Gamma Rays from the Broad 27-, 49-, and 97-keV Neutron Resonances and the Narrow 44-keV Neutron Resonance of ^{19}F

S. Y. Lee, J. Hori and M. Igashira

A paper on this subject was published in J. Nucl. Sci. Technol., **36**, 719 (1999), with the following abstract.

The capture γ rays from the 27-, 44-, 49-, and 97-keV neutron resonances of ^{19}F were measured using an anti-Compton HPGe γ-ray spectrometer. A neutron time-of-flight method was adopted with a 1.5-ns pulsed neutron source by the ^{7}Li(p,n)^{7}Be reaction. The standard capture cross sections of ^{197}Au and a pulse-height weighting technique were employed to determine the number of neutrons incident on a capture sample. The numbers of observed primary γ-ray transitions were 17, 6, 10, and 7 for the 27-, 44-, 49-, and 97-keV resonances, respectively. The partial radiative widths corresponding to those transitions were derived for the broad 27-, 49-, and 97-keV resonances, and the partial capture kernels for the narrow 44-keV resonance. The total radiative width or total capture kernel was derived by summing up the partial radiative widths or partial capture kernels of each resonance. Previous measurements and evaluations were compared with the present results. Moreover, the branching ratios of the 4,315-, 4,731-, and 4,898-keV states of ^{20}F were firstly derived.

XI-3

keV-Neutron Capture Cross Sections of Light Nuclei and Nucleosynthesis

T. Ohsaki, Y. Nagai*, M. Igashira, T. Shima*, K. Takaoka,
M. Kinoshita, Y. Nobuhara, H. Makii* and K.Mishima*

A presentation on this subject was made at the 10th Int. Symp. on Capture Gamma-Ray Spectroscopy and Related Topics, August 30 - September 3, 1999, Santa Fe, New Mexico, USA, with the following abstract.

keV-neutron capture cross sections of light nuclei are important parameters for evaluation of the primordial and stellar nucleosyntheses. In the primordial nucleosynthesis, based on the inhomogeneous big-bang model, keV-neutron capture reactions of light nuclei are assumed to be a main path to produce intermediate-mass nuclei. In the stellar nucleosynthesis, these reactions act as neutron poison, especially in low metallicity stars.

Our group has systematically measured keV-neutron capture cross sections of light nuclei, employing a 1.5-nsec pulsed neutron beam by the Pelletron accelerator of the Research Laboratory for Nuclear Reactors at the Tokyo Institute of Technology. The prompt gamma rays from capture reactions were measured by a pair of large NaI(Tl) scintillators with heavy shields against background neutrons and gamma rays.

In this contribution, we will present and discuss the new experimental results of keV-neutron capture cross sections of ^{6}Li, ^{16}O, ^{20}Ne, and ^{22}Ne. Measurement of the ^{6}Li(n, γ)^{7}Li reaction in the keV region was firstly performed. In the ^{16}O(n, γ)^{17}O reaction, we succeeded to observe the interference, for the first time, between the 434-keV p-wave neutron resonance capture and the p-wave potential capture.

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XI-4

First Measurement of Neutron Capture Cross Section of ^{6}Li at Stellar Energy

T. Ohsaki, K. Takaoka, Y. Nagai*, H. Kitazawa and M. Igashira

A presentation on this subject was made at the 10th Int. Symp. on Capture Gamma-Ray Spectroscopy and Related Topics, August 30 - September 3, 1999, Santa Fe, New Mexico, USA, with the following abstract.

The $^{6}Li(n, \gamma)^{7}Li$ reaction cross section is important for the verification of the charge symmetry of nuclear forces in A=7 systems: $^{6}Li(n, \gamma)^{7}Li$ and $^{6}Li(p, \gamma)^{7}Be$. In the ^{8}B solar neutrino problem, for example, the cross sections of the $^{7}Be(p, \gamma)^{8}B$ reaction cross sections are evaluated from those of the $^{7}Li(n, \gamma)^{8}Li$ reaction on the assumption of the charge symmetry of nuclear forces in A=8 systems.

In the present study, the $^{6}Li(n, \gamma)^{7}Li$ cross sections were measured at stellar energy by means of a TOF method with a pair of large anti-Compton NaI(Tl) spectrometers. Pulsed keV neutrons were produced from the $^{7}Li(p,n)^{7}Be$ reaction using the 3-MV Pelletron accelerator at the Tokyo Institute of Technology. A ^{6}Li sample was 4.9 moles of 98.6 atom % ^{6}Li enriched metal.

The derived cross sections were about 1.5 times as large as evaluated values from the 1/v law and the capture cross section at thermal energy. A direct capture model calculation with a folding potential reproduced the present results. Moreover, the calculation with the same potential and a Coulomb potential also substantially reproduced experimentally obtained cross sections of the $^{6}Li(p, \gamma)^{7}Be$ reaction.

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Measurement of capture gamma rays from the 35- and 53-keV neutron resonances of ^{23}Na

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A presentation on this subject was made at the 10th Int. Symp. on Capture Gamma-Ray Spectroscopy and Related Topics, August 30 - September 3, 1999, Santa Fe, New Mexico, USA, with the following abstract.

Capture gamma rays from the 35- and 53-keV neutron resonances of ^{23}Na were measured with a large anti-Compton HPGe gamma-ray spectrometer to study the resonance capture mechanism.

The measurement was performed with the $^7Li(p,n)^7Be$ neutron source by a 1.5-ns pulsed proton beam from the 3-MV Pelletron accelerator of the Research Laboratory for Nuclear Reactors at the Tokyo Institute of Technology. The energy spectrum of the incident neutrons on a capture sample was measured by means of a TOF method with a ^6Li-glass scintillation detector. The standard neutron capture cross sections of ^{197}Au and a pulse-height weighting technique were employed to determine the number of neutrons incident on the capture sample.

The numbers of observed primary gamma-ray transitions were 16 and 18 for the 35-, and 53-keV neutron resonances, respectively. The partial radiative widths corresponding to those transitions were derived for each resonance. Moreover, the total radiative width of each resonance was obtained by summing up the partial radiative widths. The present results were compared with other experiments.