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INDC **INTERNATIONAL NUCLEAR DATA COMMITTEE**

FISSION YIELD EVALUATION

Summary Report
of a Specialists' Meeting organized by the
International Atomic Energy Agency,
held at Studsvik, Sweden, 11, 14, and 15 September 1987

prepared by
Meinhart Lammer
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International Atomic Energy Agency

September 1988

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Contents

Foreword:

The Specialists' Meeting on Yields and Decay Data of Fission Product Nuclides, which was held at Brookhaven National Laboratory, USA, from 24 to 27 October 1983, concluded that further experimental, evaluation and theoretical work was needed in the fields of fission produced yields, delayed neutrons and decay heat, and recommended special meetings for these fields to review the progress made.

Following this recommendation, the present meeting was organized by the Nuclear Data Section of the IAEA and attended by evaluators and measurers of fission yield data. The purpose of this meeting was to establish a closer cooperation between evaluators, improve the communication with measurers and to define further experimental and evaluation work needed in order to satisfy user requirements. No papers by meeting participants were presented orally during the meeting. The basis for discussions was formed by a Working Paper with input from T.R. England, M.F. James, M. Lammer and Wang Dao, which was distributed to participants before the meeting. The following topics were discussed, and conclusions and recommendations drafted:

- International cooperation between evaluators and with other groups performing special evaluation tasks and measurements of deficient fission yield data.

- The proposal for an IAEA Coordinated Research Programme.

- Communication with measurers.

- Formats for the exchange and dissemination of experimental and evaluated fission yields.

- Definitions of fission yields.

- Identification of deficient (unmeasured, discrepant) data needed for application and for obtaining complete yield sets for the most important fissioning systems.

- Further improvements of models for the fission process and for fission yield distributions.

- Treatment of errors in evaluations; introduction of correlations and covariances.

- Standard sets of fission yields.

- Energy dependence of fission yields.

Glossary of Abbreviations

BNL	Brookhaven National Laboratory (USA)
CEA	Commissariat á L'Energie Atomique (France)
CENDL	Chinese Evaluated Nuclear Data Library
*CJD	Centr po Jadernym Dannym (USSR Nuclear Data Centre, Obninsk)
CRP	Coordinated Research Programme
ENDF	Evaluated Nuclear Data File (USA)
EXFOR	EXchange FORmat (for exchange of compiled experimental data between the Nuclear Reaction Data Centres)
FPND	Fission Product Nuclear Data
IAEA	International Atomic Energy Agency
INDC	International Nuclear Data Committee
JEF	Joint Evaluated File (of nuclear data)
JENDL	Japanese Evaluated Nuclear Data Library
LANL	Los Alamos National Laboratory (USA)
*NDS	Nuclear Data Section (IAEA)
NEA	Nuclear Energy Agency (OECD)
*NEA-DB	NEA Data Bank (Saclay, France)
*NNDC	National Nuclear Data Center (BNL, USA)
OECD	Organization for Economic Co-operation and Development
ORNL	Oak Ridge National Laboratory (USA)
WRENDA	World REquest List for Nuclear DAta

* The 4 co-operating Neutron Nuclear Data Centres

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1. INTRODUCTION

Up to roughly 1973 (Symposium on Nuclear Data for Applications, Paris) several evaluations of fission yield data were performed in different laboratories on a limited number of fissioning systems. Later on, the evaluation effort was confined to essentially B.F. Rider (USA) and E.A.C. Crouch (UK) and their collaborators, whereas the workload increased. Their retirements left a gap which is now gradually being filled again. However, the number of fissioning systems to be evaluated is still increasing - according to user demands - as opposed to the manpower available. Furthermore, there are still deficiencies in the available fission yield data as well as other problems in yield evaluation. Therefore it is due time to discuss new ways of international cooperation, especially since a Chinese fission yield evaluation Group (Wang Dao) has been established, and this group and other fission yield experts together with their groups are prepared to participate in such an effort.

An IAEA Coordinated Research Programme (CRP) could provide such a new way of international cooperation. The function of a CRP would be to further pursue problems, provide a basis for and coordinate different forms of cooperation, and provide means of communication to measurers and for publicizing conclusions and recommendations for further work. The role of the IAEA is to define the programme, coordinate the efforts, invite participating institutes and to give the whole project an official status.

2. INTERNATIONAL COOPERATION

R1 It is strongly recommended that an IAEA CRP should be held with the title: "FISSION YIELDS, DATA AND EVALUATION".
A CRP would enable closer and more effective cooperation between evaluators and with other groups working in the field of fission yields. The official status of the CRP should help raise funds for evaluation work and measurements needed. In particular, it should ensure the continuation of the fission yield evaluation effort in the UK and USA after the completion of JEF-2 and ENDF/B-VI in 1988.

R2 Therefore the CRP should be initiated in 1988; the actual programme should start according to the budgetary plans of the IAEA, but not later than 1989.

A1 Action on M. Lammer: in consultation with IAEA officials to initiate the CRP within the time schedule given above.

R3 Participants support the recommendation from previous meetings that fission yield evaluation should continue independently at different places to reflect different approaches. A comparison of evaluations enables the disclosure of possible mistakes and deficiences which may be due to the rather complex correlations involved in fission yield evaluation.

R4 Therefore, the CRP should not aim at the publication of a single recommended set of fission yields. However, it should produce
R5 a recommended set of yields used as standards in fission yield measurements.

Presently ongoing evaluation efforts are:

T.R. England, B.F. Rider (USA): 50 fissioning systems*) for ENDF/B-VI.
M.F. James, D.R. Weaver (UK): 15 fissioning systems, for JEF-2; to be extended later.
Wang Dao (China): 10 fissioning systems for CENDL; to be extended later.
A.C. Wahl (USA): 6 fissioning systems with emphasis on independent yields; to be extended later.

The fission yields contained in the French (CEA) and Japanese (JENDL) files have been adopted from other sources.

The above mentioned four groups should participate in the CRP. Within the CRP they could cooperate in the following areas:

- cross check of evaluated data sets;
- discussion of evaluation methods and models;
- exchange of experimental data and references;
- cooperation in corrections to originally published data;
- discussion of gaps and discrepancies;
- recommendation of further measurements to be done.

This cooperation within the CRP does, however, not solve the problem of limited manpower available to these groups; therefore assistance from other groups is required. The preparation of partial evaluations for certain yield sets (similar to a A-chain evaluations for the Nuclear Data Sheets) is not feasable because of the correlations between measurements of different fissioning systems. However, the following special evaluation tasks which are requested by users and/or needed for an optimum evaluation, could be done by other groups:

- evaluation of isotopic and isobaric independent yields;
- study of isomeric yields, influence of delayed neutron emission;
- development of models for the fission process;
- compilation of experimental data;
- checking and correction of published experimental data;
- detailed study of discrepant data;
- development of methods and computer programs for the introduction of correlations, covariances and simultaneous fitting procedures;
- evaluation of energy parameters for fast neutron spectra and the dependence of yields on them.

R6 Therefore the meeting participants recommend, that apart from the main evaluating groups named above, also other fission yield experts (and their groups) who are prepared to perform the special evaluations and contribute expertise in formulating

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*) Fissioning system = a fissioning nucleus together with a given neutron energy (e.g.: U235 thermal fission).

recommendations for measurements should participate in the CRP. The following experts are proposed:

H.-O. Denschlag (FRG)
J.K. Dickens (USA)
G. Rudstam (Sweden)

3. EXCHANGE OF DATA

3.1. Agreed Formats

In order to facilitate the exchange of data among evaluators, it would be advantageous to agree on common formats for:

- the basic experimental data file, and
- the final evaluated data for distribution.

R7 EXFOR is recommended to be accepted as the format for the compilation and exchange of experimental data, to be used in future by all evaluators.

EXFOR entries contain, in addition to coded information, a lot of free text information which is pertinent for evaluators. Due to this feature and the associated structure of EXFOR, a computation format is required that translates coded information and numerical data into a form suitable for input into evaluation codes.

R8 For the sake of the cooperation between evaluators and for a comparison of data bases, the Neutron Data Centres (see below) should consider to agree on a common computation format.

A2 Action on evaluators: to study the basic EXFOR and computation formats and coding rules for futher improvements.

R9 The ENDF format should be used for the exchange and dissemination of evaluated data, in particular ENDF-VI, as soon as it will be ready.

3.2 Completeness of the EXFOR data base

Unfortunately, compilation of fission yields in EXFOR started rather late so that many pre-1970 data are not included. Also, not all of the post-1970 and current measurements are compiled yet. As EXFOR is proposed as the common data base and format for fission yield measurements, its completeness has to be assessed. Furthermore, a considerable amount of work will be required, particularly regarding the earlier data, in order to reach completeness.

R10 Therefore it is recommended that a special effort to remove this deficiency should start as soon as possible after this meeting in cooperation with the 4 Neutron Data Centres:

USA National Nuclear Data Centre (NNDC), BNL, USA
NEA Data Bank (NEA-DB), Saclay, France
IAEA Nuclear Data Section (NDS), Vienna Austria
USSR Nuclear Data Centre (CJD), Obninsk, USSR

A3 Action on the 4 Neutron Data Centres: a completeness cross-check should be made between CINDA, EXFOR and the evaluators' files of experimental data. All data missing in EXFOR should be compiled.

NNDC has a computer program for the automatic conversion of experimental data compiled by B.F. Rider into EXFOR.

A4 Action on V. McLane (NNDC): to convert all those of Rider's data into the EXFOR format which are not in the EXFOR file, and distribute them to the responsible Data Centres. In a joint effort with evaluators, the Data Centres will complete these converted EXFOR entries with information taken from the original literature, as the workload of the groups involved permits.

3.3. Special recommendations concerning EXFOR

R11 It is recommended that EXFOR be advertised at meetings, in publications, etc. dealing (among other things) with fission yield data.

R12 Reviews and corrections of experimental results performed by evaluators should be included in the respective EXFOR entries with appropriate comments and flagging.

It is recognized that jounal editors generally do not accept too lengthy publications containing all details on data and error analysis.

R13 It is therefore recommended that such details be published in laboratory reports and/or, in particular, be provided by measurers for compilation into EXFOR.

R14 With all this detailed information, EXFOR entries are recommended to be recognized as publications, which can be quoted as references.

4. DEFINITIONS OF FISSION YIELDS

Different definitions exist for fission yield types (except for independent yields) and measurement methods (absolute-relative). The adopted definitions given below are chosen to reflect the values given by measurers when publishing their results:

- independent yield: fraction of nuclei per fission of a given fission product formed directly after fission;

- cumulative yield: fraction of nuclei per fission of a given fission product which were formed, whatever the time after fission they were formed.

- chain yield: sum of cumulative yields of the stable fission products of a given mass chain;

- fractional independent or cumulative yield: independent or cumulative yield divided by the respective chain yield.

In the above definitions, the wording "fraction of ..... formed ...." can equally be replaced by "probability .... for the formation ....". Independent, cumulative and chain yields are given as fraction per fission or in percent per fission; fractional yields are dimensionless.

Remarks on the definitions of cumulative and total chain yields:

The term "total chain yield" may be used by measurers for all cumulative yields which have practically the same value as the chain yield in the strict definition.

In work dealing with semiempirtical models and in some measurements of isobaric charge distribution the cumulative and chain yields are defined as sums of independent isobaric yields. It should be noted that this definition differs from the adopted one, as for mass chains with significant delayed neutron emission (to and/or from the chain) the independent isobaric yields do not sum up to the cumulative or total chain yields. This should be taken into account in evaluations and models of charge dispersions. The adopted definition has been chosen to avoid confusion as it has generally been used in publications of experiments.

Pertinent to evaluators is the distinction between absolute and relative determinations of fission yields. An "absolute fission yield measurement" requires the determination of the number of fissions as well as the number of nuclides or the absolute activities of fission products. All yield determinations based on assumptions or literature values for other fission yields should be regarded as relative. In particular, the fission product yield "summation method" should not be regarded as an "absolute method", since yields not measured in a particular experiment are taken from literature or estimated. The evaluator can replace these "unmeasured yields" by his own data as in the case of reference yields.

5. MODEL CALCULATIONS AND INDEPENDENT YIELDS

Mass and charge distributions predicted by theoretical models for the fission process are not sufficient for applied purposes. However, participants of the meeting recognized the importance of fission theory for evaluation and hoped that future developments would help in the understanding and improvement of semi-empirical models.

The behaviour of semiempirical model parameters near symmetric
fission (distribution width, charge displacement) is still
uncertain. Further studies are also needed for the variation of
the Gaussian width parameter σ with fissioning system. Even for
the most thoroughly studied system, U235 thermal fission, only
R15 about 1/5 of all independent yields are measured. Therefore,
further measurements of independent yields and charge
distributions, particularly in the symmetric region are needed.

More measurements for U235 thermal fission whould be useful, but measurements for other fissioning systems are even more important.
R16 It should be a task for the CRP to study and compare the Z_p and A'_p models regarding their prediction capability.

R17 For a better understanding of the fission process and to enable the further development of predicting models, the odd-even effect and isomeric yields should be studied in detail by measurers and evaluators. In particular, predicted isomeric yield ratios are unreliable, and measurements are needed.

6. FISSION YIELD MEASUREMENTS

6.1. Recommendations for Measurements

Cumulative and chain yields

For the main fissioning systems complete reliable sets of chain yields should be available, as they are needed for the calculation of absolute independent yields from fractional yields, and some of them serve as standards, apart from their significance in applications.

Deficient chain yield data (i.e.: no measurements, discrepancies)
R18 were identified for 15 fissioning systems during the meeting and are recommended for measurements. A detailed list is given in the Appendix. These and other fissioning systems will be studied by CRP participants in detail.

Independent yields:

Measurements of independent yields including those of very short lived fission products are recommended (see 5.) for model calculations. They are important for the prediction of decay heat via summation calculations.

R19 Special care should be taken by measurers and evaluators to take into account isomeric yields, branching fractions and delayed neutron emission in independent yield measurements. Measurers are
R20 requested to publish sufficient details on the method used and how these data were used in the analysis.

Ternary Fission yields:

Tenary fission yields are requested by reactor designers primarily for Tritium, but also for He4, both for thermal neutron fission and as a function of neutron energy. In evaluations, ternary fission yields enter the calculations of physical constraints on the sums of mass and charge yields.

R21 Further measurements of ternary fission yields are needed:
- for thermal neutron fission;
- as a function of neutron energy;
- versus binary fragment mass.

6.2 Statement of concern

Meeting participants are aware of the danger that radiochemistry institutes and the associated facilities like OSTIS, HAIWATHA and others are being closed down. They are worried about this development, since it will seriously reduce the possibilities for measurement of fission yields.

6.3. Communication with measurers

In order to receive world-wide attention for fission yield measurements requested by this meeting and the CRP, meeting participants recommend several means of communication with measurers.

R22 Fission yields, which will be recommended for measurement, should be maintained and updated by NDS on a computer file. A newsletter listing these requirements together with indications of the application fields for which the data are needed, could be issued by the NDS on behalf of the CRP.

R23 The same list should be published in every issue of the report series "Progress in Fission Product Nuclear Data (FPND)". The requests expressed in parts 5 and 6.1 above and the list given in the Appendix have been included in the 12th issue of "Progress in FPND" (published in January 1988).

R24 In addition, WRENDA (World Request List of Nuclear Data) and national request lists should be used to publish the required measurements, although the long intervals between publications do not promise a timely response to the requests.

However, it would be desirable that participants in the CRP contact measurers directly.

R25 Therefore the assistance of INDC members and liaison officers should be sought to establish contacts with groups prepared to measure the required fission yields.

A5 Action on M. Lammer: to present this proposal to the INDC and, if accepted, to act as a link between INDC and CRP.

6.4. Publication of uncertainties and experimental details

The errors associated with measurements are reported by measurers in a variety of ways: they range from one standard deviation corresponding to the measurement precision only, over estimated total errors to a detailed specification of error contributions and correlations.

R26 It is recommended that measures publish all contributions to the overall uncertainty in detail, i.e. statistical measurement error, systematic error contributions (determined or estimated), correlations and covariances (or at least estimates of correlation coefficients).

R27 Furthermore, sufficient experimental details should be published to allow evaluators a judgement of the error assignments and measurement results. All these details can be included in laboratory reports or in EXFOR (see recommendation R13).

7. FISSION YIELD EVALUATION

7.1. Fissioning systems

Fission yield evaluations should concentrate on fissioning systems required for nuclear energy and related applications. For example, the following list of most important systems for thermal (including the U-Th-cycle) and fast reactors is proposed:

thermal fission of U233,235, Pu239,241, Am241
fast fission of Th232, U235,236,238, Pu238-242, Am241
spontaneous fission of Cf252 (as standard).

"Fast" includes yields as a function of reactor spectrum energy parameter.

However, evaluation of existing measurements for other fissioning systems should continue since they are helpful for studies of systematics and fundamental fission theory.

7.2. Discrepant data

Detailed studies of discrepant fission yield data, as well as checking and possible correction of experimental data in general, are beyond the possibilities of present evaluators, but could be a
R28 special task for participants of the CRP. The results should be included in EXFOR entries.

7.3. Evaluation methods

This topic does not really constitute a problem, but discussions of different evaluation methods by the CRP would be fruitful. This would include the treatment of published experimental data or the use of physical constraints for final adjustments.

7.4. Assignment of Uncertainties

For many years there has been an outstanding difference of approach between UK and US evaluators towards the minimum uncertainty that should be assigned to any type of measurement. This problem was discussed at the meeting with the recommendation
R29 that the limits should be reviewed during the CRP in the light of modern techniques. These techniques need to be assessed carefully and impartially, so that possible sources of systematic error can be identified, and some idea of the best achievable accuracy may be obtained. However, it was not agreed that evaluators should use the same limits in the future, as such differences constitute part of the independent evaluation methods.

R30 It is desirable for evaluators to introduce correlations and to set up variance-covariance matrices for fission yields. The assistance of experts in measurement techniques is needed to work out correlations with typical coefficients for different methods. The collection of correlations and development of programs for covariance matrices would be a special task for the CRP, possibly within a fellowship.

7.6. Energy dependence of fission yields

For many years the evaluation of the dependence of fission yields on fast neutron spectra with varying mean energy has been requested for reactor applications. This task has never been accomplished by evaluators due to the lack of manpower, and should therefore be part of the CRP.

The main problem is to find a description or energy parameters for fast neutron spectra suitable to evaluate the energy dependence of fission product yields. This parameter should well characterize any spectrum and should have different and unique values for different spectra. The following two considerations should be
R31 addressed:

- to define the most suitable energy dependent spectrum parameter;

- to find a representation of the energy dependence of yields in evaluations to compare spectrum dependent yields with fission yields from monoenergetic neutrons.

8. FISSION YIELD STANDARDS

Certain fission yields or sets of fission yields are used as standards in relative yield measurements. In a conventional evaluation, these standard yields are evaluated first.

Certainly, U235 thermal fission yields are most frequently used for reference and can be defined as the primary standard set. Other yield sets, which in turn have been measured relative to U235 thermal yields, and which are used as standards in various yield measurements may be called secondary standards. These as
R32 well as yields of individual fission products used as reference (most important: Zr-Nb95, Mo99, I131, Te132, Cs137, Ba-La140, Nd148, sum of Nd yields) should be established by the CRP with the goal to issue a recommended set of standard yields.

9. SUMMARY OF THE CRP

The overall goals of the CRP would be:

- To ensure the continuity in fission yield evaluation;
- To establish a network for future cooperation to share the workload connected with evaluations, and for communication with measurers;
- To produce complete, consistent yield sets for fissioning systems important for applications, which are derived from experimental results and reliable model calculations.

The main tasks for the CRP would be:

- To cooperate in the compilation of yield data into EXFOR, and in the improvement of the EXFOR (and computation) format and coding rules.
- To review presently available yield data and semiempirical models and to recommend measurements needed.
- To further develop models to achieve more reliable predictions.

- To improve the whole evaluation process from the compilation of experimental data to the final least squares fitting procedure using all suitable physical constraints and correlations.
- To define special tasks to be performed by designated CRP participants or, possibly, by research fellows.
- To review the results of special tasks and the overall progress of the effort, and to recommend further steps to be taken.

The special evaluation tasks to be performed by one or more participants in the CRP are:

- evaluation of fission yields used as standards.
- evaluation of isotopic and isobaric independent yields;
- study of isomeric yields, influence of delayed neutron emission;
- detailed studies of discrepant data;
- checking and correction of experimental results;
- development of methods and computer programs for the introduction of correlations and covariance matrices in the evaluation process;
- evaluation of the energy dependence of fission yields;

The following groups were proposed at the meeting for participation in the CRP:

Ongoing evaluation efforts:
T.R. England, B.F. Rider (LANL), USA
M.F. James (AEE Winfrith), D.R. Weaver (U. Birmingham), UK
Wang Dao, Zhang Dongming (Beijing), China
A.C. Wahl (Washington U.), USA

Special evaluation tasks:
H.-O. Denschlag (U. Mainz), FRG
J.K. Dickens (ORNL), USA
G. Rudstam (Studsvik), Sweden

APPENDIX: Chain Yields Recommended for Measurement

(Re)measurements of chain yields are required as given in the tables below. The abbreviations used in the tables have the following meaning:

A = mass number
no = number of measurements
reason = reason for request (except if no = 0 {blank} or 1)
D = disrepant data with large χ^2; the number in brackets gives the probability (in %) for the occurrence of the maximum contribution (from the most discrepant measurement) to the calculated χ^2.
syst = value obtained from systematics

U233 thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	2	D(0.43)	83	3	D(4.7)	116			127	1	
4	4	D(1.6)	91	6	D(0.05)	117	1		128		
72			103	5	D(0.00)	118	1		129	1	
73			105	1		118	1		130		
74			106	5	D(0.43)	120	1		155		
75			107	1		121	1		156	1	
76			108	1		122	1		157	1	
77	1		109	1		123			158		
78			110	1		124	1		159	1	
79			113	1		125	1		160		
80			114	1		126			161	1	
82											

U235 thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
4	9	D(0.00)	106	8	D(0.02)	117	2	D(0.32)	129	5	D(0.00)
73	1		108	2	D(0.11)	118	1		130	1	
74	1		109	5	D(7.3)	119	1		131	14	D(0.00)
75			110	2	D(0.48)	120	1		132	16	D(0.01)
76			112	6	D(0.00)	122	1		149	12	D(1.5)
79	1		113	1		123	5	D(0.15)	153	8	D(0.10)
80	1		114	1		124	1		154	8	D(1.9)
82	1		115	8	D(2.5)	125	11	D(0.00)	160		
103	13	D(0.00)	116	1		128	1				

Pu239 thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
72	1		87	6	D(6.5)	118	1		133	8	D(0.00)
73			98	1		119	1		143	14	D(0.80)
74			100	1		120	1		147	14	D(0.31)
75			105	7	D(0.00)	122	1		152	6	D(0.00)
76			108	1		123			153	3	D(3.8)
77	1		109	4	D(7.1)	124	1		154	6	D(0.50)
78	1		110	1		125	1		155	1	
79			112	5	D(4.3)	126	1		156	6	D(0.00)
80			114	1		127	4	D(1.2)	157	1	
81	1		116	1		128	1		158		
82			117	1		130	1		160		

Pu241 thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1	syst	92	1		113	1		127	2	D(0.34)
4	1	syst	93	1		114			128		
72			94	1		115	1		129		
73			96	1		116			130		
74			98			117			131	4	D(4.2)
75			100			118			136	1	
76			101	1		119			139	1	
77	1		102	1		120			153	1	
78	1		104	1		121			155	1	
79			105	1		122			157	1	
80			106	1		123			158		
81			107			124			159	1	
82			108			125	1		160		
84	1		109	1		126			161	1	
86	1		110								

Th232 fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1		94			116			132	6	D(0.20)
4	1	syst	96			117	1		134	1	
73	1		98			118			135	4	D(0.25)
74			100			119			137	5	D(0.77)
75			101			120			138		
76			102			121	1		145	1	
77	3	D(7.7)	103	5	D(6.5)	122			146	1	
78			104			123	1		148	1	
79			105	4	D(0.00)	124			149	2	D(0.24)
80			106	4	D(3.8)	125	1		150	1	
81			107			126			151	2	D(3.9)
82			108			127	1		152		
84	1		110			128			153	1	
86	1		111	4	D(1.3)	129			154		
87	1		113	1		130			155		
91	7	D(2.0)	114			131	9	D(0.00)	156	1	
93	2	D(3.3)									

U233 fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1		92	1		113			134	1	
4	1	syst	93	1		114			135	1	
72			94	1		115	1		136	1	
73			95	1		116			138	1	
74			96	1		117	1		139	1	
75			97	1		118	1		142	1	
76			98	1		119	1		145	1	
77			99	1		120	1		146	1	
78			100	1		121			148	1	
79			101			122	1		150	1	
80			102			123			152	1	
81			103	1		124	1		153	1	
82			104			125	1		154	1	
83	1		105			126			155		
84	1		106	1		127			156	1	
85	1		107			128			157	1	
86	1		108			129	2	D(0.01)	158		
87	1		109			130			159	1	
88	1		110			131	1		160		
90	1		112			133	1		161	1	

U235 fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1	syst	88	4	D(0.75)	115	6	D(0.94)	128		
72			96	1		116	1		129	1	
73			102	1		117			130		
74			105	2	D(5.4)	118			144	32	D(0.00)
75			106	4	D(0.00)	119			149	6	D(0.00)
76			107			120			152	3	D(2.4)
77			108			121			154	2	D(0.00)
78			109	3	D(0.48)	122			155		
79			110			123			157		
80			111	26	D(0.00)	124			158		
81			112	7	D(0.00)	125	1		159	1	
82			113	1		126			160		
87	6	D(6.5)	114	1		127					

U238 fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1		86	1		109	3	D(6.7)	125	3	D(0.00)
4	1	syst	88	4	D(2.1)	110			126		
72	1		89	21	D(0.00)	113			127	6	D(0.07)
73			94	1		114			128		
74			96	1		115	10	D(0.13)	129	3	D(0.00)
75			98	1		116			130		
76			100	1		117			135	4	D(7.6)
77	3	D(2.9)	101			118			136	3	D(10.0)
78			102			119			139	1	
79			103	10	D(0.89)	120			155		
80			104			121	1		157		
81			106	3	D(3.8)	122			158		
82			107			123			159	1	
83	1		108			124			160		
84	1										

Pu239 fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1		95	18	D(0.00)	116	1		129	2	D(0.03)
4	1	syst	102	1		117			130		
72			103	10	D(1.6)	118			137	10	D(0.88)
73			104	1		119			144	14	D(0.99)
74			105	1		120			152	2	D(3.7)
75			107			121			153	1	
76			108			122			154	2	D(0.41)
77	2	D(0.00)	110			123			155		
78			111	11	D(0.00)	124			156	5	D(2.3)
79			112	4	D(2.6)	125	2	D(0.28)	158		
80			113	1		126			159		
81			114	1		127			160		
82			115	10	D(0.00)	128					

Pu240 fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1	syst	92	1		116			136	1	
4	1	syst	94	1		117			138	1	
72	1		96	1		118			139	1	
73			98	1		119			141	1	
74			99	1		120			142	1	
75			100	1		121			145	1	
76			101	1		122			146	1	
77			102	1		123			148	1	
78			103	1		124			150	1	
79			104	1		125	1		152	1	
80			105	1		126			153	1	
81			107			127	1		154	1	
82			108			128			155	1	
83	1		109	1		129			156	1	
84	1		110			130			157	1	
85	1		111	1		131	2	D(0.00)	158		
86	1		112	1		132	1		159	1	
87	1		113	1		133	1		160		
88	1		114			134	1		161	1	
89	1										

Pu241 fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1	syst	92	1		113			134	1	
4	1	syst	93	1		114			135	1	
72			94	1		115			136	1	
73			95	1		116			137	1	
74			96	1		117			138	1	
75			97	1		118			139	1	
76			98	1		119			140	1	
77			99			120			141		
78			100	1		121			142	1	
79			101	1		122			143	1	
80			102	1		123			144	1	
81			103			124			145	1	
82			104	1		125	1		146	1	
83	1		105			126			147	1	
84	1		106	1		127			148	1	
85	1		107			128			149	1	
86	1		108			129			150	1	
87	1		109			130			151	1	
88	1		110			131	1		152	1	
89			111			132	1		153		
90	1		112			133	1		154	1	
91	1										

Th232 14 MeV fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1	syst	98			123			144		
4	1	syst	100			124			145	1	
72	3	D(0.00)	101	1		125	1		146		
73	2	D(0.77)	102	1		126			148		
74			104			128			149	1	
75			106	1		129	4	D(1.00)	150		
76			107			130			151		
78	1		108			131	5	D(0.05)	152		
79	1		110			132	7	D(0.03)	153	1	
80			112	7	D(1.3)	133	4	D(0.55)	154		
81	1		114			134	2	D(4.0)	155		
82			115	1		135	3	D(5.3)	156		
84	2	D(1.2)	116			136	1		157		
86			117	1		137			158		
87			118			138			159	1	
90	1		119			139	2	D(7.5)	160		
94			120			142	1		161	1	
96			122								

U233 14 MeV fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1	syst	89	1		118			142		
4	1	syst	90			119			144	1	
72	1		91	3	D(8.3)	120			145		
73			92	2	D(2.5)	121	2	D(3.2)	146		
74			94			122			148		
75			96			123			149		
76			98			124			150		
77			100			125	1		151	1	
78			101			126			152		
79			102			128			153	1	
80			104			129			154		
81			106	1		130			155		
82			107			131	1		156	1	
83	1		108			134	1		157		
84	1		110			135	1		158		
85	1		113	3	D(0.28)	136			159	1	
86			114			138			160		
87	1		116			139	1		161	1	
88	1		117			140	3	D(3.8)			

U235 14 MeV fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1	syst	90	1		115	6	D(0.00)	141	1	
4	1	syst	92			116			142		
72	2	D(7.5)	93	1		117			145		
73			94			118			146		
74			96			119			148		
75			97	4	D(2.7)	120			149		
76			98			122			150		
77	1		100			123			151		
78			101			124			152		
79			102			125	1		153	1	
80			104			126	1		154		
82			105	4	D(0.00)	128			155		
83	3	D(4.7)	106	3	D(6.3)	130			157		
84	1		107			133	2	D(1.9)	158		
85	1		108			135	1		159	1	
86			109	1		136	1		160		
87	1		110			137	2	D(5.0)	161	2	D(5.5)
88	1		114			138	1				

U238 14 MeV fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1	syst	96			115	16	D(0.00)	133	10	D(0.00)
4	1	syst	98			116			134	7	D(4.1)
72	1		100	4	D(7.1)	117	1		135	11	D(0.98)
73	1		101	1		118	1		146	1	
74			102	3	D(3.1)	119			148		
75			103	9	D(0.00)	120			149	6	D(0.00)
76			104	1		121	3	D(6.3)	150		
79	1		105	15	D(0.56)	122			152		
80			107	1		123	1		154		
81	1		108			124			155		
82			109	4	D(2.4)	126			157	1	
86	1		110			128	1		158		
88	4	D(1.9)	111	14	D(0.36)	129	7	D(0.02)	159	2	D(0.52)
89	10	D(0.64)	112	10	D(2.5)	130			160		
91	13	D(0.00)	114			131	18	D(0.00)	161	4	D(0.01)
94	1										