International Atomic Energy Agency

INDC(NDS)-261
Distr. G+Sp.

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

COMPILATION AND EVALUATION OF FISSION YIELD NUCLEAR DATA

SUMMARY REPORT

of a Consutants' Meeting organized by the
International Atomic Energy Agency
Vienna, 27-29 September 1989

prepared by

Meinhart Lammer
Nuclear Data Section
International Atomic Energy Agency

September 1991

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

INDC(NDS)-261
Distr. G+Sp.

COMPILATION AND EVALUATION OF FISSION YIELD NUCLEAR DATA

SUMMARY REPORT

of a Consutants' Meeting organized by the
International Atomic Energy Agency
Vienna, 27-29 September 1989

prepared by

Meinhart Lammer
Nuclear Data Section
International Atomic Energy Agency

September 1991

TABLE OF CONTENTS

List of Participants

J. Blachot	Centre d'Etudes Nucléaires de Grenoble Lab de Physique Nucléaires F-38041 Grenoble CEDEX, France
J.O. Denschlag	Institut für Kernchemie, Universität Mainz D-6500 Mainz, Federal Republic of Germany
L.V. Drapchinsky	V.G. Khlopin Radiev Institut Leningrad, USSR
T.R. England	Los Alamos National Laboratory Los Alamos, New Mexico 87545, U.S.A.
A.A. Goverdovsky	Fiziko-Energeticheskii Institut 240 020 Obninsk, USSR
M.F. James	Atomic Energy Establishment Winfrith, Dorchester, Dorset DT2 8DH, United Kingdom
M. Lammer	Nuclear Data Section International Atomic Energy Agency A-1400 Vienna, Austria
V. McLane	National Nuclear Data Center Brookhaven National Laboratory Upton, New York 11973, U.S.A.
R.W. Mills	Atomic Energy Establishment Winfrith, Dorchester, Dorset DT2 8DH, United Kingdom
G. Rudstam	Uppsala University The Studsvik Neutron Research Laboratory S-611 82 Nypkoeping, Sweden
A.C. Wahl	Washington University St. Louis, Missouri 63130, U.S.A.
Wang Dao	Chinese Nuclear Data Centre Institute of Atomic Energy Beijing, The People's Republic of China

Glossary of Abbreviations

Abbreviations on left margin:

Ax	Action number x
CRP	Task for the CRP (see below)
Rx	Recommendation number x

Other abbreviations:

CRP	IAEA Co-ordinated Research Programme
ENDF	Evaluated Nuclear Data File (USA)
EXFOR	EXchange FORmat (for exchange of compiled experimental data between the Nuclear Reaction Data Centres, see below)
FPND	Fission Product Nuclear Data
IAEA	International Atomic Energy Agency
INDC	International Nuclear Data Committee
JEF	Joint Evaluated File (of nuclear data)
NDS	Nuclear Data Section (IAEA)
NEA	Nuclear Energy Agency (OECD)
NEA-DB	NEA Data Bank (Saclay, France)
OECD	Organization for Economic Co-operation and Development
UKFY2	United Kingdom evaluated Fission Yield file, version 2
WRENDA	World REquest List for Nuclear DAta

The 4 co-operating Neutron Nuclear Data Centres

Nuclear Data Section
International Atomic Energy Agency
A-1400 Vienna
Austria

National Nuclear Data Center
Brookhaven National Laboratory
Upton, New York 11973
USA

NEA Data Bank
Saclay
F-91191 Gif-Sur-Yvette
France

Centr po Yadernym Dannym
Fiziko-Energeticheskii Institut
240 020 Obninsk, Kaluga Region
Russia

MEETING AGENDA

Opening:

Election of chairman, adoption of agenda.

Reports from past meetings

Reports of evaluators:

Brief reports on evaluation efforts

Compilation of experimental data, including EXFOR

Cooperation between evaluators

Discussion: experiments, models, evaluations

Experimental data (general), including:
- new measurements, facilities
- measurement methods, deficiencies
- requests to measureres

Model calculations and yield data needed for their improvement

Evaluations: evaluation methods, assigment of uncertainties, correlations, special evaluation tasks

Ternary fission yields

User requirements and yield data to be included in evaluations

Communication with measurers

Co-ordinated Research Programme (CRP)

Summary of scope of the CRP

Formulation of special tasks in detail and proposal of scientists who could be assigned the tasks

Methods of work within the CRP and assignment of tasks of participants

1. INTRODUCTION

The task of this meeting was to review the progress made since the previous meeting on fission yield evaluation (Studsvik, Sweden, 11-15 September 1987; summary report published as INDC(NDS)-208) and to define the tasks for an IAEA Co-ordinated Research Programme (CRP) in detail. Improvements have been noted in measured data, model calculations and the situation of fission yield evaluation. This can partially be credited to the previous meeting, which stimulated closer co-operation among evaluators, who all are meeting participants, and improved the communication with measurers.

At the beginning of the first session, highlights from NEACRP/NEANDC task force meeting on Decay Heat, Saclay, France, 21-22 September 1989, were presented. The most important observations and conclusions were:

The situation is not satisfactory: calculations do not agree among each other; measurements do not agree (calorimetry - spectroscopy); the summation calculation results are closer to spectroscopy. One observation was that the yields are not necessarily responsible for the discrepancies between summation calculations for ^{239}Pu. Furthermore, it was concluded that decay data are most important to reach agreement between summation calculations and measurements

2. FISSION YIELD MEASUREMENTS

Recommendations for fission yield measurements are collected either only in chapter 8: "Summary of requests to measurers", or they are repeated there.

2.1 Statement of concern

Although the situation of on-line facilities has improved slightly over the last 2 years, the meeting participants are still concerned about the lack of support and funding:

- The OSTIS facility is closed down.
- Experiments are continuing on LOHENGRIN but there are manpower shortages.
- The restart of HIAWATHA at the University of Texas is planned, but an up-to-date request list for measurements is needed.

Such experimental facilities are needed for further fission yield measurements and should be maintained.

2.2 Reports on experimental facilities and recent results

Denschlag, Rudstam, Goverdovsky, Drapchinsky and Blachot reported on their own and other measurements and facilities, as summarized below:

Double ionization chambers were in use at Geel and Saclay, mainly for mass yields.

At Darmstadt (DIOGENES), multiparameter measuerements were carried out on ternary fission.

Chapman had measured ternary fission yields and the energy dependence of mass yields.

Isomeric yield ratios for ^{134}I m/(g+m) had been measured at Grenoble by the Mainz group for the fission of ^{233}U, ^{235}U and ^{239}Pu. The results show a different behaviour of the ratio with the kinetic energy of the fragments, which would not be predicted by a simple theory such as that of Madland and England.

At Studsvik, results for many isomeric yield ratios for the thermal fission of ^{235}U had been obtained. Yields from fast fission of ^{238}U were in progress.

At FEI, Obninsk, measurements with a gridded double ionization chamber were performed especially on ternary fission. Further investigations of cold fragmentation, and of fission properties for $^{234,6,8}U$ up to 15 MeV were done. Planned are studies of Th, Am and Cm isotopes.

The Leningrad Laboratory was also measuring ternary fission yields, using an ionization chamber with pulse shape discrimination in nearly 2-pi geometry.

The OSIRIS facility at Studsvik was continuing to be in use. Recent results had been obtained on isomeric yields. Plans included experiments on fast fission of ^{238}U and possibly also ^{233}U.

Accelerator measurements of the energy dependence of fission yields have been performed at Argonne (Glendenin) and Livermore (Nethaway).

2.3 Ternary fission yields

Ternary fission yields are requested by reactor designers primarily for Tritium, but also for ^4He, both for thermal neutron fission and as a function of incident neutron energy. In evaluations, ternary fission yields enter the calculations of physical constraints on the sums of mass and charge yields.

Some details of recent measurements:

The multiparameter measuerements performed with DIOGENES (Theobald) determine simultaneously the mass and charge of the lighter of the heavy fragments and of the light particle, and the angular distribution of the latter.

Preliminary results obtained at FEI, Obninsk, suggested large ternary yields from ^{238}U. A wide range of incident neutron energies (threshold to 15 MeV) were being used. Goverdovsky hoped to collaborate more with LOHENGRIN, using many targets, and looking at both ternary fission and charge distributions.

Results for ternary fission yields, especially for tritium, were obtained for 8 nuclides at the Leningrad Laboratory. These measurements were with 14 Mev neutrons; it was hoped to continue with 2.5 MeV neutrons as well. The errors are around 10%. New results will be available in 1990. The conclusions from the current results were: Ternary fission probability increases with Z^2/A; it is lower for more neutron rich fissioning nuclei, higher for spontaneous fission than neutron fission.

R1 Although a number of results from recent measurements have been reported, further measurements of ternary fission yields as function of neutron energy should be performed.

R2 Furthermore, theoretical approaches to study the variation of ternary yields with neutron energy, fissioning nucleus, etc., should be encouraged.

Goverdovsky reported new theoretical approaches that were being developed at Obninsk together with Leningrad and Dubna.

2.4 Limits and accuracies of experimental techniques

<u>On-line experiments: comments and recommendations</u>

It was noted that data obtained in on-line experiments like those done with LOHENGRIN contain a lot of physics information, but only partial yield data are evaluated. They need summing over ionic charges. This has not been done: results are only given for the mean kinetic energy. Therefore on-line experiments are presently not included in evaluations.

R3 More new multiparameter measurements over ionic charge states and kinetic energy of fragments should be performed to allow summing over these parameters. This is particularly true for ternary fission experiments.

When isomeric yields are measured with mass separators, it should be noted that the population of ionic charges may differ for the isomers: a low energy isomeric transition gamma ray may be converted, leading to Auger electron emission. Thus the ratio m/(m+g) may be a function of ionic charge, and the readily obtained value for the ratio for the mean charge may not equal the required mean ratio.

Apparatus such as LOHENGRIN and HIAWATHA have limits at low fractional yields (about 1%). These facilities separate beams according to the ratio of mass to ionic charge and according to kinetic energy. Since ionic charge and kinetic energy show distributions, the final yields are sums over these variables, and some approximation has to be made in the summation.

The volatility of fission products under the conditions in mass separator sources had to be considered: for example, Barium is volatile in the conditions of the OSTIS facility, and this has to be considered in making systematic corrections.

Discrepancies

Evaluators found systematic discrepancies: results from LOHENGRIN and HIAWATHA independent yield measurements are much higher than those from radiochemical measurements. These discrepancies constitute an unsolved problem.

CRP It should be a task of the CRP to try and resolve these and other discrepancies among measured fission yield data, as collected in the tables in the Appendix. However, advice from experts is needed.

R4 Therefore measurers should be asked to study and discuss systematic discrepancies associated with apparatus and measurement methods.

3. COMPILATION OF FISSION YIELDS

EXFOR is now adopted as the generally accepted common format and data base for the compilation of experimental fission yield data. The 4 Neutron Data Centres (listed on page v) are responsible for compiling these data into EXFOR and for the maintenance of the EXFOR data base.

3.1 EXFOR format and contents

R5 EXFOR entries should contain detailed information on the measurement method, corrections applied, data used in the analysis and sources of error, which measurers should be asked to provide.

R6 In particular, information should be given whether in independent yield measurements isomeric yields, branching fractions and delayed neutron emission were taken into account and which values were used. (See also recommendations R38 and R39 to measureres in chapter 8).

Evaluators should inform the 4 Neutron Data Centres what information should be included in EXFOR. Lammer has prepared a proposal and distributed it to meeting participants.

A1 Meeting participants should check this proposal and send any comments and/or additions to Lammer, who will forward them to the 4 Neutron Data Centres for consideration at their meeting.

A2 In addition, NEA-DB is requested to also send author proof copies of fission yield EXFOR entries to the measurers.

3.2 Retrievals from the EXFOR data base

EXFOR entries contain, in addition to coded information, a lot of free text information which is pertinent for evaluators. In order to make proper use of the EXFOR data base, evaluators need to make selected retrievals of complete EXFOR entries as well as of coded information.

R7 The Data Centres should consider the following suggestions:

- improve the indexing of EXFOR entries;
- improve the "help" section;
- retrievals from EXFOR should be possible according to:
  target
  type of yield
  neutron energy
  fission product nuclide

For the use of EXFOR in evaluation procedures, a computation format is required that retrieves coded information and numerical data from the EXFOR file and translates it into a form suitable for input into evaluation codes. At the time of this meeting there was still no agreed computation format. Therefore the corresponding recommendation from the last meeting (Studsvik, 1987) is repeated here again:

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

A3 McLane has produced a proposed revised computation format and distributed it to meeting participants. Meeting participants were asked to review and comment this proposal, to prepare a wish list of what information should be included in the the computation format and to send it to McLane.

Some comments on the computation format were already made during the meeting: It was considered a drawback that 2 normalization points are not possible; 3 different kinds of listings were proposed: absolute, relative, R-values.

3.3 Special recommendations concerning EXFOR

R9 It is recommended that EXFOR be advertised at meetings, in publications, etc. dealing (among other things) with fission yield data.

R10 Evaluators should send their reviews and corrections of experimental results to compilers for inclusion in the respective EXFOR entries with appropriate comments and flagging.

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

R11 It is therefore recommended that such details be published in laboratory reports and/or, in particular, be provided by measurers for compilation into EXFOR.

R12 With all this detailed information, EXFOR entries are recommended to be recognized as publications, which can be quoted together with the original publication.

4. MODEL CALCULATIONS

The evaluation of experimental data is not sufficient for decay heat calculations. Therefore they have to be supplemented by calculated data, based on semi-empirical models.

On the other hand, mass and charge distributions predicted by purely theoretical models for the fission process are not sufficient either 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.

4.1 Models for charge distribution

Wahl reviewed the Zp and Ap' models (details are published elsewhere) The Ap' model, which had been further developed since the last meeting, appears to give more general and consistent results than the older Zp model. Whereas the Zp model uses fractional independent yields as input, the Ap' model uses independent yields and chain yields. Hence the latter can generate chain yields in good agreement with measurements.

The model parameters are fitted by least squares to experimental data. All parameters are derived from ^{235}U data (many data points) and some are assumed to apply to other reactions. Variations of model parameters (e.g. sigma) with A of the fissioning nucleus have been observed.

It was observed that the pairing effect drops with the excitation energy and with Z of the fissioning nucleus.

R13 To confirm this observation, direct measurements of the energy dependence of the pairing effect with a double ionization chamber should be conducted. (Goverdovsky said that he could do such measurements).

R14 Several new measurements of independent yields for isomeric states had been completed recently. Now further studies of systematics should be conducted that represent these yields better than the current systematics based entirely on the spins of the isomeric states or on equal division between the states.

4.2 Models for mass distribution

Generally, mass distributions are obtained from measurement results. However, gaps in measured mass yields that are too large for linear interpolation can be filled by fitting 5 Gaussians to the distributions. Also, systematic studies of the fitting parameters could lead to predictions of unmeasured mass distributions. Such studies are conducted in the UK. The Ap' model with many Gaussians is also useful for estimation of unmeasured chain yields.

It was noted that the fitting of 5 Gaussians is not sufficient as they do not take account of the "bumps" that have been observed at the wings of mass distributions, which are also supported by theory. There is a correlation between bumps at the wings and the height of the valley region. However, the use of a broad central peak to fit the valley region produces bumps at the wings of the mass distribution that are not physically real (i.e. they do not physically stem from a broad central peak). Mills reported that this had been corrected in the UK evaluation: the new fit uses a narrower or truncated central peak which does not broaden the wings.

Wahl commented that similar wing shapes have been observed for most fission reactions, and that this should be reflected in the extrapolations. Also, the use of similar wing shapes would facilitate the detection and evaluation of deviations from these shapes. He reported that with a Gaussian fit for ^{238}U yields using the Ap' model, the bump at the low-mass wing could be reproduced, but not at the high-mass wing. Conclusion: the Ap' model cannot completely account for the bumps.

4.3 Uncertainties of estimated yields

Chain yields

Wahl discussed the uncertainty assignments for estimated chain yields in current evaluations:

ENDF/B-VI:	32% of a wing yield, less for yields near peaks.
UKFY2:	25% of a wing yield, less for yields near peaks.
Ap' Model:	25% for yields >0.1%, 50% for yields between 0.001% and 0.1%, and 100% for yields <0.001%.

Interpolated chain yields on or near peaks, for which there are many data, can probably be estimated to better than 25%, and very small yields on the wings and in the valley can probably be estimated less well than 25% or 32% and maybe even 100%. Some continuous sliding scale might be devised for variation of estimated errors with the magnitude of yields, but account should also be taken of experimental yields for nearby mass numbers.

James suggested that the format should be changed to fractional uncertainties which are more realistic and allow for errors > 100%.

Independent yields

The uncertainties of unmeasured independent yields cannot be estimated.
R15 However, to get an idea about the uncertainties of estimated or calculated yields, comparisons between earlier predictions and new
CRP measurements should be done. This could be a CRP task by a measurer (e.g. Rudstam) and an evaluator (e.g. Wahl).

4.4 Improvements of models

For the calculation of independent yields, semi-empirical models are used, the parameters of which are derived from measuerement results. However, fundamental theory can help to give some insight in these models and also help with systematics of the variation of yields with certain parameters.

R16 For the understanding of the energy dissipation in fission at the scission point it is desirable to measure simultaneously the kinetic energy, neutron emission and the emission angle versus (Z,A) of the fragments for different neutron energies.

R17 For the further development of semi-empirical models, there is a need for systematics based on theory. Thoretical studies should be conducted to find systematics in all fission yield information, the energy dependence being one of them.

R18 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.

Although a considerable number of new independent yields have been measured over the last 2 years and helped to improve the semi-empirical models, the data are still insufficient to allow a thorough study of the systematics of model parameters, and for a reliable evaluation of many fission reactions:

R19 Independent yields have been measured for only a small fraction of the products from any fission reaction. Even for the most thoroughly studied system, ^{235}U thermal fission, only a small fraction of all independent yields are measured. Therefore, further measurements of independent yields and charge distributions of any of the many unmeasured independent yield are needed.

R20 The behaviour of semiempirical model parameters near symmetric fission (distribution width, charge displacement) is still uncertain and independent yields are known only for thermal fission of ^{235}U, to a limited extent for ^{233}U. Independent yield measurements for nuclides near symmetry are needed for a number of other fission reactions with different A, Z, and excitation energies.

R21 There are insufficient nuclear-charge-distribution data for most fast-neutron-induced fission reactions to determine even-odd-Z factors directly. Further measurements are needed.

R22 To allow a systematic study of Gaussian shapes to represent the "bumps" observed at the wings of mass distributions, more measurements in these fission product mass regions are required for many fission reactions.

The priorities for measurements are:

1st priority: independent yields
2nd priority: yields at wings

Fission reactions:

1st priority for ^{235}U thermal fission
2nd priority for other reactions

5. FISSION YIELD EVALUATION

It was emphasized that evaluation is necessary as long as measurements are being made, so that the results can be digested and incorporated in useable computer files; otherwise data obtained at cosiderable expense will not become available for practical use.

R23 It will alsways be desirable to have at least two independent evaluations available world-wide so that intercomparisons can be made. However, it is recognised that this may regrettably not at present be possible, and in these circumstances it is hoped that a joint evaluation may be attainable by co-operation.

R24 To enable co-operation on an international scale, but also for the benefit of users of fission yield evaluations, all fission yield compilations and evaluations should be openly available. (ENDF/B-VI and JEF-2 will be generally available).

It was noted that as a result of the past meetings on fission yield evaluation and the announcement of the CRP, the co-operation between evaluators has improved considerably and functions now on an international basis.

5.1 Status of current evaluations (reports)

This section highlights the status of evaluations and methods employed from reports presented. Details are published elsewhere.

US file ENDF/B-VI (England):

The evaluation contains currently 50 yield sets, 10 further sets may be included later. Independent and chain yields are evaluated simultaneously.

Cumulative yields are after delayed neutron emission. Independent yields: delayed neutron emitters are included; yields are before delayed neutron emission, the evaluation process includes decay data and branching ratios Parameters for charge distribution (Zp model) were obtained from Wahl.

Evaluation of experimental data used inverse variance weighting. Constraints on the evaluation: conservation of charge and mass; adjustment of yields (not by least squares) to sum to 1 over each mass peak.

UK file UKFY2 (Mills):

The file contains presently 39 yield sets of importance for industry. The data base continues Crouch's file of experimental data. It was complete up to the end of 1988 and includes the automatic conversion of EXFOR.

Wahl's Zp model was used for fractional independent yields but with independently derived parameters. Chain yields were first obtained from experimental averages. Then short gaps were filled by interpolation, larger gaps by using the 5 Gaussian model.

Measurements were evaluated by inverse variance weighting, and discrepant values were downweighted. Final adjustments were made by least-squares methods (sum of chain yields equals 1 under each mass peak) with constraints conserving mass, charge and number of nucleons, and to make yields of complementary elements equal. The adjustment program also adjusts the errors.

French file (Blachot):

The French fission product file is used for decay heat calculations. It contains fission yields and decay data for 715 fission products. Chain yields for 6 fissioning systems are presently taken from ENDF/B. For the future it can be recommended that JEF-2 can be used in France (based on UKFY2). Independent yields were obtained from Wahl. Isomeric yields were introduced to Wahl's independent yields.

USSR (Goverdovsky):

A library of evaluated independent and cumulative yields has just been started. It will be sent to NDS.

Wahl's evaluation of nuclear charge distribution:

Data have been evaluated and Zp and Ap' model parameters have been derived for 8 fission reactions, and (fractional) independent yields calculated. Also, experimental independent yields were evaluated. Certain types of measurements that were considered to be unreliable were discarded.

Zp model parameters were obtained for another 42 fission reactions to be included in ENDF/B-VI.

Chinese file (Wang Dao):

The file contains 10 sets of evaluated yields in ENDF/B format, and includes cumulative and independent yields. The experimental data base was that of Rider and England, supplemented by pre-1979 Chinese measurements and recent publications.

Experimental data are evaluated and supplemented by model calculations. Calculated yields are assigned an error of 100%. Mass yields were adjusted and physical constraints were applied.

5.2 Use of models in evaluations

R25 Studies have shown that the Ap' model has considerable advantages over the Zp model and it could in future evaluations deal with all types of data. It is understood that in present evaluations the Zp model is still used because there is not sufficient time and manpower available to evaluators to make the necessary changes in programs for the adjustment and evaluation procedures. However, future evaluation efforts and computer programs could use the Ap' model.

5.3 Evaluation methods and treatment of input data

Certain evaluation procedures are now generally accepted for all evaluations:

- Experimental data are evaluated by inverse variance weighting.
- Estimated yields and model calculations are used where measurements are lacking, particularly for inedependent yields.
- Evaluated chain yields are finally adjusted to make the sum of yields in each mass peak equal to 1 (or 100%). Physical constraints such as the coservation of mass, charge and the number of nucleons, equal yields of complementary elements, are applied in the adjustment procedure.

Some details like the use of weights in the adjustment or the number of constraints are of course open to discussion. However, it was agreed that differences in evaluation methods and treatment of input data are part of the recommended independence of evaluation efforts.

R26 Information and data on delayed neutrons, isomeric yield ratios, half lives and decay branching fractions are important for the evaluation of cumulative and independent yields. Therefore it is necessary that these data be included in the evaluation process.

R27 Measurers are asked to perform measurements of these data.

Discrepant data

R28 Discrepant outliners are generally downweighted or discarded by evaluators for good reason. However, information on the treatment of outliers should be included in the evaluation.

CRP It was recognised as a CRP task to analyse dicrepant yield data, hopefully with the help of measurers (see section 2.4). Such data are collected again in the tables in the Appendix.

It was suggested that an indication of the source of yields and errors be included in files of chain yields. These files could be used as a source of information to update and extend the tables of deficient yield data recommended for measurement.

Uncertainties

CRP Uncertainties of estimated yields are dealt with in section 4.3. It should be a task for the CRP to investigate what typical uncertainties are associated with different measurement methods.

R29 Evaluators need to know what realistic, typical uncertainties should be assigned for each measurement method. The CRP should contact measurers to provide such information.

5.4 Correlations, covariances

R30 It is recognized that the introduction of correlations and covariances for experimental yield data in the evaluation process would be desirable. This would require detailed studies of the correlations themselves and suitable evaluation procedures and programs. However, with the manpower available for the major fission yield evaluations at present and in the near future, such

CRP an effort is not possible. Therefore this should be a special task for the CRP, possibly within a research contract.

5.5 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 not been accomplished due to the lack of manpower.

The main problem is to find a description or energy parameters ("spectral index") 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.

R31 Characterizations of fast neutron spectra should be investigated with the aim to find the most suitable "spectral index".

R32 It is further recommended to study, both by evaluation and measurement, the energy dependence of yields with monoenergetic neutrons and spectra with varying spectral index.

CRP The evaluation of the dependence of fission yields on neutron energy should be a task for the CRP. This task should include R31 and R32 (evaluation only).

Goverdovsky volunteered to take over the task of the energy dependence evaluation for the CRP. At the same time he will also make theoretical studies of this problem.

5.6 Standards of fission yields

^{235}U thermal fission yields are most frequently used for reference in relative fission yield measurements and can be defined as the primary standard set. Other yield sets, which in turn have been measured relative to ^{235}U thermal yields, and which are used as standards in various yield measurements may be called secondary standards.

CRP These yield sets should be established by the CRP with the goal to issue recommended sets of standard yields. Evaluated yield data available for this list of standards should be compiled, compared

A4 and tested (James volunteered to do a preliminary study). The task should be started with ^{235}U thermal fission yields, followed by other potential secondary standard yield sets.

6. USER REQUIREMENTS AND FISSIONING SYSTEMS

From user requirements expressed for nuclear energy and related applications, the following list of most important systems for thermal (T), fast (F) and 14 MeV (H) neutron induced and spontaneous (S) fission is proposed:

priority 1: U233TF, U235TF, U238F, Pu239TF, Pu241TF
priority 2: Pu240F, Cm245T
priority 3: Th232F, U234F, U236F, Np237T, Pu238F, Pu242F, Am241, Am242mT, Am243T, Cf252S and U233H, U235H, U238H

From this list, the following fissioning systems are included in the table of deficient chain yield data (Appendix):

T: U233,5, Pu239,41, Cm243,5
F: Th232, U233,5,8, Np237, Pu239,40,41
H: U233,5,8
S: Cf252

England reported that medical applications need yield sets in addition to the 60 included in ENDF/B-VI. For some of the Curium isotopes chain and independent yields are needed.

A5 Users are requested to notify evaluators if more fissioning systems are required. Furthermore, they are asked to consider how much detail is needed in the energy dependence of yields.

7. 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.

R33 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.

R34 The same list should be published in every issue of the report series "Progress in Fission Product Nuclear Data (FPND)". The list given in the Appendix has been included in the 13th issue of "Progress in FPND" (published in 1990).

R35 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.
A6 Schmidt and Lammer should find out how the requests for yield measurements can be included in WRENDA.

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

R36 Therefore, the assistance of INDC members and liaison officers should be sought to establish contacts with groups prepared to measure the required fission yields.
A7 Action for Lammer: to present this proposal to the INDC and, if accepted, to act as a link between INDC and CRP.

8. SUMMARY OF REQUESTS TO MEASURERS

8.1 Summary of requests from parts 2. to 5.

Ternary fission yields (section 2.3)

R1 Further measurements of ternary fission yields as function of neutron energy should be performed.

Limits and accuracies of experimental techniques (section 2.4)

Data obtained in on-line experiments like those done with LOHENGRIN need summing over ionic charges for inclusion in evaluations.

R3 More new multiparameter measuerements over ionic charge states and kinetic energy of fragments should be performed to allow summing over these parameters. This is particularly true for ternary fission experiments.

Measurers should also note other observations about limitations of on-line experiments collected in section 2.4.

R4 Measurers are asked to study and discuss systematic discrepancies associated with apparatus and measurement methods, in particular those between independent yield measurements from on-line facilities and those from radiochemical measurements.

Data for model calculations (sections 4.1 and 4.4)

The following measurements are needed for the improvement of nuclear models:

R13 Direct measurements of the energy dependence of the pairing effect with a double ionization chamber;

R16 Simultaneous measurements of the kinetic energy, neutron emission and the emission angle versus (Z,A) of the fragments for different neutron energies;

R18 Detailed measurements of the odd-even effect and isomeric yields;

R19 Measurements of independent yields and charge distributions for any of the many reactions where data are lacking (see tables in the Appendix);

R20 Independent yield measurements for nuclides near symmetry for a number of fission reactions with different A, Z, and excitation energies;

R21 Nuclear-charge-distribution data for most fast-neutron-induced fission reactions to determine even-odd-Z factors directly;

R22 Yields at the wings of mass distributions for many fission reactions.

Requests from evaluators (part 5.)

R27 Measurers are asked to perform measurements of decay data and delayed neutron data needed by evaluators for corrections.

R29 Measurers are asked to inform the CRP, what realistic typical uncertainties should be used for each measurement method.

R32 It is recommended to study, both by evaluation and measurement, the energy dependence of yields with monoenergetic neutrons and spectra with varying spectral index.

Mono-energetic measurements should be performed of:
- independent yields
- ternary fission yields
- isomeric yields
- chain yields

Energy region of interest:
- MeV region (1-20 MeV): for study of 2nd+3rd chance fission
- 100 keV region: average energy for fast reactors
- keV region: for study of the effect of spin dependence and change in nu-bar on the change in yields

8.2 Additonal requests

R37 Data for ^{227}Th thermal fission chain yields are from only one set of measurements made 20 years ago, so new measurements should be made, if possible.

Measurements of independent yields

Measurements of independent yields including those of very short lived fission products are recommended (see 4.) for model calculations. They are important for the prediction of decay heat via summation calculations.

R38 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.

R39 Measurers are requested to publish sufficient details on the method used and how these data were used in the analysis. The final data should always be before delayed neutron emission.

Re-measurements of deficient data

R40 Measurers are asked to look at the discrepant or unmeasured chain yield data in the table in the Appendix and (re)measure them, if possible.

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.

R41 It is recommended that measurers 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).

R42 Furthermore, sufficient experimental details should be published to allow evaluators to judge the error assignments and measurement results. All these details can be included in laboratory reports or in EXFOR (see recommendations R5, R6 and R11).

9. SUMMARY OF CRP TASKS AND INTERCOMMUNICATION

The tasks for the CRP have been summarized in the report from the last meeting, INDC(NDC)-208, part 9 (page 9). This part contains only discussion topics of this meeting.

Discrepancies

It should be a task of the CRP to try and resolve discrepancies among measured fission yield data. Measurers should be asked to study and discuss systematic discrepancies associated with apparatus and measurement methods.

Uncertainties of estimated yields

The uncertainties of unmeasured independent yields cannot be estimated. However, to get an idea about the uncertainties of estimated or calculated yields, comparisons between earlier predictions and new measurements should be done. This could be a CRP task by a measurer (e.g. Rudstam) and an evaluator (e.g. Wahl).

Energy dependence of fission yields

The evaluation of the dependence of fission yields on neutron energy should be a task for the CRP. This task should include R31 and R32 (evaluation only).

Goverdovsky volunteered to take over the task of the energy dependence evaluation for the CRP. At the same time he will also make theoretical studies of this problem.

Standards of fission yields

Standard yield sets should be established by the CRP with the goal to issue recommended sets of standard yields. Evaluated yield data available for this list of standards should be compiled, compared and tested (James volunteered to do a preliminary study). The task should be started with ^{235}U thermal fission yields, followed by other potential secondary standard yield sets.

Cross-check of libraries

The cross-check of evaluated data libraries should possibly be a special task for the CRP The files should be compared and reasons for discrepancies traced down.

A8 England should contact T. Yoshida or Y. Katakura if they could make such a comparison. If not: find out if this could be done on an IAEA fellowship.

APPENDIX: TABLES OF DEFICIENT YIELD DATA

Part 1: chain yield measurements required

(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 (blank or 0 = zero)
reason = reason for request (except if no = 0, blank or 1)
D = discrepant data with large chi-squared; the number in brackets gives the probability (in %) for the occurrence of the maximum contribution (from the most discrepant measurement) to the calculated chi-squared.

^{233}U thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
2	1		76			116			130		
3	3	D(0.64)	77	1		117	1		151	3	D(6.1)
4	7	D(2.8)	78	1		118	1		153	1	
6			79	1		119	1		155		
7	1		80	1		120	1		156	1	
8	1		82	1		122	1		157	1	
9	1		99	7	D(9.0)	123			158		
10	1		103	7	D(2.4)	124	1		159	1	
71			109	1		125	1		160		
72			110	1		126			161	1	
73			111	3	D(5.9)	127	2	D(3.4)	162		
74			113			128					
75			114			129					

^{235}U thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			66			116	1		165		
4	13	D(0.0)	67	1		117	3	D(5.3)	166		
6	5	D(0.15)	71			123	6	D(0.17)	167		
7	1		72			125	5	D(7.8)	168		
10	5	D(9.9)	73	1		128	8	D(6.7)	169		
11	1		74	1		130	1		170		
12	4	D(0.20)	83	12	D(8.4)	149	13	D(2.4)	171		
13	1		85	19	D(2.1)	151	10	D(8.6)	172	1	
14	1		106	10	D(1.0)	153	10	D(2.4)	173		
16	1		109	5	D(5.3)	154	7	D(7.0)	174	1	
18	2	D(0.00)	110	3	D(5.0)	161	1		175		
20	1		111	1		162	1		176		
21	1		112	1		163	1		177	1	
32			113	1		162	1				

^{239}Pu thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
1	1		71			112	4	D(1.8)	128	1	
2	2	D(6.0)	72	1		113	3	D(4.0)	130		
3			73			114	1		133	16	D(0.92)
4			74			115	8	D(0.0)	151	9	D(8.4)
7	1		75			116	1		153		
8	1		76			117	1		155	1	
9	1		77	1		118	1		156	6	D(3.1)
10	1		78			119	1		157	1	
11	1		79			120	1		158		
12	1		80			121			160		
13	1		82			122	1		162		
14	1		90	7	D(6.6)	123			163		
15	1		102	1		124	1		164		
16	1		109	4	D(9.0)	125			165		
20	1		110	1		126	1		166	1	

^{241}Pu thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1		96	1		111			126	1	
4	2	D(1.5)	98			112	3	D(4.6)	to		
71	0		99	6	D(5.6)	113	0		130		
to			100			to			132	10	D(1.0)
82			101	1		120			133	8	D(6.3)
83	1		102	1		121	1		134	4	D(8.7)
84	1		104	1		to			139	1	
86	1		to			124			155	1	
91	5	D(1.0)	109			125	2	D(0.0)	to		
94	1		110						162		

^{243}Cm thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			100			115	1		142		
4			101	1		116	0		143	1	
71	0		103	1		to			to		
to			104	1		126			147		
91			106			127	1		148		
92	1		108	1		129	1		149		
93	1		109	1		133	1		150		
94	1		110			134			151	1	
95	1		111			136			152	0	
96			112	1		137			to		
98			113			138			162		
99	1		114			141	1				

^{245}Cm thermal fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			93	3	D(3.8)	114	1		141	3	D(8.5)
4			94			116			142	2	D(1.6)
71			96			to	0		143	3	D(4.6)
to	0		98			120			144	2	D(3.2)
76			99	3	D(5.0)	121	1		145	1	
77	1		100			122			148		
78			101	1		123			150		
to	0		102	1		124			152	1	
82			103	4	D(8.9)	126			153	1	
83	1		104	1		128	3	D(0.06)	154		
84	1		105	5	D(7.5)	132	2	D(0.01)	155		
85			107	1		133	1		156	2	D(0.8)
86			108	1		135	3	D(0.0)	157		
87	1		109			136			to	0	
88	2	D(3.6)	110			137	3	D(6.0)	162		
91	4	D(1.9)	112	1		138	2	D(0.0)			
92	2	D(9.1)	113	1		140	3	D(3.2)			

^{232}Th fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			96			113			139	4	D(8.6)
4			98			114			145	1	
71			100			116			146	3	D(2.7)
73	1		101			to	0		150	1	
74			102			126			152		
75			103	5	D(8.1)	127	1		153	1	
76			104			128			154		
78			105	2	D(0.0)	129	1		155		
to	0		107			130			156	1	
82			108			131	12	D(0.63)	157		
85			109	1		132	11	D(5.2)	to	0	
86	1		110			133	3	D(9.5)	162		
91	4	D(0.04)	111	4	D(6.0)	138	1				

^{233}U fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1		94	1		116			131	6	D(0.62)
4	1		96	1		117	1		134	3	D(6.8)
71			98	1		118	1		154		
to	0		100	1		119	1		155		
82			101			120	1		156	1	
83	1		102			121			157	1	
84	1		103	3	D(3.5)	122	1		158		
85	3	D(9.2)	104			123			159	1	
86	1		105			124	1		160		
88	1		106	2	D(0.01)	126	1		161	1	
90	1		107			127	2	D(0.16)	162		
93	1		to	0		128	1				
			114			130					

^{235}U fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
1	1		107			119			153	8	D(0.05)
3	1		to	0		to	0		154	2	D(0.00)
4	1		110			124			155		
71			111	24	D(0.00)	126	1		156	19	D(0.00)
to	0		112	6	D(0.17)	127	5	D(0.13)	157		
82			113	1		128	1		158		
87	9	D(1.0)	114			129	1		159	1	
89	21	D(2.1)	115	6	D(0.00)	130	1		160		
96	1		116	1		140	39	D(2.6)	161	8	D(0.64)
99	14	D(0.13)	117			143	25	D(0.28)	162		
106	6	D(1.3)	118			144	28	D(0.48)			

^{238}U fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			86	1		110			130	1	
4	1		87	4	D(2.9)	111	24	D(0.00)	131	16	D(0.13)
66	1		88	6	D(0.92)	112	5	D(9.9)	135	14	D(0.63)
67	2	D(4.4)	89	21	D(0.00)	113	1		143	21	D(0.19)
71			91	8	D(1.8)	114			148	5	D(7.2)
72	1		92	6	D(2.2)	115	12	D(1.3)	153	12	D(0.00)
73			96	1		116			154	1	
to	0		98	1		to	0		155		
76			100	1		120			157		
77	3	D(7.2)	101	1		122			158		
78			102			123			160		
to	0		104			124			161	7	D(6.5)
82			105	8	D(3.6)	125	3	D(5.0)	162		
83	1		107	1		126	1		to	0	
84			108			127	9	D(2.1)	177		
85	2	D(0.01)	109	4	D(6.1)	128	1				

^{237}Np fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			107			123			134	5	D(6.2)
4			108			124			140	10	D(3.5)
71			109	1		125	5	D(8.8)	153		
to	0		110			126	1		155		
82			113	1		127	3	D(4.1	156	1	
85	3	D(3.6)	114			128	1		157		
87	2	D(6.1)	116			129	2	D(2.9)	to	0	
95	5	D(0.36)	to	0		130	1		162		
99	1		120			131	6	D(0.93)			
106	4	D(6.4)	122			132	8	D(1.2)			

^{239}Pu fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	1		97	19	D(0.95)	114	1		141	8	D(6.1)
4			101	1		115	10	D(0.02)	144	17	D(8.9)
71 to 76	0		102	1		116	1		153	1	
77	2	D(0.00)	104	1		117 to 124	0		154	2	D(0.41)
78 to 82	0		107			125	3	D(1.4)	155		
88	4	D(7.5)	108			126	1		156	6	D(1.8)
95	18	D(1.3)	109	4	D(2.9)	127	1		158		
			110			128	1		159		
			111	11	D(0.26)	130	1		160		
			112	4	D(3.3)				162		
			113	1							

^{240}Pu fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			94	1		113	1		153 to 157	1	
4			96	1		114			158		
71			98 to 105	1		116 to 124	0		159	1	
72	1		107			126	1		160		
73 to 82	0		108			128	1		161	1	
83 to 89	1		109	1		129	1		162 to 168	0	
92	1		110			130	1		169	1	
			111	1							
			112	1							

^{241}Pu fast fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			90 to 98	1		105			153		
4			99			106	1		154	1	
71 to 82	0		100	1		107 to 124	0		155 to 162	0	
83 to 88	1		101	1		125 to 130	1				
89			102	1		141	1				
			103								
			104	1							

^{233}U 14 MeV fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			96			125	1		156	1	
4			98			126			157		
66	1		100			128			158		
67	1		101			129			159	1	
71			102			130			160		
72	1		104			131	2	D(0.08)	161	1	
73			106	1		134	1		162		
to	0		107			135	1		to	0	
82			108			136			165		
83	1		110			138			166	1	
84			113	3	D(1.3)	139	1		167		
85	1		114			142			168		
86			115	5	D(7.1)	144			169	1	
87	1		116			to	0		170		
88	1		to	0		150			171		
89	1		120			152			172	1	
90			121	2	D(3.2)	153	1		173		
91	3	D(8.3)	122			154			174		
92	2	D(2.5)	123			155			175	1	
94			124								

^{235}U 14 MeV fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			94			123			148		
4	1		95	3	D(8.7)	124			to	0	
66	2	D(1.4)	96			125			152		
67	1		97	1		126	1		153	1	
71			98			127	1		154		
72	2	D(7.5)	100			128			155		
73	1		101			129			157		
74			102			130			158		
75			103	3	D(5.8)	131	5	D(2.1)	159	1	
76			104			132	7	D(0.63)	160		
77	1		105	3	D(3.3)	133	1		161	3	D(5.5)
78			106	2	D(1.6)	135			162		
to	0		107			136	1		163		
82			108			137	2	D(5.0)	164		
83	1		109	1		138			165		
84			110			139	1		166	1	
85	1		112	2	D(0.00)	140	9	D(2.3)	167		
86			113	1		141	2	D(9.6)	168		
87	1		114			142			169	1	
88	1		116			143	1		170		
89	7	D(8.2)	to	0		145			171		
92			120			146			172	1	
93	1		122								

^{238}U 14 MeV fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3			94	1		120			155		
4			95	14	D(9.1)	122			156	6	D(6.7)
66	1		96			123	1		157		
67	1		98			124			158		
71			100			125	8	D(1.5)	159	1	
72	1		103	13	D(2.2)	126			160		
73	1		105	21	D(7.5)	128	1		162		
74			107	1		129	9	D(0.00)	163		
75			108	1		130			164		
76			109	4	D(4.1)	131	16	D(0.32)	165		
79			110			134	10	D(3.4)	166	1	
80			111	12	D(0.71)	143	19	D(2.6)	167		
81	1		112	13	D(5.0)	146			168		
82			114			148			169	1	
86			116			150			170		
88	4	D(6.6)	117	3	D(0.00)	151	4	D(3.1)	171		
89	13	D(5.0)	118	1		152			172	1	
91	22	D(0.13)	119			154					

^{252}Cf 14 MeV fission

A	no	reason	A	no	reason	A	no	reason	A	no	reason
3	5	D(3.9)	96			117	3	D(9.5)	145	1	
4			97	8	D(3.7)	118			148		
8	1		98			119			150		
71			99	8	D(6.0)	120			151	7	D(2.3)
to	0		100			121	1		152		
82			102			122			154		
83	1		105	9	D(0.18)	123			156	6	D(1.7)
84	1		106	3	D(4.9)	124			158		
86	1		108			125	1		159	1	
87			110			126			160		
90			112	3	D(6.9)	130			162		
91	6	D(5.2)	114			132	11	D(0.56)	to	0	
92	4	D(7.0)	115	8	D(4.7)	136			165		
93	4	D(4.4)	116			137	6	D(7.5)	166	1	

Part 2: independent yield measurements required

Remeasurements of discrepant independent yields are required as given in the tables below.

A = mass number
elem. = element symbol; -g = ground state, -m = metastable state
-t = total (sum g+m)
no = number of measurements
discrep: D = discrepant data with large chi-squared; the number in brackets gives the probability (in %) for the occurrence of the maximum contribution (from the most discrepant measurement) to the calculated chi-squared.

^{233}U thermal fission

A	elem.	no	discrep	A	elem.	no	discrep	A	elem.	no	discrep
82	Br-g	2	D(0.00)	128	I	2	D(0.00)	135	Xe-m	3	D(0.00)
87	Br	3	D(0.01)	131	Te-m	2	D(0.00)	135	Xe-t	2	D(0.01)
89	Br	4	D(0.01)	131	I	2	D(0.00)	137	I	2	D(0.00)
90	Br	2	D(0.00)	132	Sn	2	D(0.00)	137	Xe	2	D(0.01)
95	Zr	2	D(0.00)	132	Sb-g	3	D(0.00)	138	Cs-m	2	D(0.01)
96	Nb	3	D(0.00)	132	Te	2	D(0.01)	139	I	2	D(0.01)
97	Nb	2	D(0.00)	133	Te-m	2	D(0.00)	148	Pm-g	3	D(0.00)
98	Nb	2	D(0.00)	133	I -g	4	D(0.01)	148	Pm-m	3	D(0.01)
99	Y	2	D(0.01)	134	I -t	2	D(0.00)				
99	Nb	2	D(0.01)	135	Xe-g	4	D(0.01)				

^{235}U thermal fission

A	elem.	no	discrep	A	elem.	no	discrep	A	elem.	no	discrep
72	As	2	D(0.00)	95	Rb	7	D(0.01)	106	Tc	2	D(0.01)
81	As	2	D(0.00)	95	Sr	4	D(0.01)	112	Ag-g	2	D(0.00)
82	Ga	3	D(0.00)	95	Y	5	D(0.01)	128	Sb-g	3	D(0.01)
83	Se	3	D(0.00)	95	Zr	4	D(0.00)	128	Sb-m	3	D(0.01)
84	Ge	3	D(0.00)	96	Rb	6	D(0.00)	128	I	2	D(0.01)
85	As	3	D(0.00)	96	Zr	3	D(0.01)	130	In-m	2	D(0.00)
85	Se	4	D(0.01)	96	Nb	7	D(0.00)	130	Sb-g	4	D(0.00)
85	Br	4	D(0.00)	97	Rb	5	D(0.00)	130	Sb-m	3	D(0.00)
86	As	3	D(0.00)	97	Zr	3	D(0.01)	130	I	2	D(0.00)
86	Se	4	D(0.01)	97	Nb-g	2	D(0.01)	131	Te-g	5	D(0.01)
86	Br	5	D(0.00)	98	Y	3	D(0.01)	131	Te-m	4	D(0.00)
86	Rb-g	3	D(0.00)	98	Zr	3	D(0.00)	131	I	3	D(0.00)
87	Se	4	D(0.01)	98	Nb-t	5	D(0.00)	132	Sb-m	2	D(0.01)
87	Kr	5	D(0.00)	99	Sr	3	D(0.00)	132	Te	5	D(0.01)
88	Se	5	D(0.00)	99	Y	3	D(0.00)	132	I -g	3	D(0.01)
88	Br	7	D(0.00)	99	Zr	4	D(0.00)	132	I -m	2	D(0.00)
88	Kr	6	D(0.00)	99	Nb-m	3	D(0.01)	133	Te-g	4	D(0.01)
88	Rb	6	D(0.00)	99	Nb-t	4	D(0.00)	133	Te-m	3	D(0.01)
89	Br	9	D(0.00)	100	Y	3	D(0.00)	133	I -g	7	D(0.00)
89	Rb	7	D(0.01)	100	Zr	3	D(0.01)	133	Xe-g	2	D(0.01)
90	Br	7	D(0.01)	100	Nb-t	3	D(0.00)	133	Xe-m	2	D(0.00)
90	Kr	6	D(0.00)	101	Y	2	D(0.01)	134	I -m	3	D(0.01)
90	Rb	7	D(0.01)	101	Zr	2	D(0.00)	134	I -t	4	D(0.00)
91	Br	7	D(0.01)	101	Nb	3	D(0.01)	135	Xe-m	3	D(0.00)
91	Sr	5	D(0.00)	102	Nb-t	2	D(0.00)	135	Xe-t	5	D(0.00)
92	Kr	6	D(0.00)	103	Zr	2	D(0.00)	136	Cs	7	D(0.01)
92	Rb	7	D(0.01)	103	Mo	2	D(0.00)	137	I	4	D(0.00)
92	Sr	4	D(0.00)	104	Zr	2	D(0.01)	137	Xe	5	D(0.00)
92	Y	3	D(0.01)	104	Mo	2	D(0.01)	139	I	5	D(0.01)
93	Kr	7	D(0.01)	104	Tc	3	D(0.00)	139	Xe	4	D(0.01)
94	Kr	5	D(0.01)	106	Nb	2	D(0.00)	139	Cs	6	D(0.00)
94	Rb	7	D(0.00)	106	Mo	2	D(0.01)				

^{239}Pu thermal fission

A	elem.	no	discrep	A	elem.	no	discrep	A	elem.	no	discrep
82	Br-g	2	D(0.01)	103	Tc	2	D(0.01)	135	Xe-t	4	D(0.00)
93	Kr	2	D(0.00)	104	Tc	4	D(0.00)	136	Cs	5	D(0.01)
93	Rb	2	D(0.01)	105	Tc	4	D(0.01)	138	Cs-m	2	D(0.00)
95	Rb	2	D(0.01)	128	I	2	D(0.01)	150	Pm	2	D(0.01)

^{245}Cm thermal fission

A	elem.	no	discrep
136	Cs	2	D(0.00)

^{235}U fast fission

A	elem.	no	discrep	A	elem.	no	discrep
135	Xe-t	2	D(0.01)	136	Cs	3	D(0.01)

^{238}U fast fission

A	elem.	no	discrep
136	Cs	2	D(0.00)

^{239}Pu fast fission

A	elem.	no	discrep
136	Cs	7	D(0.01)

^{240}Pu fast fission

A	elem.	no	discrep
136	Cs	2	D(0.00)

^{232}Th 14 MeV fission

A	elem.	no	discrep	A	elem.	no	discrep	A	elem.	no	discrep
96	Nb	2	D(0.01)	130	I -g	2	D(0.00)	136	Cs	2	D(0.01)
112	Ag	2	D(0.00)								

^{233}U 14 MeV fission

A	elem.	no	discrep
136	Cs	2	D(0.00)

^{235}U 14 MeV fission

A	elem.	no	discrep	A	elem.	no	discrep	A	elem.	no	discrep
82	Br	2	D(0.00)	135	Xe-m	2	D(0.00)	136	Cs	3	D(0.00)
96	Nb	2	D(0.00)								

^{238}U 14 MeV fission

A	elem.	no	discrep
133	Xe	2	D(0.01)

^{239}Pu 14 MeV fission

A	elem.	no	discrep	A	elem.	no	discrep
133	Xe-m	2	D(0.01)	135	Xe-m	2	D(0.00)

^{252}Cf spontaneous fission

A	elem.	no	discrep
136	Cs	3	D(0.00)